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Tangible Interaction in Museums and Cultural Heritage Sites: Towards a Conceptual and Design Framework

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Publications

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Abstract

Drawing on a design perspective, the research explores the application of tangible interaction in museums and cultural heritage sites. Tangible interaction is today a quite consolidated research area inside HCI (Human-Computer Interaction) and Interaction Design. It refers to a new way of interacting with computer systems that is more similar to the way one commonly interacts with the real world: instead of using generic devices like the mouse or the keyboard, one interacts using specific objects or the body. In this way, tangible interaction is able to bridge the gap between the world of atoms and the world of bits (Ishii et al., 1997).
Since the early 2000s, tangible interaction has also been applied to the cultural heritage field for the creation of onsite interactive installations that better integrate digital technologies, the materiality of the objects and the physicality of the experience during the visit.
So far, research in the field of tangible interaction applied to cultural heritage has mainly focused on developing new systems and evaluating them while a move towards more theoretical and conceptual works is still missing. As a consequence, there is not a common language in the field, there is not a deep understanding of what has been done and what is missing, and there is not a formalization of the aspects that make up the design of tangible interaction systems in the cultural heritage field. This situation might generate issues such as ambiguity and misunderstanding between the different professionals involved in projects, it might slow down innovation in the field, and last but not least, it might make the design process slower, less efficient and effective.
This research represents a first attempt to overcome at least partially these problems by replying to three main questions that are:

1. How has tangible interaction been applied to onsite interactive installations in the cultural sector?
2. What kind of experiences of cultural heritage does tangible interaction allow?
3. What are the aspects that make up the design of a tangible interaction system?

In order to answer these questions a theoretical framework for tangible interaction in museums and cultural heritage sites is proposed, similarly to what has been done in the past for other types of technologies (e.g. Spallazzo, 2012). The framework developed as part of

this research can be intended as both a conceptual framework and the theoretical foundations of a design framework. Indeed, not only it shows what tangible interaction is by providing a categorization of past tangible interaction systems, but it also identifies a set of aspects that make up the design of such interactive systems. These aspects represent themes around which choices have to be made during the process of design, and the knowledge of which can facilitate or inspire the design process itself.

The framework has been developed starting from the collection and analysis of more than 60 tangible interaction projects. In particular, the projects have been analysed using a thematic analysis, combining an inductive (bottom-up) and deductive (top-down) approach in order to identify themes and subthemes (categories and subcategories). In order to discuss and develop further reflections about the framework being proposed, the research goes on presenting a reconstruction and analysis of a practical case study, the interactive exhibition "Voices from Forte Pozzacchio" developed as part of the EU funded "meSch" research project.

The proposed framework can be beneficial for researchers as it provides a language and a conceptual model that can help them to reflect and discuss about the topic, to orient future research, to cooperate with other researchers. It can also be used to provide different practitioners (e.g. designers, developers and cultural heritage professionals) with a shared view of what tangible interaction is, that can help reduce misunderstandings and can facilitate collaboration between them. In addition, the framework lays the theoretical foundations for a design framework, addressed to designers or design teams, that aims to provide them with a greater awareness of important aspects to consider during the design process, potentially making it more effective and efficient.

Chapter 1

Introduction

With the advent of digital media, with the interactivity and multimedia that this entails, the traditional ways used to convey information about the objects, like labels and text panels, are no longer the only communication tools required by the visitors in museums and cultural heritage sites. As a response to this issue, since the mid-1980s, museums and cultural heritage sites have started to adopt various types of technologies among which are intra-gallery interactive installations (or interactives) [1]. In this way, museums have become an important domain for HCI (Human Computer Interaction) and Interaction design studies. This research project situates itself in the context of interaction design applied to the cultural heritage field with a specific interest in that particular kind of technology called *tangible interaction*, which represents one of the last evolutions of interactive technology in general, and whose application in museums and cultural heritage sites has started very recently. Although other uses of tangible interaction might have been proposed in the cultural sector (i.e. to support the study or restoration of artworks by experts) this thesis focuses on how tangible interaction has been used in the context of *onsite interactive installations* whose purpose is to *enhance* the visitor experience of Cultural Heritage (CH).

Tangible interaction is an area of research inside HCI and Interaction Design[2]. Research in this field, as well as the one in the areas of

[1] For more information on the kinds of technologies adopted by museums see (Hawkey, 2004; Parry, 2007, 2010; Tallon et al., 2008; Jamie et al., 2012; Kiid, 2014).

[2] Although HCI and Interaction design are strongly overlapped research areas, they are often described in literature as disciplines with their own histories and main characteristics. HCI is older and originated from the behavioural science and engineering academic fields (Löwgren, 2002). For this reason, "its methods are more quantitative" (Saffer, 2010) and "are more those of engineering and computer science than of design" (Ivi). The main intention of HCI is indeed "to accumulate empirical knowledge through controlled experiments" (Löwgren et al., 2004) about how human beings interact with computer systems so that this knowledge could be used for the creation of usable interactive systems. On the other hands, Interaction design is a younger field that "clearly owes part of its heritage to HCI, even though the turns within established design fields—

augmented reality and ubiquitous computing became prominent in the late 90s as an attempt to overcome the limit of the so-called WIMP (Windows, Icons, Menus, Pointer) interaction style and of Virtual Reality, in particular the fact that both methodologies estrange humans from their "natural environment" (Shaer et al., 2010). At that time a firm belief emerged that since "Humans are of and in the everyday world" (Weiser, 1993), rather than forcing users to enter a virtual world one should enrich the real world with digital functionalities, in this way retaining the richness of physical interaction and enabling a fluid transition between the digital and the real. Technologies of this kind are globally referred to as Mixed Reality (Milgram and Kishino, 1994; Milgram, Takemura et al., 1994; Kishino et al., 1995; Coutrix et al., 2006).

For its characteristics of being able to integrate the physical and the digital world, Mixed Reality (MR) technology has started to be employed and researched also in the museum sector. One of the problems often mentioned in the literature about digital technologies applied to museums is indeed their drawback of distracting and disengaging visitors from the objects and their materiality, that instead should be the real protagonists in the museum (Ciolfi, 2003; Stevens, 2004, Vom Lehm et al., 2003). Examples of Mixed Reality systems will be presented in the next chapter. Following several experimentations of Augmented Reality (AR) and Augmented Virtuality (AV) in museums, tangible interaction represents the outer reach of this evolution, that allows for a kind of interaction with digital technological systems that is closer to the way we interact in the physical real world (through objects, or through the body).

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such as graphic design, product design and architecture—towards the digital material are every bit as important." (Löwgren, 2002). It is therefore to be considered not a subfield of computer science but as a design discipline, and as such it makes a strong use of the methods of the design field (Löwgren et al., 2004; Winograd, 1997) "for designing interaction with (and habitation within) computer-based systems" (Winograd, 1997).
However, as stated by Rogers (2012) "While the newer fields have carved out their distinctiveness in terms of framing, rhetoric and identity to set them apart from each other and HCI, HCI keeps recasting its net ever wider, which has the effect of subsuming them" and this "tendency [of HCI] towards inclusiveness" (Ivi) makes the distinction between the two disciplines not always recognized especially by the HCI community. In this research it has been decided to mention the two disciplines since, in the academic experience of the author of this thesis, a difference in the approaches adopted by scholars coming from Interaction Design and HCI fields is often still apparent today.

1.1 What kind of tangible interaction is this thesis focused on?

The use of the expression *tangible interaction* in the CH field can lead to ambiguity and misunderstanding. *Tangible interaction* is an expression that finds its origins in the technological world, and for this reason is not generally used as such in the museum studies and cultural heritage literature. Nonetheless, when used in the museum context, this expression can easily be associated, especially by cultural heritage professionals, to a variety of meanings that are connected to topics that are instead dealt with in the museum studies literature. These meanings are reported below, along with some theoretical references[3]. The purpose of this overview is mainly to make clearer, especially for a reader who is not a technology expert, what interpretation of tangible interaction is used in this thesis and what is not.

For non ICT-expert people or for people with a human science background, what seems to be a privileged meaning for tangible interaction is the one related to the possibility of touching the objects. Indeed, if we look at the etymology of the term, "tangible" derives from late Latin *tangibilis*, from *tangere*, meaning "to touch" and one of the meaning for *tangible* reported by the Oxford English Dictionary is, indeed, "capable of being touched; affecting the sense of touch; touchable"[4]. After having considered for years the museum visit as a mainly unisensory visual experience (Candlin, 2008) and touching cultural heritage pieces as "disrespectful, dirty and damaging" (Classen, 2005, p. 282) and without cognitive or aesthetic value, recently there has been a "sensory turn" in museum studies and practice (Levent et al., 2014, p. xvii).
Contemporary museum professionals have started rethinking the multiple restrictions on the use of the senses and started to implement projects that acknowledge "the value of sensory modalities beyond the visual alone, particularly that of touch" (Dudley, 2010, p. 11)[5]. The British Museum's "Hands on" project, that allows visitors to handle some objects from their back-collection (Figure 1) (Lacey et al., 2014)

[3] These meanings have been identified as recurring themes in the many conversations and discussions the author of this dissertation had with people from different backgrounds (humanities, interaction design, technical background) during the investigation of the topic. While some theoretical sources are reported to justify the different interpretations, a complete review of the humanistic literature that links to the topic is beyond the aim of this work and would lead the research far away from the main objectives as listed hereinafter.
[4] http://www.oed.com/view/Entry/197491?redirectedFrom=tangible
[5] For a history about how the practice of visiting have changed during the centuries with reference to senses see (Leahy et al., 2012).

and the Walters Art Museum's exhibit titled "Touch and the Enjoyment of Sculpture: Exploring the Appeal of Renaissance Statuette"[6] offering visitors the possibility of touching replicas of Renaissance and Baroque sculpture, represent just two examples of this trend. In addition, more and more studies have emerged in the literature pointing to the social, cognitive and even therapeutic value of handling objects (Classen, 2005; Chatterje, 2008; Pye, 2008; Candlin, 2010). In the concept of tangible with the meaning of *to touch* we can also include all the experiences that have been designed to allow blind people to experience works of art and museum objects, allowing them to touch original artworks or replicas or bas-reliefs derived from paintings (Axel et al., 2003; Reichinger et al., 2012; Neumüller et al., 2014). The Museo Nacional del Prado, for example, has launched the initiative "Touching the Prado" for visually impaired visitors: using a relief painting technique, six works of art belonging to the museum collection have been copied allowing blind visitors to create a mental image of them through the touch[7] (Figure 2).

Figure 1 An object handling session at the British Museum
(source: http://www.britishmuseum.org/visiting/planning_your_visit/object_handling_sessions.aspx).

[6] http://thewalters.org/events/event.aspx?e=2207
[7] https://www.museodelprado.es/en/exhibitions/exhibitions/at-the-museum/hoy-toca-prado/exposicion/

Figure 2 At the Museo Nacional del Prado blind Visitors can touch works of art (source: https://www.nytimes.com/2015/03/07/arts/design/at-museo-del-prado-blind-visitors-can-touch-masterpieces.html).

The term *tangible* is sometimes used also in the more blurred sense of "that can be clearly seen to exist"[8], to refer to the experience of a cultural object in the real world as opposed to the digital experience usually offered by traditional visualization technologies.
In the era of VR, what sometimes happens is the possibility to experience CH objects in a digital form instead of its physical forms, using either classical devices like multimedia kiosks or more immersive VR systems (Carrozzino et al., 2010)[9]. The 3D reconstruction of the Camposanto Monumentale (Monumental Cemetery) of Pisa[10], carried out by PERCRO Lab (Scuola Superiore Sant'Anna di Pisa), represents a divulgation tool that allows a *virtual* visit of the monument (also in different times), and the possibility of accessing a database of information about it (Figure 3). Different from the virtual visit is instead the real – "tangible" – visit of the same monument that is

[8] http://www.oxfordlearnersdictionaries.com/definition/english/tangible
[9] Applications of this kind have been used, for example, for showing reconstructions of artworks or environments that are not existing anymore (Baracchini et al., 2004), that are not easily accessible or enjoyable in all their details (Callieri et al., 2011) but they have also been used more simply for their attractive power as divulgation and storytelling tools in alternative or in addition to classic media.
[10] http://www.opapisa.it/it/attivita/nuove-tecnologie/sistema-informativo-del-camposanto.html

possible to have walking inside it (Figure 4), although it must be admitted that modern virtual reality systems allow for an experience that is more and more similar to reality. Indeed, often the experience they provide is not limited to the sight, as virtual reality systems have been developed that allow a multi-sensory experience of digital representations of cultural objects (also tactile) through haptic interfaces. For example, in "The Museum of Pure Form" (Loscos et al., 2004), the visitor can explore the shape of a statue using a haptic device mounted on an exoskeleton (Figure 5). Summarizing, in the blurred sense analysed here, having a tangible experience of the object means encountering it in the real world through one of our sense modalities.

Figure 3 A digital experience of the Camposanto Monumentale in Pisa through a virtual reconstruction presented in a CAVE-like environment (source: https://www.santannapisa.it/it/news/giornata-della-solidariet%C3%A0-listituto-tecip-partecipa-alliniziativa-promossa-dallassociazione).

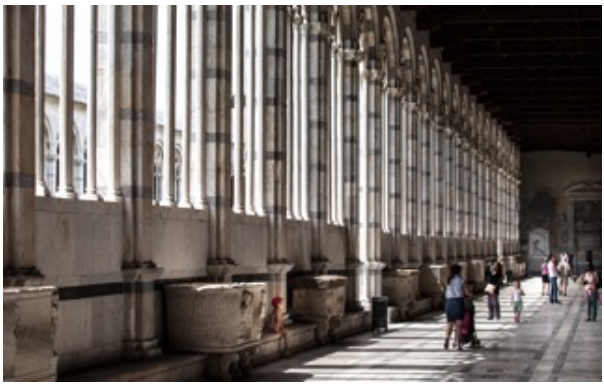

Figure 4 A real, "tangible" experience of the Camposanto Monumentale, Pisa (source: http://www.opapisa.it/wpcontent/gallery/camposanto/MG_2896rw.jpg).

Figure 5 In the museum of Pure Form, the visitor can "touch" the object using an haptic device (source: Loscos et al, 2004).

Another interpretation of the term tangible is as synonym of *embodied.* It emerges if the touch is considered as a wider concept rather than the mere contact between the hand and the object. In the literature, some people have acknowledged that "there may be more to touch than meets the hand" (Bacci et al., 2014, p.18) and that we should extend "the concept of touch to bodily sensations and to multisensory perception" (Bacci et al., 2014, p. 19). As written in (Levent, 2014b, p. 75) summarizing a text of Ackerman (1991, pp. 64-98), "when considering the sense of touch, we tend to connect it to actions that involve the hands. But touch is associated with the largest of the sensory organs and covers the entire body". Considering touch in the wider sense of embodied experience can lead to consider as tangible experiences all those where there is a strong involvement of the body, such as: moving inside or exploring a building, a landscape or an archaeological site, putting ourselves in the position of a statue to better understand it, making actions with originals or replicas of cultural heritage object in order to live a past tradition, but also experiencing bodily sensations activated in indirect way, for example just from the view of a work of art. The broad sense of touch (and thus of tangible) as outlined above, implies that "museum restrictions to one's ability to

touch do not necessarily imply a complete absence of some alternative bodily experience of art" (or other objects) (Bacci et al., 2014), and that "art can and should be a touching experience. Standing in front of a painting, appreciating a sculpture, or walking through a building, even if we are not permitted to physically touch the work we should at least be touched by it" (Peterson, 2007, p. 79).

In addition, the term tangible can find a connection with a new orientation in the museum studies literature that can be referred to as *material orientation* and that emphasizes the visitor's personal understanding of the object starting from the material encounter with it, beyond the information about its context (Dudley, 2010). As summarized in (Wood et al. 2011) for Dudley "Materiality refers to embodied engagement with physical things. The term emphasizes the physical, material characteristics of objects and focuses on the ways in which those characteristics are sensorially experienced by human beings". In this definition, the focus is on the object per se and the emotions, affects, and sensations affecting the visitor while encountering the artwork without the prerequisite of information. This is also expressed in the following quotation: "The more I looked at them, the more I studied them, the more appreciated their beauty over and above the information about their context. They were beautiful! The more I described them and handled them, the more emotionally attached to them I became… My eyes opened" (Dr. Ekpo Eyo, quoted in Vogel, S. 1991).
Opposed to the material approach is what can be called *informative approach*, "the view in which objects have value and imports only because of the cultural meanings which immediately overlie them and as result of the real or imagined stories which they can be used to construct" (Dudley, 2010)[11]. Here the material object becomes "just a part – and indeed not always an essential part – of that informational culture", in other words it "becomes part of an object-information package" (Dudley, 2010). In the extreme cases, so much emphasis is put on the information that "things dissolve into meanings" (Hein, 2006).
Finding a balance between these two positions is not always easy, not only because conceptually different but also because the tools traditionally used to convey information about objects in museums often happen to distract the visitors from the object on display, thus making difficult both to link the information to the object it refers to

11 In this regard, F. Antinucci in his book "Comunicare nel museo" argues that "exhibit objects physically is not enough, for the existence itself of the museum it is paramount to convey culture to the visitors" and this can be done "by applying the theory of communication to those particular signs that are the works of art" (translated by the author from the back cover of Antinucci, 2014).

and also precluding the possibility of a physical engagement with the object.

Finally, another source of confusion with the application of the expression "tangible" in the CH field is due to the fact that the terms tangible and intangible has some important meaning in the CH sector as they are used as a way to classify different types of CH assets. On the one hand, there is the tangible heritage, consisting of physical objects inherited from the past and considered of cultural significance; on the other hand, there is the intangible heritage consisting of "the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith-that communities, groups and, in some cases, individuals recognize as part of their cultural heritage"[12].

The perspectives and related body of literature mentioned above are not the main fields this thesis aims to contribute to. As said, this research situates itself in the Interaction design field applied to cultural heritage and, as such, it will consider a more technological concept of tangible interaction, that *always* includes a digital component, and consists of "user interfaces and interaction approaches that emphasize: tangibility and materiality of the interface; physical embodiment of data; whole body interaction; the embedding of the interface and the users' interaction in real spaces and contexts"[13], therefore representing something different compared to traditional desktop, mobile and virtual reality systems. Examples of the systems that are considered in this research are shown in Figure 6. Basically, they consist of interactive installations the visitor interacts with through the body or through specific physical objects rather than using generic devices like the mouse, the keyboard, the joystick, or a smartphone.

12 UNESCO Convention for the Safeguard of the Intangible Heritage (http://www.unesco.org/culture/ich/en/convention).

13https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/tangible-interaction. For a detailed description of this encompassing perspective to tangible interaction see (Hornecker, 2006). A more complete discussion of what tangible interaction is meant to be will be anyway present in the next chapter.

Figure 6 Examples of tangible interaction systems applied to the CH field: a) Virtex – Ara Pacis (source: http://bmuseums.net/wp-content/uploads/2014/11/141029-tangible_interfaces.pdf); b) "The Painting, a material object" installation (source: http://www.museumlab.eu/exhibition/movie/movie09.html); c) The Loupe (source: Petrelli et al., 2014a); d) Etruscanning (source: Pietroni et al., 2013); e) the interactive desk in Retracing the Past (source: Fraser et al., 2004); f) The Virtual Conductor (source: https://www.wien.info/en/music-stage-shows/city-of-music/house-music).

While a good body of theoretical work have explored the humanistic meanings mentioned above, almost nothing has been done for understanding in its entirety what the technological application of tangible interaction in CH is and what are the implications. That is one of the reason why this topic is so relevant to be researched on.

This does not imply that the other meanings will be put aside and not taken into account in this research. Since one of the reasons often cited for using tangible interaction in museums is to integrate digital and physical experience of cultural heritage, it is important to consider whether and how tangible interaction systems can elicit experiences of cultural heritage assets in the different meanings that have been mentioned above[14].

1.2 Problem definition, research aims, methodology and expected results.

One of the last trends in Interaction Design has been the application of tangible interaction also to museums and CH sites. However, as happened in the early years in the general field of tangible interaction, so far research has mainly focused on developing new systems and evaluating them while a move towards more theoretical and conceptual works is still missing.
Specifically, what is missing are theoretical and conceptual research works aiming to develop a deep understanding of what tangible interaction applied to CH is and to define a language for the specific field. Similarly, no research attempts have been done to formalize the many aspects that make the design of a tangible interaction system in the CH field[15].
This lack of theoretical works might generate issues like ambiguity and misunderstanding between researchers or between the different professionals involved in the design and implementation activities (see Sect. 1.1), it might slow down innovation in the field and, last but not least, it might make the design process slower, less efficient and less effective[16].

[14] This is indeed a key question and can be broken up into various sub-questions: 1) Is tangible interaction about touching cultural heritage assets? 2) Is tangible interaction enabling embodied engagement with cultural heritage assets? 3) Is tangible interaction enabling real encounters with cultural heritage as opposed to virtual encounters provided by digital technologies? 4) Is tangible interaction a manifestation of the material or informative approach to cultural heritage?

[15] It is important to notice that, although tangible interaction frameworks have been developed in the general field of tangible interaction, as discussed in Sect 2.3, their applicability to the CH field is limited

[16] In this thesis, the view according to which theory is needed in interaction design research is embraced (see, for example, Kaptelinin & Nardi, 2009, p. 22). As discussed by Kaptelinin & Nardi (2009) "without some theoretical connective tissues we cannot speak to one another". In particular, without a theory it is not possible to compare different works, to abstract, generalize, to "juxtapose different points of view so that each may

This research represents a first attempt to overcome these problems by replying to three main questions that are:

1. How has tangible interaction been applied to onsite interactive installation in the CH sector?
2. What kind of experiences of cultural heritage does tangible interaction allow?
3. What are the aspects that make up the design of a tangible interaction system in the CH field?

The research presented in this thesis aims to answer these questions by proposing a theoretical framework for the specific domain of tangible interaction applied to the CH field, similarly to what happened in the past in the general field of tangible interaction (see Chapter 2). It is important to specify that the creation of theoretical frameworks is not new in the field of technologies applied to the CH field. For example, the study of theoretical frameworks for the design of mobile applications has been addressed in (Spallazzo, 2012) and (Mason, 2012). However, nothing of this kind is currently existing regarding tangible interaction.

Within HCI and Design domains, a framework is a conceptual structure that acts as a form of guidance to support design, research and analysis (Rogers et al., 2006; Mazalek et al., 2009). A framework can be useful for various purposes such as providing predicting models, explanatory accounts, prescriptive guidance and generative constructs (Rogers et al., 2006). Various types of frameworks exist. *Conceptual frameworks* are those that look back and categorize past interaction systems; doing so they help researchers to look forward to possibilities and opportunities for developing new systems. *Design frameworks* are those that address different aspects or stages of the design process; they can range from very specific prescriptions to broader ones (Mazalek et al., 2009). The

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illuminate one another" (*Ivi*). Besides, "To move forward, to know where to invest our energies, we have need of theory" (*Ivi*).
In addition, in this research the view is adopted that theoretical and conceptual works can be useful to improve the design practice, helping to deal with the complexity characterizing design problems. This view is present in many past research works (see for example Sect. 2.3 for an overview of the design frameworks developed in the general field of tangible interaction), and has been also adopted in the field of design and interaction design applied to CH (see for example Spallazzo,2012; Mason, 2012; Radice, 2014). In this regard, it is important to notice that the design of interactive installations for museums is a complex problem that requires the contribution and integration of many different disciplines and the consideration of many aspects, and for this reason a framework that provides a support to practice can be useful in the field.

more prescriptive the framework, the more likely it will be made up of steps and principles that have to be followed; the more explanatory the framework, the more likely it will suggest a series of concepts or aspects to consider (Rogers et al., 2006). The motivations for applying a framework are many: to orient the research towards innovative, unexplored designs; to design systems that are more usable; to improve the design process making it more effective, also in terms of the quality of communication between researchers, designers and developers, also making the process more efficient (Mazalek et al., 2009).

The framework this research aims to develop should be able to provide a conceptualization that shows what tangible interaction applied to the CH field is, by proposing concepts, categories and a language to describe it. In this sense, it has to be intended as a *conceptual framework* that can be used by researchers to think and discuss about the topic, to orient future research endeavours, and as a basis to build further concepts on. It can also be useful to enable cooperation between different researchers because it suggests a conceptual model and a language that can be shared among more people. Besides, the framework can also be used as a basis for teaching what tangible interaction is to different professionals who might be interested or find themselves involved in the creation of tangible interaction systems (e.g. designers, developers and cultural heritage professionals)[17]. This would allow to create a shared view about what tangible interaction is that can help to avoid misunderstandings, and can also foster communication and collaboration.

Beyond providing concepts and a language, the framework should also be able to suggest a list of the various aspects that make the design of a tangible interaction system, along with possible design choice options for the various aspects. In this sense, it also has to be intended as the *theoretical foundations* for a *design framework,* addressed to designers and design teams, that aims at sensitizing them about important issues to consider during the design process and at supporting their decision making. The hypothesis is that a greatest awareness of the key aspects to consider during the process has the potential to lead to more effective products, or can make the design process more efficient, less based on trials errors, and leading more quickly to effective solutions.

[17] It is important to notice that an adaptation of the text that is used in this thesis to describe the conceptual framework might be needed in the future in order to make it easily accessible not only to researchers but also to practitioners (for example in the form of a textbook). This however goes beyond the scope of this work that, being a PhD thesis, requires the use of an academic language.

It is important to notice that, in the context of this research, it has been intentionally decided to operate mainly at a theoretical level, although being aware that, from a design perspective, the framework would benefit from further work aiming at making it more operative. Indeed, beyond suggesting the aspects that need to be considered during the design process, a fully operative design framework should also suggest how or provide useful tools to integrate these aspects and make them actionable in a design process. Given the complexity of the topic and the background of the author (not formally trained as a designer), for feasibility issues it has been decided to operate mainly at a theoretical level. For this reason, this research will be mainly focused on the identification of the theoretical building blocks of the design framework, while the development of a more practical framework has to be postponed to future research, possibly collaborating with design professionals. Indeed, as stated by Stolterman (2008) "any attempt by interaction design research to produce outcomes aimed at supporting design practice *must* be grounded in a fundamental understanding of the nature of design practice." Despite the dominant theoretical approach adopted in this research, when possible, preliminary considerations related to practice will be included.

Such a framework will be built starting from the collection and thematic analysis of a wide corpus of past tangible interaction projects. This analysis is expected to allow for the identification of themes and subthemes (categories and subcategories) in the past projects able to show what tangible interaction is, and, at the same time, what are the aspects and related choices that make up the design of such interactive systems. In order to discuss and develop further reflections about the framework being proposed, a practical project will be presented and analysed, the interactive exhibition "Voices from Forte Pozzacchio" developed as part of the EU funded "meSch" research project.

1.3 The perspective adopted in the thesis: Design

The perspective underlying this research project is a *Design* perspective. A design approach was chosen after a quite long reflection about the many disciplines that have a relevance when creating interactive installations in museums and CH sites and that can be summarized through the following graphical representation[18] (Figure 7).

[18] This graph has been built starting from the reading of publications in the fields and online resources, through the attendance at conferences and the discussion with people working in the field.

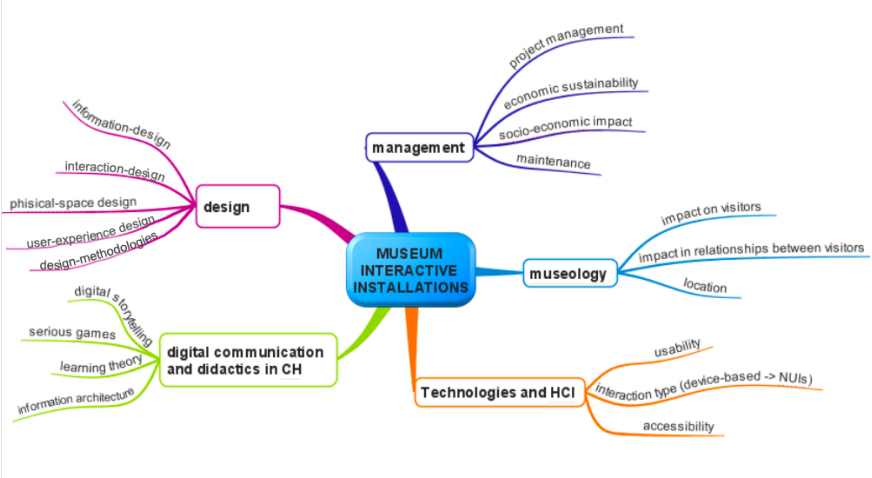

Figure 7 The various disciplines/perspectives that are relevant for the creation of museum interactives.

The proposed graph puts at the centre the main topic (museum interactive installations) and represents the various disciplines (or points of view) that are someway involved in the study and in the creation of museum interactives. Around each discipline other items are listed that represent either some relevant keywords or the name of sub-disciplines.

A first area concerns *Technologies* and *Human-Computer Interaction* (HCI). HCI is an interdisciplinary area of Computer Science that has to do with the design, evaluation and implementation of interactive computer systems and with the study of the connected phenomena.

The second area is that of *digital communication and didactics,* to be intended as an umbrella term covering several sub-areas such as: digital storytelling, serious games, information architecture, learning theory applied to digital context that have a certain relevance for museum interactives.

Then, there is the field of *museology and museography* that have tried to investigate issues like the impact of the interactive installations on visitors and on the relationships between visitors, as well as what is the best location for interactives in museums.

A fourth area is *management*, to be intended both as museum management and as project management. The former is focused on the management of the museum as an institution, along with the opportunity that the use of technologies offers in terms of value creation, business models, possibility of attracting new visitors and

increasing the revenues; the latter is focused on the specific management of technological projects in museums, and includes tools and skills to fulfil requisites of quality, time and budget.
Finally, there is the *design* term. But what has to be meant by design? As pointed out by Francesco Trabucco (2010), a widespread interpretation of design is that of "design as a remedy for applying aesthetics to everyday life, in short, as a sort of decorative praxis […] useful to make things more pretty". This is not the interpretation of design that inspires this thesis where design is considered as "an art of conception and planning whose end result is a product, whether that product is a material object or an immaterial service or system" (Margolin, 2000). This is a conception of design that acknowledges "its ability to interpret the desires of a complex and contradictory society through the research of formal and semantic product innovations" (Trabucco, 2010) that have an impact on people's lives. Indeed, design thinking provides tools to deal with "wicked problems", that is, "a class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (Churchman, 1969)[19].
After having considered for long time design ability "as something that perhaps many people possess to some degree, but only a few people have particularly strong 'gift'" (Cross, 2010) a "growing bodies of knowledge about the nature of designing and about the core features or aspects of design ability" (*Ibidem*) have recently[20] led to consider design as a discipline with specific knowledge, methods and skills that can be taught[21]. As a discipline like all the others, research in this field have "become a routine part of design in many art and design school" (Koskinen, 2010) although still debates exist about what is research in design and what are the methodologies in design research[22].
Going back to the graph in Figure 7, it is important to notice that it presents only a visualization of the various disciplines or points of view

[19] For a more complete understanding of the concept of "wicked problems" see also (Rittel & Webber, 1972) and (Buchanan, 1992).
[20] "Design has become a structural part of academic thinking only at the beginning of 1960s. Many countries haven't had a complete teaching programme in design at university level until the 1990s, and some still haven't any" (Guerrini, 2010b)
[21] "In terms of content, design knowledge is a collection of different cognitive artefacts with different purposes: visions to stimulate and steer strategic discussion; proposal to integrate into the development of numerous specific projects; tool to help to understand the state of things and implement design ideas; reflection on the sense of what we are doing or could do". This knowledge must be "explicit, discussable, transferable and accumulable". (Manzini, 2010).
[22] For more information on the debate about research in design see (Pizzocaro, 2000; Manzini et al., 2006; Guerrini, 2010a; Rampino, 2012).

that have to do with the study or the creation of museum interactives for different reasons – e.g. they analyse the topic under a specific perspective (museology), provide concrete or abstract tools for the creation of interactives (technology, communication and didactics), study methodologies for the design or management of projects regarding interactives (design, management). However, the graph in Figure 7 does not show the relationships between the different disciplines. Further reflections about this issue led to reorganize the graph into another one that puts the design at the centre of everything (Figure 8).

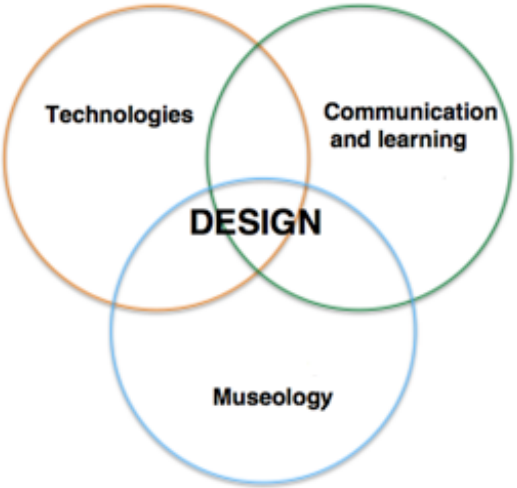

Figure 8 Design as a mediator between disciplines

According to this view, the design draws on the output/knowledge built by the other disciplines (communication and learning, technologies and HCI, museology), in this sense acting as a meeting point between different aspects and perspectives. At the same time the design should respect the constraints assigned by the responsible of the project management (time, budget, quality constrains). This view of design as mediator is not new if we look at the design literature. For example, Margolin (2000, p. 17) defined design as "an integrative activity that, in the broadest sense, draws together knowledge from multiple fields and disciplines to achieve particular results". Similarly, Lucia Rampino (2012, p. 7) defines design as "multidisciplinary in nature, welcoming contributions from other disciplines" and thinks of the multidisciplinarity of design as "both design's strength, a discipline

able to orchestrate other disciplines, and its weakness, depriving the designer of a specific, distinctive know-how universally recognized as 'designership'". Also Celaschi (2008) worked a lot on the notion of design as a mediator.
A design perspective is key for overcoming the problem that sometimes has been mentioned regarding the use of technologies in museums, the fact that despite their strong potentiality, they have not succeeded in making the cultural communication better for the visitors, revealing themselves as an end in themselves rather than a means to an end (Antinucci, 2007). Indeed, it can be argued that the reason of this failure is sometimes due to the lack of a design-based approach or a lack of a comprehensive design methodology, that sometimes led to installations that focus on a subsets of aspects while neglecting others. A consequence of a prevailing technology-driven approach can, for example, lead to technologically complex installations that however do not succeed in their purpose of communicating contents or that are not suitable for a certain museum space.

1.4 Structure and chapters

Following the introduction, the thesis is structured in five chapters. Chapter 2 is devoted to the explanation of what tangible interaction is by discussing its location among the mixed reality technologies and by providing a short history of its development. In addition, the chapter provides an overview about the existing frameworks for the general field of tangible interaction and a presentation of the EU funded research projects that have dealt with the topic of tangible interaction applied to cultural heritage. Chapter 3 is focused on the description of the work that has been done in order to develop the conceptual and design framework for tangible interaction in museums. After presenting in detail the methodology that has been followed, it provides a description and some reflections about the themes/categories that have been identified during the thematic analysis of the projects, and ends with the presentation of the framework and some conclusions regarding the areas that may benefit of further research. The chapter also provides some preliminary reflections about the type of experiences of CH enabled by tangible interaction.
Chapter 4 is devoted to the presentation of the "Voices from Forte Pozzacchio" project. It provides a reconstruction of the process of design of the exhibition and also a description of the impact the exhibition had on visitors. The "Voices from Forte Pozzacchio" project is then analysed in Chapter 5 by using the themes identified in the

framework with the goal of discussing the framework and developing possible further reflections about it. These are presented at the end of the chapter. The thesis terminates with Chapter 6 which presents a discussion about the contributions and limits of the research and points to future works. A glossary and an appendix complete the thesis. The former contains definitions of some of the technical terms used in the thesis, while in the latter it is possible to find the descriptions of all the projects that have been analysed in this research.

Chapter 2

A definition and literature review about tangible interaction and its application to CH

2.1 Tangible interaction as a Mixed Reality technology

One of the characteristics of traditional desktop computing and Virtual Reality is the separation between the real and the digital world they entail. Information and multimedia content are provided separately from the environment where we live and the interaction occurs in a different way compared to how we commonly interact with the real world. As a result, "we live between two realms: our physical environment and cyberspace" (Ishii et al., 1997). and "the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms" (*Ivi*). The separation between the real and the digital world can turn into an issue especially in sectors, like the CH field, where keeping a connection with the real environment/objects is often fundamental. The way digital technologies are used in museums, for instance, often distracts and disengages visitors from the objects on display, that instead should be the real protagonists (Ciolfi, 2003; Vom Lehm et al., 2003; Stevens, 2004). Indeed, properties of the objects, such as their materiality, their authenticity, their "aura", and their ability to foster personal emotions and sensations are fundamental in the experience of cultural heritage (Dudley, 2010). These properties cannot be conveyed through the use of digital technologies, but only through an engagement with the physical object.

Augmented Reality, Augmented Virtuality, tangible interaction and ubiquitous computing are all research areas that originated with the purpose of reducing this separation. The first technologies that merged the real and the virtual world did that from a visual point of view and have been called *Mixed Reality* technologies (Milgram and Kishino, 1994; Milgram, Takemura et al., 1994). The concept of Mixed Reality can

be better expressed through a graphical representation showing the *Reality-Virtuality Continuum* (
Figure 9), with the *Real Environment* located at one extreme and the *Virtual Environment* at the opposite side.

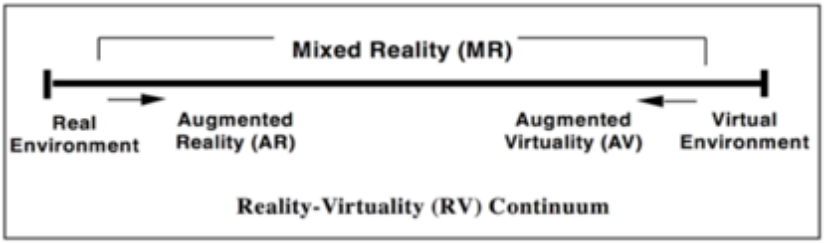

Figure 9 The Reality-Virtuality Continuum (source: Milgram, Takemura et al., 1994).

At the left side of the continuum lies the Real Environment, "any environment consisting solely of real objects and includes whatever might be observed when viewing a real world scene either directly in person […] or via some sort of a video display" (Milgram, Takemura et al., 1994). In the case of museums, this corresponds to the classic visit, consisting in walking through the rooms and looking at the real objects on display, reading panels or labels. At the opposite pole of the continuum stands the Virtual Reality environment, any "environment consisting solely of virtual objects, example of which would include conventional computer graphic simulations, either monitor-based or immersive" (Milgram, Takemura et al., 1994). In the CH sector, applications of this kind include classical devices like multimedia kiosks, mobile apps implementing the traditional GUI (Graphical User Interface) approach and immersive virtual reality systems. These systems are particularly useful for showing reconstructions of artworks or environments that are not existing anymore (Figure 10), for showing details of objects otherwise not easily visible and for their attractive power as divulgation and storytelling tools in alternative or in addition to classic media (Figure 11).

Figure 10 Virtual reconstruction of the hypothetical architecture of the Arrigo VII monument in the Pisa Cathedral (source: Baracchini et al., 2004).

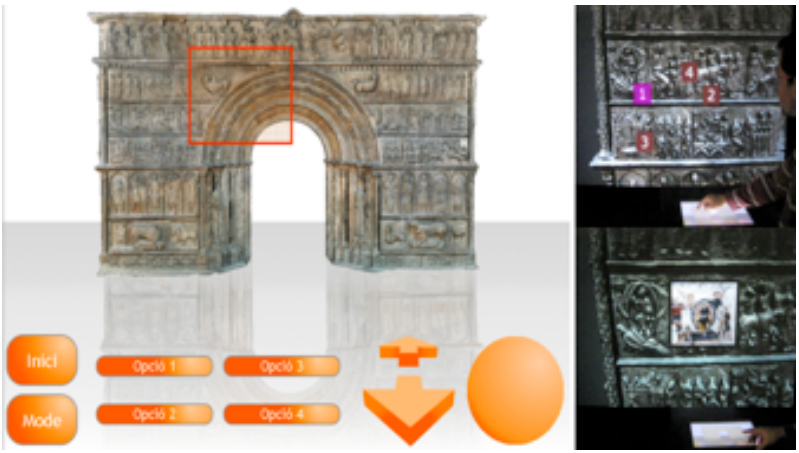

Figure 11 Graphical interface of a VR kiosk in National Art Museum of Catalonia allowing the visualization of the details and information about the "Portalada" of Ripoll Monatery (source: Callieri et al., 2011).

Between the two extremes of the continuum lays *Mixed Reality* in its different possibilities. In *Augmented Reality* systems, the real environment is augmented by overlapping digital information to it. Examples of augmented reality systems in the CH field have been implemented that make use of wearable devices (Figure 12), mobile devices (Figure 13), projections on display cases (Figure 14) or directly on the objects (Figure 15).

Figure 12 In *Archeoguide* the visitor wears a head-mounted display to see augmented reality reconstructions of the original appearance of monuments when exploring an archaeological site (source: Vlahakis et al, 2002).

Figure 13 Mobile Augmented reality app superimposing information on architectures in Darmstadt's Jugendstil (Art Nouveau) quarter (source: Keil et al, 2011).

Figure 14 Teche Parlanti at the Museo Cerite in Cerveteri (Italy). Information and animations are projected on display cases containing the real objects (source: Minelli, 2013).

Figure 15 In the *Revealing Flashlight* the original colour is projected directly on the object in the area interactively chosen by visitors (source: https://vimeo.com/109284410).

In *Augmented Virtuality*, instead, the virtual environment is augmented by overlapping direct representation of reality to it (Figure 16).

Figure 16 Example of an augmented virtuality system. The user wears a video-see-through HMD that allows him to explore a virtual museum environment that integrates a visualization of his real hands (Steinicke et al., 2009).

Although the notion of *Mixed Reality* and *Reality-Virtuality Continuum* originated years before the advent of tangible interaction, they have also been used later with reference to it. However, different locations in the continuum have been suggested for tangible interaction. On the one hands, some authors suggest that tangible interfaces should be considered part of the Augmented Virtuality concept because they consist of physical elements that are embedded in a virtual world and are used to control it (Couture et al., 2009). On the other hands, other

authors locate tangible interaction more on the left extreme of the continuum between Real Environment and Augmented Reality (Pridmore et al., 2007). For them, tangible interfaces would represent an additional move forward towards the reality compared to augmented reality, as tangible interfaces allow to manipulate digital data through physical object while augmented reality usually just overlay digital data on the real world.

This lack of agreement regarding the position of tangible interaction on the continuum is arguably determined by the fact that the virtual-reality continuum was developed for classifying different types of *visual* displays and, for this reason, only the aspect of visualization was taken into account. Tangible Interaction, instead, concerns primarily the aspect of interaction. It refers to a form of interaction that is done through physical objects (that are not the generic devices like the mouse, the keyboard, the joystick or a smartphone) or the body. As such, tangible interaction can find its application to all the visual systems outlined in the continuum: Virtual Reality, Augmented Virtuality, Augmented Reality. For instance, the integration of tangible interaction and virtual reality allows the user to use tangible objects to interact with the virtual world (Figure 17). Instead, by integrating tangible interaction with augmented reality, *tangible augmented reality* systems are obtained. Different tangible augmented reality systems exist (Figure 18; Figure 19) but have in common the fact that they combine the display possibilities of augmented reality with the manipulation of physical objects.

It is important to point out, though, that the visual aspect is not to be necessarily coupled with tangible interaction, as the interaction with the object can result in other behaviours (like audio, haptic, etc.) and that these behaviours can be incorporated inside the object itself going beyond the traditional concept of Augmented Virtuality and Augmented Reality and towards that of ubiquitous computing[23] (e.g. Figure 20).

To conclude, tangible interaction can be considered in all respects as a mixed reality technology in the sense that aims to merge the digital and physical world. However, tangible interaction as such makes this merging at the level of interaction and not at the level of visualization. Tangible interaction is centred on a "realism of behaviour" more than a "realism of appearance" (Pridmore et al., 2007).

[23] The expression "Ubiquitous Computing" was coined in 1990s by Mark Weiser (1991). It refers to the embedment of computational elements and digital components into everyday physical objects, portable devices and the built environment.

Figure 17 *Real Virtuality* is an application that allows visitors to explore an Egyptian tomb, to touch tangible objects like a tangible torch (having a digital counterpart in the virtual world) to illuminate their surroundings or other elements of the stage set, and also to interact with other visitors (source: Chagué, 2015).

Figure 18 By manipulating tangible objects (cards), the user interacts with 3D virtual objects in a wearable augmented reality system. (source: Billinghurst et al., 2008).

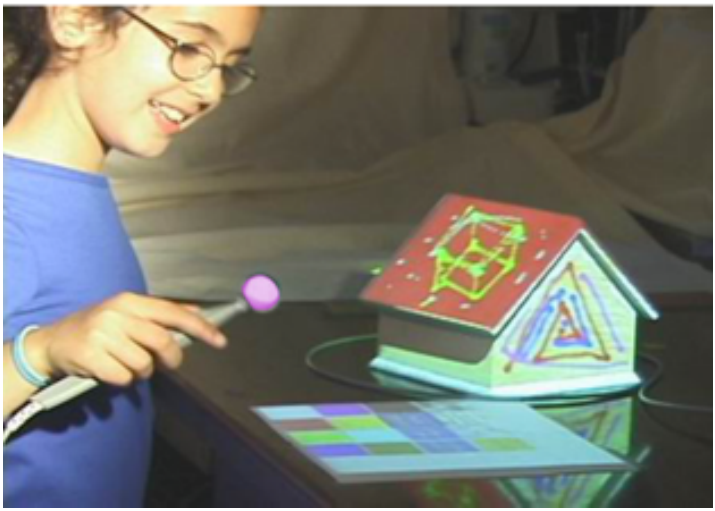

Figure 19 Tangible augmented reality systems making use of multiple projectors, to allow the user to paint on movable objects. The colour palette and the colour on the tip of the paint brush are projected (source: Bandyopadhyay et al., 2001).

Figure 20 "Touch of Kandinsky" consists of a carpet reproducing the motif of the Kandinsky's painting *Group* from 1937. Walking on or touching the carpet, sounds are triggered that are inspired to Kandinsky writings on synaesthesia (source: Gottlieb et al., 2007).

2.2 Definition of tangible interaction through a short history of its development

Tangible Interaction is today considered as an umbrella term embedding several meanings coming from the different disciplines (namely Computing and HCI, Product and Industrial Design, Arts) that over time have carried out research in the field. Retracing the history of its development can help to understand how and why nowadays a variety of different technologies have come to be included in the notion of tangible interaction[24].

The origins of tangible interaction can be traced back to the mid/late 90s in the Computing and HCI field, when George Fitzmaurice, in collaboration with Bill Buxton and Hiroshi Ishii, introduced the notion of "Graspable User Interface", developing a system where graphical representations were manipulated using multiple graspable objects with a strong-specific functionality, instead of using generic input devices like the mouse (Figure 21). This concept was further explored by Hiroshi Ishii and the Tangible Media Group at MIT, and evolved into the notion of "Tangible User Interfaces" (TUIs) (Ishii et al., 1997). The idea underlying the notion of Tangible User Interfaces was to represent digital content (data or operations) through tangible objects (referred to as tokens). These tangible objects could be manipulated by the users with their hands, in this way bridging the gap between cyberspace and the digital environment. One of the systems developed by the Tangible Media Group was URP (Figure 22), a system for urban planning consisting of a projected table surface and physical tokens representing buildings, properties of the building (e.g. materials), other properties (e.g. time of the day, wind speed, etc.). Placing physical tokens on the table, a digital simulation of shadows and pedestrian-level wind flow is obtained.

24 A summary of this history is provided by E. Hornecker in (https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/tangible-interaction). This reference is used as main source for the following part of this paragraph.

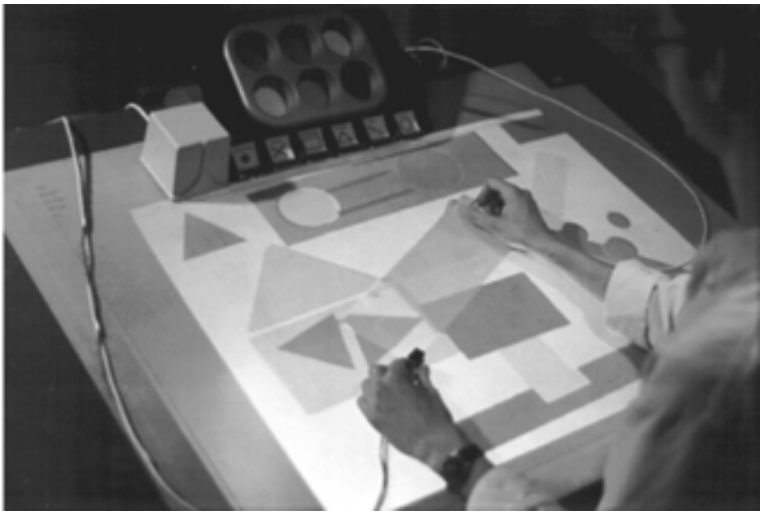

Figure 21 The GraspDraw system makes use of graspable bricks to interact with graphical representations (source: Fitzmaurice et al., 1995).

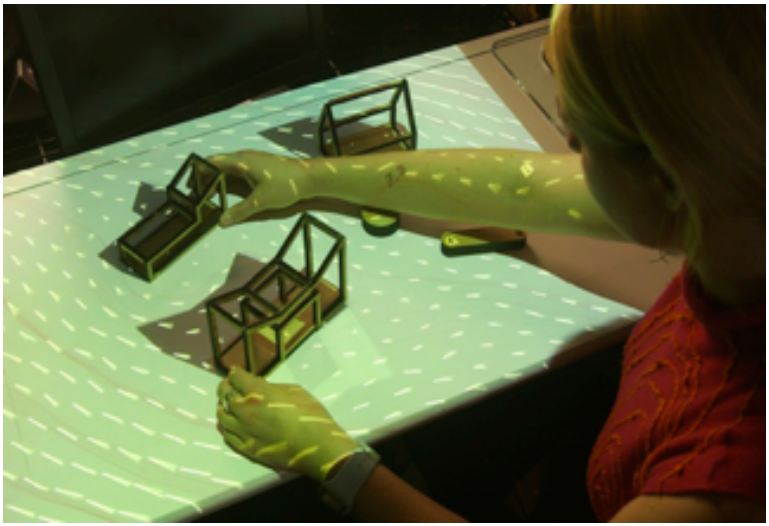

Figure 22 URP, a tangible system for urban planning (source: Underkoffler et al., 1999).

Soon after, in a world where appliances had become increasingly 'smart', also product designers became involved in the design of products merging the physical forms and digital content/behaviours. Around the early 2000s some product designers showed a sense of dissatisfaction with regards to the interaction style most electronic products presented. They noticed how all electronic devices often consisted of similar controls (buttons, sliders, rotary pots) requiring the same repertoire of actions (pushing, sliding, rotating). In addition, they noticed how these actions were arbitrary with respect to the functions that they activate and the different functions are communicated through icons and text labels, applying the so-called semantic approach (Figure 23). In other terms, only appearance was considered as carrier of meaning while the action was arbitrary. Unsatisfied with this situation, product designers claimed for a balance between appearance and action-potential as carriers of meanings. They started to design products where controls communicated their purpose directly though their form and also the actions they required. In the videodeck developed by Djajadiningrat (2004) (Figure 24), for instance, physical controls are designed with different forms and actions according to their purpose and integrate themselves within the mechanism of the device to make clear the specific function of the control. For example, the video-in and video-out sockets are differentiated in form to make it clear which is the input and which is the output; the play button is replaced by a play-slider put on the right-side of video-deck where the video-out signal comes out; while the record slider is placed on the left-side where the video-in signal comes in.

Figure 23 Example of a Espresso machine using buttons, labels, and actions similar to other kinds of products (source: Djajadiningrat, 2004).

Figure 24 Videodeck. Design: Tom Djadiningrat. Controls are integrated in the mechanism of the product and communicate their purpose directly through their form and action potential (source: Djajadiningrat, 2004).

Moving these considerations to the near field of tangible interaction, product designers criticized the data-centered approach carried on by computer scientists. This approach put the emphasis on the physicality of the objects that were created to represent and manipulate digital data and had led to tangible interaction systems with similar look and feel (similar tokens to manipulate data, same repertoire of actions). By contrast product designers claimed for a more perceptual-motor-centered approach, where the emphasis is put more on the richness with which physical objects can address human perceptual motor skills (Djajadiningrat et al., 2004), and in the meaningfulness of appearance and interaction with physical objects (Djajadiningrat et al., 2002). As pointed out by Jensen (2005) "Thus, our interest is in actions, instead of the representation of information". The greatest focus on the interaction with the physical object, rather than on the physicality of objects in itself, makes product designers prefer the term 'tangible interaction' to 'tangible user interfaces'.

More or less in the same years, tangible interaction became of interest also for the artistic and architectural field in the context of interactive installations, that is, 'interactive spaces' that reacted to visitor's behaviour (Bongers, 2002). In this context the notion of tangible interaction widened to include whole-body movements in the space with or without physical objects. One of the first examples of interactive spaces was the Water Pavilion, built in Neeltje Jans island (the Netherlands) in 1995-1997 consisting of two building, the Salt Water

Pavilion designed by the Dutch architect Kas Oosterhuis's studio and the Fresh Water Pavilion, designed by Lars Spuybroek (Figure 25). In the Water Pavilion visitors could make experience of the beauty and importance of the water, through lights, colours, images and sounds that emerged in the building when they went around and made actions and movements.

Figure 25 The Salt Water Pavillion (source: http://onl.eu/projects/salt-water-pavilion).

Summarizing, nowadays the expression tangible interaction includes three different views (Hornecker, 2006). These are:

- the *data-centered view* pursued by Computer Science and HCI: it puts the emphasis on "tangible user interfaces" offering a physical representation of digital data and "allowing users to quite literally grasp data with their hand" (Shaer et al., 2010);

- the *expressive-movement-centered view* pursued by Product and Industrial Design*:* it puts the focus more on the type of interaction performed with the object than on form and appearance of it. This view emphasized bodily interaction with objects, exploiting the "sensory richness and action potential of physical objects" (Djajadiningrat, 2002) so that "meaning is created in the interaction" (*Ivi*);

- the *space-centered view* originating from Art and Architecture: it puts the focus on "interactive spaces" that combine physical space and objects with digital displays or sound installations and that use full-body interaction.

With regards to the last view it is important to point out that, some authors prefer the expression *embodied interaction*[25] to tangible interaction[26]. Because of this, the TEI conference[27], one of the most important in the field, changed its name from "Tangible and Embedded Interaction" to "Tangible Embedded and Embodied Interaction".

2.3 Tangible Interaction frameworks

If research on tangible interaction has first focused on developing new systems, later on a move towards the development of concepts and theory can be detected. This has led to the creation of theoretical frameworks. A detailed literature review of the existing tangible interaction frameworks is provided in Mazalek et al. (2009) and Shaer et al. (2010). In this paragraph an overview of the different types of frameworks is provided based on these sources. As illustrated in Mazalek et al. (2009), several frameworks have been created serving different purposes (abstracting, designing, building) and looking at different aspects of tangible interaction they address (technologies, interactions, physicality, domains, experiences).

The "frameworks for abstracting" are the more conceptual ones and are generally built looking at what has been done in the past. These include: conceptual models about tangible interfaces, illustrating their core elements and properties (Ullmer and Ishii, 2001; Shaer et al., 2004); categorizations and taxonomies of different types of tangible interfaces (Ullmer et al., 2005; Fishkin, 2004); ways of mappings or couplings between the physical world and the digital world (Ullmer and Ishii, 2001; Holmquist et al., 1999; Koleva et al.; 2003; Fishkin, 2004; Wensveen et al., 2004). Besides, some domain-specific frameworks have been developed especially regarding the learning area. In this domain,

[25] The notion of embodiment has become particularly prominent in Human Computer Interaction since the publication of the book *Where the action is* (Dourish, 2001). Marshall et al. (2013) provides an overview regarding the application of the notion of embodiment to HCI.

[26] https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/tangible-interaction

[27] http://www.tei-conf.org/

there are frameworks trying to categorize tangible interfaces for learning (Marshall et al., 2003; Zuckerman et al., 2005) or investigating how different kinds of couplings between digital information and physical artefacts affect it (Price, 2004) [28]. Even though many of these frameworks have been created mainly with the purpose of understanding and organizing the past and to build a vocabulary of terms related to tangible interaction, they can be used also as tools for thinking by designers. They provide designers with an overview of the past and thus an inspiration for the future.

The "frameworks for designing" are those explicitly built to provide tools for thinking for designers. They can be thought as "skeletal structures within which designers can work to develop their own systems" (Mazalek et al., 2009). While most of the frameworks for abstracting focuses just on TUIs (tangible user interfaces), many frameworks for designing are focused instead on the broader fields of sensor-based and tangible interactions. Some frameworks provide guidance to address design challenges of sensing systems from a communication point of view (Bellotti et al., 2002) or with a special attention on the aspects to consider when designing the social engagement with and around tangible interaction systems (Hornecker et al., 2006). Other frameworks are focused on how to design actions with sensor-based systems. In particular, there are frameworks providing classifications of physical movements that can or cannot be sensed by a system (Benford et al., 2007); others provide considerations that can inform the design of the coupling between actions and effects to achieve specific goals (Rogers et al., 2006; Wensveen et al., 2004) or heuristics for integrating spatiality into TUIs design (Sharlin et. al., 2004). Design frameworks that focus on the specific learning area have also been developed. The Child Tangible Interaction framework developed by Antle (2007) provides a series of design guidelines that focus on spatiality and on the coupling between physical and digital aspects.

Finally, there are the "frameworks for building". They provide more concrete steps, heuristics and guidelines for creating tangible interaction systems. Most of these frameworks consist of software/hardware toolkits supporting the technical implementation of tangible systems. Examples of toolkits are Phidgets (Greenberg et al., 2001), iStuff (Ballagas et al., 2003), the Calder Toolkit (Lee et al., 2004), Papier-Maché (Klemmer et al., 2004). Some toolkits like d.tools

[28] On the topic of whether and how tangible interfaces can support learning see also (Marshall, 2007) and (O'Malley, 2004).

(Hartmann et al., 2006) and CookieFlavors (Kimura et al., 2007) not only support "implementation tinkering" but also "design thinking".

What emerges from this literature review is that so far no frameworks have been developed for the specific CH domain[29]. The application of the existing frameworks to the CH field, sometimes possible, comes however with some limitations.
First of all, some of the frameworks have been built following the data-centered view pursued by Computer Science. For this reason, they are often very technical and focused on TUIs, a limited subset of tangible interaction. In addition, being developed outside the cultural heritage field, inevitably they do not necessarily consider aspects that are instead fundamental in this delicate domain or consider them in a too generic way to be really useful.
The CH and museum field is indeed one of the most complex domain of application for HCI. Different kinds of cultural heritage places exist (from museums to open-air spaces) as well as different kinds of cultural heritage objects. In addition, museums and cultural heritage sites are characterized by a strong variety of visitors demanding for different kinds of experiences. This has led researchers and practitioners to explore various kinds of learning styles, various modes of social engagement and participation, as well as to implement different personalization strategies that exploit the use of interactive technologies. Besides, it is important to consider that in the cultural heritage field the main focus should be put on the objects and that technologies should enhance the experience of them without substitute them. Therefore, considering the relationship between the interactive installation and the physical object becomes paramount, as different design choices can determine the level of distraction from the object on display. A framework that aims to classify or guide the design of tangible interaction systems in the cultural heritage domain should take all these aspects into account.

[29] Also looking for frameworks developed in the more recent years not covered by the literature reviews developed by Mazalek et al. (2009) and Shaer et al. (2010), no frameworks developed for the specific field of CH have been identified.

2.4 Research about tangible interaction in museums and cultural heritage sites

The application and study of tangible interaction is quite recent in the CH field, dating back to the early 2000s. Since then, several projects have been designed and implemented both in the research field and museum practice. A strong contribution to the field has come in particular from two European projects that have dealt with the topic of tangible interaction. The first European project that has been carried out in this field is SHAPE (Situating Hybrid Assemblies in Public Environment), coordinated by KTH Royal Institute of Technology and involving other three partners (King's College London; The University of Nottingham; University of Limerick) (Bannon et al., 2005). The project was part of the European Disappearing Computer (DC) initiative, a EU-funded initiative whose mission was "to see how information technology can be diffused into everyday objects and settings, and to see how this can lead to new ways of supporting and enhancing people's lives that go above and beyond what is possible with the computer today"[30]. In particular, the SHAPE project aimed to develop assemblies of hybrid, mixed reality artefacts in public spaces like museums and exploratoriums through participatory design with museum professionals, and to examine how the visitors interact with exhibited artefacts and each other through social scientific methods. Although tangible interaction was not the specific and only focus of the project (that covered all mixed reality technologies that allow to link digital and physical spaces), tangible interaction was in fact included in the project. Two public exhibitions were developed in museums to demonstrate the technologies developed in the SHAPE project. The first exhibition took place at Nottingham Castle in 2002 (Fraser et al., 2003), while the second one, titled "Re-Tracing the Past: exploring objects, stories, mysteries" took place in 2003 at the Hunt Museum (Limerick) (Ferris et al., 2004). SHAPE represents a pioneering project whose merit in the cultural heritage field has been of having addressed the issue of the distraction from the physical object determined by traditional uses of technologies, experimenting with mixed reality technologies and strategies that are able to connect the physical and digital aspects of the experience. In addition, these solutions have been tested through evaluations with real visitors, so that some design guidelines for the development of similar experiences have emerged. In the context of SHAPE, Ciolfi et al. (2005) have explored how the theoretical notion of *place* as developed from humanistic geography (which includes the

[30] http://cordis.europa.eu/ist/fet/dc2-in.htm

physical aspect but also the personal, social and cultural dimensions), can be beneficial for the design of technologically-enhanced physical spaces[31].

Another European project dealing with tangible interaction is the meSch project[32] (Material EncounterS with digital Cultural Heritage) that started in 2013 and lasted four years (Petrelli et al., 2013). The project was coordinated by the Sheffield Hallam University and included twelve partners from six European countries. The goal of the project was exploring new prototypes and templates of tangible interaction with the aim of bridging the gap between heritage holdings and digital content (often available in digital repositories), and also searching for ways to empower CH professionals to create such tangible heritage experiences. This meant creating a simple hardware and software platform that allows them to conceive, design, make, and maintain interactive artefacts (Figure 26). As part of the project different smart objects were designed (
Figure 27), that is, physical objects people can interact with and through doing so certain behaviours or reactions are activated (e.g. activation of sounds, information delivery, etc.). These prototypes were used to populate the toolkit with blueprints that can be customized by future users.

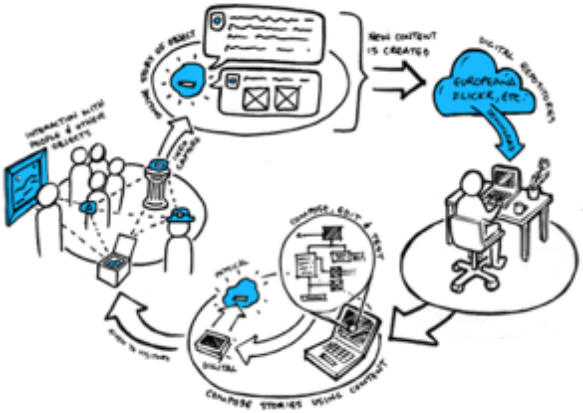

Figure 26 The process of designing, making, and using smart objects and spaces in the meSch project (source: Petrelli et al., 2013).

[31] For a broad theoretical overview on the concepts of *space* and *place* and how these have been used in the interaction design field see (Ciolfi, 2013a).
[32] http://mesch-project.eu/

Figure 27 Examples of prototypes created by the meSch project: an interactive loupe (top), an interactive book (bottom). Source: (source: meSch project, 2015a; Ciolfi et al., 2013b).

A great merit of meSch is also having studied deeply the application of co-design methodologies for the creation of interactive installations in cultural heritage sites and museums. Indeed, all the concepts and prototypes were the result of activities involving different professionals and stakeholders. These can include industrial and product designers, social scientists, technology developers, but also cultural heritage professionals like curators, educators, heritage volunteers and possibly the final visitors. The idea underlying the co-design concept is that "the

different expertises and points of view complement each other and guarantee the best possible outcome for all parties involved"[33]. Ciolfi et al. (2016) reports some reflections about co-design in museums analysing two participatory processes. A co-design booklet complemented by a co-design website was developed based on the meSch case studies in order to provide templates and guidelines for running co-design workshops (meSch project, 2015a).

Beyond the SHAPE and the meSch projects, other projects have been carried out in the last fifteen years both in the research field and museum practice[34]. These have resulted in a strong variety of systems that seems to characterize the field today. One of the purpose of this research is trying to understand this complexity by developing a conceptual framework of the field. This will be one of the topics of the next chapter.

[33] http://mesch-project.eu/co-design/
[34] A detailed description of the various projects can be found in the Appendix.

Chapter 3

Towards a conceptual and design framework for tangible interaction in museums

Following the early applications of tangible interaction to CH, many projects have emerged in the field as part of research or commercial activities. However, up to now no attempts have been made to take stock of the situation in its complexity, to understand what tangible interaction is in the CH domain and what kind of experiences it enables. Similarly, there have been no attempts to formalize the aspects that characterize the design of such systems.
This research represents a first attempt to fill these gaps through the development of a theoretical framework for tangible interaction in museums. Specifically, this research aims to develop a theoretical structure that provides a conceptualization of what tangible interaction is in the CH field while, at the same time, it shows the various aspects and related choices to consider during the design of such systems. In this sense, this structure should be intended as a conceptual framework and the foundations of a design framework.
In this chapter the methodology used for the development of such a framework is described followed by a description of the outcomes and the presentation of some conclusions.

3.1 Methodology

For the generation of the theoretical framework for tangible interaction in museums a methodology has been used consisting in the collection and classification of a significant number of past tangible interaction projects[35]. In particular, the various projects have been analysed using a

[35] The decision of collecting and including as many projects as possible in the analysis, rather than focusing on a subset of most successful projects was intentional and motivated by the following reasons:
1) From a conceptual point of view, the framework was meant to be the most accurate representation as possible of what tangible interaction is. Excluding some projects

thematic analysis, combining an inductive (bottom-up) and deductive (top-down) approach aiming to identify categories (or themes) and subcategories (or subthemes) in the projects. The thematic analysis is a qualitative research method that is used "for identifying, analysing and reporting patterns (themes) within data" (Braun et al., 2006). Although it is a method often used for the analysis of interviews (*Ivi*), it is applicable to the qualitative analysis of different types of data when the goal is to identify patterns in the data, categories, and themes. In the context of this research, data has to be intended as tangible interaction artefacts developed as part of research or commercial projects and described in research publications or other documents. Besides showing what tangible interaction is, the categories and subcategories being developed by means of this analysis represent aspects characterizing the design of a tangible interaction system, and related design choice options. A more detailed description about the way projects have been collected and analysed is presented below.

3.1.1. Collection of projects

As part of this research, both academic projects (i.e. projects developed as part of academic research), and non-academic projects (i.e. projects made by design and ICT companies independently or on commission by museums or projects developed directly by museums) were gathered.

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from the analysis would have led to build a distorted image of what tangible interaction is in the CH domain.

2) From a design point of view, at least at this stage, the framework was meant to suggest all possible design strategies currently existing with regards to the various aspects characterizing a tangible interaction installation. Excluding some projects from the analysis (trying to focus on a subset of "good" projects) would have led to exclude some design possibilities, that even though they did not work in a specific project, they could work in other projects (in combination with different choices related to other aspects).
In addition, assessing the quality of the projects would not have been an easy task. Evaluation data is missing for many projects, evaluation criteria or metrics are generally different in different projects, making the data difficult to compare. In addition, defining what makes a project good and worthy to be included in the analysis would not have been easy. Generally, a project is not all good or all bad, therefore excluding a project because of a "negative" characteristic would lead to exclude also positive aspects of it from the framework.
For these reasons, it was decided that the best option was to create a framework that suggests the various aspects to consider in the design and all possible design strategies currently existing. It is up to the sensitivity of the designers to assess which strategies could work better in their projects.

The research projects were collected through Internet-based search, consulting publication databases, international projects websites or deliverables, and using the Question and Answer service of the ResearchGate network. Therefore, the collection represents a quite complete survey with regards to research projects that have been described in the media specified above gathered until the end of 2015.

The situation is more complex with regards to non-academic projects. These projects can only be easily collected through the websites of the different companies that created them, through websites of museums that commissioned them, or through direct knowledge or oral reports by people. This makes almost impossible to make a complete survey or even to construct a representative sample of them. Since the main purpose of this research is not to carry out a statistic examination, but to better understand the possible typologies of tangible interaction experiences in the CH sector, also non-academic projects have been included in the collection, as their inclusion can help to generate a more complete overview of the field.
Another clarification to make is that the kinds of projects selected for the analyses will include:

- projects that have been actually installed in museums or exhibitions after design and implementation;
- projects that have been designed and implemented for the museum sector even though they have not been actually tested and installed in a museum environment but just in research laboratories;
- projects that have not been specifically designed for the museum sector but whose relevance for the museum sector has been recognized by the authors.

3.1.2. Creating a Classification System: goals and variables to be considered

After collecting the projects and the data about the projects, for the purpose of creating the classification, a cataloguing approach must be defined. As stated by J. Mason (2002) in her book *Qualitative Researching*, "cataloguing or indexing systems are not analytically neutral. In other words, in choosing or devising a particular system, you are at the very least making certain assumptions about the kinds of phenomena you are cataloguing and the kinds you are not (and indeed what count as data and what do not), as well as in what form you will

be able to retrieve them later on. In fact, you are likely to be making a whole series of further assumptions too, the consequence of which will be to open up to analytical possibilities, and to close off others".
As specified previously, the main purpose of the classification in this research is to provide an outline of how tangible interaction has been employed in the CH field and, at the same time, to identify the aspects that characterize the design of such systems and around which choices have to be made during the design process.
For the purpose of this research it is thus fundamental to consider several different aspects when analysing the projects and developing the classification. These aspects include:

- those related to the cultural assets the installation aims to communicate or enhance (e.g. cultural asset types, location, strategies used to foster the experience of the original object);
- those related to the interaction (e.g. interaction styles, tasks and actions, interaction devices; output types and locations);
- and other aspects, such as learning approach, social engagement, participation and personalization.

In addition, it is important to keep a record of additional information that can help in the analysis of the projects like years of creation, type of projects (i.e. academic or non-academic), type of target, developers, locations.

The classification has thus been developed by using a thematic analysis combining a bottom-up and a top-down approach. This means that some categories have emerged dynamically from the observation of the projects (bottom-up approach), while other categories have been borrowed or readapted from categories developed especially in the museum studies literature (top-down approach) that deals with relevant aspects such as learning approaches, social engagement and participation. The top-down approach is particularly useful for identifying gaps in research. Indeed, the latter may possibly allow for the identification of characteristics that have not been experienced yet in the development of tangible interaction systems in museums but whose theoretical existence is known.

In order to support the storage of the information related to the categorization of the projects and facilitate the subsequent analysis of the data, during the process of classification a spreadsheet software was used, then substituted by a relational database. More details about the classification process are presented below.

3.1.3. The classification process

For the development of the catalogue a long iterative process has taken place, in which the catalogue structure, the categories and the subcategories, have been refined as more projects were added to the analysis and as a better understanding of the reality was gained. Whilst a detailed description of the process can be overlooked for the sake of simplicity, it is anyway important to shed light on some major restructuring steps that have taken place during the analysis.
In the first phase, the various collected projects have been analysed with the support of a spreadsheet that allowed to record categories and subcategories emerging during the analysis as well as to record and show how the various projects fell in these categories. (Figure 28).

Project		references	kind of project: research	kind of project: industry	main target: general public	main target: disable people: people with learning disabilities	main target: disable people: blind/visually impaired people	single/multi-interactives installation: single	single/multi-interactives installation: multi: diverse istanze della stessa modalità di interazione in punti diversi	single/multi-interactives installation: multi: più istanze identiche della stessa installazione	single/multi-interactives installation: multi: assembly	location: indoor: lab	location: indoor: historical building/bespoke building (i.e. museum)	location: outdoor: urban environment	location: outdoor: natural environment (park, gardens, landscapes)	Type of the main cultural(natural) heritage asset the installation refers to [-]: Tangible heritage: Works of art	Tangible heritage: Artifacts	Tangible heritage: natural objects	Tangible heritage: Architectures/buildings	Intagible assets/heritage, a concept, oral history	location of main original object: original object embedded in the installation	original object present in the museum/heritage site	in another place (i.e. other museums, places etc.)	ephemeral	no longer existing	interaction device: interaction through an object	interaction through the body	form of the interactive object: main original object or a derivative of it: "smart object" (smart environment)	"smart replica"	"smart derivative"	another cultural object or a derivative of it: secondary "smart object"	secondary "smart replica"	secondary "smart derivative"	bespoke object/s
"Le Cabinet des Fable"	2011	http://www.erasme.org/Strat	•		•				•				•				•		•		•					•	•	•						
"Voice from the Trenches", meSch project	2015	http://shura.shu.ac.uk/10427/1/IJHCS-trenches-sound-design-after-reviews.doc.pdf	•		•				•						•		•				•													•
"Sheffield General Cemeteries", meSch project	2013	http://repo.nodem.org/uploads/Exploring%20historical,%20social%20and%20natural%20heritage.pdf https://www.youtube.com/watch?v=GP0wAPO84Qo	•		•				•						•		•				•													•
"Whispering Table", Jewish Museum of Berlin	2009	http://www.thegreeneyl.com/whispering-table		•	•			•					•							•				•		•								•
"Frammenti di memoria", San Martino di Sorli in Val Borbera (Alessandria)	2005	http://gabrielrapetti.com/frammenti-di-memoria/		•	•				•				•				•				•					•		•						
"The Really Simple Object Recognition Anglo-Saxon Table"; Maidstone Museum and Bentlif Art Gallery	2014	https://www.youtube.com/watch?v=tUBVwJzFHn8		•	•			•					•				•					•				•						•		

Figure 28 Part of the classification table as emerged during the initial analysis of the collected projects.

Some drawbacks of this approach emerged soon and, with it, the necessity of thinking of a different structure for the data. The major flaw of this approach was that it put all the projects on a same level, considering them as similar and comparable entities, while in reality they did not in several cases. Indeed, some projects proved to be made of single interactive stations while others were made of more interactive stations more or less integrated between them. In addition, a single interactive station could encompass several different tangible user interfaces with different characteristics and behaviours that needed to be analysed separately. Besides, some of the categories being developed were more logically related to sub-components of the installation rather than to the overall installation. Finally, the way data was organized did not facilitate data retrieval, exploration and analysis.

What was needed was a model of representation of reality that embraced this complexity, and that allowed to consider and analyse the different entities that make up a tangible interaction installation and their inter-relations. In other words, a structure that took into account the different levels of granularity in which a tangible interactive installation can be analysed was needed.
Useful tools for representing inter-relations between entities in a given domain of knowledge come from computer science and are the *Unified Modeling Language diagrams* (UML diagrams) and the *Entity-Relationships diagrams* (E-R diagrams). They allow for an abstract representation of reality allowing to represent things of interest and the relationships existing between them (conceptual data modelling). An important advantage of using these diagrams is that through a simple operation (logical data modelling) they can be easily translated into a structure to be implemented as a relational database, in this way facilitating further data retrieval, data analysis and sharing.

In Figure 29 a UML diagram[36] representing the reality of tangible interaction systems developed for museums is shown.

[36] The UML notation has been chosen for greater familiarity but could be translated easily in a E-R model by changing the notation.

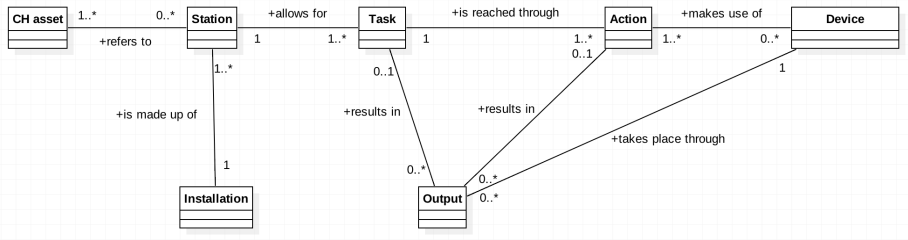


Figure 29 UML diagram representing the reality of tangible interaction systems in museums.

The diagram identifies seven main entities that are:

- *Installation*: it is the biggest unit of analysis and represents a tangible interaction installation. As shown in the diagram an installation can be made up of one or more interactive stations[37].

- *Station*: it is a single "point of interest" in a tangible interactive installation (where other stations might also be present). Although it happens sometimes that similar - if not identical from a technological point of view - stations can be found instantiated in different installations/places, it has been decided to consider them as different stations, as different will be the location, the relation with the environments, with the exhibited objects etc. For this reason, a certain station is associated to only one installation. A certain station refers to one or more CH assets, and supports one or more tasks.

[37] It is important to notice that some ambiguity can raise when trying to discern between installations and stations, in the case of more interactive systems located in the same place. Must these systems be considered as separate single-station installations or as stations belonging to the same installation? While it is impossible to set objective criteria, in this thesis it has been decided to consider as belonging to the same installation those stations that present an integration that goes beyond the purely thematic one or the fact of belonging to the same place.
In addition, in the case of identical installations installed in different places or exhibitions, it has been decided to consider them as different and as such needing to be analysed separately. Indeed, the concept of installation is considered as something that goes beyond the pure technological aspect, and that is instead strictly linked to the concept of environment. On the light of that, two identical technological installations placed in different environments are to be considered as different.
Even more so, two installations that are similar from a technological point of view but are referred to different cultural heritage objects have to be considered as different and analysed separately.

- *CH asset*: it refers to a CH asset one or more interactive stations refers to. It can be tangible (an artefact, a work of art, a monument, a building etc..) or intangible (a story, an interpretation, an oral poetry etc.). The same CH asset can serve as a reference for multiple interactive stations.

- *Task*: it is a high-level objective or activity the system allows the visitor to achieve or accomplish. It can be decomposed in sub-tasks. High-level objectives/activities refer to the general goals/activities (the "what") the user wants to reach or accomplish (e.g. get a story about an exhibited object) but not to how these are physically reached at the level of the interface. A task is materially accomplished by the visitor by carrying out one or more actions in a specific interface (e.g. touching a sensitive area of an object or approaching an object are two possible different actions the visitor might be asked to carry out in order to get a story about an object).

- *Action*: it refers to a physical action that needs to be carried out as part of a task the user wants to accomplish. A specific action is linked to one specific task but more actions are needed in order to accomplish a task. An action always involves the presence of one or more interactive devices, although not always a contact with it is required.

- *Device*: it refers to the device the person interacts with through touch, gestures or manipulation, or the device where the output is provided. It can be a traditional input/output device (a touchscreen, a mobile device, a keyboard, a mouse, a joystick, a computer screen) or it can acquire the appearance of a more traditional low-tech object (smart object). The same device can be associated to more than one action, since different actions can make use of the same object. Likely, the same device can be used as output device for different outputs.

- *Output*: It refers to the feedback provided by the system to the visitors in response to specific inputs. It can be the result of a simple input action the user has carried out using the system, or it can be the results of the accomplishment of a more complex activity (requiring more actions) which implements a task. For this reason, in the diagram the "output" has been connected both to "action" and "task". The output is always associated to a device that allows it to take place in reality.

In the following diagram (Figure 30) the entities or classes illustrated above have been detailed with the addition of some properties that characterize them. It is important to notice that while some properties have been filled out directly by examining the characteristics of the specific entity they belong to, the value of some other properties have been determined by examining the co-presence of several properties in different interrelated entities.

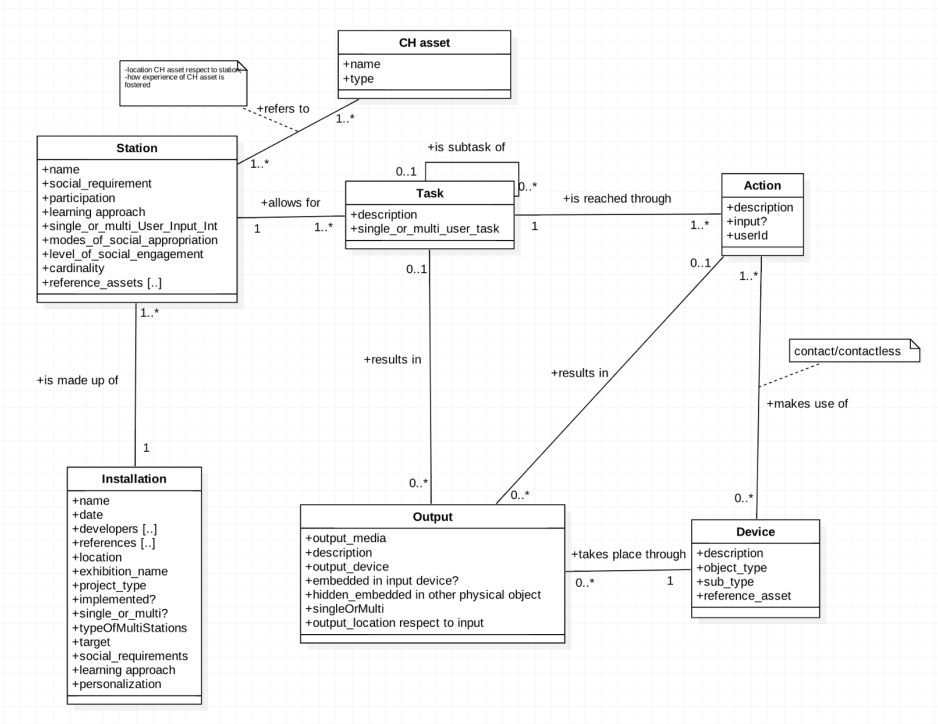


Figure 30 UML diagram representing the reality of tangible interaction systems in museums, showing entities and properties.

The representation model provided above allows for the examination of the projects under different perspectives, helping to answer questions, facilitating the process of discovery and the classification of

projects according to several aspects. The related database has been implemented using Microsoft Access[38].
A description of aspects and categories is provided in three different sections in the following pages:

- In the first section, some general observations about the project are presented (types, locations, targets, developers, etc.);
- The second section provides reflections related to the CH asset(s) enhanced by the interactive installation (types of assets, location of the asset with respect to the installation, etc.);
- The third section presents reflections related to the various elements that characterize the interactivity in the installations (like tasks, actions, interaction devices, smart objects, output).

In many cases, aspects and categories will be exemplified by referring to specific projects. Since a same project could be illustrative of more aspects or categories, in order to reduce the redundancy in the text, a description of all the projects is provided in the appendix and the reader is invited to refer to it for a complete overview of the projects. Nevertheless, some redundancy will be unavoidable. It is also important to specify that, although this research adopts mainly a qualitative methodology, during the description and discussion of the aspects and categories, results of quantitative analyses are sometimes presented. Quantitative analyses have been developed using descriptive statistics in order to quantify the presence in the corpus of characteristics identified qualitatively in the data and considered particularly relevant or suitable for this kind of analysis. The results of these analysis might be useful for the identification of some of the areas that might benefit from future research.

[38] At the moment, the database is not publicly accessible. Indeed, in the context of this research the main reason why it was created was to support the author during the analysis of the projects. However, since the database might be useful for other people working in the field, future works might regard its improvement and the implementation of its accessibility online. In addition, the database itself might benefit from its presence online by allowing the contribution from other people.

3.2 General information about the projects

3.2.1. Type of projects, years of creation

The collection includes projects coming both from academic and non-academic activities. The number of academic projects is 55 while the number of non-academic projects is 13. It is likely that being tangible interaction quite a new field, it is still mainly a research topic that has to find a concrete and diffuse application in reality. However, the way the projects have been collected does not allow to state anything with certainty regarding this difference in number. The graph (Figure 31) shows the distribution per year of the research projects in the collection. The graph shows a positive trend in the number of academic projects developed per year, allowing to state that this field is expanding more and more.

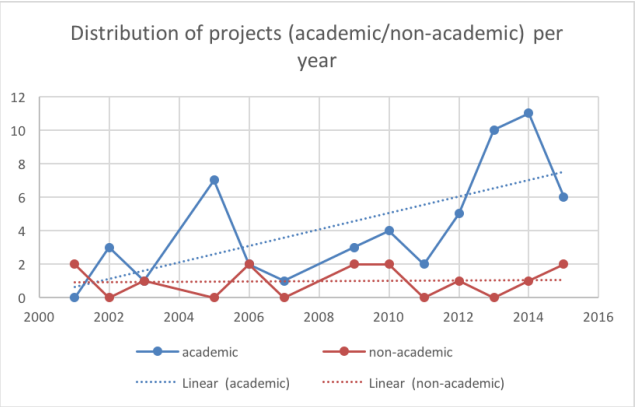


Figure 31 Distribution per year of academic and non-academic projects (colour illustration at the end of the volume).

3.2.2. Locations of projects: geography and types of locations

The following graph (Figure 32) shows the locations where the projects were installed, differentiating between academic and non-academic projects using different colours. Generally speaking, Europe seems to be the area where most of the projects were installed with a peak in countries like the UK, Ireland, The Netherlands, and Italy. A significant number of projects is located in the United States, followed by few projects located in other places, such as Canada, South America, Turkey, Qatar, Australia, Taiwan.

Figure 32 Map showing the geographic locations where the academic and non-academic projects were installed (colour illustration at the end of the volume).

Different types of locations can be distinguished: 36 museums, 7 cultural sites/monuments and 2 research labs. The majority of the projects (84%) were installed in museums, 10% in cultural sites, 4% in research labs. The data clearly shows that some museums served as locations for more projects as part of the same or different exhibitions.

3.2.3. Developers of projects: locations, types

The following map (Figure 33) shows the geographical locations of the developers of all the projects. Developers have to be intended as those institutions that took part in the design and implementation of the projects. The geographical areas with denser concentrations of developers are Italy, the UK, Belgium and The Netherlands. Different types of developing institutions can be identified and are research institutions/universities, companies and museum/cultural institutions.

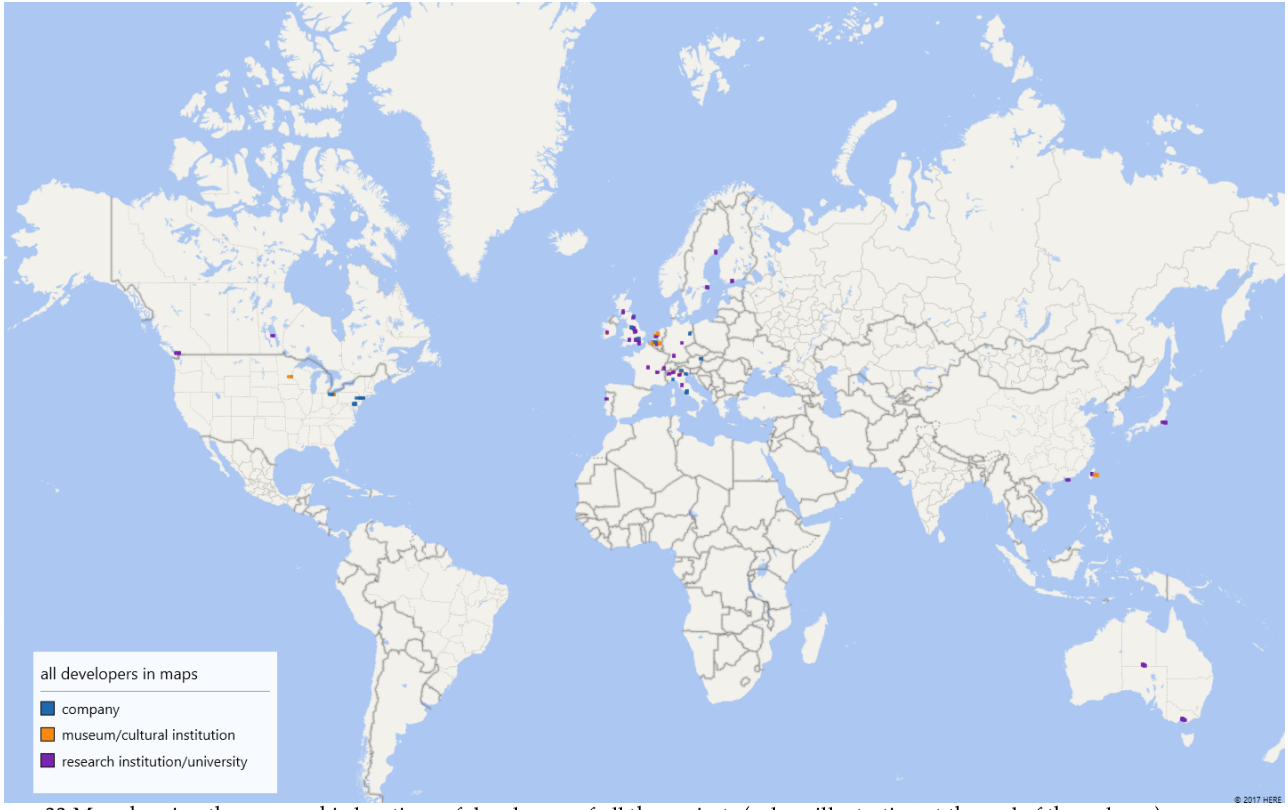


Figure 33 Map showing the geographic locations of developers of all the projects (colour illustration at the end of the volume).

As expected, the majority of developers of academic projects are research institutions or universities (73%) followed by museum institutions (17%) and companies (10%). The presence of museum and cultural heritage institutions can be motivated by the fact that more and more academic projects have been developed using co-design approaches where the museum institutions were part of the design/developer team. Moreover, companies are often present as partners in academic projects providing support for specific tasks. With regards to non-academic projects, the developers seem to be generally companies (85%), and sometimes museums developing internally the technology or co-operating with the companies (15%), although this finding has not statistical significance for the way the sample was created.

3.2.4. Target of interactive installations

Looking at the target, most of the installations are targeted to the general able-bodied public with just some of them designed specifically for children[39] (Figure 34).

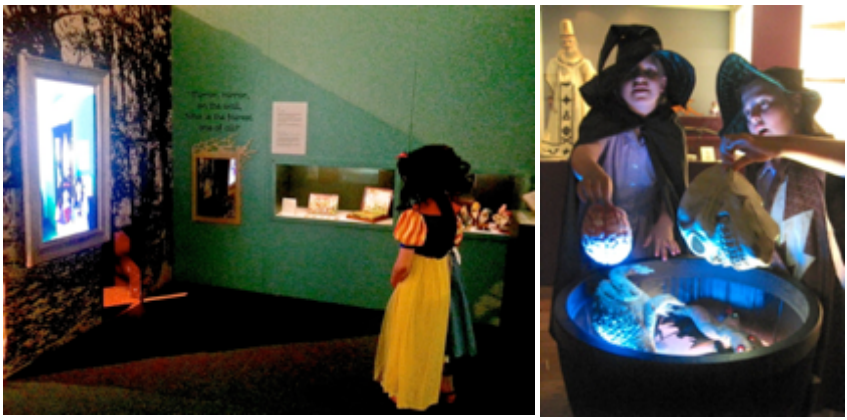


Figure 34 Magic Worlds is an exhibition about magic designed for children and includes interactive installations such as the Delay Magic Mirror and the Witch Cauldron through which children can make an active experience of magic (source: Taylor et al., 2015) [App., proj. 23].

[39] Although classifications of different profiles of museum visitors have been provided in the museum studies literature (see for example Falk, 2009) it has not been possible to apply this classification in the context of this analysis as the typology of visitors the various projects have been designed for is often not specified in the projects documentation.

There are few interactive installations that are targeted to people who have some forms of disabilities. In particular, some installations have been designed for blind and visual impaired people and aim to enrich their tactile exploration of the object (or replica) with information (Figure 35; Figure 36).

Figure 35 The "Talking Painting" at the San Diego Museum of Art. Audio explanations are activated by the visitor through the touch of a replica of the painting (source: Touch Graphics, 2015a) [App., proj. 1].

Figure 36 In Tooteko a high-tech ring is worn to trigger audio content during the exploration of a tactil e model of a cultural object (e.g. artefacts, works of art, architectures (source: Tooteko – Talking Tactile,s.d.) [App., proj. 3].

Other projects are those designed for and by people with learning disabilities. These projects aim to improve the access to and engagement with heritage and museum displays through the use of sensory objects (Figure 37). As shown in the graph (Figure 38), the interest towards the implementation of tangible interaction installations explicitly developed for children, for blind and visually impaired people as well as for people with learning disabilities has started very recently (from 2012 onward) and the majority of the projects are targeted to the general able-bodied public.

Figure 37 A "sensory box" developed by a girl with learning disabilities to share her interpretation of a visit with other people (source: Hollinworth et al., 2014) [App., proj. 53].

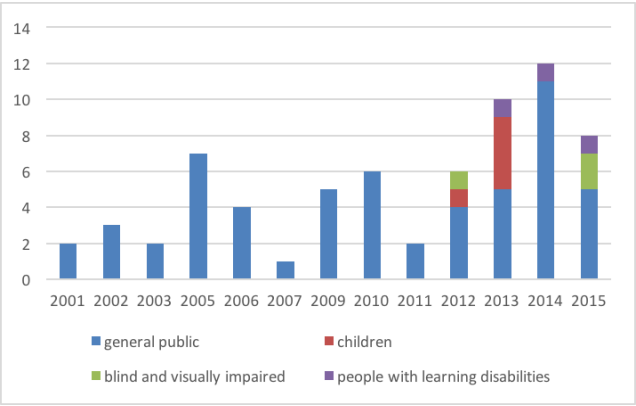


Figure 38 Distribution per year of different targeted installations (colour illustration at the end of the volume).

3.2.5. Single/Multi-Stations Installations

The application of tangible interaction in museums, temporary exhibitions and other types of cultural heritage sites, consists in inserting tangible interaction installations inside these places. As already mentioned, an installation, in turn, can consist of a single interactive station or multiple interactive stations that are integrated between them. More specifically, multi-interactive installations can be made up of more similar interactive stations distributed across an exhibition (Figure 39), or different interactive stations that nonetheless are part of the same installation (Figure 40).

Figure 39 "The Hague and the Atlantik Wall" exhibition consists of an installation made up of more similar interactive stations (interactive showcases) distributed in the space, activated by using replicas of objects that the visitors can get at the beginning and carry with them during the visit. (source: video at http://www.mesch-project.eu/smart-object-enhanced-museum-exhibition-atlantik-wall-at-the-museon) [App., proj. 12].

Figure 40 Retracing the Past exhibition consists of an installation made up of more different interactive stations (a trunk, a desk, a radio, etc.) the visitor can activate using cards representing objects (that can be gathered at the beginning) (source: Fraser et al., 2004) [App., Proj. 41].

In the case of multi-stations installations, the integration between the different parts is supposed to go beyond the purely thematic one or the sharing of a same location, for example involving the execution of activities like carrying objects or cards by one station to another as in the examples presented above.

3.3 Aspects related to reference CH assets and their relation with the interactive installation

3.3.1. Reference cultural heritage assets

In the context of museum interactive installations there is usually at least one cultural heritage asset the installations or the stations refer to or aim to enhance the experience or understanding of. Cultural heritage assets can be of tangible or intangible type, with the latter referring to "those aspects of heritage that, unlike places or objects, are ephemerals: these include oral tradition, languages, traditional performing arts, knowledge systems, values and know-how" (Deacon, 2004).
As shown in the graph (Figure 41), the majority of projects refers to tangible and intangible assets at the same time. There is then a low yet significant percentage of projects referring just to intangible heritage, and a smaller percentage of projects referring just to tangible heritage.

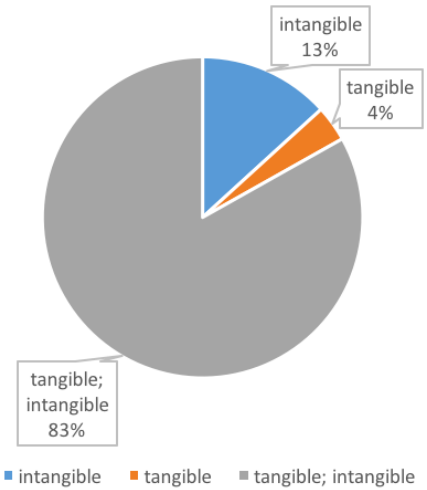


Figure 41 Types of CH assets referred by the installations.

Analysing more in depth the first category of projects, it can be seen how tangible and intangible assets are usually connected in the installation, the latter being interpretable as intangible values of the former. Examples of types of intangible values that are common to more projects are listed in the table (Table 1).

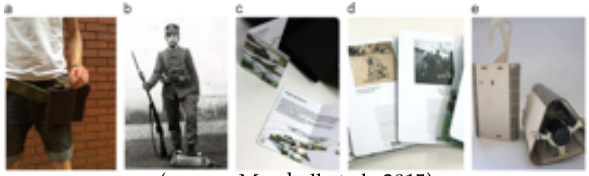
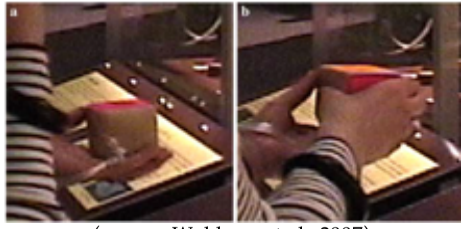
Intangible Values	Examples	Photos
Personal stories of people from the past	Personal stories of soldiers can be activated during the visit of the historical sites of Trenches of Nagià Grom by wearing a belt and selecting the content through cards (Companion Novel – Voices from the Trenches) in Trentino, Italy [App., Proj. 22]	 (source: Marshall et al., 2015)
Personal interpretations by visitors	Personal interpretations related to objects can be recorded by visitors and listened to later on through a radio in "Retracing the past". [App., Proj. 41]	 (source: Fraser et al., 2004)
Anecdotes	Informal comments and anecdotes related to exhibited objects given by scientists can be selected and listened to by visitors manipulating a cube in proximity to the objects in e(c)ho. [App., Proj. 32]	 (source: Wakkary et al., 2007)

Table 1 Common types of intangible values along with related examples of projects (continued on next page) .

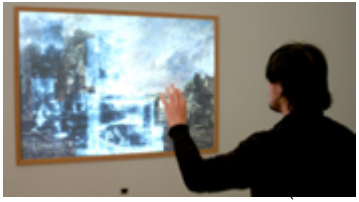
Intangible values	Examples	Photos
Historical documents/ images / other sources related to the object	In "Le Cabinet des Fable" at the "Musée des Arts Décoratifs" in Paris, the visitor can listen to fables (and other contents) that are connected to the place, by positioning himself on markers provided on the floor. [App., Proj. 10]	 http://www.erasme.org/Strat)
Reconstructions of original / historical appearance	Using his finger as a pointer, the visitor can reveal the original colour of a roman object (oscillum) in the Revealing Flashlight installation. [App., Proj., 49]	 (source: https://vimeo.com/109284410)
Invisible material properties	In "Engaging Constable", walking towards an interactive replica of Constable's "Salisbury Cathedral from the Meadows" painting, people can explore the underlying x-rays layers and analyse the "artist's pentimenti". [App., Proj. 35]	 http://allofus.com/work/tate-britain/constable-exhibition/)

Table 1 Common types of intangible values along with related examples of projects (continued on next page)

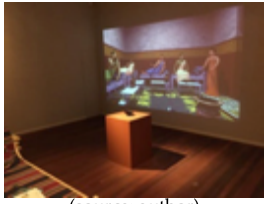
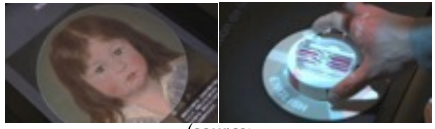
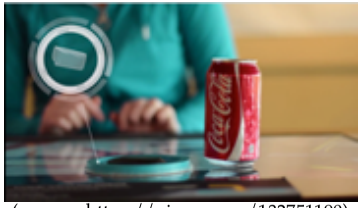
Intangible values	Examples	Photos
Context of use / activities / traditions connected to the object	In the "Drinking Symposium" installation the visitor can take part in an ancient Greece ritual by picking up a replica of a Greek bowl (kylix), or laying down on a replica of a day bed, and through doing so he triggers the reactions of virtual characters projected on the wall. [App., Proj. 18]	 (source: author)
Behaviour of the object (as a consequence of external actions / factors)	In "the painting, a material object" installation, the visitor can learn how certain external factors (humidity, light, time) can affect the structure of the painting by placing specific tokens on a hotspot. [App., Proj. 39]	 (source: http://www.museumlab.eu/exhibition/09/development.html)
Relations with other objects	In "Belongings" the visitor can connect a replica of an ancient belonging to a contemporary counterpart to discover their connection, and how traditions from the past has changed or remained today. [App., Proj. 38]	 (source: https://vimeo.com/132751190)

Table 1 Common types of intangible values along with related examples of projects .

After all, as suggested by Jean-Louis Luxen "the distinction between physical heritage and intangible heritage is… artificial" as "the tangible can only be interpreted through the intangible" (..) or, in other terms "intangible heritage gives meaning to the tangible" (UNESCO, 2000:4).
In this sense, tangible interaction can be interpreted as a practice able to associate intangible values (like stories, interpretations, etc.) to tangible objects (like artefacts, works of art, natural assets, buildings, architectures etc.), in this way enriching the experience of the latter. Although this is true also for other kinds of technologies, tangible interaction in many cases seems to be able to make the association between immaterial and material stronger, by physically embedding the former into the physical artefact or its replica. However, this aspect will be analysed better later, when examining the aspects related to the interaction.
In few cases the main focus of the installation is not a tangible asset but an intangible asset, being it a concept, a story, a practice, a ritual. In this case, tangible interaction is used to materialize these intangible assets so that they can be bodily experienced by visitors[40] (Figure 42; Figure 43; Figure 44; Figure 45).

Figure 42 The concept that "Interantarctica: an interactive environmental installation" aims to communicate is the impact that certain human actions have on the environment. The action of picking up an object (physical representation of an item whose use have a positive or negative impact on the emission of CO2 in the environment) becomes a metaphor of using that object with the related consequences on the environment (source: De Berigny Wall, 2010) [App., Proj. 19].

[40] It is important to notice that by intangible assets we should consider not only concepts, stories, practices, rituals, but also hypotheses of reconstruction of no longer existing tangible assets. Also in this case, tangible interaction can be used as a practice to give physical shape to a no longer existing object.

Figure 43 In the "Open House: If These Walls Could Talk" installation refers to stories of families who lived in an ordinary house. Although "historic objects were not essential"(Filene, 2011) as the real artefacts "were stories" they are nonetheless introduced to materialized these stories, as "vehicles for authentic connection to the past" (*Ivi)* (source: Filene, 2011) [App., Proj. 8].

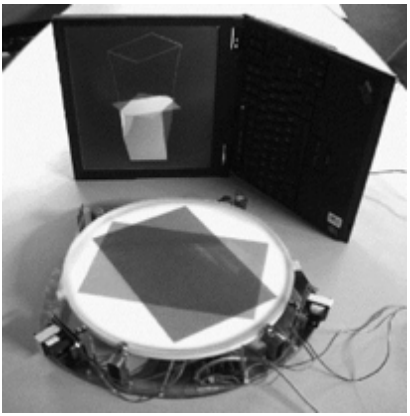


Figure 44 The "Tangible interfaces to explain Gaudi's use of ruled-surface geometries" installation consists of a tangible interface that is designed to make the modelling practice used by Gaudi to build the "rectangular" double helix columns in the Sagrada Familia easier to understand (source: Fischer et al., 2002). [App., Proj. 36].

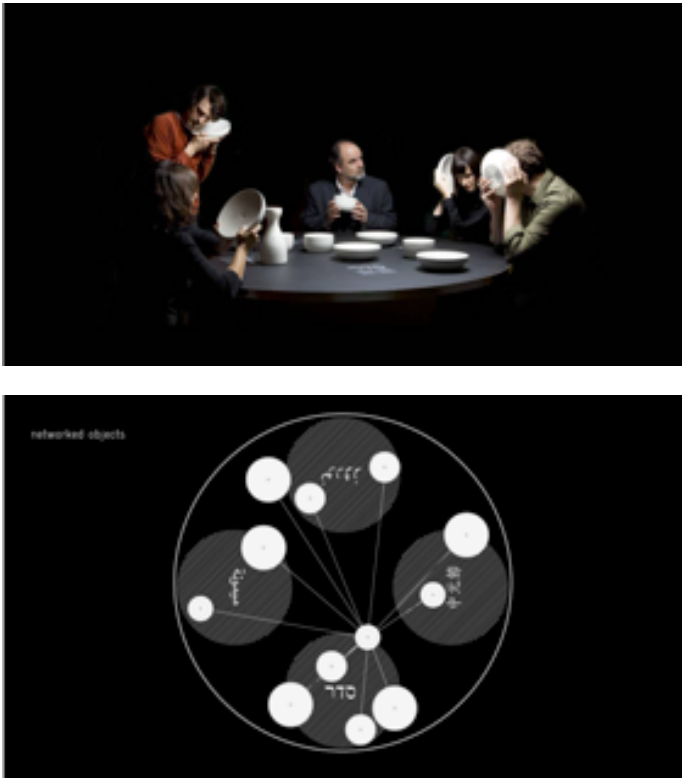


Figure 45 At the "Whispering Table" installation visitors can learn about different rituals, symbols and beliefs related to food by listening to stories coming out of physical ceramic dishes, bowls and jugs and by positioning them in different locations of the table (source: http://www.thegreeneyl.com/whispering-table) [App., Proj. 24].

Just few installations refer mainly to tangible assets without much consideration for the intangible assets associated with them. In this case, tangible interaction is mainly used to make people experience an aspect related to the physicality of the object (Figure 46; Figure 47).

Figure 46 In "Strike the Pose" the visitors tries to match with her body the pose of a sculpture, in this way gaining a better understanding of its shape and physicality (source: https://vimeo.com/60866008) [App., Proj. 52].

Figure 47 In the "Virtual touch machine" (Retracing the Past installation), visitors can experience the material qualities (shape, texture, sound) of the objects by rotating and tapping against a 3D model of the object using a "magic wand" (source: Fraser et al., 2004) [App., Proj. 41].

Summarizing, from this analysis three different uses of tangible interaction have been identified:

- as a way to associate the intangible values to tangible assets;
- to give material forms to intangible assets, or practices;
- to make people experience certain material properties of a physical object.

These different uses should not be considered as mutually exclusive but as intersected (Figure 48) as a tangible interaction installation often provides different possibilities at the same time. The VIRTEX installation at the Archaeological Museum Ename in Belgium, for example, besides allowing visitors to experience intangible values related to the artefact (i.e. information, interpretations, context of use and traditions), also allows to experience its material qualities through the sense of touch.

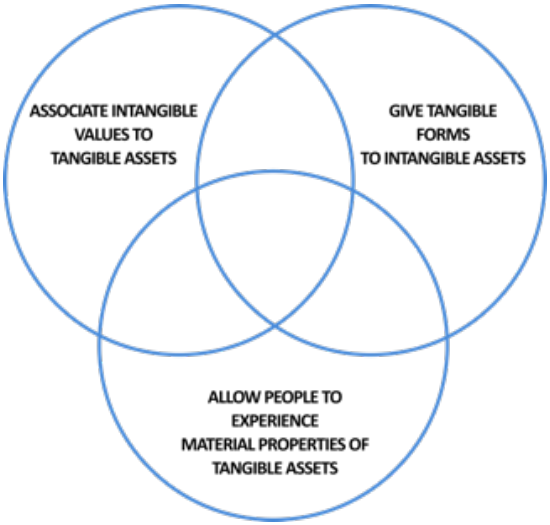


Figure 48 Different uses of tangible interaction as emerged from the analysis.

3.3.2. Location of reference tangible object

Considering the location of the original tangible object (when existing) with respect to the installation is important because the location represents one of the aspects that can determine the "level of distraction" of the interactive from the reference original object on display.
This aspect can be analysed on a continuum that goes from installations where the object is embedded inside the installation to cases where the object and the installations are located in very distant places (Figure 49).

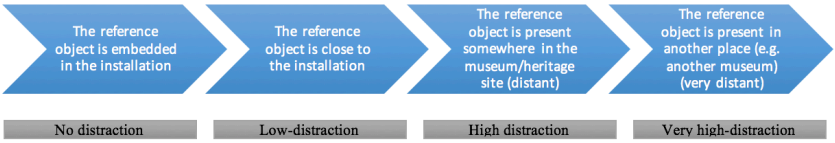


Figure 49 Level of distraction from original object depending on its location.

Different strategies for incorporating objects in the installation can be identified, sometimes combined together in the same installation. These include for instance:

- the use of the reference object as an interaction device (Figure 50);
- the provision of an output that is tightly coupled to the focus of the object (e.g. the output is overlapped on the object, it comes from the object or from the environment around the object) (Figure 51);
- the design of an interaction that has to be done in the presence of the object (e.g. augmented reality) (Figure 52).

In all these cases the level of distraction from the reference object is absent or very low.

Figure 50 In "Frammenti di Memoria" original artefacts belonging to the farming traditions are used as interaction devices. Stories of farmers and light effects are presented to the visitor, when an object is touched (source: https://gabrielrapetti.com/frammenti-di-memoria/) [App., Proj. 25].

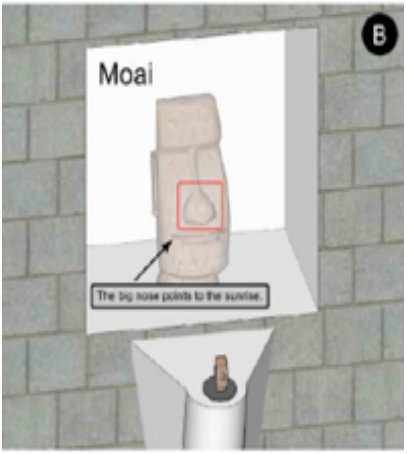


Figure 51 In the Winnipeg Art Gallery's interactive case, the information is provided on the exhibit case overlapped to the original object (source: Hincapié-Ramos et al., 2014) [App., Proj. 11].

Figure 52 The meSch Loupe in the Allard Pierson museum have an interaction that has to be done in the presence of the reference objects (source: meSch project, 2015a) [App., Proj. 27].

Moving along the continuum we find interactive installations that, even without embedding the reference object, allow for a low level of distractions from it, as the latter is placed in proximity to the installation (e.g. Figure 53).

Figure 53 At the museum Ename in Belgium, VIRTEX is used near the glass case where the original object is exhibited (source: Pletinckx, 2007) [App., Proj. 5].

The higher level of distraction potentially comes when the original object and the installation are located in distance places inside the same museum/cultural site (e.g. in Talking painting [App., Proj. 1], in Interactive Stela [App., Proj. 45], in Nottingham Castle installation [App., Proj. 13]) or in very different locations (e.g. Virtex Ara Pacis [App., Proj. 6]).

From a quantitative analysis of the academic projects, it can be seen that the embedment of the object in the installation is a quite diffuse practice in tangible interaction design (33%), more diffused than the location of the object nearby the installation (14%). However, in a large percentage of the cases the reference object is situated in distant locations (31%) or very distant location (12%).

3.3.3. Strategies to foster the experience of the reference object

From what is described above one may think that the choice of the location of the original object with respect to the installation is the only determinant of the level of distraction from the original object. Therefore, whereas the original object is embedded in the installation or is placed in proximity to the installation the experience of it is, at least potentially, fostered in a natural way, while nothing can be done in the case the object is distant from the installation. However, this is not always the case since the strategy of choosing the location is not the only possible one as summarized in Figure 54.
Indeed, another strategy to elicit the experience of the object consists in designing actions for the visitor to perform before or after enjoying the interactive installation. This strategy is particularly useful when it is not possible to act on the position of the object (embedding it in or placing it nearby the installation), thus in the cases where the object is located in a distant location inside the same museum/cultural site, or in completely different places.

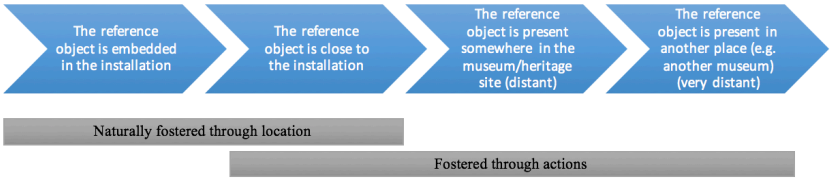


Figure 54 Strategies to foster the experience of the reference object.

Examples of projects that make use of this strategy are "Nottingham Castle Installation" (Fraser et al., 2003) [App., Proj., 13] and "Reminisce" (Ciolfi et al., 2002) [App., Proj. 16]. In the former, various locations in and around the castle are connected to the interactive stations exhibited in a section of the museum by means of (electronically tagged) paper clues. The visitor is given a paper clue to carry to specific locations, where he is asked to carry out certain tasks using it (e.g. drawings etc.), and only after, the same paper clue can be used to get digital information about the visited location at the interactive stations in the museum. Similarly, in "Reminisce" visitors have to get specific physical tokens in the various dwellings in Bunratty Folk Park, Ireland, before accessing to memories associated to them, using the interactive desk at the end of the experience.
From a quantitative analysis, it results that only in few projects (18% of projects where the reference object is in a distant location) there is an

attempt to overcome the problem of the distance, and to take the attention back to the original object.
From the analysis presented so far, it emerges that tangible interaction is not to be considered as synonym of less distraction from the existing tangible object, because the use of tangible interaction per se does not guarantee this effect. It is important to put into practice specific strategies to guarantee the original objects have the right prominence in the context of the visit.

3.4 Aspects related to the interaction

3.4.1. Preliminary considerations on interaction styles

Examining the wide corpus of installations from the point of view of the devices that are used[41], a first distinction emerges between those that make visible use of traditional devices (like screens, mobile devices, touchscreens) and those that use devices that take on the appearance of low-tech objects (smart objects). In addition, it can be noticed that, in some cases, in order to interact with the system a contact with the device/object (through touch, manipulation) is required, while in other cases the contact is not necessary and the visitor can interact just making gestures in the presence or in front of the device/object. By intersecting these two dimensions (with/without contact and traditional devices/smart objects), a graphical representation can be obtained allowing for the identification of different categories of interfaces and interaction styles (Figure 55).

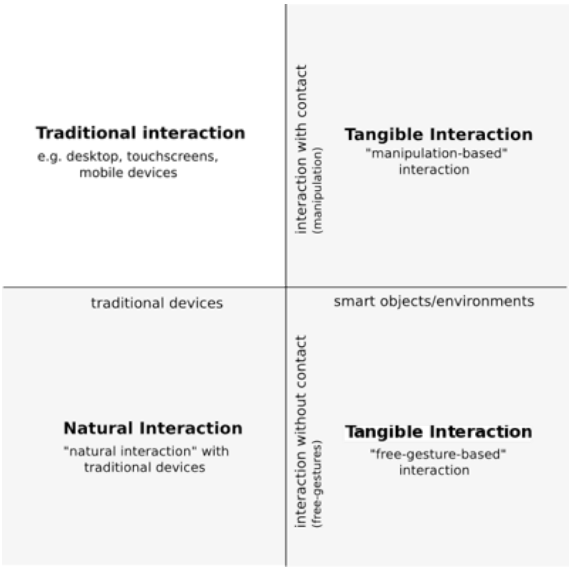


Figure 55 Different categories of interaction styles emerging from the intersection of two dimensions (contact/without contact; traditional devices/smart objects).

[41] At this stage of the analysis, a distinction is not made between input and output devices, and both are considered. This is because it has been noticed that in this kind of projects the distinction between input and output devices is often misleading and generate ambiguity.

A first category of interfaces/interaction styles (top-left) is represented by traditional interfaces/interaction. They usually require an interaction through contact with just traditional devices (mouse, keyboard, touch-screen, mobile devices) and an output is provided through a traditional output device as well (e.g. screen, loudspeaker, headphone). This traditional type of interaction is not the focus of this thesis and has generally been excluded during the collection of existing projects.
At the top-right and bottom-right there are two other categories of interfaces sharing the fact that they view the presence of only low-tech objects as input and output devices. However, while the latter category requires a physical contact with an object (e.g. Figure 56), in the former a contact with the object is not needed as the systems included in this category view the presence of objects that are able to recognize free gestures the visitor performs – more or less consciously – in front or nearby them (Figure 57). Sometimes being referred to as object-based interaction the former, and gesture-based interaction the latter, in this thesis the expressions *"manipulation-based tangible interaction"* and *"free-gesture-based tangible interaction"* are preferred as the presence of objects or gestures are not discriminants between the two types of interaction, being them present in both cases. Categories two and three are ascribable to a design attitude that can be summarized with the term "disappearing computer" characterizing a good portion of tangible interaction efforts. It is important to notice how these projects in reality do make use of traditional devices (like screens, mobile phones, loudspeakers etc..) as well, but these are made invisible by hiding or embedding them inside other objects or by integrating them within a context that gives them a different appearance.
The fourth category concerns those projects that make use of traditional devices (e.g. a screen) but, at the same time, they require the visitor to interact through free gestures going beyond the traditional interaction styles (through the mouse, keyboard, touchscreen etc.) (Figure 58). These types of projects are often referred to as *natural user interfaces* in literature. Although a wider interpretation of tangible interaction may see these kinds of interfaces as belonging to the tangible interaction paradigm, we prefer considering them as something slightly different. This is one of the reasons why not so many projects of this kind have been included in our corpus for analysis.

Figure 56 In the talking tactile panel at the San Diego Museum of Art, exploring the surface of a replica of the painting the visitor can hear a voice explaining the meaning of what he is touching (source: Touch Graphics, 2015a) [App., Proj. 1].

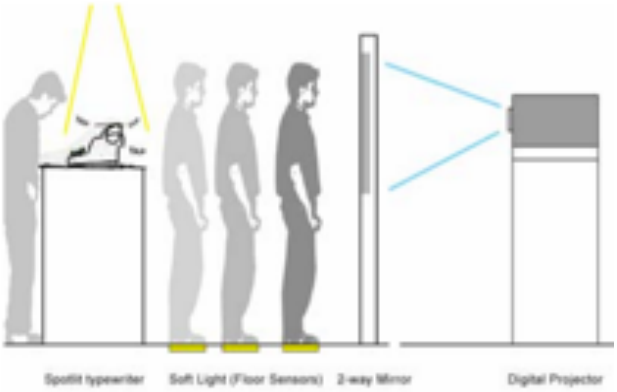


Figure 57 The first part of the Magic Mirror installation, consists of a typewriter placed on a pedestal. In the idle state the visitor can hear sounds of tapping, and the object is spotlit. As the viewer goes closer to the object, the intensity of the light varies according to his proximity, and the sounds of tapping stop (source: Rawat, 2005) [App., Proj. 47a].

Figure 58 In "Strike the pose" the visitor interacts using her body in front of a screen trying to match the pose of sculptures (source: https://vimeo.com/60866008) [App., Proj. 52].

However, the reality of tangible interaction is more complex, and a rigid classification would not help to reflect about its complexity. So, on the border between the different categories illustrated above other styles of interaction emerge that, anyway, can be ascribed to the category of tangible interaction. In particular, smart objects and traditional devices often coexist in a same project albeit with different functions. The smart object usually acts as a controller to interact with a traditional device (e.g. a screen) that, in turn, acts as an output device (Figure 59). In addition, on the border between manipulation-based tangible interaction and free-gestures based tangible interaction, there are projects where both types of interaction are supported and/or needed (Figure 60).

Figure 59 In VIRTEX (Augustus of Prima Porta) installation, pushing specific sensors on the physical scale model of the statue, a virtual view of the specific area along with related information are provided on a screen
(source: https://www.youtube.com/watch?v=nQbdn2NVlls)[App., Proj. 7].

Figure 60 "Wonder objects" combines both free-gestures and manipulation-based interaction. In the idle state, the visitor sees and hears hands typing on the machine's keyboard. As the visitor goes closer another video is triggered showing a set of instructions. Then, pressing specific hotkeys, video content is projected on the typewriter's sheet of paper animating the object (source: Rawat, 2005) [App., Proj. 47d].

This research is mainly focused on projects that either contain smart objects only or a combination of smart objects and traditional devices, and only marginally on those projects that are made just of traditional devices although requiring a more natural interaction.

3.4.2. An analysis of tasks and actions

Visitors interact with a museum installation/station in order to achieve specific objectives or accomplish specific operations that are supported by the interactive system itself. These high-level objectives/operations are known as **tasks** in Interaction Design, can be decomposed in **sub-tasks** and can be materially reached through specific **actions** to be performed at the level of the interface. In this paragraph an analysis of tasks and actions in tangible interaction systems is provided.
Through an analysis of the high-level tasks supported by the various installations/stations an approximate differentiation of categories of tasks can be derived. These categories should not be considered as mutually exclusive but often intersecting at the level of a specific project.
A list of possible high-level tasks is presented below.

- "**activating content about an object**" tasks: the visitor interacts with the system in order to select and activate multimedia information about the object;
- "**getting instructions**" tasks: the visitor interacts with the system in order to get instructions about how it works and how to interact with it;
- "**comparing/connecting two objects**" tasks: the visitor interacts with the systems in order to get information comparing two objects or showing the connection between them;
- "**producing content**" tasks: the visitor interacts with the system in order to create a personal content;
- "**searching**" tasks: the visitor interacts with the system in order to search for specific information;
- "**activating simulations**" tasks: the visitor interacts with the system in order to get a simulation of a behaviour of an object or an environment in reaction to certain external actions or factors;
- "**navigating 3D models/environments**" tasks: the visitor interacts with the system in order to navigate a 3D representation or reconstruction of a cultural heritage object;
- "**experiencing material properties of the object**" tasks: the visitor interacts with the system in order to get an experience of the material quality of the object, not accessible otherwise;
- "**playing games**" tasks: the visitor/s interacts with the system in order to play a game;

- "**expressing an interest**" tasks: by making an action the visitor expresses its interest in a specific exhibit/object;
- "**personalization-related**" tasks: i.e. the visitor communicates its preference/profile to the system in order to have a personalized experience.

These high-level tasks are usually reachable through a combination of interaction subtasks, that are typically **selection tasks**, **edit tasks** and **control tasks** or a combination of them (Paternò, 2000). Selection tasks consist in the selection of "one or more item from a set or range of items" (Paternò, 2000). Edit tasks are those that allows user to input data in the system. Control tasks are those that allow user "to trigger actions explicitly" (*Ibid*). In order to accomplish these subtasks, the visitor will need to carry out certain actions with the interface. As an example, in "The Hague and the Atlantic Wall" (Marshall et al., 2015 [App., Proj. 12]) the visitor can get information about the objects exhibited in a glass case from a specific perspective (high-level task). In order to reach this goal, the visitor needs to select a specific perspective (selection subtask), to activate the story from that perspective (control task) and finally he will enjoy the content. At the level of a single glass case in the installation, the selection and activation of the story from a desired perspective is done by placing a specific object (e.g. a mug, a tea bag, a sugar packet, each representative of a specific perspective) on a hotspot near the glass case. In response to this action, the system will provide the content in the form of an audio personal story through an earphone and some images that are projected on the glass case. In this example, in order to enjoy the content certain actions are needed as well: picking up the earpiece and taking it to his/her ear[42].

[42] What emerges from this description is also a distinction between online and offline actions (Esteves et al., 2013). The former are those actions that are in some way recognized by the system (e.g. placing a mug on a hotspot), while the latter are those that, although they are required to the visitor to carry out, they are not recognized as an input by the system (e.g. taking the earpiece to the ear). Nevertheless, since both types of actions are needed and contribute to the perception and reactions the user has of the interactive system, is fundamental to design them accurately.

3.4.2.1. Codified actions and Performing actions[43]

A characteristic that is common to most of the projects that have been described so far is the fact that they require the execution of *codified actions* in order to allow visitors to accomplish the tasks.
Just to mention few examples: placing a mug down on a hotspot (e.g. The Hague and the Atlantik Wall, [App., Proj. 12]), pressing a button on the replica of a monument (e.g. Virtex - Ara Pacis [App., Proj. 6]), translating/rotating an object on a surface (e.g. Yongzheng emperor's interactive tabletop [App., Proj. 20]). These are not natural actions people commonly do with these objects, they are not culturally meaningful with reference to the specific cultural heritage object.
Every object of reality, both present and past, has a repertoire of actions and gestures that are associated to it. These actions are determined by the use or function - practical or symbolic - that that object has in a certain culture. We learn about these gestures by living in a certain cultural context, through imitation, through formal education, through experimentation. Among the gestures associated to a mug there will be, for example: taking the mug to the mouth for drinking, pour some liquid into it, serve the cup on a plate on a table and so on. In addition, different actions can be thought of for a same object in different contexts. For example, actions such as exploration, observation, etc. will be carried out by a person wishing to choose and buy a new set of cups in a shop; and yet different actions will be those carried out by the maker of the cup.
Inserted into a new context, that of the interactive installations in a museum, in most of these projects, these cultural objects view their function redefined along with the gestures associated with them. The designer defines a new vocabulary of actions and the visitor is required to carry out these actions in order to achieve certain goals (e.g. the activation of information).
Not all the projects under investigation, however, make use of codified actions. Indeed, it is possible to find projects where the actions are not the result of a codification made by a designer. Instead, these projects require visitors to perform actions that are part of the repertoire of gestures related to the specific objects. These are actions that are culturally meaningful with reference to the specific objects. We can refer to these actions as *performing actions*. In the "Virtual Conductor"[44] installation in the House of Music in Vienna (Figure 61a) the visitor can lead a video projection of the Vienna Philharmonic Orchestra by using

[43] The distinction between codified and performing actions presented in this paragraph is based on the distinction between codified and performative gestures presented in the paper (Duranti, Spallazzo and Trocchianesi, 2016a).
[44] https://hci.rwth-aachen.de/actibits/po/virtualconductor.html

a replica of a conducting baton, and through doing so he can experience what conducting an orchestra is like. Another example that is close to this approach, regards the installation "The Drinking Symposium"[45] (Figure 61b) in the Allard Pierson Museum, Amsterdam. It represents a drinking session that used to happen in ancient Greek after a meal, with people reclined on couches placed in a U-shape. Here the visitor performs actions that are part of the ritual, like picking up the bowl, reclining on the daybed, and as a consequence, animated virtual characters projected in the room walls react accordingly. Another example is the already mentioned "Olivetti typewriter" installation. The visitor interacts with the installation by pressing keys on the keyboard and video contents are projected on the typewriter's sheet of paper.


a)


b)

Figure 61 (a) The Virtual Conductor (source: https://www.wien.info/en/music-stage-shows/city-of-music/house-music) [App., Proj. 17] (b) The Drinking Symposium (source: the author) [App., Proj. 18].

[45] https://vimeo.com/146224161

Installations like these can be considered to implement the model for heritage enhancement envisaged in the context of the European Project MeLa* (European Museums in an age of migrations), the "Performing Heritage Model" (Lupo et al., 2014). According to this model, "intangible heritage is experienced in the first person by the user, who can play and perform cultural practices, alone or in a shared situation" (*Ivi)*, that is, "cultural contents is performed and re-produced, individually or in a social context, in a space that becomes a stage, created by users' gestures" (*Ivi*).
The use of performing gestures can be seen as a strategy that allows to associate intangible values and meanings to tangible objects in tangible interaction installations, by integrating them implicitly into gestures. This strategy can be referred to as "embodying meaning" (Duranti, Spallazzo and Trocchianesi, 2016a), because by performing specific gestures or bodily interactions, the visitor implicitly understands and experiences an intangible value related to a certain object.

It is important to point out that the already presented distinction between interaction with contact and without contact is still valid. Codified actions can either require the contact with the object (e.g. Ara Pacis) or not (e.g. Constable) and the same can be said of performative actions[46].

3.4.3. Devices: an analysis on the form and role of smart objects

In order to achieve specific objectives or accomplish specific tasks, the visitor has to perform certain actions (with or without contact) at the level of the interface and get the desired feedback from the interface itself. The interface implies the presence of one or more devices that, as said, can be categorized as traditional devices or smart objects depending on whether their digital nature is explicitly declared (e.g. a smartphone) or hidden inside the appearance of non-digital objects (e.g. the meSch Loupe [App, Proj. 27]). The devices can act as input devices, as output devices or, sometimes, as input and output devices at the same time.

[46] Although all the performative actions presented so far required the contact with an object, performing actions without contact with an object can be envisaged. As an example, it would be possible to implement the Virtual Conductor installation, in such a way that the visitor does not need to handle the baton, but just simulates the movements he would do with his hand, although the effect would likely be less realistic.

This paragraph focuses on *smart objects*, being them a distinguishing feature of tangible interaction, and proposes an analysis and categorization of smart objects from the point of view of their form and relation with the main cultural heritage asset.

A first category of smart objects concerns those that present a direct **formal relation** with the tangible cultural asset the interactive installation refers to (*primary object*). These include smart objects consisting of:

- *smart original:* the very original object that is made smart (Figure 62);
- *smart replica:* more or less accurate copies of the reference object (Figure 63);
- *smart derivative:* objects that are derived from the reference object through processes of abstraction or translations (Figure 64; Figure 65).

From a practical point of view, the use of original objects has the advantage of allowing to overcome the problem regarding the distraction from the original object that characterizes traditional uses of technologies in museums, since the original object is incorporated in the installation itself.
Instead, smart replicas provide an alternative to the use of original objects in tangible interaction stations, e.g. when the incorporation of the latter is not possible for preservation reasons. However, it must be noticed that, with the use of smart replicas the problem of distraction could even be amplified in that they could present themselves as identical copies or even more appealing substitutes of the original objects, unless proper design strategies are adopted to limit this negative effect. However, smart replicas offer some advantages in terms of flexibility compared to smart originals. For example, it is possible to print small objects in larger scale in order to make details more visible, to make the object easier to grasp or able to accommodate the desired sensors (e.g. Virtex – Ivory Object).

Figure 62 In the "Olivetti MP1" exhibit, the visitor interacts directly with the original object. Pressing specific hotkeys on the typewriter, video contents are projected on the typewriter's sheet of paper animating the object (source: Rawat, 2005) [App., Proj. 47d].

Figure 63 The Interactive stela installation consists of a plastic sensorized replica of an Egyptian stela that is present in the museum (source: the author) [App., Proj. 45].

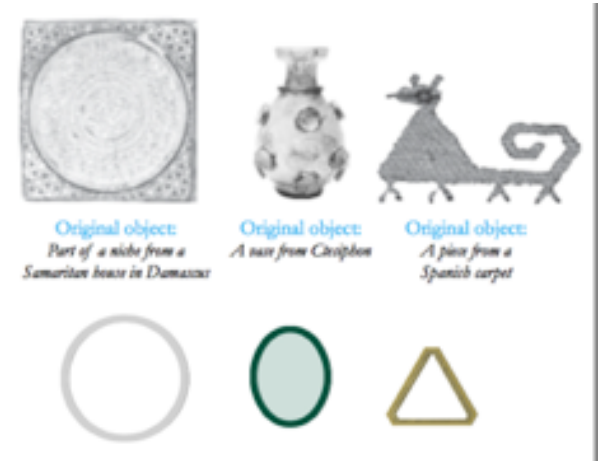


Figure 64 In "Interactive histories" the interactive objects are physical tokens consisting of abstract representation of objects that are in the collection (source: Kettner, 2013) [App., Proj. 42].

Figure 65 In the "Talking Painting" installation a Juan Sànchez Cotàn's still-life painting is "translated" into a bas-relief that can be accessed by blind people (source: Touch Graphics, 2015a) [App., Proj. 1].

Another category of smart objects concerns those that take on the appearance of an object that is different from the main heritage asset the installation aims to enhance (*secondary object*). Although different from the main cultural heritage asset, sometimes this object presents a cultural relation with it in reality (*related object*). An object can relate to the main object for example because it belongs to the same historical context of the main object (Figure 66; Figure 67), or to one of the contexts of activities that characterizes or characterized the main object[47]. An example is the Loupe (Figure 68), inspired to an existing tool that is actually used in real life both by expert and ordinary people for the exploration of a detail of an object, such as a vase. Similarly, related objects are also all those smart objects that are inspired to tools that are traditionally used in the context of the visit of a cultural heritage object/site, such as traditional visiting aids (leaflets, books) or exhibition equipment (glass cases, drawers, etc.) (Figure 69; Figure 71). Finally, there are some projects in which the smart object relates to the main object because it represents the contemporary counterpart of an historical object (Figure 70).

Figure 66 In the "Companion Novel – Voice from the Trenches installation", the main reference object is the open-air "Trenches of Nagià Grom" site. The smart object consists of a wearable belt inspired to the WW1 army clothing activating audio contents during the exploration of the site (source: Marshall et al., 2015) [App., Proj. 22].

[47] The notion of "context of activity" comes from activity theory. For more information about the notion of "context of activity" and activity theory and its application to the interaction design field see Kaptelinin and Nardi (2009), while see Kaptelinin (2011) for more information about how activity theory can be applied to the field of ICT in museums.

Figure 67 In the "Atlantik wall installation" the main objects consist of documents and artefact related to the life and events at the time of the Atlantik Wall in the Hague. In order to trigger stories related to the exhibited artefact, secondary related objects are used as representative of different perspectives (civilians, Germans, officials) (sourc e: https://www.youtube.com/watch?v=sK3AdQU9kkc) [App., Proj. 12].

Figure 68 The "meSch Loupe" for example is a sort of magnifying glass, which beyond providing information overlapped over the object, also provides a magnifying function (source: Petrelli, 2014b) [App., Proj. 27].

Figure 69 The Companion Novel installation made for the Sheffield General Cemetery consists of an interactive book that visitors can carry with them during the exploration of the cemetery (source: Ciolfi et al., 2013b) [App., Proj. 21].

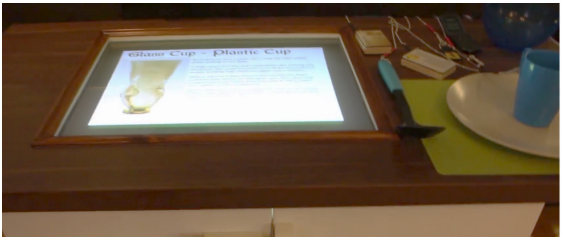


Figure 70 In the "The Really Simple Object Recognition Interactive Anglo-Saxon Table" made for the Maidstone Museum and the Bentlif Art Gallery, contemporary objects are used to activate contents about Anglo-Saxon counterparts. In the picture, a contemporary plastic mug is used to get information about an Anglo-Saxon Glass Cup (source: https://www.youtube.com/watch?v=tUBVwJzFHn8) [App., Proj. 55].

Figure 71 In the Fryderyk Chopin Museum an exhibition equipment is made smart. Opening the drawers, the visitor can observe Chopin's original scores and at the same time listen to the music and see projected information on the table
(source: http://www.designboom.com/design/chopin-museum/) [App., Proj. 40].

In other cases, smart objects have the appearance of objects that have no relation in reality with the main heritage asset the installation refers to (Figure 72; Figure 73). We can refer to them as *unrelated objects*. Often these objects are abstract objects like cubes, balls, etc. that are used to activate contents about the main object. It is the responsibility of the designer to define the type of relationship the unrelated object has to establish with the main object once it is inserted in the installation. Beyond being an activator of content, in many cases the object becomes a *symbolic representation* of aspects or intangible values that characterize the main object (e.g. different interpretation or points of view).

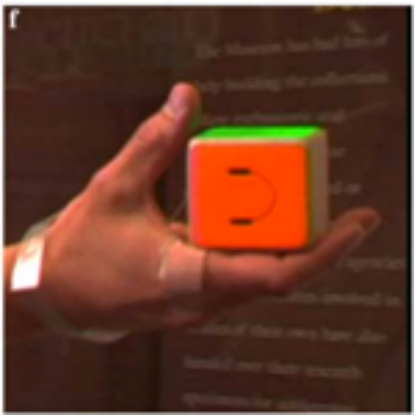


Figure 72 In "ec(h)o", a wooden cube having three coloured sides is used by the visitor to select specific audio contents in front of specific natural objects exhibits (source: Wakkary et al., 2007) [App., Proj. 32].

Figure 73 At the Museo delle Culture di Lugano, using a ball the visitor can select a visit profile according to which information is provided on a monitor (source: Bacconi, 2011, August 26) [App., Proj. 43].

It is interesting to highlight that often the boundary between smart objects and traditional devices is very subtle, as in many cases traditional devices like screens, loudspeakers, and mobile phones are actually used as part of smart objects. However, what makes traditional devices different from smart objects is the fact that, while in the former the digital devices manifest themselves as such, in the latter digital devices are hidden or integrated inside objects, and this gives them another aspect and interpretation. A smartphone inserted in a loupe is no longer perceived as a smartphone, as well as a screen showing a painting and that is inserted in a physical frame is no much perceived as a screen but as a painting.

Smart objects and Intangible values

This paragraph provides some reflections regarding the relation between smart objects and intangible values, aiming at shedding light on different ways of using smart objects for associating intangible values to cultural heritage. This analysis is carried out with reference to the two broad categories of smart objects that have been defined above, namely primary objects and secondary objects.
In most of the projects that make use of primary objects, these either act as physical activators and/or output devices for intangible values that

are related to the object itself. By interacting with the object, the intangible values connected to it manifest themselves explicitly in the form of digital content. This use of smart objects allows for a better integration between the material aspects of the object and its intangible value, as well as for a reinforcement of the link between these two elements, that are often presented in more separated ways in museums.
A second category of smart objects concerns secondary objects. Belonging to this category there are all the smart objects that take on the appearance of objects that are either related for some reasons to the ones the installation aims to enhance, or that seem to be completely unrelated from it. In all cases the smart object acts as a mediator, an additional tool to be used in couple with the main object for the activation of its intangible values. Beyond being used as activator of contents, sometimes the smart object becomes *symbolic* of an aspect or intangible value related to the main cultural heritage object[48]. In "The Hague and the Atlantic Wall", for example, the mug and the other objects become symbolic of specific points of view on the object on display.

These reflections about smart objects, allow to shed light on different design actions that can be used to convey the intangible values related to the objects through the use of smart objects, a practice that can be referred to as "embedding meaning" (Duranti, Spallazzo and Trocchianesi, 2016a).
In the projects that make use of primary objects, the intangible values related to an object are communicated by means of digital content that can be activated by physically interacting with the objects itself or its replica. In this case, the design action concentrates mainly on the definition of the content and how to link it to the object, and less on the object itself, that has mainly a denotative function[49], as it represents itself. In the projects where secondary objects are used, the objects are not always just activators of contents, but can sometimes become symbolic of certain intangible assets. In this case, the design action goes beyond the definition of contents, to include an effort towards the definition of the shape of objects that is suitable to become symbolic of certain intangible values (connotative function).

[48] Sometimes, however, more than symbolic of an intangible value related to the main object, the smart object is symbolic of a functionality of the system, as in traditional TUIs.
[49] The concepts of connotation and denotation have been borrowed by semiotics. "Connotative meaning is a secondary meaning which a sign may have in addition to a primary, standard, or core meaning, called denotative" (Nöth, 1998, p. 102).

3.4.4. Output: type and location

In Interaction Design, the output is the feedback provided by an interactive system to the user in response to the input and can involve various sensory channels (visual, audio, haptic, but sometimes even taste and smell). In most of the tangible interaction systems analysed in this thesis the output consists of visual feedback (images, 3D models, light effects, videos and texts) and audio feedback (songs, vocal texts) often coupled together, with a minority of them also using haptic feedback (e.g. vibration). In some cases, traditional devices (screens, loudspeakers, mobile devices, etc.) are used for the output, other times the output is provided through smart objects or environments.
In addition, the output can take place in various locations with respect to the input device (i.e. the smart object) the person interacts with. Analysing the location of the output with respect to the interactive object is important because it can influence the level of embodiment, that is, the perception of the computation as embodied in the object the visitor is interacting with (Fishkin, 2004). The four levels of embodiment proposed by Fishkin have been applied to the analysis of the projects and have allowed to identify four categories of projects with respect to the location of the visual output (Table 2).

Location of output	*Visual Output*
The output is on another screen/object (distant) e.g. Virtex – Ara Pacis, Allard Pierson Museum, Amsterdam [App., Proj. 6]. e.g. The Drinking Symposium, Allard Pierson Museum, Amsterdam [App., Proj. 18].	 

The output is around the user (environment) e.g. Frammenti di Memoria (source: https://gabrielrapetti.com/frammenti-di-memoria/) [App., Proj. 25].	
The output is tightly coupled to the focus of the interactive object (nearby) e.g. Yongzheng emperor's interactive tabletop (source: Hsieh et al., 2010) [App., Proj. 20].	
The output device is the interactive object (full embodiment) e.g. Wonder Object (source: Rawat, 2005) [App., Proj. 47d].	

Table 2 Application of Fishkin's classification to the analysis of tangible interaction in museums.

The first category concerns projects in which the output is provided on a visual device that is separated from the object that is used to interact (distant). In most of the cases the visual device is a traditional output device (e.g. a screen as in VIRTEX [App., Proj. 6]), but it can also be another smart object. In the interactive storytent station in Nottingham Castle installation [App., Proj. 13], for example, the visitor interacts by means of paper clues and a turntable and gets the output on a storytent. A drawback of the separation between input and output objects is that the visual attention is continuously switched between the object and the output and this can be perceived as annoying if it is not properly designed.

A second case is when the output is perceived as around the user, like in "Frammenti di Memoria" [App., Proj. 25]", where light effects are created in the environment when the objects are touched. Sometimes, the differentiation between the first and second category is subtle. The "Drinking Symposium" [App., Proj. 18] is a project that can be considered mid-way between the first and the second category, because, even if the output is provided through a separate "screen", the way the projection and its content are integrated in the room, with virtual characters reacting in a likely way to the actions of the visitor, make the output perceivable as "around the user" rather than distant, on another screen.
The third case is the one concerning interactives where the output is tightly coupled to the focus of the input, because it takes place directly proximate to it. This level of embodiment is typical of tangible tabletops where the visitor is asked to move objects (tokens) on a surface and the information is shown on the table surface directly proximate to the object (e.g. Yongzheng emperor's interactive tabletop [App., Proj. 20]).
In the fourth case we have the full level of embodiment as the output device corresponds to the input device. The object is manipulated by the visitor and it changes in the aspects or behaviour (e.g. Olivetti typewriter [App., Proj. 47d]). This technique should be used anytime it is important not to divert the attention from the object, or the goal is endowing an object with a behaviour.

Types of output and intangible values

An output can be provided through a traditional device (screens, loudspeakers, mobile devices, etc.) or through a smart object or environment.
The way the output is provided through traditional devices in tangible interaction systems echoes the traditional ways of presenting information in desktop computers, smartphones and other traditional devices, although there is a difference in the style of interaction.
The use of objects for the provision of the output gives the possibility of endowing those objects with certain behaviours (behavioural output). In some cases, the object emulates behaviours that are typical of the object (emulative output). The sounds of tapping coming from a typewriter can be considered as an example of emulative output. In other cases, completely new behaviours are defined that do not emulate real behaviour of the object. The projection of an historical reconstruction on the surface of the tent in Nottingham Castle installation [App., Proj. 13] is an example of non-emulative output.
Anyway, in most of the cases the output consists of a manifestation through a certain digital media of intangible values related to the

cultural heritage asset the interactive installation is based on. It is important to notice that the same type of intangible value can often be manifested through different media, devices and locations. For example, traditions and contexts can be provided in the form of a text, an explanatory video/audio on a screen or through an augmented environment reacting to the actions of the visitor like in the Drinking Symposium [App., Proj. 18]. It is up to the designer to decide what is the best solution for the specific project, although certain types of intangible values might be more suitable for specific styles of output[50].
It is important to notice that, sometimes, the output does not aim to communicate an intangible value but is focused on the provision of information related to the internal status of the system (control feedback), for example confirming that certain actions in input have been recognized by the system (e.g. the use of vibrations in Kurio tangible devices to confirm that a selection of an object has taken place [App., Proj. 14]), or on the provision of instructions on how to use the system.
As already mentioned, also the location of the visual output with respect to the reference object is important as it is one of the determiner of the distraction or not from the reference object. Based on this aspect, the installations can be classified in two big categories: those were the visual output is tightly coupled to the focus of the reference object and those where the visual output is not coupled to the focus of the object.

3.4.5. An analysis of the agency of tangible interaction systems[51]

A well designed interactive system is one that clearly communicates to the visitor about: the possibility to interact; what the possible actions are; what to expect when the actions are carried out.
Indeed, when interacting with a system, it is paramount for the visitors to be able to set their goals and tasks and identify what actions are needed in order to accomplish those tasks and goals. This happens in the *stages of execution* characterizing the user interaction with a system (Norman, 2013, p. 41). In addition, a well-designed interactive system should communicate clearly to the visitor about the status of the system and the results of his interaction. Indeed, in the *stages of evaluation* the visitor should be able to clearly interpret the state of the system and whether his actions led him to reach his goal (*Ivi*).

[50] The exploration of this topic was not possible in the context of this thesis. It represents anyway an interesting topic that requires future investigation.
[51] This paragraph is partially based on the paper (Duranti, Spallazzo, Trocchianesi, 2016b).

With no claim to be exhaustive, this paragraph focuses on the analysis of aspects related to the stages of execution in tangible interaction systems applied to cultural heritage, trying to outline some reflections about the strategies these systems seem to use to trigger the interaction of the visitors, to communicate the possible actions and to make people guess the consequences of their actions.
These aspects can also be intended in terms of *agency*, a concept originated in philosophy and social science, but also borrowed in more or less explicit or implicit ways by the design and interaction design disciplines[52]. The concept of agency refers to the ability of an agent to act in the sense of producing effects in the world. In this specific case, the agents are tangible interactive installations, that we examine for their ability to act on the people, in the sense of stimulating the interaction, suggesting the right actions, and what to expect as a consequence of the actions. The latter aspect is often mentioned in the interaction design literature in terms of *feedforward*, the ability of a system of communicating "the purpose of an action" (Djajadiningrat, 2002).

On the ability to trigger the action of the people

In order to trigger interaction, tangible interaction systems need first of all to find a way to communicate to visitors the possibility to touch or interact with the object. As explained in previous sections of this chapter (see 3.4.1), different types of tangible interaction systems exist. Some of them, belonging to the "disappearing computer" paradigm, consist of just smart objects or environments, while others view the explicit presence of digital devices, alone or in combination with other smart objects. While the explicit presence of digital devices in the latter type of projects might be likely to trigger the actions of the visitor, the situation can be more complicated with reference to projects were just smart objects are present, as the system might not declare explicitly its interactivity.
In any case, a certain hesitance on the part of the visitors about interacting with the object might occur in the cases where originals are present, because touching the objects goes against one of the rules that have characterized museum visits for long time, the prohibition of touch. In this context, the role of designers is important in that they have to enact strategies to communicate that touching the object is not only allowed but also required. In the case of originals, however, the possibilities of design interventions are limited as invasive

[52] For an overview of the concept of agency of things see (Duranti, Spallazzo, Trocchianesi, 2016b)

interventions altering the shape or the structure of the object with the aim of introducing "perceived affordances"[53] are not usually possible. Therefore, common design strategies to trigger interactions with original primary objects are the use of labels, instructions or the use of sounds, light effects or video-mapping on the object that activate in the presence of the visitor, the latter trying to make the object perceivable as "alive". An example that combines both strategies is the installation "Wonder Objects" [App., Proj. 46d] consisting of an original Olivetti typewriter placed on a pedestal. Typing hands are projected on the machine keyboard, and the typing sounds can be heard as well. As the visitor goes closer to the machine, instructions about how to interact with the installation are projected on the typewriter's sheet of paper, inviting him to interact.
The use of replicas in place of original objects instead, provides designers with additional possibilities in terms of design intervention, allowing them to intervene on the material properties of the objects, for example, changing the materials and size, in order to introduce "perceived affordances" (e.g. buttons), and make clearer that touching and handling these objects is allowed. In the Virtex-Ara Pacis installation [App., Proj. 6], for example, touch sensors (push buttons) are embedded in the small replica of the monument. In the case of secondary objects (related or unrelated, originals or replicas) the perception of these objects as something that need to be used in some way can be more straightforward, for the role they often have in the visit: they are usually offered at the beginning of the visit to visitors as tools to carry and use. Nevertheless, sometimes they are accompanied by instructions to enforce their agency, like in the "Hague and Atlantic Wall" [App., Proj. 12] exhibition where instructions inviting the visitor to pick up and use replicas objects are present at the beginning of the exhibition.

On the ability to communicate what the possible actions are

Not only it is important for these systems to trigger interactions. It is equally important for them to communicate to visitors how to use them and what the possible actions are.
Projects that make use of codified actions require the visitor to perform actions that do not belong or contrast with the repertoires of gestures that are culturally associated to a certain object. These actions are difficult to guess by visitors as objects require an interaction that is

[53] Perceived affordances are action possibilities of an interactive systems that are made perceivable for the user, for example through physical qualities of the interface. For more information on the notion of affordance see (Norman, 2013)

different than expected. Different strategies are adopted in order to make the visitor understand how to interact with the system. These usually involve the use of instructions or signifiers (e.g. labels) in the case of originals (e.g. instructions in Wonder Object [App., Proj. 47]), to which we have to add the possibility of using "perceived affordances" in the case of replicas or bespoke objects (e.g. the buttons in Virtex-Ara Pacis [App., Proj. 6]). Sometimes "perceived affordances" are designed and placed externally to the object, like in "The Hague and the Atlantic Wall" exhibition [App., Proj. 12] where a lighted hotspot is created to indicate the place where the smart replica has to be put in order to activate stories.
Projects that make use of performing gestures, instead, require the visitor to perform actions that belongs to the repertoire of gestures that are culturally associated to a certain object. When the object pertains to the culture of the visitor, it might be quite easy for him to guess what the possible actions are. In the "Virtual Conductor" [App., Proj. 17], the visitor is given a conducting baton to use inside a reconstruction (partially physical and partially digital) of an orchestra stage theatre. In this context[54] it should be quite easy for him to understand what is the right action to do, that is, moving the baton in the air like a conductor would do. In addition, sometimes, even in the case of objects that do not belong to the culture of the visitor or are completely new for him, the visitor might be able to guess how to act, on the basis of his knowledge of similar objects, and the perceived affordance of the object. Nevertheless, often instructions are present anyway in order to enforce the ability of these object to communicate the right actions to the visitors. In the "Drinking Symposium" [App., Proj. 18] a signifier in the form of the label "pick me up" is written on the plinth where the kylix (a Greek drinking bowl) to enforce the agency of the kylix and prompt the visitor to actually pick the object up. Instructions, signifiers, explanations become instead fundamental when the object (i.e. an ancient object) does not belong to the culture of the visitor, because it is necessary to transfer to him the cultural background needed to understand how to use it.

On the ability of communicating the purpose of the actions

In order to be able to set and reach his goals, besides identifying possible actions, the visitor should also be put in the condition of understanding what the consequences of these actions will be.

[54] The use of the context seems to play an important role in suggesting the visitor that he is in presence of a project that make use of performative gestures. This information is fundamental in order for the visitor to adopt the right behaviour.

This operation could be easier in the systems where actions trigger reactions similar to those one would expect in reality, as long as it is made clear that we are in the presence of simulation-based systems. In the "Virtual Conductor" [App., Proj. 17], for example, since the visitor finds himself immersed in a reconstruction (partially physical and partially digital) of an orchestra theatre stage, it could be quite immediate for him to guess that moving the conducting baton will have an influence on the behaviour of the virtual musicians. Nevertheless, also in this installation, explanations and training are provided at beginning of the experience.

Understanding the consequences of the actions, however, is not generally easy since, in many cases, cultural assets or their replicas view their role and behaviour re-defined compared to the one they have in the reality. Inserted in the installation, the object often reacts in a different way one would expect and the natural expected cause-and-effect relation between action and reaction can be disappointed. Placing a cup on a table does not imply in reality the activation of audio and video narratives [App., Proj. 12]. Similarly, manipulating a replica of a statue does not imply in reality the activation of videos, audio description, or the rotation of a 3D-model rendering [App., Proj. 7]. Unless instructions are provided in advance, the visitor will not be able to build a "conceptual model" of the system at least until he tries to interact with it.

If, on the one hand, this can be seen as an issue characterizing these systems, on the other hand, as noticed by E. Hornecker (2012), designing tangible interaction systems that behave in perfectly natural and intuitive ways, and that rely on the users' prior knowledge of the real world would be limiting in that "computer systems by their nature are not like the real world and because systems need to go beyond real-world behaviour to be powerful." (Hornecker, 2012).

Although we strongly believe that this view should be embraced for it allows to go beyond the pure imitation of reality, we also think that the museum context offers possibilities to adopt some measures to make the new role and behaviour of the object become more plausible, more meaningful for the visitors, and more integrated in the "narrative" context of the exhibition. Although this topic should be investigated more in depth, it seems that some steps in this direction can be done by working on the physical or the narrative context where the object is exhibited. For example, if an object is exhibited in a way that makes it perceivable as magical (this can be done, for example, by avoiding a high-tech appearance, eliminating buttons or screens, framing it inside a narrative context where certain behaviours are normal, or exhibiting it in an evocative and suggestive way), possible behaviours that diverge from reality will become more plausible, and also the visitor

will not be just a visitor, but he will be given a more profound role inside the narrative context of the visit. An example that seems to go towards this direction is the installation "Frammenti di memoria" (App., Proj. 25), where objects belonging to the farming traditions are distributed inside the inner space of an almost ruined building in a suggestive way with illuminations and sounds "magically" evoking the atmosphere of past times. By touching the objects light effects are created and the objects start to tell the related stories of farmer. In a magical context like this, it becomes plausible for the visitor to accept this "unnatural" behaviour and start to perceive himself as endowed with a magical power, that of being able to read the memories of objects through touch.

Some reflections

What emerges from this analysis is that tangible interaction systems, in one way or another, strongly rely on the presence of an external paratextual apparatus in the form of signifiers, labels, instructions, or training sessions to make people understand how the systems work, how to interact with them, and what they get out from the interaction, or to provide visitors with the cultural background needed to understand on their own. This external apparatus is used as a way to enforce, substitute or re-define in toto the agency that the interactive artefact, in its own pure physicality, would have on visitors.
As discussed in (Duranti et al., 2016b), this apparent need of an external apparatus can be interpreted in different ways. A possible interpretation is that given the novelty of these systems for visitors, instructions or labels are needed to let them overcome their instinctive hesitance to interact with them. Another interpretation is that these systems are still in their initial stages of development and designers have not yet reflected upon or find ways to "fully exploit the persuasive power of design (Redström, 2006) and the agency of designed objects" (*Ivi*). On the other hand, another plausible explanation is that tangible interaction systems "cannot avoid the use of labels and/or a paratextual apparatus to guide user's actions" (*Ivi*). If this is the case, further research could be useful to reflect on ways to make external information as less intrusive as possible.
An additional aspect that emerges from this analysis (and that is in some way connected to the previous one) regards the strong influence that the *context* (physical, narrative, etc.) could have on the perception of the interactive installation and the meaning-making process carried out by the visitor. It seems that tangible interaction installations, even more than other kinds of installations, cannot be conceived and designed as stand-alone artefacts, if we want to fully exploit their

potential. For this reason, including reflections on the wide concept of context, and make decision with regards to it might be useful during the design phase of a project. In other words, the notion of context should be included as part of a conceptual and design framework this research is going to develop.

3.5 Aspects related to learning, social engagement, participation, and personalization

In the previous section, aspects related to the physicality of the projects and their interactivity have been presented. In this section, the projects will be analysed on the basis of aspects that represent important topics in the museum studies literature, such as museum learning, social engagement, participation, personalization. Although some of these aspects may seem very abstract, design choices related to them are able to influence the physicality and interaction styles of the projects. Since these topics are very broad, the analysis presented in this section is not to be considered as a complete analysis, but just as an overview.
Drawing on categories developed in the museum studies literature, we will try to map these projects on these categories to see what areas have already been covered and what instead needs further experimentations. It is important to notice that this analysis will be partially based on the first spreadsheet-based classification of the projects, where slightly fewer projects were present, since a full implementation of these aspects in the database has not been possible yet for reasons of time. Results from this analysis are presented below for their ability to give already some interesting information or at least indications for further investigations.

3.5.1. Learning approach

Education of visitors is one of the goals of museums and heritage sites. Different approaches to learning exist and have also been discussed and theorized by the museum studies literature[55]. Whether it is the result of a conscious choice or not, the adoption of a specific approach is able to influence the way education actions are designed in museums, included those that make use of digital technologies. In this paragraph, tangible interaction systems are analysed in order to understand what types of learning approaches they implement. For its ability to summarize the different learning models and how they apply to the museum and cultural heritage context, Hein's model (1998) is used for the purpose of this analysis. Juxtaposing orthogonally two continua on each other – one representing the different theories of

[55] Studies on the topic of museum learning have been carried out mainly by the Anglo-Saxon museum studies literature. See for example Falk (2000), Hein (1995, 1998), Hooper Greenhill (1994, 2007), Lord (2007), Pearce (1989).

knowledge (epistemology) and the other representing the theories of learning – Hein's model identifies four education theories (Figure 74).

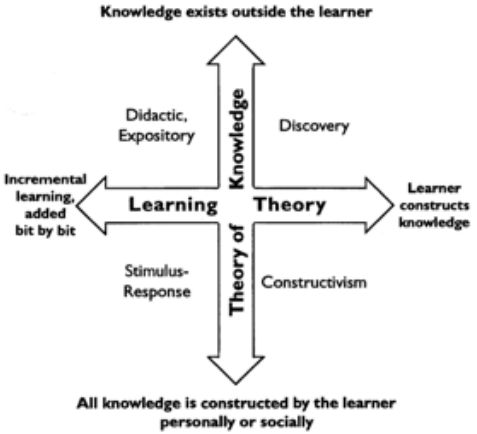


Figure 74 Hein's model of learning in museums (source: Hein, 1998).

The theories of knowledge can be classified on a continuum between two extremes: the realistic position, according to which there is an objective knowledge, an external truth, and the idealist position according to which there is not an objective knowledge since this is constructed by people. The theories of learning can be classified using a continuum between two extremes. On the one hand, there is the transmission-absorption model according to which people learn by absorbing information that is transmitted to them in small pieces, bit by bit. On the other hand, there is the belief that people play an active role in the construction of their knowledge.

The types of educational theories identified by Hein are: didactic/expository; stimulus-response education; discovery learning; constructivism.

According to the *didactic expository* educational theory, the teacher would present the "true" knowledge, dividing the content in more units and presenting them to people in order of increasing complexity so as to facilitate the learning process. Museums organized in this way tend to have clear education goals and to present exhibitions with a specific beginning and end, with the subject presented in a sequential order from simple to complex. In addition, they claim –more or less explicitly- for the objectivity of the information that is presented.

This claim for objectivity is instead absent in the *stimulus-response* educational theory however it presents the same learning theory as the

didactic expository one. Museums organized according to the stimulus-response approach are structured similarly to the didactic/expository ones, but in addition, they "have reinforcing components that repeatedly impress the stimulus in the learner and reward appropriate response" (Hein, 1998) and, in doing so, they adopt a behaviourist approach[56].
In the *discovery learning* educational approach, active learning is combined with a realistic position on knowledge. It is based on the assumption that if people are exposed to the raw data, they will be able to discover the true knowledge by themselves through mental or practical activities.
Museums that are organized in this way will have, for example: "exhibitions that allow exploration, probably including going back and forth among exhibits components; a wide range of active learning modes; didactic components that ask questions, prompt visitors to find out for themselves; some means for visitors to assess their own interpretation against the correct one" (Hein, 1998).
Finally, according to the *constructivist position* visitors should be provided with opportunities to construct their own knowledge and with ways of validating their conclusions, independently by those intended by the curators. A constructivist exhibition will: "have many entry points, no specific path and no beginning and end; provide a wide range of active learning modes; present a range of point of view; enable visitors to connect with objects (and ideas) through a range of activities and experiences that utilize their life experiences [..]" (Hein, 1998).

The different education theories proposed by Hein have been used as a basis for understanding which learning approaches have been applied in tangible interaction installations in the cultural heritage field and what are possible gaps in the research. For this analysis, just three of the learning approaches will be considered here that are: didactic expository, discovery learning and constructivist approach. From the analysis, all the learning approaches turn out to be represented in the corpus of projects. The didactic approach is the most used (47%), followed by the constructivist approach (16%) and the discovery

[56] Behaviourism, like cognitivism and constructivism, is a psychological learning theory. This theory considers the mind as a black box without focusing on internal processes and structures, but only on the observable behaviours. In this perspective, different behaviours in response to external stimuli are interpreted as learning. Positive or negative reinforcement are used in order to shape the intended behaviour. Hein considers the educational theory at the bottom left of the graph as behaviourist since, especially at the beginning, behaviourism did not make any claim about the objectivity of the knowledge that is learned (Hein, 1998).

learning approach (13%). There are also projects combining didactic and discovery learning approaches (about 3%) and discovery and constructivist approaches (about 15%).
While further analysis would be necessary in order to understand how each learning approaches have been applied concretely in the projects, and to identify recurring design patterns, for reasons of feasibility, just some preliminary considerations are presented below.

Many of the projects pursuing a *didactic learning* approach seem to do this by providing didactic descriptive contents in the form of audio, graphics and text that represent factual contents about the subject. In addition, they often look very traditional in their aspect: the screen is often well evident and the novelty is in the type of interface that is used to activate contents. Also the actions that are required to activate the content are often very simple codified actions like pushing buttons on the surface of a replica (e.g. Virtex – Ara Pacis [App., Proj. 5]), touching portions of the object (e.g. Interactive Stela [App., Proj., 6]).
Projects pursuing a *discovery learning* approach, instead, wants the visitor to gain a specific knowledge about the subject or understand a specific concept, but instead of conveying this in a traditional didactic way, they use strategies to enable visitor to discover this knowledge on his own. This is often done by involving people in activities that allow them to get to the correct conclusion or to experience directly some concepts. In "Tangible interfaces to explain Gaudı's use of ruled-surface geometries" [App., Proj. 36], for example, a tangible interface is designed to make it easier for the visitor to understand the column modelling methods Gaudi used to build the Sagrada Familia, compared to a verbal description or complex geometric representation. "Performing actions" seem to be more common in projects pursuing discovery learning approaches. For example, in "Waltz-dice-game" [App., Proj., 33] people can experience directly the dice game "The Instant Minuet and Polonaise Composer" invented by the German violist and composer J.P. Kirnberger, by throwing dices for generating complete music compositions from pre-composed options.
Finally, projects applying a *constructivist approach* usually do that by providing first-person narratives instead of factual descriptions, and they often do that from multiple points of view. Listening to different stories visitors can build their personal interpretation of what they are looking at. An example of installation implementing a constructivist approach is the installation "The Hague and the Atlantic Wall" [App., Proj., 12] where people are enabled to listen to stories related to the objects on display from different perspectives (the civilians, the officials, the Germans). In this kind of projects, sometimes people are

also given the opportunity to contribute to the content of the installation with their interpretation and contents. In "Reminisce" [App., Proj. 16], for examples, the visitors not only can listen the personal memories of characters at specific locations in "Bunratty Folk Park" in Ireland, but are also given the possibilities to record their own thoughts, and all these visitor's recordings will be available for listening to other visitors at an interactive station at the end of the visit.

3.5.2. Social Engagement

Another aspect that characterizes interactive installations in museums is related to the type of social engagement they provide to visitors. Analysing tangible interaction projects in relation to this aspect can be important for understanding the type of social engagement projects are designed for (and how this affects their structure), and for identifying new areas of research and experimentation for tangible interaction in museums.
Many studies have investigated the topic of sociality in museums and looked at it as "a primary factor in visitors' motives and satisfactions" (Debenedetti, 2003). With regards to this topic two interesting models can be identified in the literature: Debenedetti's "together-alone" semiotic square (Debenedetti, 2003) and Simon's *me-to-we* design model (Simon, 2010). The former identifies the different modes of social appropriation of museum space while the latter is a tool aiming to help designer in building social and participatory experiences in museums. Below, the two models are presented more in details and used to analyse the modes of social appropriation and social engagement provided by tangible interaction installations in museums.

Modes of social appropriation in tangible interaction installations

Debenedetti's semiotic square (Debenedetti, 2003) is based on the observation that a cultural activity is not only a personal and intimate experience but also a social activity that can be shared with companions, like friends, family members or "strangers". Visitors have to balance between these two opposite poles: conviviality on the one hand and introspection on the other hand. The semiotic square proposed by Debenedetti (Figure 75) describes the dynamic between these two polarities, and through doing so it identifies four different modes of social appropriation of the museum space: fusion visit, private visit, separated visit, pursuit of social contact. In the *fusion visit* mode, the visitor shares the visit with companions: they arrive together, look at the objects together and leave together. In the *private visit*, the

visitor experiences the museum alone, without companions. In the *separated visit*, the visitor experiences the gallery apart, establishing verbal or physical barriers to the social interaction with companions. Finally, in the *pursuit of social contact* mode, the visitor, in absence of companions, tries to make social contacts. According to Debenedetti (2003), "the space should be designed so as to address four modes of socially appropriating the museum, enabling visitors to pass at will from one pole to another".

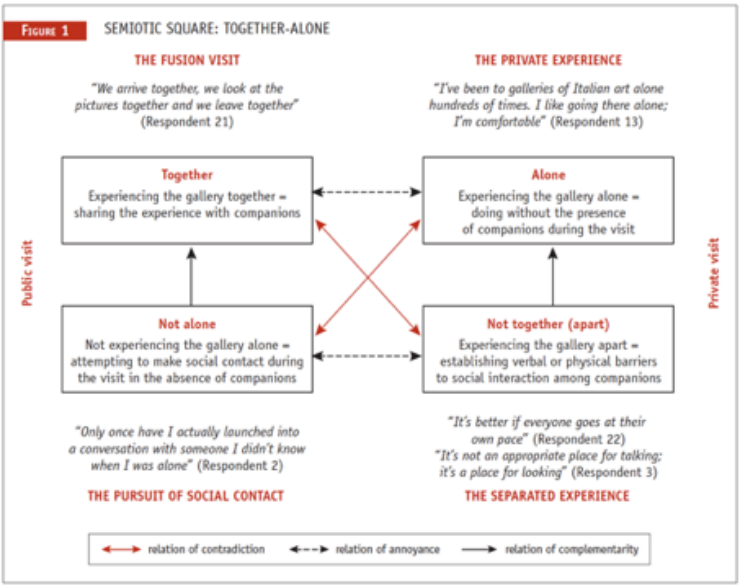


Figure 75 Debenedetti's semiotic square (source: Debenedetti, 2013).

Although this is a model that focuses on the entire visit experience, it could be used to analyse single installations as well, and understand what modes of social appropriation they elicit.
But what to look at for understanding this aspect? To the intentions of designers or to effective reactions of the visitors? Human beings are social beings, thus social behaviours could emerge also in the presence of an installation that is designed for a personal experience or even when the social aspect is not taken into account during the design process. Both aspects are often difficult to catch as in many cases the intention of the designers are not declared in the documentation or papers, and the effective reactions of people are not always reported either. Therefore, the only possible thing to do is to look at some of the

physical characteristics of the installations that can potentially have an impact on the social aspect and elicit certain modes of social appropriation (Table 3). Findings emerging from this analysis will be presented below.

Social appropriation of interactive installation	**Characteristics that potentially foster a certain type of social appropriation of the interactive installation.**
Private visit	• The installation proposes an interaction which makes sense when the installation is used by a single person: o It is a single user installation; o It is a multi-user installation that makes sense also in case of a single user o The installation requires the asynchronous participation of more people.
Separate visit	• The installation is made up of multiple independent interactive stations.
Fusion visit /Pursuit of social contact	• The interface at the level of the single interactive stations allows more people to interact at the same time; • The output of the interaction is visible or accessible to more people at the same time; • The installation proposes activities that require the interaction of more people in order to make sense.

Table 3 Summary of the physical characteristics of interactive installation that potentially foster certain modes of social appropriation.

A first observation emerging from the analysis is that almost all the installations (about 87%) in the corpus are suitable for a private visit because either they are single user installations or are multi-user installations that make sense also in case of single-person usage. There are then some installations (24%) supporting the separated visit in that they are multi-stations interactive installations. Overall, 41% of the installations seems to be able to allow for the fusion visit or the pursuit of social contact. This is done through the presence of an interface that allows more people to interact at the same time (about 3%), through the presence of an output that is accessible by more people at the same time and that is able to potentiate spectatorship effects (about 71%), or by proposing activities where the involvement of more people is required in order for the installations to make sense (12%).
Synthesizing, all modes of social appropriation are represented in the

corpus of projects. However, it is worth noticing that, although a good number of projects seems to be able to foster social engagement among visitors, only few of them reach this by presenting *activities* that have been designed in such a way that they require the interaction of more people to become fully meaningful.

Social activities and modes of social engagement

At this point an interesting topic regards the identification of the different **modes of social engagement** social activities can be designed for. Some help can come looking at Nina Simon's me-to-we design model (Simon, 2010). It describes a process which enables cultural institutions to move from personal to communal engagement through contents, identifying multiple levels of social engagement. It is a bottom-up process as it "*builds on individual (me) experiences to support collective (we) engagement*" (Figure 76).

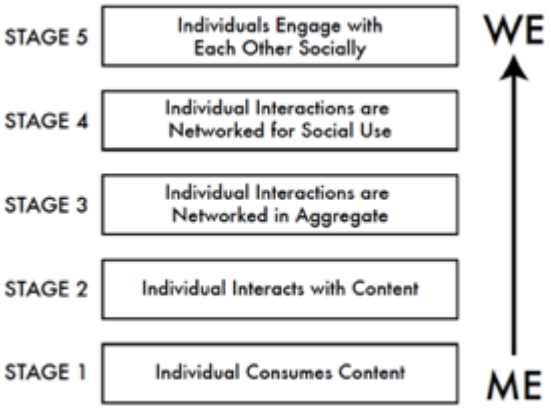


Figure 76 Nina Simon's me-to-we design model (source: Simon, 2010).

The process consists of five stages starting from a total absence of social engagement, going through forms of indirect social relationships (e.g. awareness about the choices done by other visitors), up to the working of the museum institution as a social hub. The stages are progressive in the sense that it is not possible to design a five stage experience without laying the groundwork of the previous stages. The various stages differ for the type of interaction with content and how this allows visitors to

connect socially with other visitors. Quoting the words of Simon (2010),

"Each stage has something special to offer visitors. Stage one provides visitors with access to the content that they seek. Stage two provides an opportunity for enquiry and for visitors to take action and ask questions. Stage three lets visitors see where their interests and actions fit in the wider community of visitors to the institution. Stage four helps visitors connect with particular people – staff members and other visitors – who share their content and activity interests. Stage five makes the entire institution feel like a social place, full of potentially interesting, challenging, enriching encounters with other people".

It is important to note that Simon's model is a tool for design. It shows to designers what aspects need to be considered in projects that aim to enable certain types of social engagement. But what is even more interesting for the purpose of this research is that, in doing so, Simon's model also implicitly identifies different modes of social engagement. Concerning this, Simon's model suggests the existence of at least three types of experiences going beyond the pure personal experience. These are: personal experiences with social awareness, indirect social experiences, direct social experiences. *Personal experiences with social awareness* are those in which the visitor does not interact with anybody else, but he is made nonetheless aware of the choices and opinions of the other visitors, and of how his interests and actions are located inside a community of visitors. The traditional guest book, often present in cultural institutions, is an example of analogic tool that enables a personal experience with social awareness. *Indirect social experiences* are those that are completely mediated by the device and do not require a physical contact with other visitors. Sharing pictures or comments on the web or communicating through personal devices are two example of indirect social experiences. Finally, in the *direct social experiences* the visitor interacts face-to-face with other visitors (with or without) a device. An experience of this kind is the one visitors can have when engaging in a group activity or a game around an interactive table.
Looking at the few projects where visitors are required to take part in social activities[57], examples of installations/stations belonging to the different categories mentioned above can be identified. Belonging to the "personal experience with social awareness" category is the installation "Re-tracing the Past" (Figure 77). Using a phone located in

[57] Here the focus is on those installations where there are clearly intentionally designed social activities, although we are aware that spontaneous social behaviours can also emerge in reality.

the "room of opinion", the visitor can record a personal interpretation about an object. When this happens, a murmuring sound that is based on previous visitor's recorded opinions increases in volume as the new opinion is added to the others. In addition, a new brush stroke is added to a digital painting located in the same room. Through these strategies, the visitor is made aware that his opinion goes to contribute to the interpretation of the same object that is made by the community of visitors. The same installation also enables a form of "indirect experience", as the comments left by the visitors are recorded and made available to other visitors for listening to later on through a radio station located in the "Study Room".

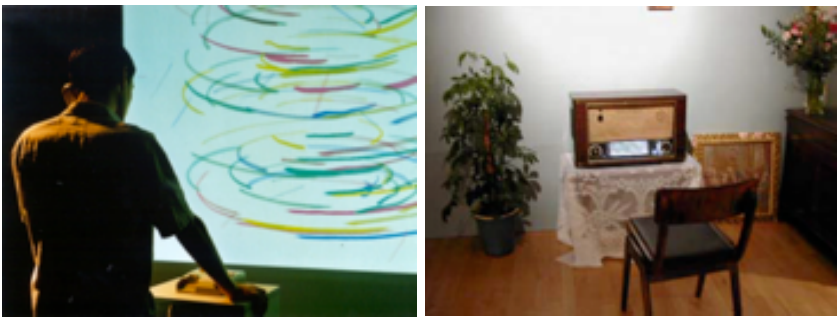


Figure 77 (a) The Recording station in Re-tracing the past. (b) The radio in Re-tracing the past (source: Fraser et al., 2004) [App., Proj. 41].

An example of activity implying a direct engagement of more people is implemented in the "Historical Orchestra" (Ferhat et al., 2011), an interactive designed to enhance the experience of a 16th century Turkish manuscript documenting through illustrations an arts and crafts festival organized by Sultan Murad III for the circumcision celebration of his son (Figure 78). Using three tangible musical interfaces, that replicate those represented in the illustration, the visitor can impersonate the role of players and make the animation goes on (the players move forward; the audience increases in number of people; the Sultan appears on the Palace window when all the players arrive there).

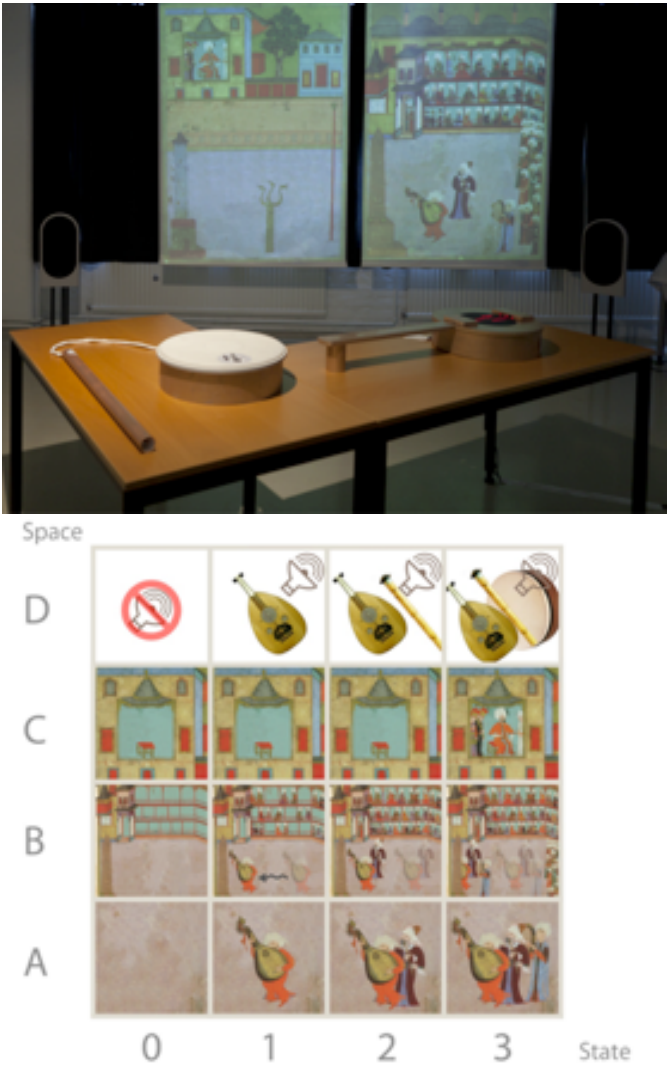


Figure 78 The 'Historical Orchestra' installation and a description of the interaction/animation phases (source: Şen et al., 2011) [App., Proj. 30].

The most complex example of social activity is the one proposed by the installation "Kurio" (Figure 79) consisting of tangible interfaces, a PDA, and a tabletop, that are used by family members to collaborate in the accomplishment of missions as part of a game. This game views the visitors in the role of time travellers stuck in time and needing to fix their time map. The missions are received on the PDA by a family member that assign challenges to the other members. The challenge requires the family members to collect information in the museum using tangible interfaces. Finally, a tabletop display can be used by them to assess their progress in the missions and get reward videos or information.

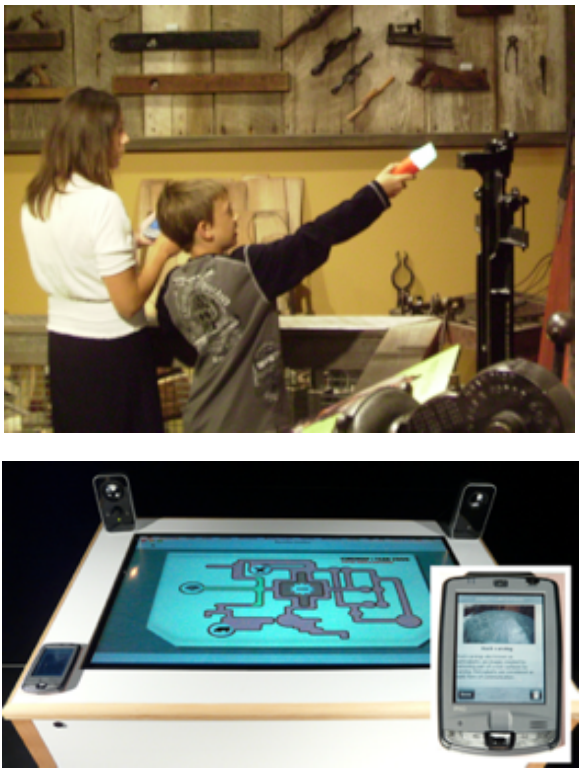


Figure 79 In "Kurio" people collaborate in the accomplishment of a mission using a combination of tangible interfaces and traditional devices (source: Wakkary et al., 2009) [App., Proj., 14].

Summarizing, what emerges from this analysis is that while many projects present characteristics that might elicit spontaneous social behaviours, only few of them really propose activities (e.g. collaboration, competition, conversation, game activities etc.) that require the participation of more people in order for the installation to make sense or to become more meaningful. The design of social activities is thus an aspect that might be worth exploring more in depth in future research.

3.5.3. Personalization

Museum visitors can have different needs and motivations for visiting museums based on their identities, personal experiences and memories (Falk, 2009). In this context, personalization becomes key because it allows to "treat visitors as individuals" (Simon, 2010) and to provide "audience-centric ways to enter and access cultural experiences" (Simon, 2010). When applied to interactive technologies, personalization connects to the topic of interfaces adaptation that is studied in the HCI literature (Paternò, 2013) and that searches for ways to adapt the various aspects of the user interface (presentation, dynamic behaviour, content) according to changes of the context of use (user-related aspects, technology-related aspects, environment-related aspects, social aspects). The personalization of interactive technologies in museums has also become the object of several studies, as summarized in Kuflik et al. (2012). Analysing whether and how adaptation and thus personalization has been applied in tangible interaction installations in museums can be interesting for the importance that this topic has in museum, and also for identifying possible gaps.
Taking the cue from the HCI literature and from an attempt of classification developed in (Hincapié-Ramos, 2014) different categories related to personalization can be identified:

- absence of personalization;
- personalization just based on manual filtering of content[58];
- interfaces that are personalized on explicit declaration of the visitor of certain characteristics like user type, preferred mode of interaction, preferred topic/perspective (adaptable interfaces);

[58] Manual filtering can be considered as a basic form of personalization and consists in allowing the visitor an open exploration through the selection of the contents they want to access to instead of presenting a single navigation path.

- interfaces that are automatically personalized on the basis of users models (adaptive interfaces).

Installations that are characterized by total absence of personalization are quite rare (absent in the sample of academic projects), and are those that are based on simple forms of interactivity that do not allow for the selection of different contents. Although rare, this is a situation that can sometimes be found at the level of the individual stations that are part of wider installations. In "Frammenti di Memoria" [App., Proj., 25], for example, touching a specific object that is part of the installation, a story and light effects are generated that are the only ones available for that object.

The majority of the installations (80%) provides a personalization that is based on manual filtering. In single-station installations this is done by allowing the visitor to activate only the content he is interested in. In Virtex installation [App., Proj., 5,6,7], for example, by touching different areas of the replica of a cultural heritage object, the visitor activates specific stories or explanations. Multi-stations installations automatically provide a basic form of personalization through filtering, since the visitor can choose the stations he wants to interact with. Analysed as a single wide installation, "Frammenti di Memoria" [App., Proj., 25] offers this type of personalization as well.

Some installations (15%) provide some forms of adaptability, e.g. allowing visitors to get different contents on the basis of certain preferences explicitly expressed by them, like visitor characteristics, preferred perspectives etc. The expression of preferences can be done in different ways. One possibility is to design objects that are symbolic of possible preferences or profiles. In the "Hague and the Atlantik Wall" [App., Proj. 12] exhibition, the visitor is given at the start the possibility to choose and pick up one or more smart replicas, each representing a different perspective and language on the subject of the exhibition (civilians, officials or Germans in English and the same perspectives in Dutch), to carry with them during the visit. When reaching specific glass cases, the visitor can use one of the replicas to listen to stories from the favourite perspective/language. As an alternative to the design of different objects representing different profiles, there are other installations that provide only one type of object for the visitor to pick up, complemented by an interactive way to select preferences or visitor profile and associate them to the object itself. In "Keys to Rome" exhibition at Allard Pierson Museum, at the beginning, the visitor can take a card [App., Proj., 2014] and associate to it, through a touch screen station, a favourite perspective with regards to the exhibited objects in the exhibition (Egyptian, Roman, Lowland). Once the association is

done, the card can be used in the various stations in the exhibition to access digital content from the selected perspective. Sometimes the two adaptability strategies are combined together in the same project as in the case of "Interactive Histories" [App., Proj., 42], where a welcoming station allows the visitor to choose among different physical tokens each representing a different thematic tour in the exhibition, but also to associate to it other preferences such as level of background knowledge and age.

To conclude this overview, there are very few installations (5%) that provide also some forms of adaptivity, that is, where the content that is offered to the visitor not only depends on preferences expressed by the visitor himself, but also on the application of certain user models or automatic rules. The most complex example of adaptivity is represented by "ec(h)o" [App., Proj., 32]. This installation requires the visitor to explore an exhibition while carrying a wooden cube with three coloured sides while wearing headphones. While the visitor moves through the exhibition, he can hear immersive ambient sounds providing a context for the nearby objects and attracting him to go closer and, as he approaches the objects showcases, different audio contents can be selected and listened to. The content provided by the system is dynamically selected on the basis of the visitor's movement in the exhibition, and the interaction history.

Adaptive personalization of the visit experience through tangible interaction seems to be a topic that could benefit of further research, given the apparent low number of projects making use of this form of personalization.

3.5.4. Participation

Simon (2010) defines "a participatory cultural institution as a place where visitors can create, share, and connect with each other around content", in this way including in this definition also the aspect of sociability and not only the aspect of the creation of contents.
According to the definition of Dalsgaard et al. (2008) participation is intended as "(co-)exploring, (co-)constructing and (co-)contributing to the place as a resource for knowledge".
While (co-)contributing and (co-)constructing regards the creation of new contents (in the forms of comments or something new), the aspect of (co-)exploring refers to the cases in which the visitor co-contributes to the interaction, as his action have an impact on the other choices, in this way being an aspect that is very linked to social engagement.

Having analysed the aspect of sociability in a previous section (3.5.2), a narrower definition of participation is used here which excludes the aspect of sociability and focuses instead on the level of involvement of the visitors in the creation of contents. We will simply distinguish between projects where visitors are consumers of contents and others in which the visitors are producers of contents.
Most of the projects that have been analysed view the visitors simply as consumers of contents (64%). In these projects the visitor interacts with the systems in order to get predefined content (in the form of text, audio, video etc.). Anyway there are few examples in which the person can participate in the generation of content.
The content that is generated by visitors usually consists of comments, opinions, drawings etc. that are shared and can be later accessed by other visitors. For this reason, participative installations require the design and the presence of both a way to allow visitors to generate and record their own content, and a way to allow them to enjoy the content other visitors already shared. These two functionalities can be designed either separately by creating two separate stations as part of the installation, or can be integrated inside a single interactive station.
"Retracing the Past" [App., Proj., 41] is an example of the first type of installations. Visitors can record their interpretations about mysterious objects using a phone in the "room of opinion", in this way contributing to the content of the exhibitions. These interpretations can then be listened by other visitors through the radio station in the Study Room. Another interesting participatory project, belonging to the second type, is an installation in the United States Holocaust Memorial Museum consisting of a series of desks where the visitors can hand write a pledge about how to face the problem of genocide today (Figure 80). After depositing the pieces of paper in a glass vitrine, the same text appears in a big pledge wall projection.

Figure 80 Installation about genocide at the United States Holocaust Memorial Museum (source: Conley-Zilkic, 2011) [App., Proj. 44].

In addition to these types of projects that are clearly participative, there are some projects, where the visitor is a producer of content rather than a mere consumer, however this content is just enjoyed by him at the moment of the interaction with the system and not shared later on with other visitors. In "Waltz-dice-game" [App., Proj. 33] at the Philharmonic Museum in Vienna, for example, by rolling two dices two visitors can generate new music compositions. For the sake of simplicity, in this thesis, also this kind of projects have been classified as participatory.
Additional reflections would be necessary in order to identify different design strategies for the creation of participatory projects and also to understand whether tangible interaction offers more or different opportunities in terms of designing for participation compared to traditional technologies. However, this question is beyond the scope of this thesis.

3.6 What experiences of CH does tangible interaction enable? Some preliminary observations

In Chapter 1 it has been observed that, although the expression "tangible interaction" has its origins in the technological world and denotes a specific field in Human-computer interaction and Interaction Design, when used with reference to the cultural heritage field, it lends itself to be easily associated, especially by cultural heritage experts and professionals, to various meanings and topics that have to do with: 1) a tactile experience of cultural heritage; 2) an embodied experience of cultural heritage; 3) a real encounter with an object as opposed to the virtual encounter as usually provided by digital technologies; 4) a material approach to cultural heritage as opposed to the traditional informative approach. Although in the course of this research tangible interaction has been considered in its technological meaning of "user interfaces and interaction approaches that emphasize: tangibility and materiality of the interface; physical embodiment of data; whole body interaction; the embedding of the interface and the users' interaction in real spaces and contexts" (Hornecker, 2006, 2010), it can be interesting to reflect upon what experiences of cultural heritage tangible interaction systems enable. Below some preliminary reflections are provided.

Is tangible interaction about touching cultural heritage assets?

From the examples presented in the course of the analysis, it should be clear that tangible interaction is not necessarily associated to the tactile experience of cultural heritage objects. In some cases, the interaction is carried out without contact with the smart object or the object is absent, in other cases the objects consist of abstract entities like cards, balls, or other objects (secondary objects) that are different from the cultural heritage that is the focus of the installation. On the other hand, in projects where primary objects are used in the form of original objects or smart replicas and the contact with the objects is allowed, tangible interaction allows tactile experiences of cultural heritage. However, it should be noticed that often the actions that are required to interact with the object (pushing button, touching single areas with a finger) are not the same of or contrast with those actions a person would do when exploring an object through the sense of touch. This suggests that, at least in some cases, a traditional, non-technological replica could be sufficient and more suitable to enable actual tactile experience of objects.

Is tangible interaction enabling embodied engagement with cultural heritage assets?

An embodied engagement with cultural heritage is an experience that views an involvement of the body beyond the mere contact between the hand and the object. Tangible interaction seems to be able in certain cases to enable or to prompt embodied engagement with cultural heritage object. This goal is sometimes reached by designing installations that require gestural interaction with objects that goes beyond the mere touch like in the already mentioned Drinking Symposium installation [App., Proj. 18] where "performing actions" like picking up the bowl for drinking or laying down on the daybed are performed by the visitor in order to participate in a simulation of the ritual. Another example is "Strike the pose" [App., Proj. 52], where the visitor is required to match with his body the position of sculptures that are part of the collection.
Besides, an embodied engagement with cultural heritage sites seems to be fostered by certain uses of tangible interaction, that aim to conceal the technology in seemingly non-technological artefacts and/or to integrate it in the environment so that the technology does not compete with the experience of "being there". The "Companion Novel- Voices from the Trenches" [App., Proj., 22] is an example that goes towards this direction. In this installation the technology is completely hidden in seemingly non-technological objects: a belt worn by the visitor while exploring the site, some cards that can be inserted in belt pocket to change the theme, and some lanterns used to hide loudspeakers in various points of interest and emitting sounds/narrations as the visitor approach the specific point of interest in the site. Findings from the visitor evaluation suggest that this use of technology is able to facilitate the experience and the sense of place in the visitor (Marshall et al., 2015).

Is tangible interaction enabling real encounters with cultural heritage as opposed to virtual encounters usually provided by digital technologies?

A drawback characterizing traditional uses of digital technologies in museums is the fact that they distract and disengage visitors from the objects and their materiality. Indeed, traditional installations are often presented as detached from the original object, or push visitors towards a virtual experience of heritage rather than a physical experience. Certain uses of tangible interaction seem to be able to overcome these issues and foster a real encounter with the original object. Different strategies to reach this goal have been identified previously in this research. In some cases, the encounter with the original object is

fostered through the embedment of the original object in the interactive installation. In addition, as explained above, the physical experience with a cultural heritage object or site, can be facilitated through the use of tangible interaction as it allows for a hidden use of technology that does not compete with or distract from the experience of the real object/site as it would do for example a mobile device (see for example Marshall et al, 2015; Petrelli et al., 2016a; Petrelli et al., 2016b). Finally, other strategies can be adopted in order to enable the encounter with an object that is distant from the interactive installation. These consist in the design of actions for the visitor to perform before or after enjoying the interactive installation. These actions consist, for example, in carrying tangible objects from the interactive installation to the place where the original object is located, or vice versa, like in "Reminisce" [App., Proj. 16].

However, it must be noticed that, tangible interaction is not to be considered as synonym of less distraction from the existing tangible object as the use of tangible interaction per se does not guarantee this effect, unless design strategies (like those mentioned above) are put into practice to make the original objects have the right prominence in the context of the visit. Indeed, for example, when smart replicas are used the problem of distraction from the original object might even be amplified. Smart replicas indeed, allowing to reproduce not only the visual appearance of the objects (like in traditional uses of digital technologies) but also their physicality, might present themselves as exact copies of the objects or even more appealing substitutes of the original objects, in this way discouraging the experience of originals even more than traditional technologies. Although further studies are needed to investigate this issue, it certainly represents a potential risk.

Is tangible interaction a manifestation of the material or informative approach to cultural heritage?

A material approach is one that emphasises the visitor's encounter with the object along with the emotions, affects, sensations, and personal interpretations that emerge from it, without the prerequisite of the information (Dudley, 2010). On the other hand, the informative approach emphasises the information on the basis of the view that "objects have value and imports only because of the cultural meanings which immediately overlie them" (Dudley, 2010). In this view, the object becomes just a "part of an object-information package" (Dudley, 2010), but if too much emphasis is put on the information the object risks to "dissolve[] into meanings" (Hein, 2006).

While tangible interaction might be intuitively associated to the material approach, from the analysis carried out in this research it should be clear that it is not the case. In the majority of the projects, indeed, something is proposed that goes beyond the object per se, like information, stories, interpretation etc. On the other hand, though, tangible interaction cannot be considered fully a manifestation of an informative approach either since, in almost all the projects a prominent role is also given to the object in its materiality. For these reasons, tangible interaction could be considered as a way to find a balance between the two positions, since emphasis is put both on the information and the physical engagement with the object.

3.7 Conclusions

The work presented in this chapter represents an attempt towards a better understanding of the complexity that characterizes tangible interaction in museums and cultural heritage sites. In order to reach this goal, a large number of projects have been gathered, analysed, classified, and a database has been created to facilitate the analysis. Beyond showing the state of the art of tangible interaction applied to cultural heritage, this analysis has allowed to identify different aspects that make the design of a tangible interaction system, and that, de facto, represent themes around which choices have to be made during the process of design. For each aspect, the analysis has also allowed to identify possible categories of choice options. These aspects and related choices are summarized in the following table, representing a conceptual framework and the foundations for a design framework for tangible interaction applied to museums and cultural heritage sites (Table 4).

Main target					
Able-bodied public		People with disabilities			Universal target
adult	children	blind and visually impaired	learning disabilities	etc.	

Purpose of the installation		
associate intangible values to tangible assets	give tangible form to intangible assets	allow people to experience the material properties of tangible assets

Cultural assets								
Tangible assets			Intangible assets/values					
works of art	architectures/ buildings	etc.	concept	Story	practice	ritual	factual inf.	etc.

Location of original tangible asset			
embedded in the installation	close to the installation	located in the museum (distant)	located in another place (very distant)

Strategy to foster the experience of original tangible asset		
naturally fostered through location	fostered through action	not fostered

Single/Multi interactives installations	
Single station installation	Multi stations installation

Tasks					
Activating information	Getting instructions	Producing content	Navigate a 3D model	Activating simulation	Etc..

Devices (activating object)					
Smart object					Traditional device
Primary object			Secondary object		
Smart original	Smart replica	Smart derivative	Related object	Unrelated object	

Actions	
Codified actions	Performing actions

Interaction style	
Interaction with contact (manipulation-based interaction)	Interaction without contact (free gesture-based interaction)

Output purpose		
Communicating the intangible value of a tangible CH asset	Communicating the status of the system	Provide instructions

Output media			
visual	audio	haptic	Other…

Output type	
Emulative output	Non-emulative output

Location of output (with respect to input interface)			
Output device is the input device	Nearby (output tightly coupled to the focus of the input)	Environment (the output is around the user)	Distant (the output is on another screen/object)

Context
Physical context
Narrative context

Strategy of association of intangible values		
Linking contents to primary object	Embedding in secondary object (symbolic smart object)	Embodying into action (performing action)

Agency				
The ability to trigger the action of the people				
Explicit presence of digital devices	Instructions/labels	Attracting sounds	Perceived affordance	Object offered at the beginning
The ability to communicate what the possible actions are				
Instructions/labels	Perceived affordances	Context		
The ability to communicate the purpose of the actions				
Instructions/explanations	Context (physical/narrative)			

Learning approach		
Didactic expository	Discovery learning	Constructivist approach

Mode of social appropriation			
Fusion visit	Private visit	Separated visit	Pursuit of social contact

Modes of social engagement (in on-purpose designed social activities)		
Personal experience with social awareness	Indirect social experience	Direct social experience

Participation	
Visitors as consumers	Visitors as contributors

Personalization			
none	Manual filtering	adaptable	adaptive

Table 4 Conceptual and design framework developed through the thematic analysis of the projects.

While further work is needed to fully understand all the aspects at play in the design of tangible and embodied interaction systems and their interrelations and to build a more comprehensive conceptual framework, what has been done represents already a valuable contribution to the field. As such, it is already able to provide researchers, practitioners and museums professionals with a better understanding of different possible applications and characteristics of tangible interaction, and with a possible language to talk and reflect upon the topic. In addition, this work is able to provide researchers with an account of what has been done, and with the possibility to identify gaps. The identification of gaps can be useful to orient new research efforts in the field and might be facilitated in the future by making the database accessible online.

Some of the gaps or topics that need further exploration have already been identified in this thesis. A first area that would probably benefit from further research is the one related to the design of social engagement of visitors through the use of tangible interaction. While many projects have characteristics that seems to be able to prompt spontaneous social behaviours, only few of them propose activities that demand the participation of more people in order for the installation to make sense or become more meaningful.
A second area that could be explored further regards the design of participatory experiences through tangible interaction, as not many examples of participatory installations have been registered. In addition, further research in the design of installations that are targeted to specific types of public (like children, blind and visually impaired people, people with learning disabilities, etc..) could be useful, as the attention to these categories of people by designers and researchers has started only recently. There is then the issue related to the design of the agency of tangible interaction systems. Further reflections and practical experimentations on this topic, could be useful to make tangible interaction systems easier to interact with for the visitors.
Another area that would benefit from further experimentations is the one concerning the use of tangible interaction to give material form to intangible heritage. This is a promising area since not many projects attempting to materialize intangible assets can be found in the database, while it is more common to find projects where there is an attempt to associate intangible values to existing tangible objects.
Finally, a recurring topic that implicitly emerges in several parts of this thesis, concerns the issue of the meaning/sense of tangible interaction systems for the visitor. Indeed, in this thesis tangible interaction has been analysed mainly for its ability to associate intangible values, thus meaning, to tangible cultural heritage objects. As seen, this association can be made by acting on the different elements that characterize a tangible interaction installation, i.e. the smart object, the actions, the output and their relations. As we have seen, the simplest way to reach this goal, consists in the definition of an output that is representative and communicative of an intangible value and in physically linking this meaning to an object. Sometimes, the design action goes further concentrating on the definition of the shape of the objects that become symbolic of certain intangible values (embedding meaning) and/or in the integration of actions that are representative of certain intangible values related to the object. (embodying meaning). Under this perspective, tangible interaction can be interpreted as a practice of meaning making. On one side, there is a designer who through his design choices more or less consciously influences the meaning-making process of the visitor. On the other side, there is a visitor, who tries to

make a sense out of what he experiences and in doing so he will be influenced by the designer choices. While a divergence between intended meaning and actual meaning made by the visitor can always occur[59], and sometimes is to be encouraged, this does not diminish the importance that making design choices with awareness has, in order to create more meaningful experiences. The topic of the meaning in tangible interaction systems applied to cultural heritage surely deserves further investigation, also with the help of the tools provided by a discipline that, more than others deal with issues of meaning, the semiotics[60].

In addition to provide researchers and cultural heritage professionals with an account of what tangible interaction is and what is missing, this work lays the basis of a design framework aiming to provide designers or design teams with a greater awareness of important aspects to consider during the design of tangible interaction systems in museums. Further reflections about the framework being developed will be presented in the next chapters through the presentation and analysis of a practical case study.

[59] This connects to the concept of persuasive design (Redström, 2006), the idea that, on the one hand "design can be seen as inherently persuasive and that objects can be understood as a kind of arguments in material form" (Ivi, p. 121), but on the other hand, there can be a divergence between intended and actual effects since "there is a certain dialogue going on: the designer proposes certain things through the design thing and the user accepts, refutes or modifies these in relation to her own position" (Ivi, p. 115).

[60] Studies on the application of semiotics to the general design discipline have been already carried out in (Deni et al., 2008) and (Bianchi et al., 2010).

Chapter 4

"Voices from Forte Pozzacchio" project

In the previous chapter, a detailed account of different tangible interaction approaches applied to the CH field has been proposed, highlighting different aspects that make up the design of a tangible interaction system, and that all together make up a conceptual framework and the foundations for a design framework.
In order to discuss and develop further reflections about the theoretical framework being proposed, a case study is presented, the "Voices from Forte Pozzacchio" project, consisting in an interactive exhibition developed as part of the EU funded "meSch" research project[61].
This project was chosen as a case study for various reasons. It was a quite complex project that involved many different professionals in order to design an interactive exhibition in a quite problematic physical environment, a fort. In addition, a (co-)design approach was explicitly followed by the team. Finally, the timing of the project fitted the timing of this PhD research, allowing the author to follow in first person most of the phases[62] of the project. The application of this analysis to different previous existing projects was evaluated but then excluded, because of the complexity in getting the needed data about the design and development process (these are usually unpublished data, in many cases even un-documented).
After providing general information about the project, this chapter will present a reconstruction of the design process of the exhibition followed by a description of the impact that the exhibition had on visitors. The content presented in this chapter will form the basis for the analysis that will be carried out in the next chapter, aiming to develop a discussion and reflection around the theoretical framework by comparing it with the "Voices from Forte Pozzacchio" project.

[61] The project was developed independently by the theoretical framework proposed in this thesis.
[62] In particular, the author participated as external researcher during the co-design session and during the final evaluation of the project.

4.1 General Information about the project[63]

4.1.1. Aim of the project and professionals involved

"Voices from Forte Pozzacchio" is one of the case studies developed inside the FP7 EU funded *"meSch - Material EncounterS with Digital Cultural Heritage"* project, aimed at exploring new prototypes and templates of tangible interaction with the aim of bridging the gap between physical and digital experience during the museum visit. In addition, meSch aimed to create a simple hardware and software DIY (Do It Yourself) toolkit to enable CH professionals to conceive, design, make and maintain tangible interactive artefacts (Petrelli et al., 2013). In order to reach this goal, several case studies were developed regarding the co-design and implementation of tangible interaction concepts and prototypes for different sites. These interaction concepts and prototypes were used to populate the toolkit with blueprints that can be customized by future users.

Forte Pozzacchio was chosen as a location for one of the meSch case studies, because it allowed to explore the application of tangible interaction inside a problematic environment: a fort excavated in the rocks, with all the challenges that this implies. The general aim was to enhance the visitor experience of the fort through the introduction of digital technologies and tangible interaction.
The project was developed using a co-design methodology. This means that all the different stakeholders involved in the project cooperated in the design of the interactive exhibition. In particular, the different people involved in the projects and their roles were:

- A.P. and T.V. (curators of "MDG" - Museo della Guerra di Rovereto)
- D.P. (professor of Interaction Design, Sheffield Hallam University, coordinator)
- E.N., M.Z., Mi.M. (researchers in HCI, experts in personalization, FBK)
- N.D. (product designer, Sheffield Hallam University)
- M.M. (computer scientist expert in HCI, in charge for the technical implementation)

[63] The author got the permission to use the images and illustrations presented in this chapter for which sources are not specified in the captions. The images have been taken from private documents like the meSch project deliverables, the meSch team's blog, or have been provided by the team members.

- eCTRL Solutions, a company in charge of the development of the meSch authoring tool
- P.M. (graphic designer, Sheffield Hallam University)
- An external company commissioned by MdG for the creation of multimedia contents
- F.M. (researcher from the University of Limerick, in charge of the video-documentation of the co-design session)

4.1.2. General information about Forte Pozzacchio

Forte Pozzacchio (Figure 81) is the last fort of the Austro-Hungarian Empire, located on the border between Trentino and what once was the Kingdom of Italy. The process of construction of the fort began in 1913 and went on until the outbreak of the war with Italy. The fort was never completed. Abandoned by the Austro-Hungarian army, in June 1915 it was occupied by the Italian soldiers. In 1916 the fort went back to the Austro-Hungarian Empire and remained to it until the end of the war. Strongly damaged during the war, afterwards it was deprived of the metal parts. The recent restoration of the fort, supported by the Provincia autonoma di Trento has made the structure available again for visitors. The restoration consisted in the removal of debris and in making the structure safe. All the interventions are highlighted in orange.
The fort can be reached on foot following the military path built by the Austro-Hungarians army since 1912. The journey takes about 20 minutes. The ticket office is located near the fort. The fort is almost entirely dug in the rock, the only visible structures being the artillery's armoured cupolas. As shown in the map (Figure 82), the fort is made up of three floors, each consisting of several rooms. The fortress is today completely empty.
The original uses of the rooms can be derived from an Italian report from November 1918. On the main floor there are the rooms that contained billets for soldiers, service spaces, observation and artillery emplacements. Using metallic stairs, it is now possible to reach the upper floor where the artillery's armoured cupolas were and where today there is a platform from which it is possible to see a panoramic view of the valley and the nearby mountains. The lower level is only accessible to guided groups because of the steep stairs.
A series of panels are distributed on the path. The panels describe the more relevant events that characterize the history of the fortress from its construction to the recent restoration, and illustrates the original function of the various spaces. About one hour and a half is needed for a complete view of the site.

Figure 81 Old photograph of Forte Pozzacchio (source: http://www.fortepozzacchio.it/).

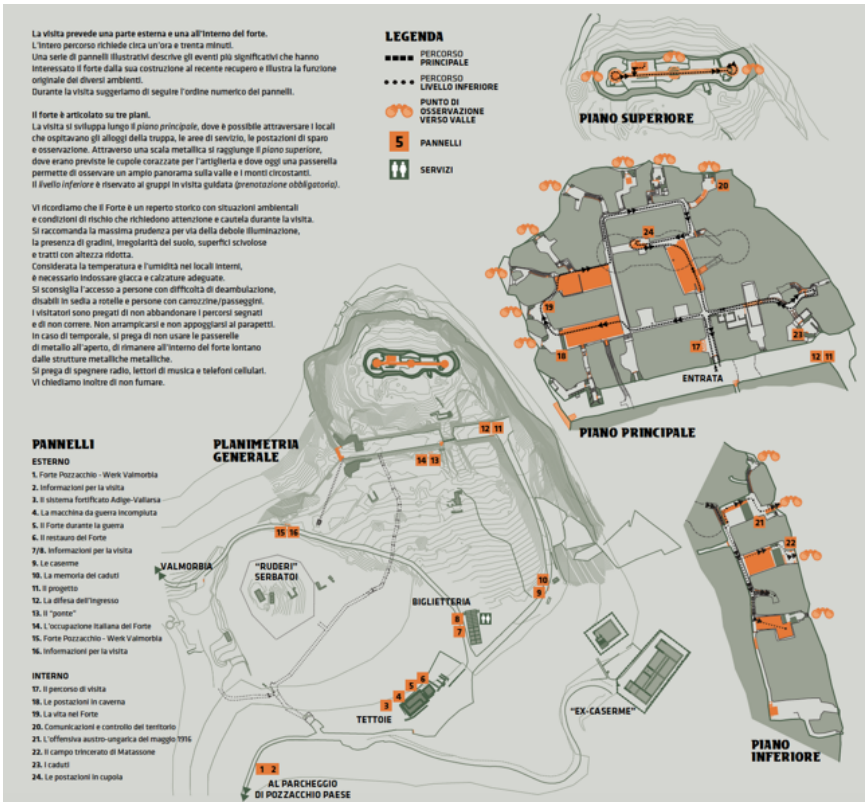


Figure 82 Map of Forte Pozzacchio (source: leaflet that is given in Forte Pozzacchio).

4.2 Reconstruction of the process of design of the interactive exhibition

4.2.1. Methodology used for the reconstruction

The information needed for the reconstruction of the design process was gathered from multiple sources. For the reconstruction of the preliminary phases of the project, information was mainly taken from a blog the meSch team kept to document the process of design and to facilitate communication between the different team members.
For the reconstruction of the co-design workshop, the author was given the possibility to attend the workshop, to observe and take notes of what happened during the meeting. This information was also complemented by the one obtained through the access to the project deliverables, and through interviews or discussions with the professionals who were involved in the project. The latter represented also the main source of data for the reconstruction of all the phases that followed the co-design session, since a direct participation to all these phases and the direct gathering of data through observations was not possible. Below, some general information about the project and the professionals involved in the project are provided, followed by general information about Forte Pozzacchio and a description of the different design phases as emerged from the reconstruction.

4.2.2. Different phases in the process of design

4.2.2.1. Towards a preliminary brief for the project

On Friday, 16th January 2015 a preliminary discussion between A.P. (MdG curator) and E.N. (FBK HCI researcher) took place in order to reflect about possible aims and solutions for Forte Pozzacchio's interactive installation. Starting from the observation that the existing text panels were mainly related to the construction of the fort and the description of architectural aspects, it was thought it would be interesting to offer to the visitors the possibility to understand how the fort was experienced by the people – i.e. who designed the fort, the soldiers, the civilians - in other words, its impact on the society, both from an economic and social point of view.
Various issues/constrains were preliminarily discussed such as: the darkness of the environment that makes it difficult to read; the humidity and cold that can shorten the time of the visit; the fact that a high number of visitors for the fortress is possible (and desirable); the

fact that electricity is available in the fort but it is important to assess how to use it; the difficulty of movements inside the fort; the dimensions and distances between the different areas of the fort that can affect wayfinding and sound propagation.
From these issues and constrains what emerged is that:

- It is necessary to think of a solution that works for more people at the same time;
- If the interaction is done through a tangible object/device carried by the visitor this should be robust, easy to use and to carry and economic to make;
- It would be useful to provide contents in different languages (Italian, English, German);
- It is necessary to think about possible ways to attract visitors to possible points of interest;
- It is important to find a solution that allows visitors to change narrative theme during the visit.

4.2.2.2. Some preliminary concepts proposed by the curators

Also some preliminary thoughts about how to implement the interaction making use of tangible interaction was done.
Three different "guides" that lead the visitors inside the fortress were envisaged:

1. the project architect, a lieutenant of the Austro-Hungarian army who, from 1912 dealt with the design of the fort and other works connected to it (like the street, aqueduct, barracks etc.). He will provide information about the building of the fortress and will describe the novelties from an architectural and technological point of view;
2. a soldier that will tell the personal experience of the soldiers inside the fortress. Along the way the soldier will change identity: there will be an Italian soldier and an Austria-Hungary one telling two different perspectives;
3. civilians, such as: a man who worked in the creation of the fort; a woman from a nearby village that, because of the outbreak of the war had to abandon her house and take shelter in a refugee camp; a saver that after the war used the fort as a source of material to sell.

Inside the fortress three different POIs could be envisaged where the three "guides" show up. As the space inside the fortress is very dark and empty, a possibility could be to use projections of the image of the guide (a still photo or a short video) along with an audio telling the story. A specific theme would correspond to each POI. Another option could be to follow a chronological order (what happened before, during and after the war); sounds and light could be used as elements of attraction.
Before going inside the fort, the visitor goes through the ticket office where he receives information and gets a device (a bracelet, some cards) that inside the fort activates the projections. According to the typology of objects, a bag or a belt might help them to carry them.
In addition, other tangible devices were envisaged like a telescope and binoculars to be used to visualize the front line. Historical and geographical information could be overlapped on the current landscape using augmented reality technology. Also the implementation of a complementary app with geo-located touristic information was discussed. Finally, August 2015 was identified as the best period for the exhibition to take place.

4.2.2.3. Preliminary concept brainstorming at SHU

A preliminary discussion about possible solutions for the project followed in June 2015 at the Sheffield Hallam University, starting from the notes written by the curator. A professor in interaction design (D.P.) and a product designer (N.D.) participated in the meeting. A series of generic observations emerged:

- if there are themes that have multiple stories and others that have just one, a solution can be to have different installations;
- the fortress is dark and the walls can be suitable for projections that can be effective especially if they are very big (the height of a room or gallery);
- the projector can suffer because of the humidity. A test in place is necessary;
- it is important to understand how to provide power to the projectors and how to locate them;
- the system must be independent from the Internet as it is not available. All files must be local and not accessible via URL.

Various options were discussed about how to activate the projections:

Projection controlled by the presence of the visitors
The projection could be controlled by the presence of visitors, and could also follow them as they walk along the galleries, projecting stories that go on along the corridor in a synchronous way with visitors.

Living Wall
If the stories are related to different times but same place, we can think of a single place with more stories. On the wall different historical period are presented and the visitor can activate different stories touching or locating himself in different activation points (
Figure 83). Different characters will be projected on the wall in correspondence with their historical period.

Time Machine
The visitor carries a box that is a time machine (
Figure 84), with a crank that allows to set the historical period and that contains a projector. Poles are put in specific points and the box can be placed over to project on the wall.

Active Helmet
The projector and the technology are not in the box but in the helmet (not clear if there is enough space for all the technology and if the weight is too high) (Figure 85).

Stick
The concept is that there are different stations marked in the floor and the visitor carries a stick containing all the technology (Figure 86). Positioning the stick on a specific point a story is projected on the wall.

Belt
Another option could be a new version of the belt+lanterns concept developed for a previous project (Marshall et al., 2015), improved taking into account the feedback of the previous evaluation.

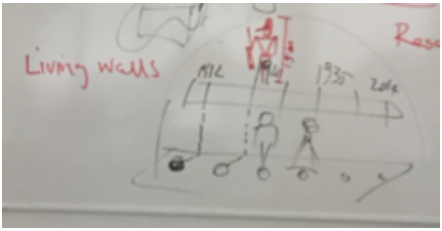


Figure 83 Living Walls.

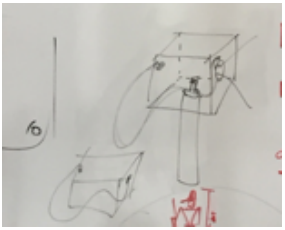


Figure 84 Time machine.

Figure 85 Active Helmet.

Figure 86 Stick.

4.2.2.4. Survey in Fort Pozzacchio

On the 18th of June, a survey of Forte Pozzacchio was carried out by a group made up of the curators of the MDG and some members of FBK with the purpose of understanding more deeply the conditions of the site and identify technical constrains for the exhibit before the co-design session took place. The director of the restoration works and the technical person responsible for the electrical system were present.
Among the most relevant observations that emerged there were the following:

- the walls can be drilled to fix a projector or other things, but as the rock is very friable, all the solutions must be verified with the architect;

- each big room has easy-to-reach plugs, elsewhere it would be necessary to lay cables;
- Wi-Fi and data connection: in some points (especially those facing outward) there is good signal although unstable;
- humidity (generally above 70%) varies depending on the rooms and the weather; there are points where the water drops from the ceiling;
- voltage: more or less the same in each floor but it could vary in case of storm;
- light: the biggest rooms has suffused lights that would not disturb the projection; the smallest rooms are not lighted;
- the sound propagation is very high especially in the big rooms (the stations should be organized in a way that they do not disturb each other);
- the inner temperature is low;
- the lower level is accessible only to guided groups (and under reservation) because of the steep stairs;
- in the ticket office there will be a bar, that can become a place where the people can stop also after the visit (to be taken into account for a possible check-out station or feedback);

4.2.2.5. Co-creation workshop

On the 22nd and 23rd of June a co-creation workshop took place at Sheffield Hallam University. Two curators from Museo della Guerra (A.P. and T.V.), two researchers from FBK (M.Z., Mi.M.), a professor in interaction design (D.P.), a product designer (N.D.) a computer scientist (M.M.), and a researcher from the University of Limerick participated in the workshop.

Brief refinement on the light of the field survey and more detailed overview of the content

The starting points in the co-design session were the technical observations about the Fort as emerged from the survey of the site, the expectations of the museum and the type of experience to offer to the visitors, taking into account the limited amount of time available for the experimentation. This information allowed to refine the brief as follows.
For the museum professionals the most important things were: to communicate historical content in the form of stories from the people whose life was linked to the fortress in some ways. The fortress should

live again through voices and faces; the emotional experience should prevail over the experience of the technology.
The themes to be implemented in the exhibit were presented in details:

- the fortress as structure: the building of the fortress in 1912 – told by the Austrian designer, the worker; the life condition during the war, 1915 – told by a soldier; the dismantlement after the war, 1925 – told by a "recuperante"; today's restoration 2010 – told by the architect);
- life around the fortress: civil (women workers before the war; women during the war with the presence of the Italian army; refugee in 1916 both in Italy and Austro-Hungarian Empire; boys playing in the fortress or grazing the goats after the war; the interviews to the members of the social club "Il Forte" that today manages the site;
- life inside the fortress: (testimonies of soldiers during the war, both Austrian and Italian ones).

Another constrain was that, if the interaction is to be done through a tangible object/device carried by the visitor, this should be robust, easy to use and to carry (leaving freedom of movements), and economic to make. In addition, a solution should be found that enables a post-visit experience (e.g. through a website).

Creative phase

After presenting expectations and constrains, a creative phase started with the aim of finding a proper solution for the project.
In particular, some choices should be done concerning:

- places to be used for the exhibit taking into account all the technical constraints;
- how to implement the interaction, what device to use[64];
- how to convey and select the stories;
- post-visit and possible link between the fortress and the museum.

The creative phase was led by the product designer, who invited everybody to temporary free up the mind from the constrains (related

[64] Since the case study was developed inside the wider meSch project exploring the use of tangible interaction in cultural heritage sites, the use of tangible interaction is indeed a constrain for the solution. Therefore, other types of technology (touchscreens, mobile devices) etc. were excluded.

to time, environment and technology) and to write down, draw or communicate some concepts to the others.

At the beginning some concepts concerning the interaction methods were brainstormed.
A first concept that was proposed for activating contents is the *living wall* (Figure 87), with projections of actors telling stories to the visitor as he walks to specific places in the fortress, possibly guided by signals projected overhead or on the floor.
A second concept consisted of a time/themes line (Figure 90): a specific content is selected by the visitor by positioning himself in a specific point in front of a time/theme line.
A third concept was the use of cards to be put into a sort of box embedded with a projector and a speaker (
Figure 88).
Another concept was the use of a stick (
Figure 89) to be positioned at specific stations so that a story is projected on the wall. Also the possibility of using an interacting leaflet was mentioned during this phase, but almost immediately discarded.

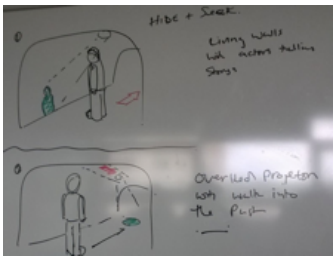


Figure 87 Living Wall.

Figure 88 cards + interactive box.

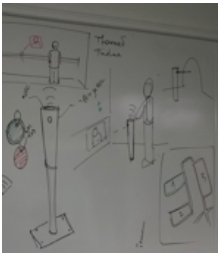


Figure 89 Interactive stick.

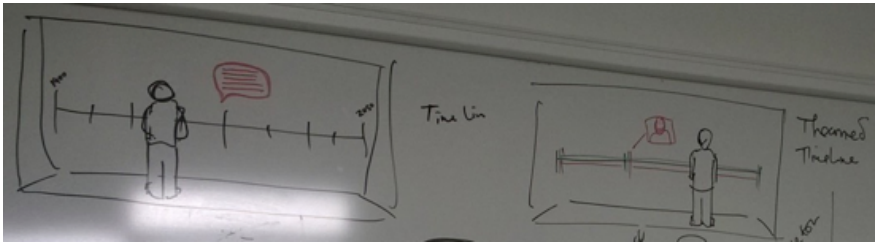


Figure 90 Time/themes line.

Then the discussion moved to the place where the interaction should take place. All the members of the team agreed upon the necessity to find a match between content and places, while taking into account the technical constrains. As the themes were three, the option of implementing three different installations in different points of the fortress was considered as a good one. A first proposal was to provide more intimate contents as the visitor reaches the more inner parts of the fortress. Then the focus moved towards associating specific themes according to the physical characteristics of the single spaces as illustrated in Figure 91.

Room 19 was chosen to tell the story of the construction, demolition and restoration of the fort. This room is divided into two areas separated by a wall (with a space to pass through) on which the line of a roof is visible as this was the place where the Austro-Hungarian military leadership planned the construction of barracks to accommodate the soldiers.

Room 29 was chosen to tell about the impact the Fort had on civilian. The room indeed accommodates the artillery emplacement of the fort and provides a panoramic view on the valley, the place where the stories of civilians come from.

Room 4 was chosen for telling the stories of soldiers as it is the more intimate of all.

Figure 91 Location of the different interactive stations inside the fort.

A reflection about what type of media to use to convey contents in each room and also the type of interaction followed. With regards to the first room (room 19) given the darkness of the place, it was decided that a projection on the wall could be a good choice to tell the stories related to the construction, demolition and restoration of the Fort (Figure 92). The projection would be made on the concrete partition in the middle of the room, as it is the only one to be flat. The actors, in foreground, will tell the stories of the characters that they interpret. Various options for selecting and activating contents were discussed: 5 cards are in the room and the visitor takes one and put it in a box; the visitor uses a timeline to select and activate contents.

For the second room (room 29) it was decided to use just audio to leave visitors free to look at the view from the windows while they listen to the stories of civilians. Also in this case the option of the card + box to activate contents was mentioned, while another option was the use of a tune-in radio (hand + foot) (Figure 93).

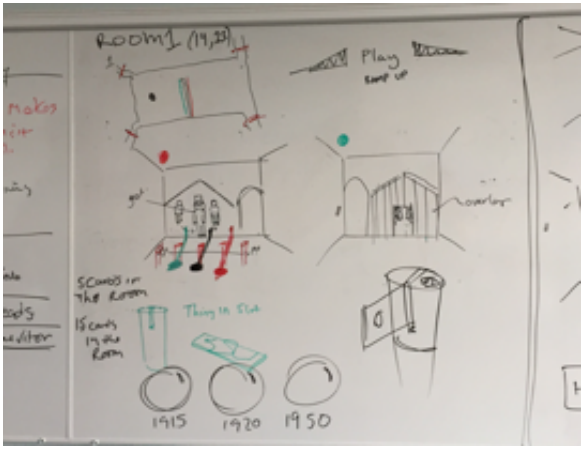


Figure 92 Concepts regarding type of media and type of interaction in room 19.

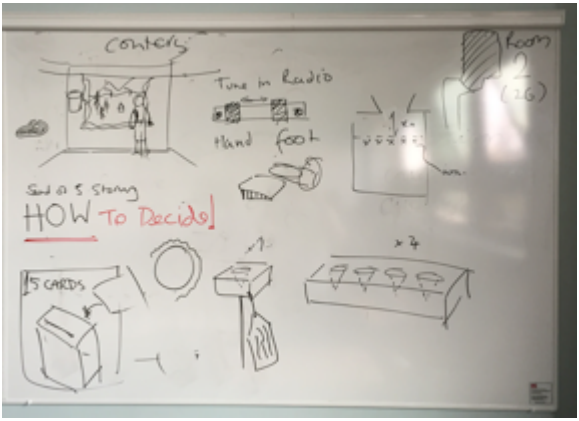


Figure 93 Concepts regarding type of media and type of interaction in room 29.

Also in the case of the third room (room 4) various options were discussed (Figure 94). One option could be to have different portraits of soldiers one next to the other. When the visitor moves in front a specific portrait, the portrait animates and starts to tell a specific story. Another option could be to have a single portrait projected on the wall according to the selection of the visitor. The selection could be done through a button selector, through hotspots on the ground, through cards. At the end it was opted for the use of projections on a plexiglass surface as the wall surface did not allow for a good projection.

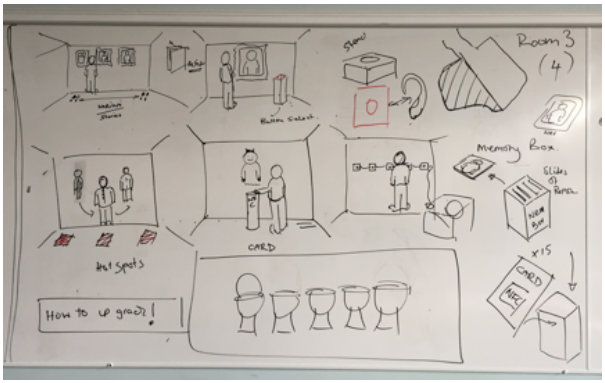


Figure 94 Concepts regarding type of media and type of interaction in room 4.

At the moment of selecting the most suitable ways for activating contents at the different stations, the solutions described above were excluded. According to the museum curator the reasons for this exclusion were the following:

- cards or buttons were perceived as too "cold" by the museum professionals;
- it was preferable to use the same interaction style in the different stations;
- the solution should have allowed to keep track of the interaction of the single visitor to make it possible to offer a personalize post-visit experience to the visitor. For this reasons, for example, concepts relying on gesture-based interaction were excluded;
- the museum professionals wanted something that was very easy and intuitive for the visitors.

This led to another concept (Figure 95). The visitor would be given an object at the ticket office before starting the visit to be carried and to be used to select specific stories in the three interactives in Forte Pozzacchio, that will be all very similar except for the media used to present the output. Each interactive will consist of a platform with as many slots as the number of different stories, put on a horizontal axis in chronological order. Each slot in the axis will be labelled with minimal information (like the dates associated to the story, the name of the characters, other keywords). The visitor will select the story by positioning the object on a slot activating specific contents (large projection, audio only, small projection + audio). A platform will be placed also in the ticket office so that the visitor can have some preliminary information about the fort and also familiarize with the technology before entering the site.

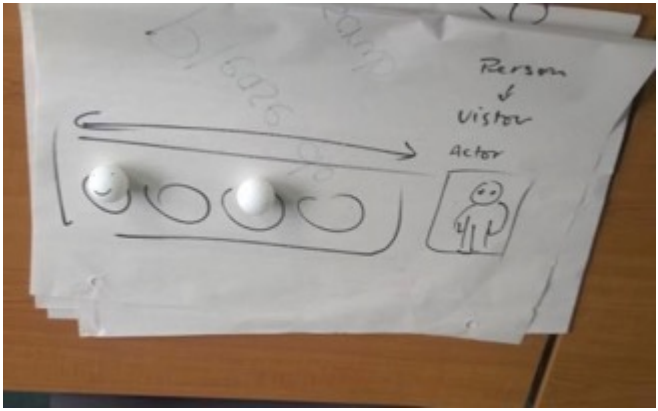


Figure 95 Final concept for the interaction as emerged during the co-design session.

The object should be small in size, possibly orange as the other structures in the fortress built during the restoration works. The visitor can keep the object after the visit to take home as a memento or to use again in the future. This solution allows to collect logs about what the visitor does. Therefore, after the visit, the visitor could stop again at the ticket office to print e.g. a personalized postcard also with links to additional information about what he has seen. In addition, the object and the logs could be used to link the visit of Forte Pozzacchio to the museum where an interactive installation could be created in the near future: in particular, the visitor could re-use the same object in the museum to deepen some contents.

4.2.2.6. Second on-the-spot visit, concepts refinement, prototyping

Another on-the-spot visit was done in July by a group encompassing people from MDG, FBK, ECTRL and SHU. The purpose was to check out whether the technology that was envisaged could actually be installed and work properly in Forte Pozzacchio by gathering further information (e.g. more specific characteristics and space available for the various locations) and by making some tests with low-fidelity prototypes. This allowed to refine the concepts (through the identification of precise positions for the platforms, definition of forms, dimensions, and materials for the interactive platforms and identification of the best technical solutions). In the refinement of the concepts, the main responsible for the physical design (platforms and activating object) was the product designer (N.D.), while the computer

scientist (M.M.) was responsible for the technical part. The people in charge of the design and implementation of the souvenir to be given to the visitor at the end of the visit, were a graphic designer (P.M.) and a computer scientists expert in personalization (E.N.). Nevertheless, the communications with the all the other members (SHU, FBK and MdG) was constant.

Check-in station

The check-in station will be located in the ticket office and would allow to listen to personal witnesses' accounts from the people who are protagonists of the current history of the place (public administrators, architects and volunteers involved in the restoration and maintenance of the place) and to allow the visitor to familiarize with the technology. It will consist of a wooden platform similar to a table with an indentation on the top surface where it is possible to place the activating object to activate the multimedia content on a small screen that is embedded in the station itself (Figure 96). As reported by the curator the choice of the size, of the shape (a table with just the two front legs) and material –wood- were chosen so that the station was well integrated in the coffee shop/ticket office furniture. In particular, the station will be incorporated into a wooden bookshelf in the ticket office.

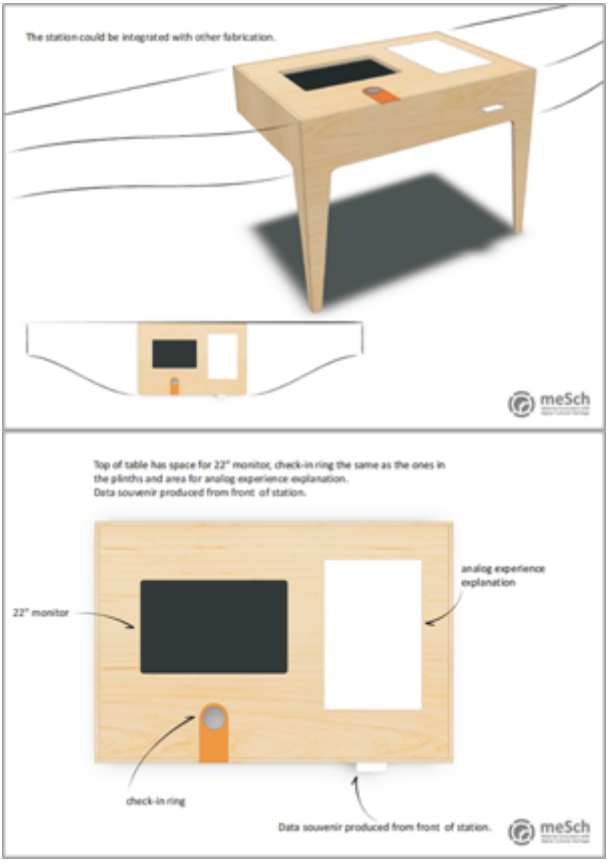


Figure 96 Concept refinement of the check-in station that will be incorporated into the ticket office.

First station: the fortress as structure

The on-the-spot visit allowed to understand the specific characteristics necessary for the projector: it needed to be suitable for long distance projections and resistant to humidity. A position for the station was determined so that the projection had a good quality, was not disturbed by the presence of visitors, and did not impede their movements. In addition, as a result of some experimentations, it was opted for the use of animations with white drawings on a black background. In this way the borders of the projection would not be perceived and the story would seem to emerge from the darkness of the cavern. The station will consist of a metallic platform similar to a "counter" with a line of indentations on the top surface, labelled with minimum information

related to the different stories (e.g. character, role and date) that are distributed according to a chronological order (Figure 97). The structure of the platform clearly represents a physical translation of the abstract concept that emerged during the co-design session, consisting of the notion of timeline showing the available contents and allowing to select the desired one through the use of an activating object. As reported by the curator, the metal was chosen as material for the platform instead of wood because more resistant in the environment of the fort and to prevent any fire risk. The dimensions were chosen so that the platform were large enough to contain the technology, to suit the wide dimensions of the rooms, and in such a way they were not too invasive. The dimensions and shape were also chosen in such a way that the platform looked like a counter inviting the visitor to place himself in the best position to enjoy the content. The use of a lid that seals the platform from the top was chosen to prevent water penetration that could damage the internal technology.

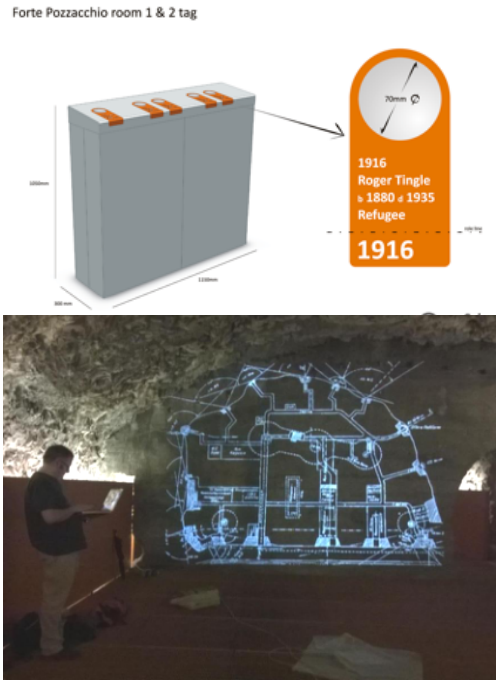


Figure 97 Concept refinement for the first station with regards to the platform (left) and the type of contents for the projection (right).

Second station: Life around the fort
In the second interactive station, visitors can listen to audio stories of civilians while looking at the panorama from the windows. The platform will be in metal, and will have the same appearance as the others, apart from the number of slots and the labels. In order to call the visitor's attention specific sounds were introduced at the beginning and at the end of the audio files such as: a drop of water to introduce a story related the building of the fort; a train whistle for a story related the departure of soldiers for the front; the wind to introduce a story related to a refugee's departure; a bomb blast for a story describing an accident that happened during the search for war material after the war; the bell sound to introduce the story of a young girl describing her daily life after the war.

Third station: Life in the fort
In the third interactive the visitor can listen the stories about events that took place in the fort, narrated by Austro-Hungarian and Italian soldiers. The platform will have the same appearance as the others. As for the video contents, it was decided that the actors should look into the camera while performing in order to create a greater connection and intimacy with visitors.

The activating object
Through a discussion with the product designer who was in charge for the physical aspects of the installations, it has been possible to reconstruct the process that took place in order to finalize the design of the activating object. The design of the object was informed by different and sometimes conflicting goals and requirements. These regarded three main aspects: the human aspect, the technology, the making process. In particular, the object should have good ergonomics since it was something visitors carry with them throughout their visit, it should be able to foster positive emotions, it should contain an NFC tag and enable its proper working, it should be easy and affordable to produce. In addition, the object should fulfil the requirements expressed by the curators, that is, "it should be small enough to fit the palm of one's hand or to be put in a pocket, and it should be economic" (A.P., curator, MdG).
In order to work properly the NFC tag must be in an optimal place inside the object. This requirement constrained the shape of the object on the "z dimension", that is, its height. Therefore, the object should be flat at least in one dimension. In addition, it should be sealed to prevent water and humidity to get inside. In order to foster positive emotions in the visitors it was important for the object to be perceived as high-

quality, and to have good ergonomics. According to the designer these goals could be reached by endowing the object with qualities like smoothness, and relatively high heaviness.
To reach these qualities while making the production process affordable, fabrication techniques like 3D printing were discarded. 3D printing techniques would have not been able to give the desired heaviness and smoothness to the object and the production process would have been more complicated as the object should have been printed in more steps in order to make the incorporation of a NFC tag inside the object possible. This led to opt for the application of a moulding technique consisting of using liquid resins mixed up to colours that are poured inside a mould made of silicone. The mould was made of two blocks so that the NFC tag could be incorporated inside before joining the two parts into the single block and pouring the resins into it.
Various forms and formats for the object were conceived, prototyped and discussed with the staff of the Museo della Guerra, eventually opting for the object in figure. In order to make the object more evocative of the fort, the altimetry of fort Pozzacchio was engraved on one side. The object was produced in two different colours: in orange in order to be consistent with the restoration interventions that were all made in orange, and in grey, being it a more neutral colour.
With regards to the connection between the object and the fort, the designer said that for him, the connection lays in the fact that is an artefact, a human made object while at the same time it is reminiscent of something natural, "organic". Similarly, the fort was excavated in the mountain by human beings and, in the landscapes around the fort, "you see colours, the natural environment" (N.D., product designer, SHU) but also "things that come out that are man-made" (N.D.), and these two aspects –natural and artificial - are integrated in a mixture. Therefore, the object has "a form that doesn't distract from the fort, it can be associated with it, it is simple and natural" (N.D.). In addition, the designer explained that the object started to be called "pebble" after it was created and started to be tested and that, although probably there was a discussion with the staff of the MdG about the rocks and the fort "this object is not a replica like in the case of the Atlantik Wall, it is more an abstract form" (N.D., product designer, SHU). Also the curator said "we have started calling it pebble after a certain moment, not immediately. At the beginning it was just a plastic disk and then, I don't remember whether it was the designer who defined it as a pebble, and since then we kept calling it that way" (A.P., curator, MdG).

The post-visit souvenir: the post-card

In order to foster the memory and sharing of the visit, and to stimulate further curiosity towards the theme of the exhibition, it was decided that a personalized post-visit souvenir should be provided at the end of the visit, once the activating object is returned to the ticket office by the visitor.

This post-visit souvenir consists of a postcard, containing a photo of fort Pozzacchio on the front (Figure 98) and a textual summary of what the visitor has experienced on the back (Figure 99). The text is composed at the check-out station located at the ticket office using adaptive natural language generation technologies on the basis of the information that were stored in the activating object during the visit. The text also provides a link to the museum website where it is possible to find the transcription of the stories that are communicated in the exhibition along with the bibliographic references. Finally, the postcard contains a stamp with the current date. The postcard will be printed through a check out station.

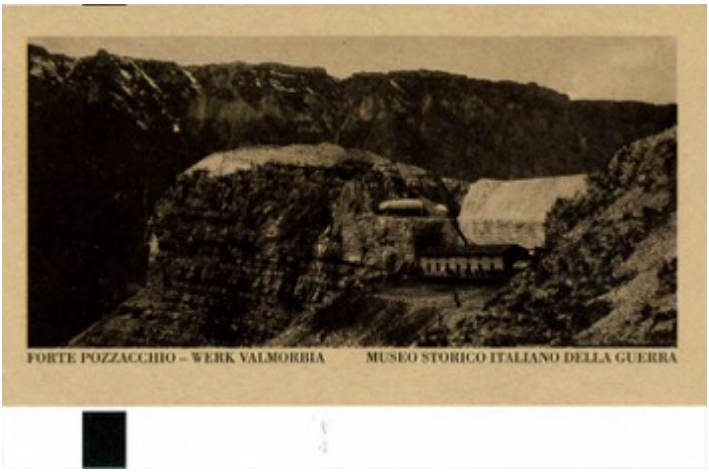


Figure 98 The front of the postcard.

Figure 99 Back of the postcards containing personalized textual summaries of the visit.

Prototyping and Testing in lab

After the concept was refined, high-fidelity prototypes started to be built and tested in lab. The building of prototypes has required the integration of different expertises: product design (N.D.), IoT programming (M.M.) and the creation of multimedia contents (MdG and external society) (Figure 100).

Figure 100 High-fidelity prototypes of the platforms and activating objects.

4.2.2.7. Re-adjustment, Implementation and Installation

Even though Forte Pozzacchio seemed to be appropriate for the installation of the exhibition, later on some logistic and administrative issues started to emerge. The major problems were some architectonic restrictions that imposed long authorization process that would not allow to meet the deadline for the case study (Autumn 2015), also considering the closure of the fort at the end of October. All project

partners agreed upon a change of location and a partial re-adjustment of the project in order to be able to carry out the case study on schedule. As a new location for the case study the Artillery section of Museo Storico Italiano della Guerra was identified (Figure 101), because, due to the similarity with the physical environment of the fortress, it could be evocative of the Fort. The Artillery section is indeed located in what once was an air-raid shelter of the Second World War. It is excavated into the ill over which the museum castle was built, and for this reason it consists of dark, humid and cold caverns. However, differently from Forte Pozzacchio, the Artillery section is not an empty space: inside this environment several Italian, Austro-Hungarian, German and English artillery pieces from the First World War – howitzers, mortars, and canons – are exhibited and complemented by traditional labels and informative panels.

Figure 101 Artillery Section of Museo della Guerra.

Another issue regarded whether or not to keep or change the content for the installation as this was not focused on the new location and its content but on Forte Pozzacchio. It was decided to keep the same content as in Forte Pozzacchio for issues of time and costs and also because the recording of some of the multimedia contents had already been done.
At the same time, to make sure that the visitor did not perceive it as something detached from the other elements of the museum tour, a connection was created. Some panels that give information about the history of Forte Pozzacchio were inserted in specific points in the museum. In addition, the visitor would be given a map to highlight certain themes in the museum building that complement and are connected to the meSch exhibition in the Artillery section.

Another problem concerned the need to identity new proper locations for the interactive stations and to plan possible minor adjustments where needed. A field survey allowed to envisage the location and positioning of the interactive stations in the Artillery as shown in Figure 102 and Figure 103.

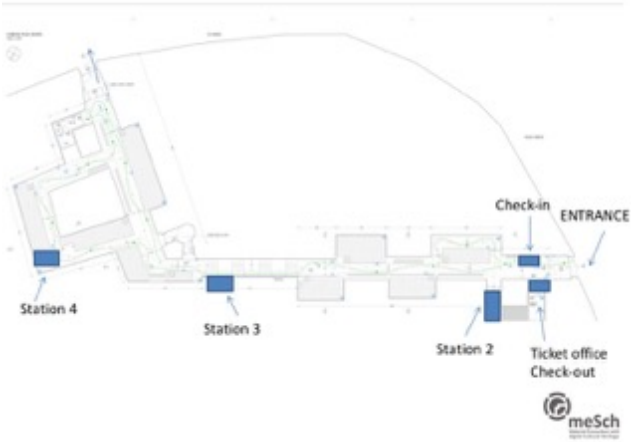


Figure 102 Map showing the location of the different interactive stations in the Artillery Section.

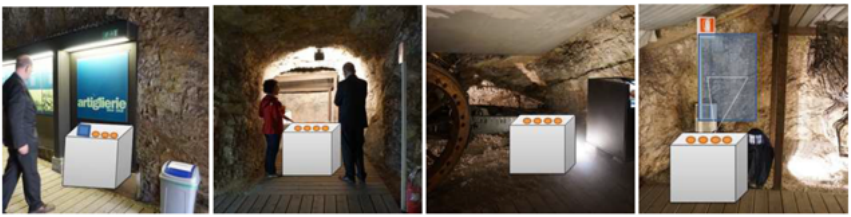


Figure 103 Envisaging the various interactive stations in the chosen locations.

The check-in station would be located at the entrance of the Artillery section in front of the ticket office. Because of the change of location, the contents need some major modification. Instead of providing personal witnesses' account, in the new context the check-in station will provide an introduction to the specific topic of the exhibition so that the visitor can create a connection between what he has visited in the museum and what he will encounter in the exhibition. Three videos are offered: the first video explains how to interact with the exhibition, the second one presents a short history of the fort, and the latter presenting

historical pictures related to the fort. Given the proximity to the entrance, to the ticket office and to the first station, it was decided to avoid audio contents. In addition, since the station would be no longer incorporated into a bookshelf, two additional legs are necessary to make it stable.
With regards to the first station, this would be located inside a small tunnel dug in the rock similar to the original location (dark place, excavated into the rock, suitable for projection) apart from the smaller scale. However, since the roughness of the wall could decrease the quality of the projection, a black projection screen will be fixed at the back of the cavern.
As for the second station a problem was that in the Artillery section there was not a place similar to the artillery emplacement and there was not a possibility to have a panoramic view of the valley. For this reason, the station will be located along the main corridor in proximity of original cannons. The connection between landscape elements and stories is lost, however, the presence of original cannons nearby could help to evoke the context related to the stories that are told.
The final interactive station would be situated in a corner at the end of the cavern allowing to create a more intimate and private space. The inclusion of four different projections as designed for the fort would not be possible in the new location for space constrains. Instead, a single projection would be used showing different contents according to the one selected by the visitor by placing the pebble on a specific slot on the platform. Each slot is labelled with the name, rank and allegiance of the soldiers and the date. After that the re-adjustment process took place, high-fidelity prototypes were built for the different stations and installed in the Artillery (Figure 104; Figure 105).

Figure 104 Check-in and first station installed in the artillery section.

Figure 105 Second and third station in the artillery section.

4.2.3. A visual synthesis of the co-design process and some general considerations

The following diagram (Figure 106) proposes a visual synthesis of the co-design process, illustrating the different phases, the professionals who took part in the process, as well as the outcomes of each phase. This diagram is obviously a simplification of reality, since design processes are rarely linear and usually consist of multiple iterations of phases. Nevertheless, this diagram represents a useful tool as it shows clearly not only the single phases of the process, along with their outputs and the people involved, but also how they fit inside the overall process.

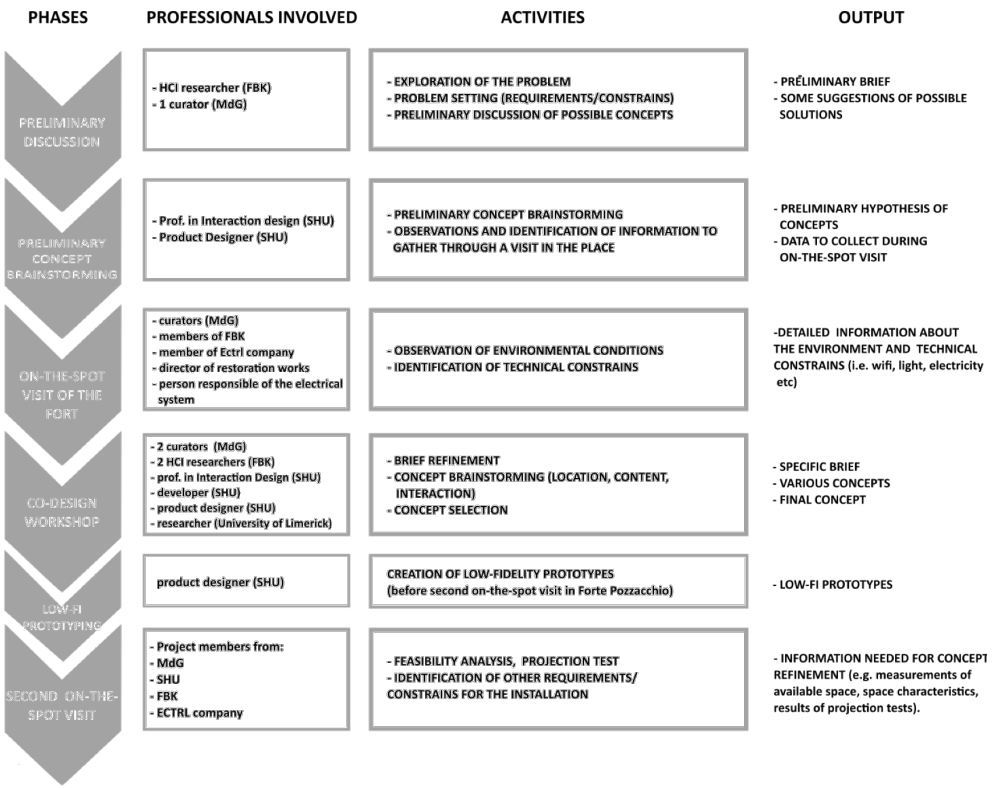


Figure 106 Diagram summarizing the different phases of the project, the professionals involved and the output of each phase (source: the author) (continued on next page)..

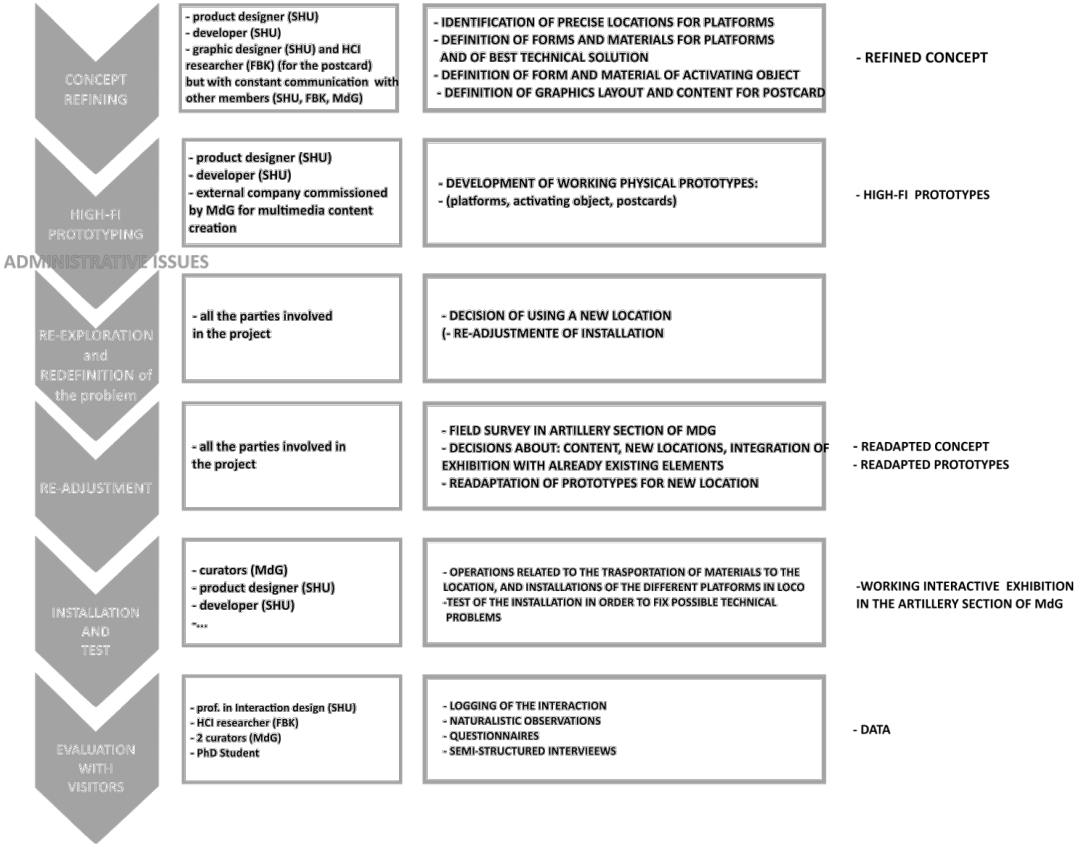


Figure 106 Diagram summarizing the different phases of the project, the professionals involved and the output of each phase (source: the author).

In the design of "Voices from Forte Pozzacchio" exhibition, a classic design process characterized by more sequences of divergent and convergent thinking was used. This is indeed a peculiarity of many design processes, and can be summarized through the Double Diamond model proposed by the British Design Council (2005) and illustrated in the following graphical representation (Figure 107).

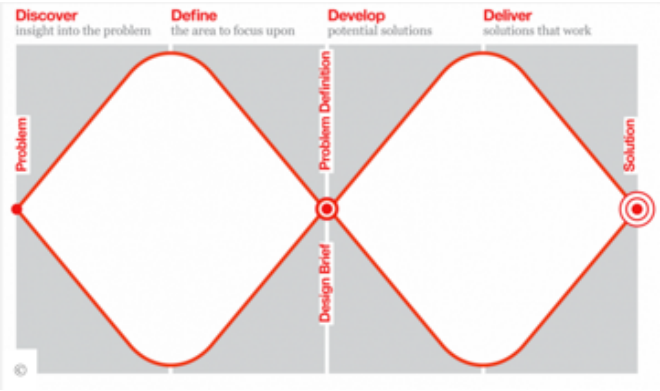


Figure 107 The Double Diamond Model developed by the British Design Council (source: http://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond).

The model identifies four phases - *discover*, *define*, *develop*, *deliver* - that allow to reach a specific solution starting from a generic problem. The discovery phase consists in a research phase that has the goal to gain insights into the problem and its context. A definition phase follows that allows to better define the problem and to come up with a well-defined design brief, with specific requirements and constrains. After the problem has been properly set, a development phase starts where many potential solutions and concepts are explored. Some of them will be prototyped and tested in the delivery phase. Several iterations back and forth of the development and delivery phases will allow at the end to finalise, produce and launch a specific solution to the problem.

The following figure (Figure 108) presents how the different phases that characterized the design process of the "Voices from Forte Pozzacchio" exhibition fit inside the general phases identified by the double diamond model. The phases are numbered to make it clear the chronological order in which they happened.

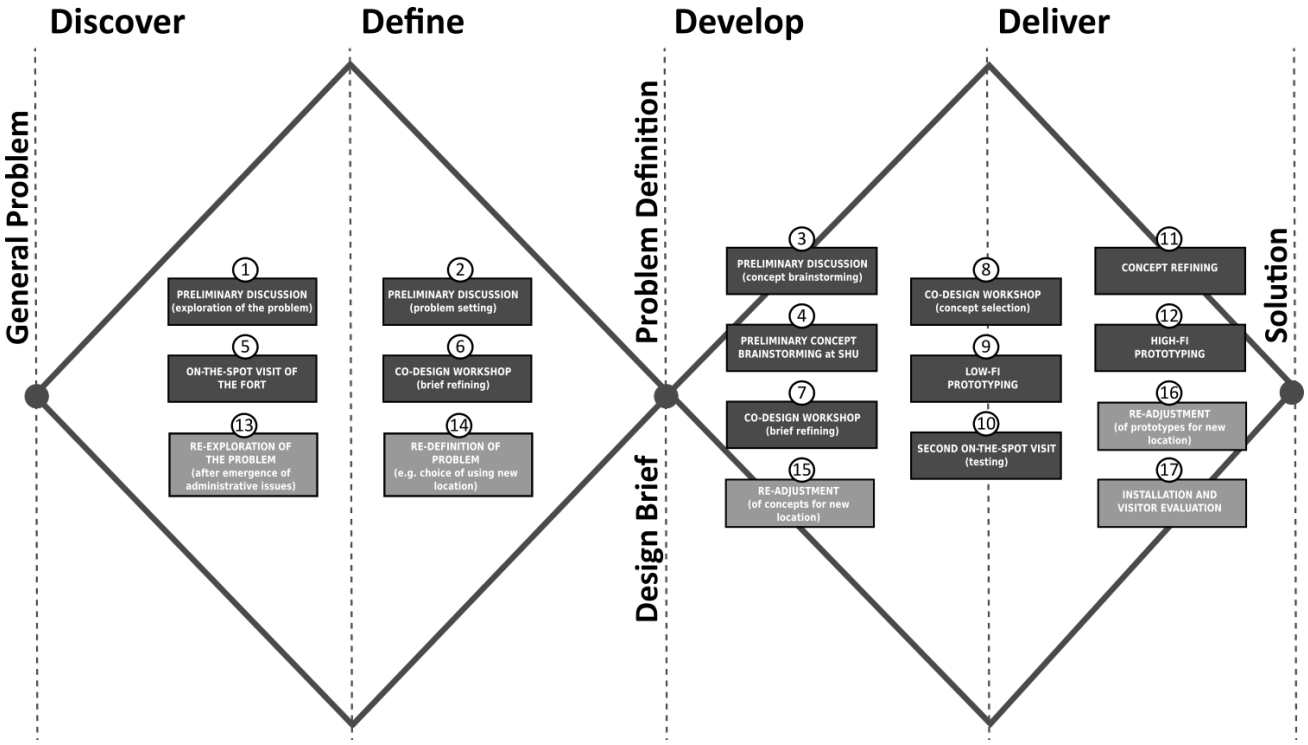


Figure 108 Illustration showing how the different phases that characterized the design process of the "Voices from Forte Pozzacchio" exhibition fit inside the general phases identified by the double diamond model (the phases belonging to the first iteration of the double diamond are in dark grey, those belonging to the second iteration – after the emergence of administrative issues- are in light grey).

In the specific case study, the initial problem was to find a way to enhance the visit of the fort through the use of tangible interaction. The initial phases of the project, from the preliminary discussion up to the first part of the co-design session, were devoted to the discovery and definition phases. Two iterations of discovery and definition phases took place before the specific brief for the project was defined. In particular, a first exploration of the problem was carried out in a meeting between a MdG curator and a HCI researcher (FBK) that, on the basis of the curator's strong knowledge of the location, of the visitors as well as of the mission of the museum, allowed to define a preliminary brief for the project. An on-the-spot visit of the fort was planned later in order to gain further insights about the environment and the technical constrains, that were needed to refine the brief. It is important to highlight that some concepts were preliminarily brainstormed already in these preliminary phases, by two separate teams, one made of a museum curator and a HCI researcher, and one made by a professor in Interaction design and a product designer. This was done in order to get to the co-design session with already some ideas to suggest. Some iterations of the development and delivery phases followed. In particular, a large number of concepts was proposed and discussed during the co-design session (divergent phase) until one was selected as more appropriate (convergence phase). Some tests in place followed in order to refine the concepts and build working prototypes. The unexpected impossibility of using the fort as a location for the exhibition, led to a new exploration and definition of the problem and the decision of using a location with similar characteristics in place of the fort, the artillery section of the MdG (discover and define phases). This in turn led to the need of reflecting about possible alternative solutions regarding the adaptation of the previous design to the new location (divergent phase) until the final one was chosen, tested and installed (convergent phase).

The project was developed using a co-design approach where the different stakeholders/professionals involved in the project took part in the process of design. As illustrated in the following graphical representation developed by Petrelli et al. (2016c) (Figure 109), the co-design approach is characterized by the alternation of meeting and breaking phases. In the former, the different professionals collaborate together towards the definition of the design of the artefact in a shared creative space. In the breaking phases, the different professionals work separately to develop their own contribution, but keep communicating with the rest of the team in order to "maintain the feeling of a shared ownership and to enable constructive criticisms" (Petrelli et al., 2016c).

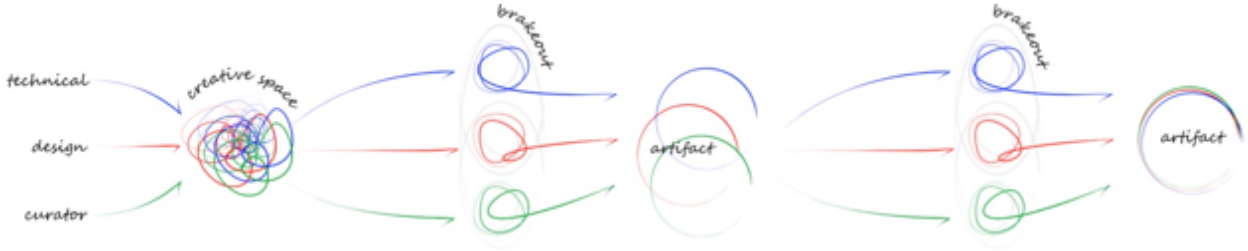


Figure 109 Illustration of how the different professionals are involved in the co-design process (source: Petrelli et al. 2016c).

4.3 The impact on visitors of the interactive exhibition

In the previous section, a reconstruction of the process of design of the "Voices from Forte Pozzacchio" exhibition has been presented. In this section, the impact on visitors of the exhibition is reported.

4.3.1. Research methodology

Data collected during the final evaluation of the installation, carried out as part of the meSch project, is used here for the analysis. Various members of the meSch team participated as evaluators in this phase. Also the PhD thesis author contributed to this phase as visiting researcher.

Various methods were used for data collection:

- an initial questionnaire to be filled in by the visitor before starting the visit;
- naturalistic observations of visitors during the visit;
- logging of the interactions through the activating object;
- a questionnaire after the visit and a final semi-structured interview. Most of the interviews were audio-recorded, others were video-recorded, while for some of them only written notes taken by the interviewers are available.

The initial questionnaire was made up of 5 closed-ended questions aiming at collecting information about the visitor and the context of the visit (e.g. demographics information, general preferences on the use of technologies and other informative material, emotional state before the visit, whether the visitors were alone or with companions). Naturalistic observations, instead, aimed at gathering information about how the visitors interacted with the system, with the companions, with the other elements of the exhibition, as well as at observing the effects of the physical environment and of the personal stories. A common protocol to carry out observations was shared by the evaluators, who were provided with guidelines and observation sheets to take notes. The final questionnaire was made up of 18 closed-ended questions aiming at investigating various aspects such as: their behaviour and their opinions about the different elements of the exhibition, about the use of the activating object, about the multimedia contents, about the postcard and their emotional state at the end of the visit. The final interviews

aimed at collecting qualitative information that could facilitate the interpretation of the data gathered through the questionnaires. These were based on general guidelines provided to the interviewers, defining six aspects to investigate (i.e. general impression of the experience; effect of personal narratives contrasted to factual information; effect of introducing digital content in a particular physical space; effect on social interaction; effect of using the pebble; preferences regarding the post-visit experience). However, it is important to highlight that given the presence of different interviewers, there is not a consistence in the way the interviews were carried out. Some interviewers followed the planned set of questions, others conducted more open interviews although covering all the topics, and finally others limited the scope of the interviews to a subset of topics according to the availability of time of the visitors. As a result, interviews length varies in the corpus ranging between 10 and 50 minutes.

For the purpose of this analysis mainly questionnaires, interviews, and observations of visitors' behaviour will be used. Data from questionnaires that are related to aspects that are relevant for the study will be analysed quantitatively using descriptive statistics. For the analysis of the interviews a *thematic analysis* will be used. Thematic analysis is a qualitative research method that is useful "for identifying, analysing and reporting patterns (themes) within data" (Braun et al., 2006). Although the interviews differ in length and covered topics, they all have been included in the analysis to contribute to the identification of the themes. Audio and video recorded interviews were transcribed verbatim. The transcription activity resulted in 141 pages. For non-recorded interviews written notes taken by the interviewers were typed[65].

Through the analysis of the questionnaires it is expected to get a general overview on the impact certain characteristics of the system had on visitors, while through the analysis of the interview it is expected to get more in-depth understanding about certain responses of visitors. When needed, in addition to the data from questionnaires and interviews, data coming from naturalistic observations of the visitors will be used in order to identify patterns in the behaviours of visitors.
The analysis will be focused on the understanding of the impact – both positive and negative – that certain aspects characterizing the

[65] All the interviews were carried out in Italian. Interview extract reported in this document have to be intended as translations into English of the original extracts.

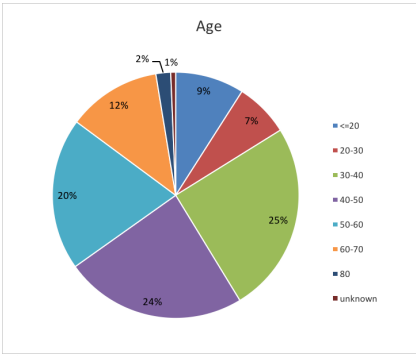
interactive exhibition had on the visitors. In particular, this analysis will be focused mainly on the aspects that make up the proposed conceptual framework for tangible interaction[66] (Ch. 3) and that might be useful in developing reflections about the framework in the next chapter.
The analysis will combine an inductive (bottom-up) and deductive approach (top-down). It will start with a set of general list of topics to be identified in the data. For each of these aspects, extracts will be identified from the interviews corpus, to build the datasets. Within each dataset, a coding process will be applied. The coding will be mainly based on an inductive identification of themes in the data themselves and partially also influenced by what is expected to be found in the data on the basis of the theoretical analysis that has been presented in the previous chapter. Starting from the codes, themes will be elaborated and presented.

4.3.2. Participants' profile

155 people participated in the evaluation. However, data related to all the phases of the evaluation (interviews, questionnaires and observations) are available for only 55 people, while for the others data available varies[67]. The profile of the visitors participating at the evaluation were varied. All age groups were represented (Figure 110) however only very few people under the age of 20 participated. In addition, there is an equal presence of men and women.
Only a small percentage (27%) of the participants visited the exhibition alone, all the other visited the exhibition together with family members or friends. For the majority of visitors (65%) that was the first visit to the Artillery section of the museum.

[66] It is important to notice that, since the analysis was done using the data gathered according to the goals of the meSch team and not specifically collected on the basis of the framework, some aspects might be missing. This situation was inevitable since asking visitors for additional questions was generally not possible as the participation to the evaluation already required a long time.

[67] Only data related to questionnaires is available for some visitors, for 7 visitors we have data related to questionnaires and observations; for the rest we have data related to interviews and questionnaires without observations.



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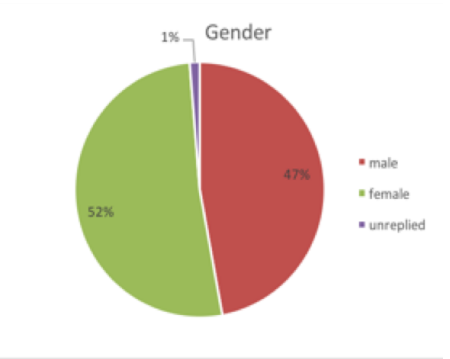

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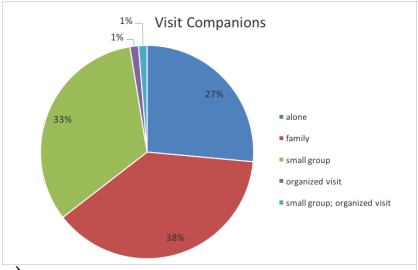

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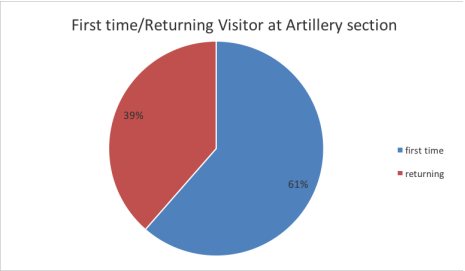


d)

Figure 110 a) distribution of visitors by age; b) distribution of visitors by gender; c) distribution of visitors on the basis of typology of visit (alone, with family, small group, organized visit); d) percentages of First Time and Return Visitor a the Artillery Section of the MdG (colour illustrations at the end of the volume).

4.3.3. Effects of the form of smart objects on visitors

4.3.3.1. Activating object

As explained in the previous chapter, the activating object has an abstract shape although it embeds in itself some of the aesthetics characteristics of the fort and of the surrounding environment (e.g. it mixes natural and artificial) so that it can be associated to the fort. To make the association with the fort stronger the altimetry of fort Pozzacchio was engraved on one side. Although it started to be called 'pebble' for its physical resemblance with a stone, it was not created explicitly to represent a stone, or any object culturally related to the fort. Its shape and material characteristics were also chosen with the intention of fostering positive emotions in the visitor. In this paragraph,

the impact that the *specific form* chosen for the activating object had on visitors is illustrated.

Aesthetic and sensorial impact

A first theme that emerges and that is connected to the form chosen for the object regards the positive impact that the activating object has from an aesthetic and sensorial point of view. Many visitors consider the activating object to be beautiful and mention different yet positive material qualities of the object (e.g. the round shape, the smoothness, the weight etc..), the pleasure of holding it and of being stimulated at a tactile level.

"Beautiful... I liked it... because I always like having something in my hand, and so, having that thing, I don't know, it gave me a good sensation; also, holding it in your hand, it is not so heavy, it is not light, I mean, a good sensation" (Interviewee 12A)

"It is so nice from a tactile point of view, because it is smooth, round, light" (Interviewee 15A)

"I really liked the shape of the object, that you place in your hand" (Interviewee 23A)

Comfort

The activating object is also considered by several visitors to be comfortable as it is not bulky to hold and to carry from a station to another.

"[it is] *not bulky, easy to hold, so I never asked to myself, where do I put it? it never happened to me of being bothered by the fact of having it in my hand."* (Interviewee 24)

"it is comfortable, easy, both to carry and to use" (Interviewee 39)

"the hindrance of the pebble is minimum [..] it is not a long way from a station to another. But if it was a longer way, then, you can keep it in your pocket without problems." (Interviewee 15A)

Personal Interpretation

The shape of the object can be interpreted as one of the determinant of how the object is named by the visitors and interpreted in the context of the exhibition. The majority of the visitors refers to it as a *'pebble'* or a '*rock*', sometimes as a *'disk'*, more rarely as a *'token'*, a '*chopper*' or a *'soap'*. Although in the naming of the activating object the visitors might have been influenced by the evaluators, who might have used different names to present the object at the beginning of the visit or during the interview[68], a role must have been played also by the actual shape of the object, in addition to other aspects like the context, the type of interaction, the effects of the interaction, and the personal background of the visitors that will be taken in consideration later on in this chapter. It is interesting to notice that, although many visitors call the object 'pebble' only one in the interview explicitly associates the form to the fort ("*and also the shape and colour that resemble a pebble, a stone, can be linked to the fort that is dug in the rock"* – Interviewee 16C*).*
Many visitors said they noticed the presence of the engraving on one side of the activating objects and were in most of the cases able to understand it was the altimetry of Forte Pozzacchio. Only two visitors, visiting the exhibition together, reported they were not able to interpret correctly what the engraving represented for different reasons. One of them reported she did not see it very well, the other one interpreted the engraving as a phallic symbol, probably because she had never been to Forte Pozzacchio before.

4.3.3.2. Platforms

Not many comments are present in the interview corpus regarding the perception of the form of the interactive platforms to be able to identify actual themes. However, few comments make reference to the appreciation of the material qualities of the installations and the fact that they are well integrated in the environment.

"[They are] very beautiful... I mean, these things in metal, in aluminium, in steel... these spaces, little bowls to contain [the activating object], I mean, very beautiful [..] aesthetically I like it very much" (Interviewee 28A)

[68] In the interviews the object is named differently by the various interviewers, although 'pebble', 'disk', and the generic 'activating object' seem to be the most frequent names.

4.3.4. Effects of the type of actions

The type of actions the installation requires the visitor to perform – placing the activating object down on the platform to play contents, carrying the object while visiting the exhibition – belongs to the category of actions that in this thesis have been defined as *codified*. In this paragraph the impressions and comments reported by the visitor regarding the type of actions are presented.

4.3.4.1. Placing the object on the platform to activate contents

With regards to the action that is used to activate the multimedia contents, various themes emerge as described below.

Easiness and naturalness of the action

Several visitors in the interview speak about the easiness and the naturalness of the action:

"It is really a rock and you just have to put it down, it is very simple" (Interviewee 15A)

"I mean... of course [it is] *very simple, you just place it down"* (Interviewee 16)

The adjective *natural* is also very frequent in the interview when referring to the use of the activating object. Only one visitor says "*for me it is easier to think about something like a button, that you press and does everything"* (Interviewee 7C)

Pleasantness of the action

Several visitors also describe the action as something pleasant and fun.

"I like very much the idea of placing this pebble down on the different platforms. It is very simple" (Interviewee 19)

"With regards to my impression, I like to have something to put, to turn [..] so I think that also for the children it would be more fun" (Interviewee 38A)

Greatest awareness of one's active role

Many visitors refer that the type of interaction with the activating object let them perceive their role as more active compared to more traditional solutions (i.e. a button).
The action of placing the object down on the hotspot is perceived by many visitors as something you do with great awareness.

"having this thing in my hands that I have to place down… maybe it was… the gestures have been more conscious, in my opinion" (Interviewee 26)

"There is almost a will you have to put when positioning it there, and it goes from you to the platform through this pebble. It seems to me like an old communication disk" (Interviewee 23A)

"Because anyway in the end the visitor wants to be, in some way, the protagonist of something when he visits, so this is the thing, the simple fact of placing it down implies an action" (Interviewee 16A)

"Having this object in your hand gives you the sensation that you are the one who "enters" the contents that you are provided with and of being more active as a visitor" (Interviewee 36)

It is interesting to report that some visitors also refer that the use of an object for selecting the contents, made them feel more in control or more responsible of the choice of what to activate compared to the use of a button although they report different reasons:

"The button is more impersonal, I mean, the impression is that it is something ready for whoever pass through there, while having this object in your hand you feel more in control of the choice of the content" (Interviewee 16C)

"Well, the pebble is new compared to the button, […] I feel I had a more active role, I mean, to have a… the weight of the choice in the weight of the pebble… [..] it's banal, however it is a sensation, I mean, [..] it is something more than pushing [a button]" (Interviewee 16A)

"[The difference compared to a button] is this very possibility to choose also the moment when to use it and not being forced to follow a default route" (Interviewee 37)

"the button would have determined the constriction to listen until the end" (Interviewee 10)

Only a couple of visitors said the type of interaction is exactly the same as pushing a button (Interviewees 17, 8).

Personal Interpretations

The use of the activating object (but also the effects produced by its use) gives rise to some personal interpretations of what the object *represents* or what the action with it *means* for the visitor:

"It is like a key that you use with the doors you want to open" (Interviewee 6)

"it reminded me of how the hand was used in prehistoric times, when there were the first choppers that helped to build the first tools. Therefore, I felt like a person who has something in her hand that allows to choice" (Interviewee 36)

"Having this object in your hand gives you the sensation that you are the one who 'enters' the contents that you are provided with and of being more active as a visitor" (Interviewee 36)

"There is almost a will you have to put when positioning it there, and it goes from you to the platform through this pebble. It seems to me like an old communication disk [..] yes there is a human contact" (Interviewee 23A)

"instead the pebble… you put it down there, you have a thing that gives you the idea of… I don't know... I liked very much the object, the shape, beautiful... But also the very red light that switched on when... it seemed to me… I have created the contact, I mean, very much Zen!" (Interviewee 28A)

"And also placing it down was a bit... you never know what is going to happen. [..] Pushing a button or placing the pebble down? It is different... if you push the button, I mean, it is like you can expect something [..], instead that was more, I don't know, a bit more magical, a bit more... I don't know how to say that... yes, something different. (Interviewee 12A)

The interpretations provided by the visitors are clearly determined by the connection of the object and its perceived role in the exhibition to other contexts that are part of their background and previous knowledge.

But there is also a couple of visitors complaining about the lack of sense in the way the activating object is used in the exhibition. This is probably due to the fact they cannot find a meaningful connection

between the use of the object in the exhibition and their knowledge of other contexts.

"If you want to create an interaction and a greater involvement also the devices must have a sense. Why should I have a soap in my hand? The device is extrinsic, it does not have a sense inside the exhibition, it is the same as a button. An idea could be to use it in different ways in the installation made up of different stations". (Interviewee 35B)

4.3.4.2. Carrying the object around

Regarding the action of carrying the object around some themes have already been described (4.3.3.1) like the pleasantness of experiencing the material qualities, or the fact that the object is not bulky to hold and to carry from a platform to another. Other themes emerge as described below.

Greater involvement of the visitor

A couple of visitors describes the greater involvement that having an object to carry around determines.

"In my opinion, the fact of carrying it with you, the visitor is more involved, it is not the button that you abandon but I have an object that I have to carry with me during all the visit and that at the end you have to return" (Interviewee 25A)

"Perhaps you feel more involved, the button is something more… I mean… on the side of the machine, having this [the activating object] *in your hand and moving around the museum with this, makes you more involved"* (Interviewee 40B)

The meaning of the action

The action of carrying the object around gives rise to personal interpretations of the experience by some visitors. A couple of visitors attributes the same meaning to the action. For them carrying the object during the visit means carrying with them their past experience with the exhibits:

"Carrying the pebble around is like carrying the history around" (Interviewee 22)

"This pebble is something that you carry with you along the path, it seems like an object that allows you to make choices, it's as if you take the experience along with you" (Interviewee 38B)

4.3.5. Agency of the interactive system

In Chapter 3 tangible interaction systems have been analysed in terms of their agency, that is, their ability to trigger the interaction of the people, to make people understand what the possible actions are and what to expect as a consequence of their actions. In this section, the interactive system proposed in Forte Pozzacchio exhibition is analysed in terms of its agency on visitors.

4.3.5.1. On the ability of the system of triggering the interaction/action of the visitors

A recurrent theme in the interview regards the power of the system of stimulating the interaction with the interactive exhibition, and to take on a more active role, although different visitors provide different reasons to explain this effect.

The object as an invitation to use it

According to three visitors, for example, getting an object at the beginning of the visit is like an invitation to use it.

"Because the fact that you are given something at the beginning is a sort of assignment and I live that as an active role, it is not like something I stumble upon and that I can either push or not. Therefore, it is... in my opinion it is an invitation, it means to strengthen an invitation to participate in an experience, I mean, the fact that you are given something, and... thus, I mean, I appreciated that." (Interviewee 16A)

"Because an object is anyway an invitation to use it" (Interviewee 10)

The object as a presence

Some visitors lived the activating object as a *presence*, something that you constantly remember to have in your hand and that, for this reason, pushes you to look for the multimedia stations and to use the object.

"The pebble generates an immediate bias, in the sense that once you have the stone in your hand the search for the 'little game' to put the stone on and see what happens is almost irresistible... thus probably if I did visit without the pebble I would read all the text panels [..] *Anyway, I believe that the presence of the pebble causes the visitor to search for the multimedia resource that is also easier to access than reading a text panel"* (Interviewee 28B)[69]

"*you are, I mean, like forced, I mean, you have it in your hand, thus you say, I'll stop and use this object, thus probably if instead you pass by and there is the usual button [you would say] no, I will skip that"* (Interviewee 9B)

The object as a tool on the side of the visitors

According to a couple of people this object makes the people more involved because it is lived as a tool, something on the side of the visitor rather than on the side of the machine. This might have played a role in prompting to use the object.

"The button is, let's say, located in a more static way in front of the objects, while this is an object you carry with you. So this is lived more as an instrument than as a button" (Interviewee 39)

"Perhaps you feel more engaged, the button is something more… I mean... on the side of the machine, having this [the activating object] *in your hand and moving around the museum with this, makes you more involved"* (Interviewee 40B)

[69] It is interesting to notice that the presence of the object was lived in different ways by the visitors. In the case of this specific visitor the presence of the object is lived as something annoying, as in another comment said *"I would have preferred a button instead, because I have found this annoying, because there is a presence, and also constantly reminds you about this presence, while instead one serenely goes around in a museum, and when he gets curious about an electronic object, he pushes the button, but the object does not accompany him during his route. I mean, I prefer the item that stay there quietly to do its duty and when I require it I push it, although I recognise that holding this object in your hand leads you to look for these objects that otherwise, probably, many of these machines would be unnoticed if one would not have the pebble*".

The object as a novelty

Also, the novelty of the type of interaction, mentioned by many visitors, the fact that the interaction is done using an object, might have played a role in making the visitors more curious and willing to interact.

"Perhaps also the fact that it is the first time that one uses this, but also compared to the traditional buttons it is a bit more… it encourages you more" (Interviewee 1)

"And also the novelty factor probably plays a role. The button is used everywhere, this is instead something that characterizes a visit path, a specific visit path" (Interviewee 40B)

"anyway, also that thing of the object is interesting. I had never seen it, I did not even know it existed [..]" (Interviewee 14)

4.3.5.2. On the ability to communicate what the possible actions are

Easiness of use of the interface

What emerges from the questionnaires is that the majority of visitors immediately understood how to use the activating object and found it easy to use.

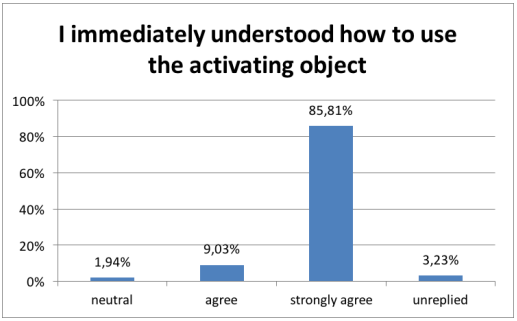


Figure 111 "I immediately understood how to use the activating object". Distribution of the answers.

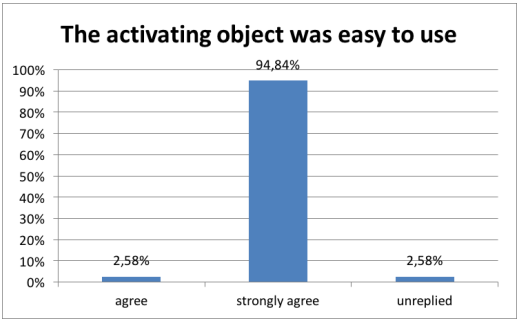


Figure 112 I feel I have shared the experience with my group". Distribution of the answers .

Also in the interviews the theme of the easiness of use is very present. A great number of visitors defines the activating object easy, intuitive and immediate to use.

"*it is very simple to use, intuitive and also the slots where to put it on the various stations are very simple and clear so… I find it a very natural thing*" (Interviewee 38A)

"*I mean, it is very simple, you place the pebble and if you don't want to listen the thing anymore, you take it off, it is really…*" (Interviewee 1)

On the role of instructions

Only four comments are present in the interviews regarding the initial how-to video. However, only one person mentions the importance for the visitors to see the video in order to understand how the interactive exhibit works:

"the how-to video is very nice, hoping that everybody watches the video about how it works" (Interviewee 19)

For others visitors, given the easiness of the interaction, the initial video providing instruction is not necessary or, in case, it could be substituted by shorter explanations.

"*we have watched the video more for curiosity than for understanding*" (Interviewee 25A)

"maybe [the video] *about how to use was a bit long, I mean, I guessed how to use it.* [..] *I mean, for me it was intuitive. In case, we could do it with a small piece of paper, something that explains immediately without requiring me to watch the video, however it is not annoying"* (Interviewee 20)

"*So maybe in the how-to video I would give more information about why these contents, rather than how to use the token. Intuitive, I had no difficulties about that."* (Interviewee 16A)

4.3.5.3. Ability of communicating the purpose of the action

The system does not always allow visitors to predict exactly what they will get as a consequence of placing the activating object on one of the hotspot. This unpredictability is lived by different visitors in different ways. A couple of visitors refers to appreciate the unpredictability as it generates a surprise effect:

"You never know what to expect, whether just a projection of something, or just something to hear, the sounds are sudden, thus this creates a surprise effect, there is a simulation effect." (Interviewee, 28B)

"[..]holding it [the activating object] in your hand, it is not so heavy, it is not light, I mean, a good sensation... and also placing it down was a bit… you never know what is going to happen. [..] if you push a button, I don't know, it seems like you can expect something [..] instead that was a bit more... I don't know... a bit more magical... a bit more... I don't know how to say it... Yes, something different" (Interviewee 12A)

Other visitors, instead, explain that they expected a video would be activated in the audio-only station, and found the fact that did not happen unsettling or confusing.

"In the third station I saw the canvas, I thought, maybe here... because I didn't think there was only audio, I thought there was also... I thought, where is it? So that I can see… Instead in the end it was only audio. It's definitely a bit unsettling" (Interviewee 6)

"it was a bit, maybe unsettling it is a wrong term, but it left you confused" (Interviewee 25B)

Just one visitor suggests that more information about the type of content that is activated should be provided at each station to make it possible for the visitor to choose what to see:

"In order to choose the content with a bit more awareness, we need to have some additional information... [..] for examples, the duration of the contents in some cases, or whether the content is just audio or audio/video because in some cases, I mean, it's evident, however…" (Interviewee, 16C)

Various visitors also refer that for them it was immediate to understand that removing the activating object from the platform would cause the multimedia content to stop.

"*I mean, it is very simple, you place the pebble and if you don't want to listen the thing anymore, you take it off, it is really…"* (Interviewee 1)

"I supposed it was like that, I supposed it was like that but it was also my instinctive reaction, I would say"[70] (Interviewee 24)

4.3.6. Additional considerations about the activating object

It emerges from the questionnaires that the majority of visitors prefers the pebble to a button (Figure 113), and that this preference does not depend on the age (Figure 114). The only exception seems to regard visitors over the age of 70, whose majority don't see a difference between the two types of interaction, however the number of visitors over the age of 70 is too low (3 visitors) for the data to be significant. However, for all the segments there is a significant percentage of visitors who consider the two types of interaction not different.

[70] This comment belongs to a visitor who instinctively took the activating object off, because embarrassed by the audio volume.

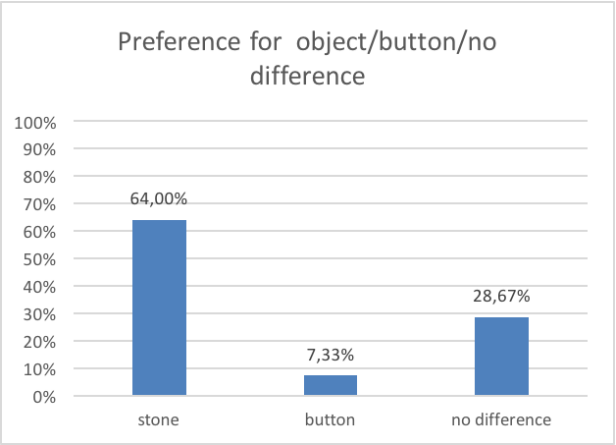


Figure 113 "If you could choose whether activating the contents using the activating object or a button, which method would you choose?". Distribution of the answers.

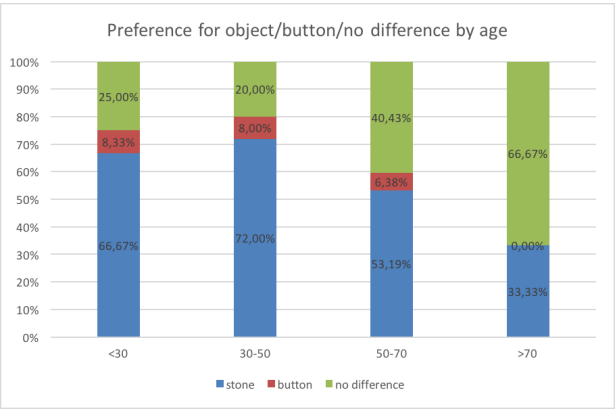


Figure 114 "If you could choose whether activating the contents using the activating object or a button, which method would you choose?". Distribution of the answers by age (<30;30-50;50-70;>70) (colour illustration at the end of the volume).

Many of the reasons why the object is considered to be a better solution compared to a button have been mentioned above and can be summarized as such: positive and sensorial impact, comfort, pleasantness of use, greater involvement, novelty. An additional reason mentioned by three visitors is the robustness of the activating object

compared to a button, the fact that "*it does not break down so easily as a button would do*" (Interviewee 19) or it does not get stuck (Interviewee 26).

Analysing the interviews, very few comments are present from visitors who said to prefer the button to the object to be able to create themes out of them. These make reference to the fact that the button is something more familiar, for someone more easy, less intrusive than the button.

Regarding those visitors expressing indifference between the use of a button or the activating objects, the reasons mentioned by them make reference either to the fact that the two devices present similar characteristics (simplicity, limited interactivity, no hindrance, they produce the same effects, they both do not have a specific sense in the exhibition), or the fact that for them the focus is on the exhibition and for this reason using and activating object or a button is exactly the same.

4.3.7. Effects of the installation on the social appropriation of the exhibition and social behaviour of visitors

As analysed in the previous chapter, there are three elements that seem to be the most likely to determine specific social appropriation of the exhibition, or social behaviours of the visitors: the activating object, the output accessible to more people at the same time (open audio, wide projections), the presence of more interactive stations. In this paragraph the impact that these choices had on the social experience/ appropriation are described.

4.3.7.1. The activating object

During the experimentation just one activating object was given to visitors visiting the exhibition in groups, to understand the dynamics that the activating object elicits. What emerges from the observations is that usually the object is shared during the visit, although there are rare cases in which a single person controls the activating object for all the visit. The object is sometimes asked for or offered, although sometimes it is taken directly from the platform by another member of the group. In some cases, the object is always carried by the same visitor but it is used by the companion to activate contents on the platforms. The

distribution of use of the activating objects among the different visitors varies in different groups. In some cases, there is a dominant visitor who uses it for most of the time, in other cases the visitor shares the activating object in a more balanced way.

Various visitors in the interviews comment on the fact that the use of a single activating object elicited peculiar groups dynamic and facilitated the sharing of the visit experience.

"the pebble blocks the group but hold it together" (Interviewee 32)

"it's clear that thing in a dynamic of group is very different compared to a button, because the button allows anybody to act in an autonomous way. This requires a sort of coordination [..], sharing and respect for what each one suggests in that moment" (Interviewee 16C)

"and who goes on must wait for the others to be able to see, so it triggers interesting dynamics in my opinion" (Interviewee 16A)

"because you wait for each other, you look at each other, one person slows down, also the other slows down, I mean, we are influenced" (Interviewee 28A)

Since many teachers or museum guides were present among the visitors, some comments regard the possibility of using this type of interaction in case of classes or large groups. In this regards, according to the visitors giving an object to every single person should be avoided, while the system could work if students, with the help of the teacher, were divided in groups (Interviewees 15A, 41, 26) or if it is the teacher/museum guide to activate the contents (Interviewee 19). A problem that could arise is the competition for the use of the activating objects (Interviewees 8, 9B).

4.3.7.2. Presence of open audio / video accessible to more people

The presence of open audio and of video accessible to more people is generally appreciated by visitors, because it allows to share the same experience and foster the exchange of opinions.

"I like open [audio] more for a shared visit also just in pairs. I mean, we listen together, we can comment, we can... I mean, I prefer it" (Interviewee 2A)

"it becomes more beautiful in the sense that you have the images and you share, as long as you visit in a small group of people that you know and it is not so crowded [..] (Interviewee 40C)

From the observations we have seen instances of visitors expressing their comments when viewing/listening to multimedia contents, while other people were quiet or preferred to express their comment at the end.

Some visitors also consider the use of open audio a good choice not only for the visitor who are enjoying content at the station, but also for the others who are visiting the artillery, although they report different reasons. For one visitor the open audio is good because *"it makes the environment more alive"* (Interviewee 10), for another visitor it is a way to draw the attention of the people towards a station that sometimes could go unnoticed (Interviewee 25). The fact of hearing in advance contents activated by other visitors is not considered a problem for two visitors because "*you hear them but you do not perceive the words, the subject, if you are looking at something else*" (Interviewee 12b) and "*so you hear it in background but you do not pay attention to it"* (Interviewees 9b) while a couple of visitors refers they did not want to hear the experience of other visitors (Interviewees 21A, 21B).

In general, from the interviews, it emerges a positive feeling regarding the sharing of the experience with companions and no negative comments are reported. In addition, from the analysis of the questionnaires data, it emerges that the majority of visitors felt they shared the experience with their companions (Figure 115). This feeling is stronger in the case of visitors who visited with their family compared to those visiting as part of a small group.

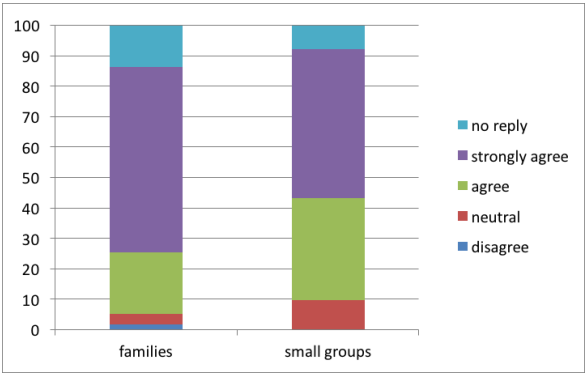


Figure 115 "I feel I have shared the experience with my group". Distribution of the answers both for families and small groups (colour illustration at the end of the volume).

For some people the use of open content makes the stations enjoyable also by big groups like classes (Interviewees 13, 14, 19) although some visitors suggest that since keeping a big group of people around a single station could be problematic the creation of groups would be a better solution (Interviewees. 15A, 26). There are also some people who said that the installation is not usable in the case of big groups or classes but they do not specify the reason – whether it is linked to the type of interaction or the way the contents are provided. (Interviewees 17A, 17B, 34B).

4.3.7.3. Effect of the distribution of content among the stations

An issue that is mentioned by some visitors in the interviews is related to the queue that could emerge in case many people are visiting the artillery section (e.g. Interviewees 2B, 40C, 9A). This is linked to the fact that there are too many contents and listening to/watching all of them requires too much time. Some visitors suggest that this problem could be solved by re-distributing the contents among a higher number of stations (Interviewees 8, 9A). Actually, the queue issue did not emerge very often in the course of the experimentation since not many visitors were present. Only few visitors in the interview describe a real situation where they had to cope with the problem of the queue: for a couple of visitors visiting together, the queue was not a problem since he just had to change installation going to another one (Interviewees 12A, 12B); another couple of visitors said they had to wait but they did not want to listen to what the others were listening (Interviewees 21A, 21B); a visitor reports that in the presence of another person waiting

behind him he felt he had to leave the station to allow her to interact (Interviewee 3).

4.3.8. Effects of the physical context

For administrative issues the exhibition was installed in the Artillery section of the Museo della Guerra. The Artillery section is located in what once was a WWII air-raid shelter, consisting of caverns excavated into the hill, and containing several artillery pieces from the First World War complemented by traditional labels and informative panels. Despite the differences, the environment was chosen because it presents similarity with the fort, and for this reason it could be evocative of the fort. In this paragraph, the effect of having chosen the artillery environment for the installation of the exhibition is explored.

4.3.8.1. Effects of using an environment that is not the fort

For a good numbers of visitors, the choice of using the artillery section for the exhibition about Fort Pozzacchio is a good choice since the environment of the artillery section is similar and recall the environment of the fort.

"the fact of having this humid cavern, because it absorbs the humidity of the whole mountain, also recalls a bit the environment that is described by the voices" (Interviewee 10)

"because I understood we were not inside Forte Pozzacchio in here, you are not there but it gives you the idea of being there, when it says about the galleries and you hear the drop of water it's like being there, isn't it?" (Interviewee 12A)

For a couple of visitors, the fact of using the environment of the Artillery is even better because it is more accessible and easier to visit than the fort itself.

"In Forte Pozzacchio it would have been worst [..] because it is much more humid there [..] visiting the fort is not very comfortable. It would be also much more dangerous because one can get lost" (Interviewee 10)

"In my opinion this choice makes everything more accessible [..] The idea of taking the students to Forte Pozzacchio could be interesting but [..] there are

those who do not want to walk, who can't walk because many classes have a lot of disable people[..] therefore in this way it is much more accessible" (Interviewee 15A)

Other visitors instead refer they perceived a disconnection between contents and context.

"*to me the thing that clashes a little bit is that the installations [..] are a bit detached from the context, I mean, I enter the section of the museum of Rovereto devoted to the artillery and I am led to find out the stories of Pozzacchio. I have found the link in the fact that we are in a hypogeum context like in the fort but actually I am not in the fort, I am in the artillery section of the museum of Rovereto and for this reason I perceive a strong discrepancy, but this is my instinctive reaction, I don't know"* (Interviewee 7C)

"*it is a bit strange to speak about Pozzacchio out of context"* (Interviewee 21A, 21B)

Some visitors also report that the fact of presenting contents related to Forte Pozzacchio in the artillery section makes the understanding of the contents more difficult, especially for visitors who have never visited Forte Pozzacchio.

"*in Pozzacchio you would understand immediately, here it's more difficult to contextualize"* (Interviewee 17b)

"maybe because I had in mind how it is done, where it is located, for me it was much easier imaging it... Therefore, I don't know whether [..] somebody who has never visited it would be able to imagine it, whether these devices are able to transmit this..." (Interviewee 3)

Therefore, for some visitors a possible improvement would be the addition of other information supports (e.g. additional videos, a scale model) showing the current structure of Forte Pozzacchio or the surrounding environment.

"I would have liked to watch a video about how the fort is today so that... yes, I have the witnesses' accounts etc., but visually I have no idea about what it is, how it is done etc., and for me that was something missing" (Interviewee 27b)

"I would not reject the idea of making something like the scale model that is in Forte Belvedere in the artillery, because that is very precise, I mean, one understands even if he doesn't want [..], a scale model of the fort, so that I

understand what the mountain is like, I understand what side the Italians came from[..]" (Interviewee 7d)

4.3.8.2. Effect of the presence of pre-existing objects and informative labels in the artillery section

Many visitors view the interactive exhibition as an improvement to the artillery section and something that integrates and supports the understanding of the traditional exhibit of objects.

"I have visited the artillery section other times, but this time the level of understanding has been higher and I also protracted the visit and so, it has been more useful, otherwise there was just an exhibition of objects disconnected from the understanding" (Interviewee 10)

"the multimedia installation [..] has allowed all the exhibited objects to come to life and have greater meaning for who observes them" (Interviewee 36)

These comments clarify that these visitors do not seem to perceive a contrast between the theme of the artillery section and the theme of the exhibition. As explicitly said by one visitor "*after all these weapons, not all of them but at least a part of them they were used there, therefore, even though they are not exactly those of Fort Pozzacchio, they are like those[..]"* (Interviewee 15A).

A good number of visitors, instead, perceived a disconnection between the traditional exhibition and the interactive exhibition about Fort Pozzacchio. Different visitors react differently to this disconnection. For someone it is not a problem because it is not so strong:

"[the interactive exhibition] does not perfectly match, I mean, you can perceive it is something extra compared to the permanent exhibition. But this is not an issue, also because essentially there is a slight link" (Interviewee 4B)

For other people instead the disconnection is stronger and this can generate a sense of confusion:

"It would have been better to use a more neutral environment, with less exhibited materials, that would have led to a greater involvement. Now there is too much confusion, with old captions, objects exhibited in showcases according to a traditional concept and where these new things have been added in a non-organic way" (Interviewee 35b)

"well, we went straight to [the multimedia stations] [..] because we had already seen the artillery section [..], so, I don't know, for a generic visitor: what am I looking at? Am I looking at 'Pozzacchio'? Am I looking at the exhibited mortar? Am I looking at the… I don't know… I put a question mark" (Interviewee 7D).

4.3.8.3. Relation between technology and environment

The insertion of multimedia in a cavern, a peculiar environment compared to a traditional museum room, seems to be well received by the visitors. Indeed, none of the interviewed visitors report negative comments in this regards. However, the motivations why they find the use of multimedia content appropriate varies a lot among different visitors to make it possible to identify actual themes. However, a reason seems to be that today is not uncommon to find technology anywhere, and visitors have previously experienced the use of multimedia in peculiar environment like forts or similar. Other visitors report they liked the contrast between old and modern because it makes the exhibition more interesting. For others multimedia contents are appropriate for a dark environment, and are even more accessible in the dark than text panels. For others, the multimedia content is appropriate because it modernizes the artillery section, and because there is a good integration between multimedia contents and the environment.

However, three visitors suggest that a further improvement could be the use of emulative sounds, that recreate the context of the war.

"*I don't know whether it is feasible in a context like this, to add some sounds, the sounds of the war or something like that which recreates the atmosphere, because in the end they are very effective in my opinion"* (Interviewee 2A)

"Since we are told about the Austro-Hungarian reconquest of the fort, I mean, I would add something to make visitors more involved, and let them think that in the end they [the Austro-Hungarians] shot and they created, I mean, terror, also associated just to the noise" (Interviewee 15A)

With regards to the location chosen for the interactive stations, most of the comments of the visitors refer to the audio-only station. Since a video accompanying the audio is not present, many visitors end up looking around in the environment or observing the objects as confirmed by the observations. From the comments available in the interview, the reaction to this situation seem to be different for different

visitors. While this is not a problem for some of the visitors, other visitors report they found the connection with the nearby objects weak or absent and they would have preferred instead something, not necessarily digital, more connected to the stories being told.

"yes, the audio [..] was a bit, maybe unsettling it is a wrong term, but it left you confused [..] especially in that context because we were in front of a weapon, maybe a howitzer and so there was no match with the words we were listening to in the recording" (Interviewee 25B)

"*the second audio I have understood the reference to the train departure, there was the train whistle e the howitzer can be associated to it because it has the train wheels. But I understood this because I know by heart all the objects that are there, a person coming here for the first time would unlikely understand the connection"* (Interviewee 16B)

"I would have liked an object or something to contextualize" (Interviewee 38B)

For the other two stations not many comments regarding the location are present in the interviews and the few comments that are present are generally positive, although a couple of visitors did not fully appreciate the type of screen that was used in the last station (Interviewees 21A, 35A) and would have appreciated something more integrated in the environment.

4.3.9. Effects of the personalization

In terms of *personalization* the installation allows the manual filtering of contents, since the visitors can choose which stations to visit, and also which contents to activate at each station through the activating object. From the analysis of the interviews it emerges that the possibility of choosing the contents to watch is very well received by many visitors.

"*For this reason I felt like a person that has something in her hand that allows to choose. Because the provided material has different form, the times of fruition are different, and you can decide how much time to linger, what to skip, and so it increases the autonomy of those who visit this installation"* (Interviewee 36)

"As an object it seems to me a good choice because it is not bulky and most of all has the advantage that can be used when you want therefore theoretically it also gives you the possibility to create your own visit path that respects the

time you personally need to enjoy and learn the information" (Interviewee 37)

Although visitors comment positively about the possibility of choosing the contents, from the observations it emerges that the majority of the visitors generally watched *all* the videos and *in the order* they appeared on the platforms, from left to right in the three thematic stations.
The reason why they watched all the videos might be linked to the new type of interaction that stimulates and motivates the visitors (see 4.3.5.1), and the curiosity of the visitors about the contents (*"With regards to these contents there is a curiosity that remains alive also at the end of the tour.. after one hour I think I wouldn't have skipped any content"* - Interviewee 2A*)*. An additional reason is reported by three visitors visiting in groups who said that not enough information (e.g. the duration, types of media) were provided in the labels to allow to choose and for this reason people might end up looking at all of them (*"either you decide that you give more information to choose, then you can say, ok, I am going to select just two, it has a length that I choose and I choose what I am interested in, otherwise in this way one is encouraged to listen to everything because obviously this is a thing he does not know, that you want to listen to"* - Interviewee 16A*)*.

In the rarer cases in which visitors decide to select a subset of stories to listen to this seems to be linked mainly to the personal interest, although other factors mentioned less frequently regard the perception about the duration of the contents, the environmental conditions (cold and humidity), the fact that there was a visitor behind them waiting to use the station.

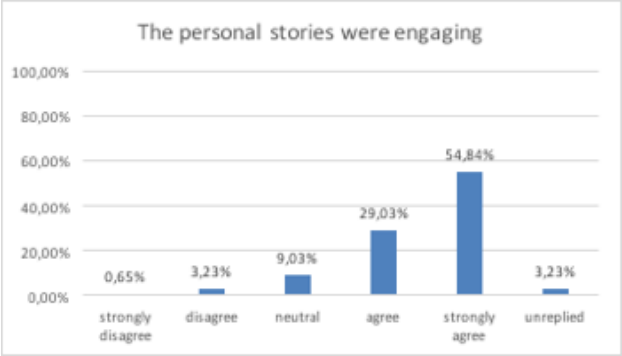
Visitors generally refer they selected the content in the order from left to right either because they found it natural to select the contents in the order they appear in the station, or because reading the labels they figured out that the stories were placed in chronological orders.

4.3.10. Effects of conveying personal stories in the interactive exhibition

The curators from the very beginning expressed their willingness to provide visitors with intimate contents narrated from the point of view of the people who experienced the fort (the architect, the soldiers, the civilians), in this way adopting more or less consciously a constructivist approach to learning, one that is not based on the conveyance of factual

contents in a didactic way. In this paragraph the impact that the use of personal stories had on visitors is examined.

From the analysis of the questionnaires, it emerges that the stories were considered engaging by over 80% of the visitors.



This is also confirmed in the interviews where a large number of visitors reports that they felt strongly engaged at an emotional level.

"What we heard today conveyed much more emotions than information" (Interviewee 15B)

The emotional impact is clearly connected in many cases to the empathic feeling the stories generate on visitors.

"coming and listening to the stories narrated by people like civilians, allows you to have an almost emotional experience and you find yourself to look at these objects with different eyes because it is not just a cannon but you know how much it affected the lives of many people[..]" (Interviewee 38B)

The stronger engagement might also be connected to the fact that the stories are perceived as more real or something representing the "real" history, a theme that is mentioned by a certain number of visitors.

"I'd say that this is the real history, because obviously they have lived it and [it is] not somebody else that after 30, 40, 100 years tell them but never lived them" (Interviewee 14A)

Also the fact that personal stories – especially stories of civilians – are considered by visitors as rarer to find compared to historical

information might have played a role in creating a stronger interest in the visitors, and a higher level of engagement.

"Because the historical fact, maybe, you find it... you find it. Personal and individual experiences are more difficult [to find]"

On a more cognitive level, the personal stories are told to increase the understanding of objects (see Interviewee 38B) and historical facts.

"I liked the interactive part very much for the fact that it reported real witnesses' accounts, so that we can understand the history, what happened through witnesses' accounts" (Interviewee 24)

In addition, the personal stories are said to be easier to remember compared to factual information that is forgotten very quickly.

"also because places and data are remembered just for the moment, but after one or two hours, maybe, we are not going to remember them anymore. Instead things like those remain [in your memory]" (Interviewee 24)

While comments regarding the personal stories are generally positive in the interviews there are also very few people who said they would have appreciated also the presence of more factual information regarding the history of the fort or the war for the exhibition to be more clear and complete.

"maybe, a narration of facts of that time [..], something at the beginning that illustrates, that explains the event of the fort. Because I am from here, I know the history but if a tourist comes that does not even know Forte Pozzacchio..." (Interviewee 6A)

"I would have liked to get out of the museum with a review of some knowledge about the first world war, because if someone is not a professional historian, when he gets older, he has completely deleted it from his memory. And these are pieces of information, that if I found on the panels or told in one of your stories, I would have listened willingly" (Interviewee 28B)

If, on the one hands, these comments can be interpreted as an actual lack of enough factual information in the exhibition, on the other hands, this perception of visitors could have been generated by the fact that they might not have visited the overall museum before accessing the exhibition or looked at the introductory video in the check-in station.

Chapter 5

A discussion of the theoretical framework through an analysis of the "Voices from Forte Pozzacchio" project

In this chapter, the "Voices from Forte Pozzacchio" project (see Chapter 4) is analysed by using the aspects identified in the theoretical framework (see Chapter 3). This analysis is expected to allow for the identification of relations (e.g. concordances, divergences) between the theoretical framework and the specific practical project that can be useful to enable a discussion and a reflection on the theoretical framework itself. In addition, this analysis is expected to show and enable reflections about how the different aspects, identified as static in the theoretical framework, emerge dynamically in a real design process.

5.1 Analysis of "Voices from Forte Pozzacchio" project using the aspects identified in the theoretical framework

As explained in Chapter 3, the theoretical structure proposed in this research can be intended as both a conceptual framework and the foundations of a design framework. On the one hand, it shows what tangible interaction is by proposing a list of categories that can be used to classify tangible interactive systems. On the other hands, these categories represent aspects that make up the design of such interactive systems, that is, themes around which choices have to be made during the design process and the knowledge of which can facilitate or inspire the design process itself. Therefore, for each aspect identified by the framework an analysis is proposed below that tries to reply to two main questions that are:

1. How does the exhibition fit in the categories identified in the framework with regards to the specific aspect under analysis?

2. Did the specific aspect emerge during the design process of the exhibition? *How* and *when*? What reflections (if any) does this analysis enable regarding the framework?

When needed, considerations about the impact on visitors of the exhibition will be included in order to strengthen or develop further reflections connected to the framework.

5.1.1. Target

A first aspect identified by the framework as one to be considered during the design of an interactive installation regards the target. Concerning this theme, the framework proposes the following categories, although admitting they are not exhaustive and other aspects should be considered[71].

Main target					
Able-bodied public		People with disabilities			Universal target
adult	children	blind and visually impaired	learning disabilities	etc.	

Observing the characteristics of the installation, it seems clear that the project is mainly targeted to able-bodied people, since the technology and/or the content would not be completely accessible for people with some disabilities like blindness, deafness etc. In addition, the installation can only be enjoyed by Italian visitors since the contents are only provided in Italian. Apart from that, it does not seem that the installation has been designed for a specific subset of people, like children, adult or people with specific backgrounds, but more with the intention to include as many people as possible.

From the available data (notes from the preliminary discussion, deliverables, personal notes from the co-design session, etc.) reflections about the target emerged during the initial discussion aimed at defining a preliminary brief for the project, and regarded mainly the language with the idea of providing contents in Italian, in Dutch and in English so that they could be accessible to visitors of different

[71] The focus of the framework on just these categories of target was linked to the easiness of categorizing the installations with respect to these characteristics compared to other for which not enough information is generally specified in the documentation of the projects.

nationalities. However, during the course of the project, probably for reasons of time and budget the contents were developed just in Italian. Anyway, according to what referred by the coordinator of the project, the exhibition was not created with a specific target in mind, but with the intention of being suitable and accessible for everybody.

5.1.2. Reference CH assets

As specified in the framework, the cultural assets the installation refers to can be tangible or intangible.

Cultural assets								
Tangible assets			Intangible assets/values					
works of art	**architectures/ buildings**	etc.	concept	**Story**	practice	ritual	**factual inf.**	etc.

The cultural assets the installation refers to include a tangible cultural asset, Forte Pozzacchio, but also a set of intangible assets like the history of the fort and personal stories of the people who worked on the construction of the site, of civilians and of soldiers.

The choice of using personal stories was indeed posed as a requirement by the curators during the preliminary discussion, starting from the observation that text panels providing more factual and technical information about the fort were already present and that it would be interesting to offer the visitor a more emotional experience and the possibility of enjoying the fort through the voices and faces of the people whose life was linked with the site. The inclusion of factual information related to the history of Forte Pozzacchio (in particular in the check-in station) is something that was decided at a later stage of the project (re-adjustment) due to the change of location.
The choice of referring the installation to Forte Pozzacchio was instead a decision that was already taken before the project started because it allowed to explore the application of tangible interaction and the meSch technologies inside a challenging environment.

The importance of choosing carefully the type of intangible values to associate to the tangible asset is confirmed by the strong impact that the choice had on visitors, with some of them referring about the positive effect of the personal stories, while others suggesting they would have appreciated the presence of more factual information (see 4.3.10).

5.1.3. Purpose of the installation

As illustrated below, three different purposes of a tangible interaction installation have been identified as part of the framework.

Purpose of the installation		
associate intangible values to tangible assets	give tangible form to intangible assets	allow people to experience the material properties of tangible assets

The purpose of the installation is clearly mainly that of connecting intangible values – personal stories of people whose life was connected with the fort – to a tangible asset, Forte Pozzacchio.

Although it was not discussed in the terms used in the framework, this decision was implicitly taken during the preliminary discussion, and then confirmed at the beginning of the co-design session (brief refinement), when it was thought it would be interesting to allow visitors to experience the fort through the voices and faces of the people whose life was linked with the fort. Also after the location for the exhibition changed, the overall purpose of the installation remained the same.
From the available data, it is not possible to say whether others among the purposes proposed in the framework were discussed or not.

Reflecting on what emerges from the analysis of the interviews (4.3.8) it seems that the association between the fort and its intangible values is not always completely reached. For some visitors the association is fully reached thanks to the use of an environment made of caverns that is similar to the fort or because they visited the fort previously. In the case of other visitors, especially those who have never been to Forte Pozzacchio before, the connection is made more difficult by the use of an environment that is not the fort. In many cases, a strong association is instead mentioned by the visitors regarding the narrations being listened and the objects on display as though the narrations were created to make the objects more understandable and alive. These different behaviours can be interpreted as a consequence of the change of location for the installation and therefore the co-presence of two different themes that led the visitors, depending on the circumstances, to put the focus on one theme or another (or both) and to interpret their visit accordingly.

5.1.4. Location of original tangible asset

Concerning the location of the original tangible asset the installation refers to, the framework proposes different options as illustrated in the following table.

Location of original tangible asset			
embedded in the installation	close to the installation	located in the museum (distant)	**located in another place (very distant)**

According to this classification, the original tangible asset the installation refers to – Forte Pozzacchio – has to be considered as very distant because located in another place with respect to the installation, the artillery section of the Museo della Guerra.

The choice of installing the exhibition in a distant place, the artillery section of the Museo della Guerra took place after the emergence of administrative issues, that led to a reconsideration of the situation. Indeed, according to the original plan and design (and even before the actual design process started), the interactive exhibition should have been located inside the fort.

From the interviews it emerges the impact that the distance of Forte Pozzacchio had on the visitor experience. While for some visitors, especially those who had been in Forte Pozzacchio before, the distance between Forte Pozzacchio and the installation is not perceived as a problem, for other people the distance makes the understanding of the contents more difficult (see 4.3.8.1). In addition it has been noticed how the association between the form of the activating object and the environment (and in some cases also the correct interpretation of the engraving on the object) was made more difficult for the visitors probably by the distance of the cultural site (see 4.3.3.1). The strong impact the location has on the visitor experience confirms the importance of considering this aspect during the design.

5.1.5. Strategy to foster the experience of the original tangible asset

Different strategies are illustrated in the framework that allow to foster the experience of the original tangible asset as summarized below.

Strategy to foster the experience of original tangible asset		
naturally fostered through location	fostered through action	**not fostered**

In the exhibition the experience of the original tangible asset - Forte Pozzacchio - is not fostered. Indeed, none of the strategies described in the framework have been used.

This is probably connected to the fact that, according to the original plan the installation should have been located inside the fort itself, and for this reason the experience of the fort would have been naturally fostered through the location. According to what reported by the coordinator, although after the change of location it was thought it would be nice for the visitor to see Forte Pozzacchio, an explicit discussion about the design of a strategy to push the visitor to visit the site has not been done, probably for reasons of time (the goal was to have the installation installed as soon as possible), because the fort would have closed soon and because the team still hoped that the installation could be moved to Forte Pozzacchio in the future.

Someway connected to the topic analysed in this paragraph, there is a comment made by a couple of visitors during the interview. While commenting about the postcard they got at the end of the visit, they say they would have appreciated the presence on it of a map showing where Forte Pozzacchio is and of information about whether and when it is open to visitors or, alternatively a "*small brochure, a small print about the fort or about the other forts in Trentino, on what you want to promote on the basis of this visit[..]*" (Interviewee 28B). This confirms the importance of considering this aspect during the design process.

5.1.6. Single/Multi stations installations

On the basis of the number of stations that make up an interaction installation the framework distinguishes between single station installations and multi stations installations.

Single/Multi interactives installations	
Single station installation	**Multi stations installation**

"Voices from Forte Pozzacchio" exhibition falls in the "multi-stations installation" category, as it is composed of three different stations each devoted to different themes.

The choice of having three different stations was something that was already envisaged in the preliminary brainstorming sessions professionals involved in the project had, decision that was then confirmed during the co-design session. This decision was a consequence of the organization of the stories in different themes, but it might also be linked to the decision of allowing more people to interact with the exhibition. In addition to the three thematic stations, a check-in station is present at the beginning of the exhibition. The presence of a check-in station is something that was decided during the co-design session in order to allow visitors to familiarise with the technology and to provide personal witnesses' accounts from the people who are protagonists of the current history of the place. In the new location, the check-in station has a slightly different purpose: to provide an introduction to the topic and to create a connection between what the visitor has seen in the museum and the new exhibition.

The analysis of this aspect reveals the connection between the cardinality of the installation and other aspects, some of them identified in the framework (i.e. social appropriation) and others not present in the framework (i.e. organization of the contents). The latter aspect can be included in the framework in order to make it more complete.

The importance of considering the cardinality of the installation is confirmed also by the strong impact the aspects had on the visit experience. For example, the presence of more stations allows more visitors to interact with the exhibition at the same time, or to find an alternative station to enjoy in case there is a queue. For some visitors having just three stations with so many contents to listen to is not enough to overcome the problem of the queues that might arise when there are many visitors and they suggest that a redistribution of the contents among more stations should be considered (see 4.3.7.3).

5.1.7. Tasks

The framework distinguishes between different types of tasks interactive installations typically allow to accomplish, as illustrated below.

Tasks					
Activating information	**Getting instructions**	Producing content	Navigate a 3D model	Activating simulation	Etc..

In “Voices from Forte Pozzacchio”, the tasks supported by the thematic stations are the activation of multimedia contents related to Forte Pozzacchio, to which we can add the acquisition of instructions about how to use the exhibition provided by the check-in station. These tasks logically require a combination of selection and control subtasks, that is, the selection and triggering of a specific content by visitors.

The choice of providing and supporting the activation of multimedia information emerged during the co-design process as a consequence of the purpose of the installation (associate intangible values to tangible assets) and of the organization of the contents, that is, the presence of more stories in the different thematic stations to be chosen. Also the choice of supporting the acquisition of instructions through the check-in station is something that emerged during the co-design process, although the specific type of media to use is something that was decided later on.

5.1.8. Devices (input)

Concerning the input devices, a first distinction proposed by the framework is between smart objects and traditional devices. Different possibilities regarding the form of the smart objects are also presented. These are based on the formal and cultural relations between the smart object and the main heritage asset, distinguishing between primary objects (smart original, smart replicas, smart derivatives), that is, objects that have the same shape as the reference asset, and secondary objects, that is, objects that do not have a formal relation with the reference asset. In turn, secondary objects have been distinguished in related and unrelated objects, on the basis of the existence or otherwise of a cultural relation between the smart object and the reference asset. In addition to the cultural relation between the smart object and the reference object, this research has suggested another element that can play a role in the determination of the form of a smart object: a form can be chosen because representative or symbolic of an intangible value connected to the reference asset (see 3.4.3).
In “Voices from Forte Pozzacchio” exhibition, the various interactive stations look very similar from the point of view of the input devices that are used. The latter consist of metallic or wooden stations and a small activating object to be used together. These two elements are analysed below.

The activating object

As explained in the previous chapter, the activating object is small, has a lenticular shape, is made up of coloured resin and is endowed with qualities like smoothness and relatively high heaviness. In addition, it has the altimetry of the fort engraved on one side. It has physical characteristics that are similar to those of the fort and of the surrounding environment in that it mixes together natural and artificial. Indeed, it has a quite natural shape although it is an abstract man-made object.

For sure, the activating object is not a "traditional device". Since the technology is not visible, the device can be considered to be a smart object. However, associating this object to one of the categories of smart objects identified in the framework is not straightforward as the object seems to be open to a variety of interpretations especially for people who do not know the intentions of the designer.

Devices (activating object)					
Smart object					Traditional device
Primary object ??			**Secondary object ??**		
Smart original	Smart replica	**Smart derivative ??**	**Related object ??**	**Unrelated object ??**	

Given the presence of the altimetry of the fort, one could interpret the object as an abstract representation of the fort, a *primary smart derivative*. On the other hand, the object can be considered as something different from the fort, a secondary object. More specifically, strictly applying the conceptual framework that considers as related objects those that have a cultural relation with the reference object (i.e. an object belonging to the same context of activity as the reference one), the activating object should be considered as an *unrelated object* in that it is an abstract bespoke object with no cultural relation with the fort. However, referring to this object as something unrelated does not seem to be very appropriate in this case, as a relation between it and the reference object is present however it is of different kind compared to the one presented in the framework. Although the object is not culturally related to the fort, the object can be associated to it and to the environment around it in virtue of its physical characteristics that recall the material qualities of the environment. Therefore, in this case the type of relation regards mainly the physical and aesthetics similarity. In addition, instead of considering the object as symbolic of an intangible value related to Forte Pozzacchio, in this case the object might be considered as

symbolic of tangible values regarding Forte Pozzacchio in that it embeds the physical characteristics of the fort and the surrounding environment.
These observations suggest that the proposed framework could be improved by including different types of relations between a secondary smart object and the reference object that go beyond the pure cultural one. In addition, it should be considered that the symbolic relation between a secondary smart object and the reference object does not necessarily need to regard an intangible value of the reference object but it could also regard a tangible value.

The use of smart objects as input devices instead of traditional devices is something that was decided even before the design process started and was connected to the general orientation of the meSch project to hide and integrate the technology inside objects or environments.
However, the specific form of the smart object was the result of a design process going through various phases during the design of the exhibition. The idea of using an object to activate contents on a physical station provided with a timeline is something that emerged almost at the end of the co-design session after discarding previously proposed concepts. The specific form the object was not discussed at that stage. Only some requirements for the object were mentioned during the co-design session: functional requirements (i.e. it should be able to activate contents by placing it on a timeline, it should be able to collect logs about the interaction), and formal requirements (i.e. it should be small in size, possibly orange as the other structures in the fortress).
The actual form of the object was conceived by the product designer during the activities that followed the co-design session. According to what reported by the designer, the form of the object was the result of a design process aiming at meeting several objectives and constrains regarding the human aspect, the technological aspect, the making process. This determined the physical characteristics of the object such as the small size and its relatively high weight. In addition, the willingness to create an object that could be associated to the fort had a role in the determination of the form of the object, that, like the fort, integrates natural and artificial.

What emerges is that in this specific case study the design of the form of the object did not emerge as a consequence of a reflection on the cultural relation between the form of the smart object and the reference object (Forte Pozzacchio), as suggested by the framework but as a consequence of a process placing the focus on different criteria such as the functionality, aesthetic, sensorial, emotional and comfort-related ones, as well as on those related to the technology constrains and the

making process. Many of these aspects proved to have a relevance for visitors, since many of their comments have regarded, for example, the positive aesthetic and sensorial impact of the object and the comfort of holding it. This suggests that it might be worth including these aspects in the framework to make it more complete. The absence of a cultural relation between the smart object and the fort is not reported as a criticality by the visitors, allowing to state that also the use of smart objects that have no cultural relation with the reference asset can be a satisfactory tangible interaction strategy. On the other hands, from this analysis it emerges the potentiality the framework could have had in suggesting an alternative design strategy, one that is more focused on the cultural relation between the object and the reference asset[72], but this does not allow to say anything about the effectiveness this strategy would have on visitors in terms of appreciation compared to the current solution.

Besides, the process of construction of the meaning of the object in this project is different compared to the one proposed in the conceptual framework. In this case study, the process does not aim to embed an intangible value – a cultural meaning related to the object- into the object but a tangible value into an abstract object as to suggest interpretations of it as something related to the fort (e.g. a pebble, a stone) but still leaving the visitor free in the process of interpretation. These are design strategies that might be worth including in the framework to make it more complete. However, nothing certain can be said about the effectiveness of this strategy. In this specific case study, many visitors for various reasons referred to the object using the term pebble or stone, but just one of them explicitly associated the stone to the fort. This can be interpreted as a weakness in the association between the form of the object and Forte Pozzacchio, not necessarily determined by the design choices that were made, but as a consequence of the change of location, that determined a change in the context compared to the one that should have been used.
In addition to the interpretation of the object as a pebble or a stone, also different interpretations of the object arose that are not easily linkable to Forte Pozzacchio (e.g. as a disk, a token, a chopper, a soap, a key, something magical or Zen). Examining the comments of the visitors,

[72] It can be assumed that the application of a strategy that is focused on the cultural relation between the object and the reference CH asset could work better if the form of the object is discussed during a co-design session where different professionals collaborate in the design of the interaction. This would allow the curators to share possible intangible cultural values connected to the reference asset with the other team members (e.g. product designer, interaction designer etc.) and then to discuss how to translate these values in the interaction and in the form of the object

the various emerging meanings could be intended as a consequence of the interplay of various factors such as the form of the object, the context, the type of interaction, the effects of the interaction, and the personal background of the visitors. This suggests a series of aspects that have to be taken into account when designing the meaning of a tangible interaction system. The designer will have to concentrate on each of these aspects in order to create a mix able to communicate the meaning he wants to, although he must be aware that also other meanings can emerge according to the personal background of the visitor, an aspect over which the designer has just limited control. In projects where the communication of a specific meaning is really important, a hypothetically good strategy a designer can adopt is to create a mix as strong and as coherent as possible so that the meaning he wants to communicate prevails over the others. The more ambiguous or weak is the mix the more likely is that it will generate personal interpretations. In "Voices from Forte Pozzacchio", the use of an abstract object and the change of the context are likely to have determined ambiguity and fostered many different interpretations of the object by visitors. However, it is important to notice that in the specific case of the "Voices from Forte Pozzacchio" exhibition, the generation of personal interpretations that were weakly connected to Forte Pozzacchio did not generally bother the visitors but were well received[73] maybe because the process of generation of personal meanings is something enjoyable in itself and able to foster feelings of appropriation.
This analysis confirms the importance that the meaning has both in the process of design and in the impact on visitors of the installation suggesting the importance of the presence of this aspect in a design framework as hypothesised more times in this thesis.

The interactive stations

As specified above, the activating object is used in couple with other input devices, that is, the various thematic stations that make up the exhibition. The thematic stations consist of metallic platforms similar to counters, with a line of indentations on the top surface, labelled with information related to the stories that can be selected.
Using the classification of smart objects presented in this thesis, the platform cannot be considered to be a "primary object" or a "related object" as it does not have a formal relation with Forte Pozzacchio, nor

[73] There is only one visitor who commented *"Why should I have a soap in my hand?"* but also in this case it is not clear whether the doubt is connected to the object resembling a soap or the way it is used in the exhibition.

it is an object that has previously existing cultural relations with Forte Pozzacchio. It is a new bespoke object, an unrelated object that has been designed specifically for this project.

Devices (interactive platforms)					
Smart object					Traditional device
Primary object			**Secondary object**		
Smart original	Smart replica	Smart derivative	Related object	**Unrelated object**	

The preliminary concept underlying the interactive platforms emerged during the co-design session, and consisted in the idea of a timeline showing the available contents and allowing to select one of them using a physical object. The final structure of the platforms emerged later on during the phases that followed the co-design process, in a process of refining that went from low-fidelity prototypes, to high-fidelity prototypes. In particular low-fidelity prototypes were developed after the co-design session for a feasibility test in place. The test in place allowed to get additional information about the environment (e.g. available space, space characteristics etc.) that allowed to refine the concept (forms, dimensions, materials etc.) and develop high-fidelity prototypes (prototyping phase). Generally speaking, the prototypes being developed in these phases can be considered as the result of a physical translation of the abstract concept of timeline developed during the co-design session.

From the analysis of the process of design of the physical platform what emerges is that also the form of the object did not emerge as a consequence of a reflection about the cultural relation between the form of the smart object and the reference object (Forte Pozzacchio), as suggested by the framework but as a consequence of a process mainly placing the focus on different aspects such as functionality, aesthetics, and suitability for the specific environment. This, on the one hand suggests that there are aspects that are missing or not made explicit enough in the framework. On the other hand, it suggests an alternative design strategy that could prove to have a positive impact on visitors and that put the emphasis of the design process on the reflection around the cultural relation between the smart object and the reference CH asset.

5.1.9. Actions

Regarding the actions, the framework proposes a distinction between performing and codified actions, depending on whether the actions

belong or not to the repertoire of gestures that are culturally associated to the specific object. The use of performing actions has been presented as a way to embody an intangible value – a cultural meaning – related to the object into an action.

Actions	
Codified actions	Performing actions

The selection and activation of contents related to Forte Pozzacchio is reached through a single physical action consisting in placing the activating object down on a specific slot among those available on each station. This can be considered to be a codified action, since it is not an action that is culturally meaningful neither in relation to the activating object – whether it is interpreted as an abstract object or even as a pebble – nor in relation to Forte Pozzacchio. Also the off-line action that the visitor is required to do while visiting the exhibition, that is, carrying the activating object with him, is a codified action.

The action of placing the object down on the platform emerged as part of the concept that was defined at the end of the co-design session, requiring indeed the coupling between the smart object and a slot on the platform in order to activate the multimedia contents. Placing the object down on the platform was the most direct way to implement this concept and also an easy and intuitive action for the visitor to do, and it can be assumed that these were the main reasons that determined the choice of the specific action, since the creation of an interaction that was easy and intuitive for the visitor was a goal mentioned during the process.
The action of carrying the object during the visit also emerged during the co-design session as a practical necessity imposed by the choice of providing a personalized souvenir at the end of the visit. In order for this to be possible, it was necessary that the same object was carried by the visitor so that the information related to the interaction was recorded in the object itself.
Similar to what happened for the design of the form of the object, also the type of action did not emerge as a consequence of a reflection about the cultural relation between the type of action and the specific object used or the reference asset (Forte Pozzacchio), as suggested by the theoretical framework, but as a consequence of more practical criteria (e.g. easiness, functional requirements).
The importance of the easiness and naturalness of the action is an aspect mentioned by several visitors in the interviews, in addition to other themes like the pleasantness of the action. This suggests that these other criteria should be added in the framework as aspects to

consider during the design of an action. On the other hands, the framework seems to be able to suggest a different way to design the action that puts at the centre a reflection around the cultural relation between the type of action and the object, and that could orient the design towards alternative solutions based on the cultural meaningfulness of the gesture in relation to the reference object. However, the effectiveness of this strategy should be assessed through further studies.

From the analysis of the interviews another aspect emerges and has to do with the generation of meanings and sensations by the visitors starting from the execution of an action.
The high occurrence of the theme related to the meaning of the action shows the importance that this aspect has on the visitor experience. This suggests that it is important to reflect about the meaning of the action during the design process. Actually, the framework already considers this aspect but only when dealing with the design of performing actions, interpreted as an embodiment of intangible values or cultural meaning into actions, while this analysis suggests the importance of considering this aspect also in the case of codified actions. Indeed, also in the case of codified actions, we might want to design actions that are oriented towards the communication of certain meanings or in leaving the interpretation open so that personal meanings emerge. In "Voices from Forte Pozzacchio" the second strategy seems to have been more or less consciously used, leading to a variety of interpretations of the action by the visitors.

5.1.10. Interaction style

The framework proposes a distinction between manipulation-based interaction and free-gesture based interaction, on the basis of whether the interaction requires a physical contact with an object or not.

Interaction style	
Interaction with contact (manipulation-based interaction)	Interaction without contact (free gesture-based interaction)

With regards to this aspect, the exhibition proposes an interaction that is based on the contact and manipulation of a physical object. This choice was the final conclusion of a quite long decisional process started with the preliminary concept brainstorming various members had in separate teams at the beginning of the project and that went on during the co-design session. Before a concept was selected at the end of the co-design session, free-gesture-based interaction was considered

to be a good option for the installation as it would not have hindered the movement of the visitor in the difficult environment of the fort, leaving his hands free. Although some concepts involving free-gesture-based interaction were also envisaged, later on they were excluded as it was thought that the use of an object would be an easier solution to implement and to use, it would have created a stronger relationship with the visitor, and it would have allowed to keep track of the interaction during the visit so that a personalized postcard and post-visit experience could be offered.

This analysis suggests that the decision of the type of interaction style to use does not depend just on creative preferences but it can also be influenced by practical requirements (i.e. use of the object for personalization purposes) or the characteristics of the environment (i.e. difficult environment that requires a minimum hindrance of the movement of the visitor).

The choice of an interaction style based on the manipulation and contact with an object had a strong impact on the visitor experience as illustrated above (see sections 5.1.8 and 5.1.9).

5.1.11. Context

The framework also identifies the context as an important aspect to consider during the design of a tangible interaction system because it is able to influence not only the agency of the installation but also the meaning-making process it sparks in the visitors suggesting certain behaviours and interpretations of the experience. In chapter 3, a distinction between two types of contexts to design for has been proposed, that is, the physical context and the narrative context.

Context
Physical context
Narrative context

In "Voices from Forte Pozzacchio" installation the physical context can be analysed on a macro level and on a micro level. On a macro level the physical context for the exhibition is the Artillery section of the Museo della Guerra, a Second World War air-raid shelter, excavated into the hill over which the castle that today hosts the museum was built and consisting of dark, humid and cold caverns where artillery pieces from WWI are exhibited.

The choice of using this context emerged in a late stage of the design process due to the emergence of issues regarding the installation of the exhibition in Forte Pozzacchio, that according to the original purpose of the project should have been the location. In particular, this situation led to re-consider and re-define the initial problem –designing an exhibition to be installed inside Forte Pozzacchio- and ended up in the choice of using the artillery section of the Museo della Guerra because, for its similarity to Forte Pozzacchio, it could at least be evocative of the fort.

On a micro-level, each station is characterized by its own physical context inside the environment. The station related to "the fortress as structure" is located inside a small cavern dug in the rock; the one related to the "life of civilians around the fort" is located along the main corridor in proximity to some canons; the one related to the soldiers is situated in the corner at the end of the cavern. These locations were chosen during the re-adjustment phase with the aim of providing a suitable context for the themes of each station, in line with those that were originally chosen inside Forte Pozzacchio (during the co-design session) and on the basis of the opportunities and constrains posed by the physical environment.

This analysis shows that strong emphasis was put on the design of the physical context during the design of the installation so that the latter was well integrated in the environment. Indeed, the locations for the stations were chosen on the basis of the themes.

The importance of designing the context is confirmed from the analysis of the interviews where many visitors refer about the perception of a thematic connection or disconnection[74] between the installation and the context. The analysis of the interviews also suggests some of the criteria that should be taken in consideration when deciding about the context for an installation. Beyond the thematic connection between interactive stations and physical context, other important criteria to take into account regards the accessibility of the place, and the suitability of the place for the type of media that will be used (i.e. the dark environment of the cavern is suitable for projections). These factors can be added to the framework to make it more complete.

[74] The reason why some visitors found a connection while other did not is clearly connected to the fact that the installation was not originally designed for that specific location, and despite some adjustments were done, more sensitive visitors were able to perceive a certain level of disconnection.

While great emphasis is put on the design of the physical context, this exhibition does not seem to provide an explicit overall narrative context that provides a more specific role and mission to the visitor in the exhibition and that allows to connect all the elements that characterize the visit experience in a stronger way, neither a reflection about this aspect seems to be present in the design process according to the available data. However, the perception of the narrative context as something missing in this installation is not something that emerges in the interviews of the visitors. Although further investigation on the relevance of designing a narrative context should be done in the future, the theoretical framework seems to be able to suggest an additional aspect to consider and that could be able to orient the design towards alternative solutions.

5.1.12. Agency

Another aspect the framework identifies as important to consider during the design of a tangible interaction system is the agency of the system. Designing the agency of a system means designing: its ability to trigger the action of the people; its ability to communicate what the possible actions are and its ability to communicate the purpose of the actions (what to expect as a consequence of an action). On the basis of the analysis of previous projects, the framework also suggests different strategies that can be used to design each of these aspects as illustrated below.

<table>
<tr><th colspan="5">Agency</th></tr>
<tr><td colspan="5">The ability to trigger the action of the people</td></tr>
<tr><td>Explicit presence of digital devices</td><td>Instructions/labels</td><td>Attracting sounds</td><td>Perceived affordance</td><td>Object offered at the beginning</td></tr>
<tr><td colspan="5">The ability to communicate what the possible actions are</td></tr>
<tr><td colspan="2">Instructions/labels</td><td colspan="2">Perceived affordances</td><td>Context</td></tr>
<tr><td colspan="5">The ability to communicate the purpose of the actions</td></tr>
<tr><td colspan="3">Istructions/explanations</td><td colspan="2">Context (physical/narrative)</td></tr>
</table>

In the "Voices from Forte Pozzacchio" exhibition, since an object is given at the beginning of the exhibition, it should be immediately clear for the visitor that the object is something to be used in some way during the visit, in this way triggering the interaction of the people.
What to do with the object – the actions that are supported by the interactive system – should be quite clear from the "perceived

affordances" that are available. Indeed, the presence of indentations on the top surface of the platform that have the same shape of the activating object, should be able to trigger the right action, that is, the placement of the object in one of the slots available. The possible actions are also shown in the how-to video in the check-in station, although its real usefulness for this purpose is questionable since in order to see the video, the visitor has to place the object in the specific slot. Guessing exactly what to expect when the object is placed on a slot might instead be more difficult for the visitors. First of all, this is not something the visitors can guess from their previous knowledge since the installation proposes an interaction with smart objects that are new to them. While the presence of labels providing minimal information about the story associated to specific slots is likely to make quite easy for the visitor to guess at least the subject of the content, understanding exactly what type of media to expect might instead be more difficult since this varies in the various stations. In addition, the introductory video in the check-in station showing a visitor interacting with the last station and getting a video, might led the visitors to expect to get videos at all the stations as a result of the interaction, but this expectation will be disappointed in the second stations where there are just sounds/voices.

The decision of offering the object at the beginning of the visit emerged already in some of the concepts discussed in the preliminary discussions, and then in the co-design session. The idea of providing slots able to contain the object is something that emerged at the end of the co-design session. The idea of providing instructions in some way at the check-in station emerged during the co-design session, however the choice of using a video is something that emerged at a later stage (probably during the re-adjustment of concepts and prototypes that followed the change of location). Also the idea of labelling the slots with minimal information about the contents is something that emerged during the co-design session and was physically implemented later on (high-fidelity prototyping). From the available data, it seems that the relative unpredictability of what media will be activated as a consequence of the placement of the object in a specific station, was not a deliberate choice made to reach a specific effect (e.g. surprise) but a consequence of other decisions (e.g. the use of different media for the different stations). Generally speaking, this analysis shows that the aspects related to the agency where considered during the design process.

The importance of considering the agency is confirmed by the important impact that agency-related choices made in the design of the system had on visitors as reported in the interview (see 4.3.5).
The system is able to trigger the interaction because the object is perceived by visitors as an invitation to use it, as a presence, as a tool on the side of the visitor and as a novelty. This also suggests an additional aspect –the novelty of the interaction- that should be included in the framework as another design strategy to trigger interaction.
Regarding the ability of the system to communicate what the possible actions are, the visitors report that for them it was easy to understand how to use the interface. From their comments it emerges that the perceived affordances of the system more than the presence of the how-to video played a role in this.
As expected, visitors reported it was not always possible to predict what they would get as a result of the interaction and this unpredictability is appreciated by some visitors and not by others. The appreciation of the unpredictability of the system shed light on the fact that not always the system needs to communicate clearly what to expect as a consequence of the actions, and that in certain contexts an acceptable strategy can be that of designing for the unpredictability of the system. This strategy should therefore be integrated to the framework.

5.1.13. Output purposes

The output of a tangible interaction system can serve different purposes as suggested in the framework below.

Output purpose		
Communicating the intangible value of a tangible CH asset (THEMATIC STATIONS)	Communicating the status of the system	**Provide instructions** **(CHECK-IN STATION)**

In "Voices from Forte Pozzacchio" all the thematic stations share the same output purpose, that is, communicating intangible values related to Fort Pozzacchio through digital media. The purpose of providing instructions must be added in the case of the check-in station.

The decision of using the output to communicate intangible values related to Forte Pozzacchio is something that emerged during the preliminary concept brainstorming sessions and was then confirmed in the co-design session, as a consequence of what was decided to be the purpose of the installation. Also the decision of providing instructions

through the check-in station is something that emerged in the co-design session.

5.1.14. Output devices and media

The same categories proposed for the input devices can be used for the analysis of the output devices.
Although all the thematic stations share the same output purpose, from the point of view of the output devices and output media the various stations look different. The station related to the "fortress as structure" uses a black projection screen fixed on the end wall of the cavern on which animated white drawings are projected accompanied by audio narratives. In this way, the output device is not perceived as a separate screen but as something that is part of the environment with the animation seeming to emerge from the darkness of the cavern. The station related to the "life of civilians around the fort" uses audio coming from a loudspeaker that is contained in the station so that the audio is perceived as coming from the environment. Finally, the station related to the soldiers uses a projection surface supported by two legs on which video portraits of soldiers are projected accompanied by the audio of their voices telling their stories. Also in this case there is an attempt to integrate the screen in the environment through the use in the video recordings of the same background as the real one however the screen is still quite visible.
For this attempt to integrate the devices in the environment, the output devices of the three thematic stations[75] are not to be considered as belonging to the category of traditional devices but as belonging to the category of smart object/environment. Therefore, analysing the installation on a macro level, the output could be said to be provided through a smart environment that physically resembles and can be representative of Forte Pozzacchio, and that, in a way, can be interpreted as sort of "replica" of it.

<table>
<tr><th colspan="6">Devices (output)</th></tr>
<tr><td colspan="5">Smart object</td><td rowspan="3">Traditional device</td></tr>
<tr><td colspan="3">Primary object</td><td colspan="2">Secondary object</td></tr>
<tr><td>Smart original</td><td>"Smart replica"</td><td>Smart derivative</td><td>Related object</td><td>Unrelated object</td></tr>
</table>

[75] The check-in station adopts a different solution compared to the other stations since the information is provided through a screen that is embedded on the top surface of the wooden station, the same smart object that is used for the input.

Decisions related to the output devices and media used in the various stations were partially taken during the co-design session and in some cases were refined in the following stages (e.g. second on-the-spot visit, testing, concept refining, re-adjustment).
Regarding the station related to the "fortress as structure", for example, the choice of using a visual output emerged already during the co-design session also because of the darkness of the place that made it suitable for that. However, although at the beginning projections of actors telling the stories were envisaged, after the on-the-spot visit and some tests, it was decided that the use of a white animation on black background could have more impact. Concerning the station related to "the life of civilians around the fort", the choice of using just audio coming from a loudspeaker contained in the station was taken during the co-design session. This decision was determined by the theme and location that was chosen for the station in Forte Pozzacchio, that is, in proximity of the artillery emplacement that allowed visitor to look at the valley surrounding the fort while listening to the voices of the people. After the change of location and the consequence re-adjustment of the installation, it was decided to keep the output devices and media for these two station unchanged. As for the station related to soldiers, the idea of using one or more surfaces on which video portraits of soldiers were projected emerged during the co-design session, inspired by the idea of the pictures that soldiers used to send to their families during the war. The decision of using projection surfaces was linked with the impossibility to get a high quality projection directly onto the wall surface. In the new location, the concept remained the same, although it was decided to have just one video-portrait due to space constrains.

This analysis allows to identify some of the aspects that might be important to consider during the design process when taking decisions about the types of output devices to use and the type of media. These aspects concern the level of integration with the environment, the theme of the installation, the physical characteristics of the context where the installation is located. The importance of some of these aspects is confirmed by the interviews (see 4.3.8.3). Some visitors, for example, comment about the suitability of the use of multimedia content for the specific environment since they are also much more accessible than text panels. Also some comments regarding the integration between output devices and environment are present in the interviews, with some visitors either appreciating it or suggesting some improvements (e.g. the substitution of the screen that was used in the final station with something better integrated in the environment).

5.1.15. Output type (emulative/non-emulative)

Regarding the output, the framework suggests also a differentiation between emulative and non-emulative output. In the first case, the smart object/environment emulates behaviours that are typical of the specific object/environment while in the latter, completely new behaviours are defined.

Output type	
Emulative output	**Non-emulative output**

Under this perspective, the outputs provided in the first thematic station of "Voices from Forte Pozzacchio" are to be considered as non-emulative. Indeed, the black and white animations coming from the darkness of the cavern and the accompanying voices do not emulate a known or past "behaviour" of the environment but provide a new one. Also in the second thematic station, the audio contents that are provided are generally non-emulative, although in some cases, some of the sounds that are used to introduce the stories (e.g. the sound of drops of water falling from the ceiling, of the wind, of a bomb) can be considered as emulative since they correspond to sounds one can or could hear in the fort. In the third thematic station, the video can be interpreted as though soldiers manifest themselves in the present time to tell their past stories[76]. Therefore, in general, the type of output provided by the installation is non-emulative with the exception of few introductory sounds in the second station.

In general, the types of outputs chosen in the various stations were linked to the consideration of various aspects during the co-design session and in the following phases (like theme, environment, type of content etc..) however their non-emulative nature could have been influenced by a specific decision that emerge during the co-design session of avoiding too strong special effects (e.g. sounds of bombing or similar). As reported in the available documentation and confirmed by the coordinator, the introductory sounds in the second station have been chosen on the basis of the content of the stories so as to be evocative of them. Therefore, their emulative nature should be interpreted as a coincidence rather than a deliberate choice.

[76] The only exception is a video in which a soldier, an Austro-Hungarian military chaplain is portrayed in his past activity of writing a letter.

The importance of taking in consideration the emulative aspect of the output during the process of design emerges from the analysis of the interviews. In the interviews we find instances of visitors commenting positively the emulative nature of some sounds in the second station (*"[..] when it says about the galleries and you hear the drop of water it's like being there [in Forte Pozzacchio], isn't it?"* –Interviewee 12A) (see 4.3.8.1), and others suggesting that an improvement to the exhibition could be the introduction of sounds that recreate the context of the war (see 4.3.8.3).

5.1.16. Learning approach

With regards to the learning approach the framework provides different design approaches as summarized below.

Learning approach		
Didactic expository	Discovery learning	**Constructivist approach**

In general, the learning approach adopted by the installation is a constructivist approach, where the visitor is given the possibility to build his own interpretation of the subject that is presented in the exhibition. Apart from the check-in station that is more didactic in the sense that it provides more factual information about the history of the fort, all the other stations provide a wide range of points of view on the subject through personal stories. In addition, apart from the check-in station that clearly represents the start, the exhibition does not impose a specific path to follow, in this way leaving the visitor free to explore the contents in the order they want and according to their personal interest.

The decision of providing personal stories instead of factual information is something that emerged during the preliminary discussion that led to the definition of a preliminary brief for the project. The provision of multiple, and sometimes contrasting personal stories is, after all, a general approach adopted by the meSch project in all the case studies in order to foster personal interpretations by the visitors. It is important to notice that the choice of adopting the constructivist approach, clearly influenced the choice of the type of the intangible cultural assets to associate to Forte Pozzacchio.

The importance of considering the learning approach during the design approach is also confirmed by the strong impact that the choice of

using mainly personal stories had on visitors (e.g. strong emotional engagement, empathy, understanding, remembrance) (see 4.3.10).

5.1.17. Social aspects

Drawing on Debenedetti's semiotic square of social appropriation (Debenedetti, 2003), the framework proposes different modes of social appropriation of the installation space by visitors: private visit, fusion visit, separated visit, pursuit of social contact.

Mode of social appropriation			
Fusion visit	**Private visit**	Separated visit	**Pursuit of social contact**

With regards to this aspect, the installation has physical characteristics that seem to facilitate different types of social appropriation. Not only the installation makes sense when used by a single visitor (private visit) but it also potentially allows for a fusion visit and the pursuit of social contact to take place. The separate visit is instead discouraged in the case of visitors coming to the exhibition with companions in favour of the fusion visit since only one activating object is given to groups of visitors. The fusion visit, as well as the pursuit of social contact, is also facilitated by the presence of an output that is accessible to multiple visitors at the same time. Indeed, the output is generally provided through large video-projections and/or "open" audio.

With regards to the social aspects, the framework also suggests different ways of designing social activities (modes of social engagement): personal experience with social awareness, indirect social experience, direct social experience.

Modes of social engagement		
Personal experience with social awareness	Indirect social experience	**Direct social experience**

In the case of the fusion visit, the installation requires the visitors to engage in an activity regarding the collaboration in the choice of what contents to play (selection), in the activation of the contents and in the sharing of the activating object. This can be considered as a direct social experience since it is based on a face-to-face interaction between visitors.
The design of solutions that do not isolate the visitors, that are able to elicit direct group dynamics and that work for more people at the same

time is a general approach adopted by the meSch project (Marshall et al., 2015), and the choice of adopting this approach in this project was a deliberate choice since the beginning of the project (preliminary discussion). The importance of designing the social appropriation of the visit experience and the social engagement is confirmed by the importance visitors seem to give to these aspects in the interviews and by the impact they have on the user experience (see 4.3.7).

5.1.18. Participation

Regarding the participatory aspect, the framework suggests two design possibilities: designing interactive experiences where the visitor acts only as a consumer of contents, or designing experiences where the visitor is a producer of contents.

Participation	
Visitors as consumers	Visitors as contributors

"Voices from Forte Pozzacchio" cannot be considered as a participatory project since it does not allow visitors to get engaged in the generation and/or sharing of personal contents.

According to what referred by the curator, although the idea of allowing visitors to generate personal contents was something that was considered at an initial stage of the project, this was then excluded for lack of time, lack of suitable space in the fort, privacy issues and because there were no clear ideas about how to use the content and make it available for other people.

5.1.19. Personalization

The framework identifies the personalization as another aspect to consider during the design process, suggesting different levels of personalization to design for as summarized below.

Personalization			
none	**Manual filtering**	adaptable	**adaptive**

In terms of personalization the installation allows the manual filtering of contents, since the visitor can choose which stations to visit and also

which contents to activate at each station. In addition, adaptive methods are used for the automatic generation of the postcard at the end of the visit.

These were goals that were explicitly defined in the preliminary discussion and introduced in the brief, along with other personalization objectives like the provision of contents in multiple languages that, however, was not implemented probably for reasons of time.

The importance of considering the personalization aspect is confirmed by the strong impact that this aspect had on the visitor experience. Many visitors commented positively about the possibility of choosing the contents, even those visitors who played all the available contents (see 3.5.3).

5.1.20. Strategy of association of intangible values

For installations aiming at associating intangible values to tangible assets, the framework provides a summary of different possible strategies to achieve this goal. The first strategy – linking contents to primary object – consists in the definition of an output that is representative and communicative of an intangible value and in linking this meaning to the reference asset by means of tangible interaction. The second strategy – embedding in secondary object – consists in the creation of a smart object whose form is symbolic of a certain value related to the reference object. The third strategy – embodying into action – consists in the design of actions that are representative of certain intangible values related to the reference object.

Strategy of association of intangible values		
Linking contents to primary object	Embedding in secondary object (symbolic smart object)	Embodying into action (performing action)

With regards to this aspect, the strategy that better represents what has been done in "Voices from Forte Pozzacchio" exhibition is the one consisting in linking contents to primary objects. Indeed, no smart objects that are symbolic of an intangible value of the fort are used, and no actions that are representative of an intangible value related to the fort are used either.
The primary object in this case is Forte Pozzacchio, or better, an environment – the artillery section of the Museo della Guerra - that recalls the physical characteristics of the fort and that can be considered as representative of it, a sort of "replica" in a way. The intangible values are all incorporated in the stories contained in the multimedia

contents. The association between intangible values and the primary object is done by integrating the technologies and multimedia contents in the physical environment and by allowing their selection and activation by means of the activating object and the physical stations.

The strategy used for associating intangible values to the fort did not emerge as a direct choice but as a consequence of a series of choices that were taken during the co-design process concerning the smart object, the interaction, the contents, the output and their relations.

5.2 Discussion

The analysis of the relations between "Voices from Forte Pozzacchio" project and the theoretical framework allows to infer a series of observations and/or reflections:

- *Many of the aspects considered in the theoretical framework were discussed explicitly in the design process of the exhibition.* This shows that the aspects identified in the framework are not just theoretical and detached from reality, but they appear in a real design process. This, in turn, demonstrates the ability of the framework to formalize aspects that take part in real processes of design of tangible interaction installations in museums. On the other hands, though, the fact that many aspects emerged without the need of any theoretical guidance puts into question the real usefulness of a theoretical framework for the design of such kinds of experiences[77]. However, it must be noticed that, in the specific case study, the awareness of the different aspects to consider is probably associated to the adoption of a co-design process that brought together different professionals and also to the fact that most of the team members had a high level of experience in the design of interactive technologies in the cultural heritage fields. For this reason, a design framework might prove to be useful especially when the adoption of a co-design approach is not possible for some reasons, or when the

[77] It must be noticed, however, that the fact that the various aspects have been considered during the design process, does not mean that there was an awareness of all the possible design options available for the various aspects and that these were assessed during the process of design. From the data available it is not possible to state anything sure about this, but it is likely that this awareness varied for the various aspects. In those possible cases where the level of awareness was lower, the framework could be anyway useful in providing a greatest awareness about the various possible alternatives to consider.

people involved in the process are not very experienced yet in the specific field. For its ability to formalize the aspects to consider during the process of design, the framework might find its application in the training of designers and cultural heritage professionals interested in learning how to design tangible interaction installations in museums. This would potentially make the learning process faster, and the design processes more straightforward, less based on trials and errors, minimizing the failures and the waste of resources.

- *In some rarer cases aspects emerged implicitly in the process of design and not as a consequence of an explicit discussion.* Certain aspects characterizing the exhibition were not the consequence of an explicit discussion, but emerged as a consequence of decisions taken with regards to other aspects. For example, the emulative nature of some of the sounds in the second station (e.g. the sounds of a drop of water, the wind, a bomb) did not emerge as a deliberate choice but as a coincidence, since the sounds were chosen on the basis of the contents of the stories and not with the purpose of emulate a behaviour of the environment. A similar thing can be said with regards to the surprise effects that is generated in the visitors by the use of different media in different stations. Different media were chosen for different stations not with the goal of making the behaviour of the system unpredictable (as part of the design of its agency) but on the basis of their suitability for the theme and context of the various stations. It can be assumed that cases like these, very rare in this specific project, could become more frequent when the level of experience of the designer/ design team in the design of these kinds of systems is lower. This suggests the potentiality of the framework of making the designers more aware of the aspects to consider and in control of the effects they will have on visitors. On the other hands, a potential risk connected to the use of framework is that, providing designers with a tool that enables them to control most of the aspects that characterize the design process, it could stifle the natural creative process and block spontaneous innovation. However, it can be assumed this risk can be avoided through a non-rigid application of the framework, that can allow to reach a balance between totally spontaneous creativity and rigid control of the process of design. This can be done by considering the framework just as a guidance and a source of inspiration and not as a prescriptive tool.

- *For many of the aspects considered in the theoretical framework, the analysis has allowed to show the impact that these aspects have on the visitor experience*. This confirms the importance of investing time and resources in the design of these aspects.

- *With regards to some of the aspects identified in the framework, the analysis of the case study has allowed for the identification of additional possible choice options or of criteria to consider when choosing between the options already provided in the framework.*

  For example, when designing the agency of a tangible interactive system, namely its ability to trigger the interaction of the visitor, besides the options provided by the framework (i.e. instructions/labels, attracting sounds, perceived affordances, object offered at the beginning, explicit presence of digital devices) another possibility to consider regards to design an object that is perceived as new, since the novelty is an aspect that seems to play a significant role in making the visitors more curious and willing to interact. In addition, regarding the design of the ability of the system of communicating the purpose of the action it has been shown that a valid choice could also be that of designing for the unpredictability of the system to produce surprise in the visitor.

  With regards to criteria to consider when choosing between the various choice options, these have been identified for example with regards to the design of the output devices and output media and include the level of integration in the environment we want to achieve, the theme of the station, the accessibility in the specific environment. Criteria have also been identified concerning the decision about the interaction style (object-based vs free-gesture based) and include the consideration of the acceptable level of hindrance in a specific environment, and other practical requirements (e.g. necessity to track the overall interaction for personalization purposes). The analysis has also allowed to identify an aspect that was missing in the design framework and that had instead an important role in the specific project, namely, the organization/structuring of contents. The organization of the contents by themes and chronological order determined for example the choice of using multiple stations located in different locations, the way the contents were presented for selection and activation in the stations as well as, in some cases, the type of devices and media used.

- *Some of the choices related to the design of the specific aspects in the case study have not been made on the basis of criteria implied in the framework.* This happened especially with regards to the design of the form of the smart objects and the actions. Concerning these aspects, the framework implies that these choices are guided by a reflection about the cultural relation between object and the reference asset, while in the case study other criteria (i.e. easiness and intuitiveness for the design of the action; aesthetics, sensorial, emotional and comfort-related criteria for the the design of the activating object) guided the decisions and led anyway to successful results. This suggests that in the design of the form of the object and the action also these criteria should be considered because they can have an important impact on the visitor experience, as well as other criteria that emerged through the analysis of the interview (i.e. pleasantness of the action).
  On the other hand, this suggests the ability of the framework of pushing the designer to reflect about the cultural relation between the smart object/action and the reference CH object when choosing the form of the object and the action. This might lead the designer to consider the opportunity of designing an interaction that is culturally meaningful, in the sense that incorporates intangible values/meanings related to the reference CH asset in the materiality of the object or in the action. This can be an alternative strategy (compared to the anyway successful strategy followed in the project), that might turn out to be useful in certain cases but whose effectiveness should be evaluated in further studies.

  An enriched version of the framework, that includes the new aspects, design choice options and criteria identified through the analysis of the "Voices from Forte Pozzacchio" exhibition is provided below (Table 5).

Main target					
Able-bodied public		People with disabilities			Universal target
adult	children	blind and visually impaired	learning disabilities	etc.	

Purpose of the installation		
associate intangible values to tangible assets	give tangible form to intangible assets	allow people to experience the material properties of tangible assets

Cultural assets								
Tangible assets			Intangible assets/values					
works of art	architectures/ buildings	etc..	concept	story	practice	ritual	factual information	etc.

Location of original tangible asset			
embedded in the installation	close to the installation	located in the museum (distant)	located in another place (very distant)

Strategy to foster the experience of original tangible asset		
naturally fostered through location	fostered through action	not fostered

Single/Multi interactives installations	
Single installation	Multi interactive installation

Tasks					
Activating information	Getting instructions	Producing content	Navigate a 3D model	Activating simulation	etc.

Table 5 Theoretical framework enriched with aspects, options, criteria identified through the analysis of the case (dotted elements) (continued on next page).

CRITERIA	Devices (input/output)					
- relation with reference CH object (i.e. formal, cultural, symbolic of a tangible/intangible value, no relation) - function - characteristics of technologies needed - aesthetics, sensorial, emotional criteria - comfort-related aspects - meaning - context	Smart object					Traditional device
	Primary object			Secondary object		
	Smart original	Smart replica	Smart derivative	Related object	Unrelated object	

CRITERIA	Actions	
-relation with reference CH object (i.e. cultural, no relation) - functional requirements - usability requirements - meaning	Codified actions	Performing actions

Table 5 Theoretical framework enriched with aspects, options, criteria identified through the analysis of the case (dotted elements).
(continued on next page)

CRITERIA
-functional requirement (e.g. track the interaction, etc.) - acceptable level of hindrance in the specific context - type of visitor experience

Interaction style	
Interaction with contact (manipulation-based interaction)	Interaction without contact (free gesture-based interaction)

CRITERIA
-level of integration in the environment - theme of the installation - physical context

Output purpose		
Communicating the intangible value of a tangible CH asset	Communicating the status of the system	Provide instructions

Output media			
visual	audio	haptic	Other…

Output type	
Emulative output	Non emulative output

Location of output (with respect to input interface)			
Output device is the input device	Nearby (output tightly coupled to the focus of the input)	Environment (the output is around the user)	Distant (the output is on another screen/object)

Table 5 Theoretical framework enriched with aspects, options, criteria identified through the analysis of the case (dotted elements).
(continued on next page)

CRITERIA
-thematic connection -accessibility -suitability for type of media used

Context
Physical context
Narrative context

Strategy of association of intangible values		
Linking contents to primary object	Embedding in secondary object (symbolic object)	Embodying into action (performing action)

Agency					
The ability to trigger the action of the people					
Explicit presence of digital devices	Instructions/labels	Attracting sounds	Perceived affordance	Object offered at the beginning	novelty
The ability to communicate what the possible actions are					
Instructions/labels		Perceived affordances		Context	
The ability to communicate the purpose of the actions				Designing for the unpredictability of the system	
Instructions/explanations		Context (physical/narrative)			

Learning approach		
Didactic expository	Discovery learning	Constructivist approach

Table 5 Theoretical framework enriched with aspects, options, criteria identified through the analysis of the case (dotted elements). (continued on next page)

Mode of social appropriation			
Fusion visit	Private visit	Separated visit	Pursuit of social contact

Modes of social engagement (in on-purpose designed social activities)		
Personal experience with social awareness	Indirect social experience	Direct social experience

Participation	
Visitors as consumers	Visitors as contributors

Personalization			
none	Manual filtering	adaptable	adaptive

Organization of contents		
By theme	By chronological order	Etc..

Table 5 Theoretical framework enriched with aspects, options, criteria identified through the analysis of the case study (dotted elements).

- *The analysis of the case study allows to shed light on how the aspects identified in the framework emerged dynamically during the process of design.* The analysis of the case study has allowed to describe how the aspects that have been presented statically in the theoretical framework emerged dynamically during the process of design of a real project. This can be summarized through the graphical representation in Figure 116, built by placing the different aspects on the two iterations of the double diamond that have characterized the process of design of "Voices from Forte Pozzacchio" exhibition (see Section 4.2.3), with the second iteration emerging as a consequence of administrative complications connected to the use of Forte Pozzacchio as a location for the experimentation. As to make the graphical representation easier to read, the two iterations are presented through two separate representations of the double diamond.

  This visualization brings to the fore different groupings of aspects on the basis of their appearance within different macro-phases characterizing the design process. A first small group of aspects regards those that emerged already as part of the initial problem that regarded the enhancement of the visitor experience of Forte Pozzacchio through the introduction of digital technologies and tangible interaction. These aspects included the tangible cultural asset the installation refers to (i.e. Forte Pozzacchio), the general context of the installation (i.e. Forte Pozzacchio), the strategy to foster the experience of the fort (by embedding a tangible interaction installation in the fort) that also determined the location of the Forte with respect to the installation. In addition to the aspects that were part of the problem, there is another small group of aspects –the learning approach, the social aspect, the type of device, the personalization - for which decisions have already been made as part of the general orientation of the meSch project (Marshall et al., 2015), which the exhibition represents a case study of. Decisions around these aspects (e.g. the use of a constructivist approach with the provision of personal stories rather than factual information, the design of an interaction able to elicit groups dynamic, the avoidance of screens and explicit technologies through the integration of them in objects and environments, the personalization of contents) have clearly influenced the decisions that have been taken with regards to the same aspects during the design of the specific exhibition.

There is then a significant group of aspects that emerged during the definition phase characterizing the first diamond, and another significant group of aspects that emerged inside the second diamond as part of the development and delivery phases[78].

Belonging to the first set, there are aspects like: *target, cultural assets (intangible assets), purpose of the installation, constructivist approach, learning approach, modes of social appropriation, modes of social engagement, participation, personalization*. Instead, belonging to the second set, there are aspects such as: *single/multi stations, tasks, devices (input), actions, interaction style, physical context (for the single stations), agency, output purposes, output devices and media, output type, strategy of association of intangible values.*

In general, the aspects belonging to the first set seems to be more abstract and generic compared to the others. Indeed, in virtue of their genericity, choices related to these aspects are able to provide a general orientation to the process of design by allowing to define the requirements characterizing the design brief and to get to a better definition of the problem. However, they do not specify how these choices will be physically implemented in the project.

The aspects belonging to the second set seem to be more specific, and therefore able to give concrete implementation to the requirements expressed in the design brief.

As explained in the previous chapter the emergence of administrative issues led to a second iteration of the double diamond, consisting in a redefinition of the problem and a readjustment of some of the choices that were made with regard to some aspects. After an examination of the new situation (discover), it was decided to change the context for the exhibition, that determined a distance and separation between the installation and Forte Pozzacchio. As part of the second diamond, some of the specific aspects of the installation underwent some minor changes.

[78] Although, as shown in the analysis of the single aspects (see Section 5.15.1), in many cases the aspects underwent more refining steps during the specific phases belonging to development and deliver phases of the diamond (concept generation, concept selection, low-fidelity prototyping, testing, high-fidelity prototyping), in order to make the visualization easier to read they are all presented just one time.

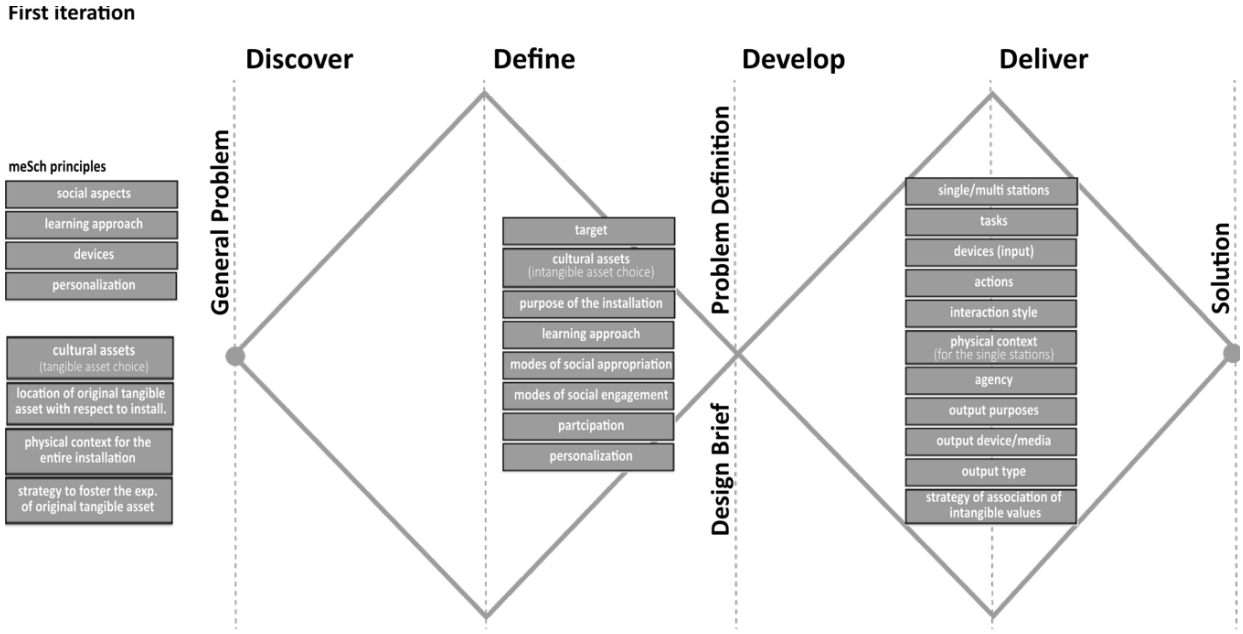


Figure 116 Graphical representation showing how the various aspects identified in the framework emerges in the design of "Voices from Forte Pozzacchio" exhibition (continued on next page).

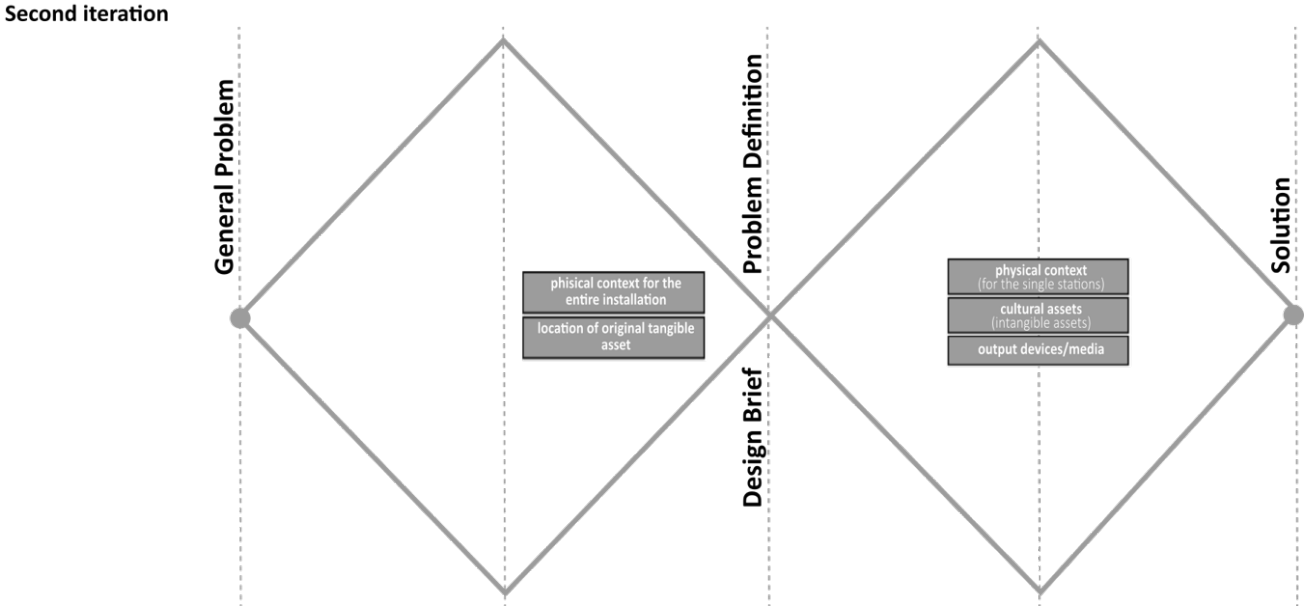


Figure 116 Graphical representation showing how the various aspects identified in the framework emerges in the design of "Voices from Forte Pozzacchio" exhibition.

The diagram presented above represents the emergence of the aspects within the specific project, "Voices from Forte Pozzacchio" exhibition and for this reason is not generalizable since every project is likely to be different[79]. However, this analysis allows at least to reflect about the existence of two categories of aspects among those proposed in the framework, some more generic and some more specific. The strategy of considering more generic aspects during the phase of definition of the brief and more specific aspects during later phases that characterize a design process (e.g. concept generation, prototyping, test, refinement etc..) seems to be a meaningful strategy that hypothetically could be able to provide at least a general orientation during the design of other projects, although further research is necessary to evaluate its real effectiveness and to refine it.

- *The presence of an interconnection between the various design aspect has been mentioned more times during the analysis*. Choices related to an aspect might influence choices related to other aspects. For example, the choice of organizing the contents in different themes determined the choice to create more stations, one for each themes, to locate the stations in different physical contexts according to the theme, and also influenced the choice of media and output devices. In some cases, choices related to an aspect are able to constrain choices related to other aspects. For example, the choice of providing a personalized souvenir at the end of the visit led to exclude the use of a free-gesture-based interaction (that at the beginning was considered as a good option because of the low hindrance for the visitor) in favour of the use of the activating object. This suggests that although the framework provides a list of important design aspects to consider, the design team should not consider each aspect only individually but also in relation to the others and should not be aiming at finding the best solution for every single aspects but at finding the best compromise between the various aspects.

[79] In the context of this research, for feasibility issues, it has not been possible to analyse the design process of other tangible interaction cases, nor to discuss the working flow of the "Voices from Forte Pozzacchio" installation with the authors of other cases. However, the analysis of other cases and the comparison of the results might provide useful insights for the definition of a general design framework.

Chapter 6

Conclusions

6.1 Research contributions

The research presented in this thesis has been developed with the intention of providing a first response to the lack of theoretical works in the field of tangible interaction applied to museums along with the consequences that this implicates (e.g. lack of a common language in the field; lack of a deep understanding of what tangible interaction is in the CH field; lack of a formalization of the aspects that make up the design of tangible interaction systems in the CH field) (Chapter 1).
Three main research questions have guided the research that are:

1) How has tangible interaction been applied to onsite interactive installations in the CH sector?
2) What kind of experiences of cultural heritage does tangible interaction allow?
3) What are the aspects that make up the design of a tangible interaction system in the CH field?

In order to provide an answer to these questions, after presenting a definition and literature review regarding tangible interaction (see Chapter 2), a theoretical framework has been developed, starting from the collection and thematic analysis of a high number of past tangible interaction projects (see Chapter 3). The framework has to be intended as both a conceptual framework and the foundations for a design framework. As a conceptual framework it provides a categorization of past tangible interaction systems and thus it shows what tangible interaction is and provides a language to describe it. As foundations of a design framework it provides a formalization of the aspects that characterize the design of these types of interactive systems in museums. These aspects represent themes around which choices have to be made during the process of design.
Starting from a set of meanings that can be associated to the expression tangible interaction by CH professionals (i.e. as a tactile experience of

CH; as an embodied experience of CH; as a real encounter with an object as opposed to a virtual encounter; as a material approach to cultural heritage), Chapter 3 also proposed some preliminary reflections about the type of experiences of cultural heritage enabled by tangible interaction.
Then, a case study – the "Voices from Forte Pozzacchio" exhibition - has been presented in Chapter 4, providing a description of both the process of design and the impact the exhibition had on visitors. This has allowed to lay the basis for the analysis presented in Chapter 5, where the themes proposed by the framework have been used for the analysis of the case study. The analysis has allowed to develop further reflections about the framework regarding its usefulness, validity, how to use it, additional aspects/criteria to include.

The main originality and contribution of the thesis regards the theoretical approach it has adopted in the study of a field – tangible interaction applied to museums and cultural heritage sites – that, so far, has been mainly characterized by practical experimentations without many theoretical reflections. In particular, this research has proposed a theoretical framework that can be beneficial for researchers in the field as it suggests a language and a conceptual model that can help them to reflect about the topic, to orient future research and to cooperate with other researchers. It can also be used to provide practitioners (e.g. designers, developers and cultural heritage professionals) with a shared view of what tangible interaction is, that can help to reduce misunderstandings and to foster collaboration.
In addition, the research lays the theoretical foundations for a framework addressed to designers or design teams aiming to provide them with a greater awareness of important aspects to consider and a support in the decision making during the design process, potentially making it more effective and efficient.

6.2 Research limits and future works

Various limits can be identified in the research presented in this thesis. First of all, it must be noticed that, due to the adoption of a design perspective, that is, of a discipline that is "multidisplinarity in nature" (Rampino, 2012, 7), this research is characterized by a strong interdisciplinarity. If, on the one hand, this can be considered as a plus because it has allowed to identify the different aspects to consider when designing a tangible interaction system, on the other hand, it can also be interpreted as a limit since it has required in some cases to neglect or oversimplify certain themes. This has been inevitable given the complexity of the topic addressed in this research and the limited

available resources. This issue could be overcome in the future by deepening the analysis of the themes or extending the view to other domains or topics such as theatre and performance practices, embodied learning, the Internet of Things applied to homes, offices etc., that could allow to identify a richer set of aspects for the framework.
In addition, while this research provides quite exhaustive answers with regards to the research questions 1) and 3) by means of the proposed theoretical framework, only preliminary reflections about the types of experience enabled by tangible interaction are provided, a complex topic that should be studied further in the future.
Another limit concerns the fact that the framework has been created starting from a collection mainly made up of academic projects since commercial projects were too difficult to gather. The difficulty in gathering commercial projects could partially be overcome in the future, by making the database available online so that museum professionals can contribute to it through the insertion of new projects. Future works might also regard the full implementation and improvement of the database that has not been possible yet for reason of time.
As explained at the beginning, for feasibility issues as well as for reason connected to the background of the author, the work presented in this research is quite theoretical at the moment. Although some general guidelines about how to apply the framework to the design of a project have been proposed (i.e. using the framework as a guidance and source of inspiration rather than a rigid tool; considering the aspects not only individually but also in relation to the others in order to find the best compromise between them; defining specific aspects during the early stage of the project and others in the later stages), a more comprehensive understanding about this issue is still missing. This limitation could be overcome in the future by working together with designers in order to translate the framework into other formats so that it can be more easily applied as a tool during a design process. Possible other general insights about how to use the framework might come out also trying to apply the framework to the design of practical projects. The application of the framework to the design of practical projects is something that has not been possible due to the lack of resources (e.g. time, budget, etc.). This is a fundamental activity to be done in the future also to evaluate the effectiveness of the framework.
To conclude, it is important to noticed that, despite the limitation described above, the framework as-it-is already provides a valuable contribution to the field in that it provides the theoretical building blocks and some guidelines for the definition of a more practical framework aiming to sensitize designers on important aspects to consider during the design process and to support the decision making.

Glossary

Affordances: defined by Norman (2013) as "possibilities in the world for how an agent (a person, animal, or machine) can interact with something". Affordances can be either invisible or perceivable. Perceivable affordances are action possibilities that are made perceivable for the user, for example, through qualities of a product and its interface.

Augmented Reality: Specific type of mixed reality system where the real environment is augmented by overlapping digital information to it. Different technologies are often used to implement an AR system such as mobile devices, wearable devices, spatial augmented reality.

Augmented Virtuality: Specific type of mixed reality system where the virtual environment is augmented by overlapping direct representation of reality to it.

Internet of Things: "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols" (INFSO D.4 Networked Enterprise et al., 2008).

Mixed Reality: It refers to a class of technologies aiming to merge visual representation of the real and the virtual/digital world. It includes Augmented Reality and Augmented Virtuality technologies.

Natural User Interface: "one that enables people to interact with a computer in the same ways they interact with the physical world through using their voice, hands, and bodies" (Preece et al., 2015) instead of using the mouse and the keyboard.

Signifiers: Norman (2013) defines signifiers as "signs, labels, and drawings placed in the world, such as the signs labeled 'push,' 'pull,' or 'exit' on doors, or arrows and diagrams indicating what is to be acted upon or in which direction to gesture, or other instructions."

Ubiquitous Computing: coined in 1990s by Mark Weiser (1991), the expression *Ubiquitous Computing* refers to the embedment of computational elements and digital components into everyday physical objects, portable devices and the built environment.

Virtual Reality: Coined by computer scientist Jaron Lanier in 1988, the expression refers to an artificial environment generated through a computer system. Inside this digital three-dimensional space, the user is usually given the possibility to interact with digital objects and to move by means of specific user interfaces.

Appendix – Descriptions of projects

List of Projects

1. San Diego Museum of Art Talking Tactile Exhibit Panel

The project consists of a full scale bas-relief derived by Juan Sànchez Cotàn's master still-life, "Quince, Cabbage, Melon and Cucumber" painted in Spain in 1602 and now part of the San Diego Museum of Art's collection (Figure 117). Visitors can explore the bas-relief with their hands. Holding down the fingers on a specific area, a voice explains the meaning of what they are touching. The project has been designed with the purpose of making the work of art accessible to everyone (universal design), included blind visitors.

Date: 2015
Location: San Diego Museum of Art (Balboa Park, San Diego, CA)
Designers/Developers/Researchers: Touch Graphics (Elkton, Maryland)

Figure 117 Talking Tactile Exhibit Panel (source: Touch Graphics, 2015).

References

Touch Graphics. (2015). *San Diego Museum of Art Talking Tactile Exhibit Panel*. Retrieved from Touch Graphics Inc | Tactile Design for Universal Access:
http://touchgraphics.com/portfolio/sdma-exhibit-panel/

video: http://touchgraphics.com/cotan/

2. Talking Sculpture, San Diego Museum of Art

The project consists of a full scale 3d printed replica of the small Guanyin Bodhisattva sculpture that is part of San Diego Museum of Art's collection and is exhibited in another room. As the visitors touch the bas-relief with their hands, a voice explains the meanings of each thing they are touching. The talking sculpture is mounted from the back and not standing on a pedestal (Figure 118) so that the visitors can observe and touch the characters under the feet, and hear the description (Figure 119). The project has been designed with the purpose of making the work of art accessible to everyone (universal design) included the blind visitors.

Date: 2015
Location: San Diego Museum of Art (Balboa Park, San Diego, CA)
Designers/Developers/Researchers: Touch Graphics (Elkton, Maryland)

Figure 118 The talking sculpture installation (source: Touch Graphics, 2015).

Figure 119 Visitors can observe and touch the characters under the feet. (source: Touch Graphics, 2015).

References

Touch Graphics. (2015). *Talking Tactile Sculpture*. Retrieved from Touch Graphics Inc | Tactile Design for Universal Access: http://touchgraphics.com/in-production-talking-tactile-sculpture/

3. Tooteko

Tooteko (Figure 120), a system developed by an Italian start-up company that allows the blind visitors to explore replicas or models of objects, works of art and architectures through the sense of touch, and to get information about what they are touching. Tooteko consists of three main components: a hi-tech ring, a tactile model embedded with HFC tags and an application for tablets/smartphones. When the visitor, exploring the models, reach specific hotspots, a specific audio content is played by a mobile application.

Date: 2012
Location: generic
Designers/Developers/Researchers: Tooteko srls

Figure 120 Tooteko (source: Tooteko – Talking Tactile, s.d.).

References

Tooteko - Talking Tactile. (n.d.). *Tooteko - Talking Tactile*. Retrieved 2015, from Tooteko - Talking Tactile: http://www.tooteko.com/

D'Agnano, F., Balletti, C., Guerra, F., & Vernier, P. (2015). Tooteko: a Case Study of Augmented Reality for an Accessible Cultural Heritage. Digitization, 3d Printing and Sensors for an Audio-Tactile Experience. Isprs - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 207-213.

The interactive consists of a projection and a platform on which four minerals are placed (Figure 121). In the idle state the images of the four minerals are projected on the screen, along with a text that invites the visitor to choose one of them; all the minerals are illuminated with blue light. When the visitor picks a mineral up, the related area on the platform is lighted in red and related information is shown in the projection in the form of text and images (Figure 122). The information is also provided in audio format. In case two mineral samples are picked up, a comparison between the two is provided in the form of audio/visual/textual information, and the related areas on the platform are lighted in red (Figure 123).

Date: 2014
Location: MM Gerdau – Museu das Minas e do Metal (Belo Horizonte/MG, Brasil)
Designers/Developers/Researchers: Roberto Ivo Ferdandes Vaz

Figure 121 The platform with the minerals and the projection (source: Vaz, 2014).

Figure 122 Example of information provided on the projection for a single object (source: Vaz, 2014).

Figure 123 Example of information provided on the projection in the case of two objects (source: Vaz, 2014).

References

Vaz, R. F. (2014). *Interfaces tangíveis no contexto da experiência da visita a um museu.* Master's Dissertation, Universidade de Aveiro, Departamento de Comunicação e Arte.
http://lavgraft.com.br/wpcontent/uploads/2015/01/dissertacao_roberto_vaz.pdf

Video: https://vimeo.com/122708170

5. VIRTEX (Ivory object, 11th century, Archaeological Museum Ename, Belgium)

Virtex is a presentation method to be used near the original object that enables visitors not only to hold an untouchable object as a replica and feels all details of it but also to explore the meaning of the object through sounds, images, and video. The implementation of Virtex in the Archeological Museum Ename has been used to present an 11th century ivory object that is part of the collection and is exhibited near the installation (Figure 124). The installation is made of a replica of the object and a screen. As the original object is quite small, the replica has bigger dimensions so that can be properly handled and the small detailed can be perceived as well (Figure 125). The replica is embedded with an orientation sensor so that moving the physical replica, the digital replica of the same object is visualized accordingly (Figure 126). The replica is also embedded with touch sensors (small buttons) so that touching specific areas of the objects stories are told in the form of small video or animation sequences explaining the meaning and the history of the object (Figure 127). An introductory video is triggered when the object is picked up for the first time showing the context and the way the object was used for and the main symbolism of the object (Figure 128). Pushing the touch sensors, other stories are triggered that explains inscriptions, other symbolisms and the process of creation of the object from ivory.

Date: 2007
Location: Archaeological Museum Ename, Belgium
Designers/Developers/Researchers: Daniel Pletinckx

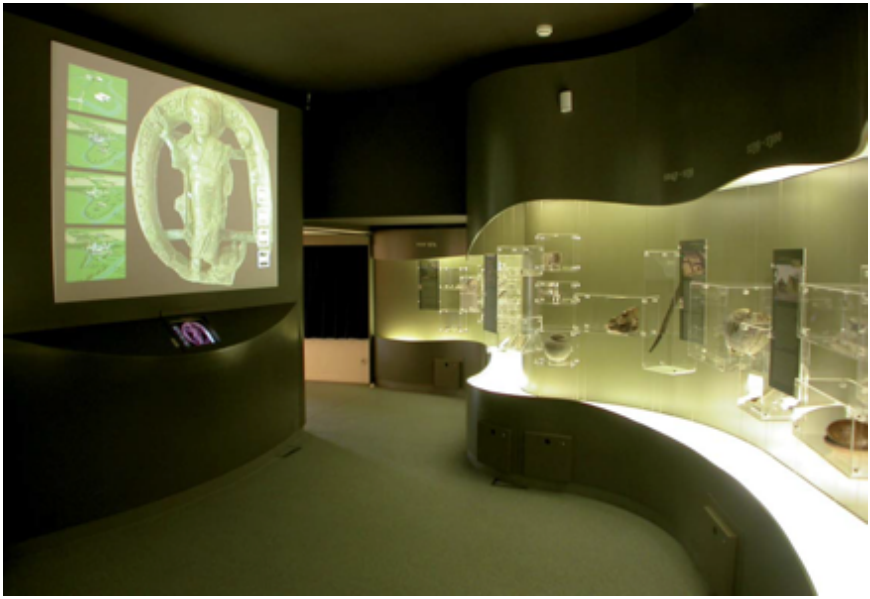


Figure 124 Virtex installation and its location in the Archaeological Museum Ename, Belgium. The original object is exhibited in the display cases in front of the installation. (source: Pletinckx, 2007).

Figure 125 The original object (source: Pletinckx, 2007).

Figure 126 The sensorized replica of the object (source: Pletinckx, 2007).

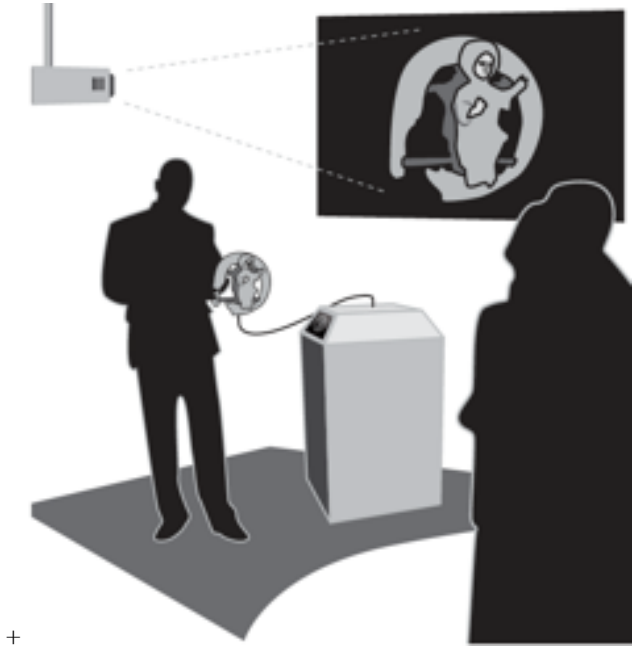


Figure 127 Scheme of the use of the installation (source: Pletinckx, 2007.)

Figure 128 The introductory contextual video triggered when the object is picked up for the first time (source: Pletinckx, 2007)

References

Pletinckx, D. (2007). *Virtex: a multisensory approach for exhibiting valuable objects.* Stockholm: The interactive institute AB.
(http://media.digitalheritage.se/2010/07/Virtex_TII.pdf)

6. VIRTEX (Ara Pacis) Allard Pierson Museum, Amsterdam

Virtex is a presentation method that enables visitors not only to hold the untouchable object as a replica and feels all details of it but also to explore the meaning of the object through sounds, images, and video. In the implementation at the Allard Pierson Museum, Virtex is used to present contents related to the Ara Pacis Monument in Rome. The installation consists of a small replica of the monument embedded with touch sensors (push buttons) placed in interesting areas of the monument and a small screen (Figure 129). Pushing specific sensors, a virtual model of the monument is oriented and zoomed to show the specific area of interest. After that, a specific video content (with subtitles in Dutch and in English) is shown explaining the meaning of that specific part and showing other related historical sources. Behind the installation, a plaster copy of a panel of Ara Pacis is also exhibited (Figure 130).

Date: 2014
Location: Keys to Rome Exhibition, Allard Pierson Museum, Amsterdam
Designers/Developers/Researchers: Daniel Pletinckx, C. Capurro (Visual Dimension); Texts, I. Cerato, P-Vigliarolo – CNR ITABC; Digital 3D model: E. Demetrescu, CNR ITABC

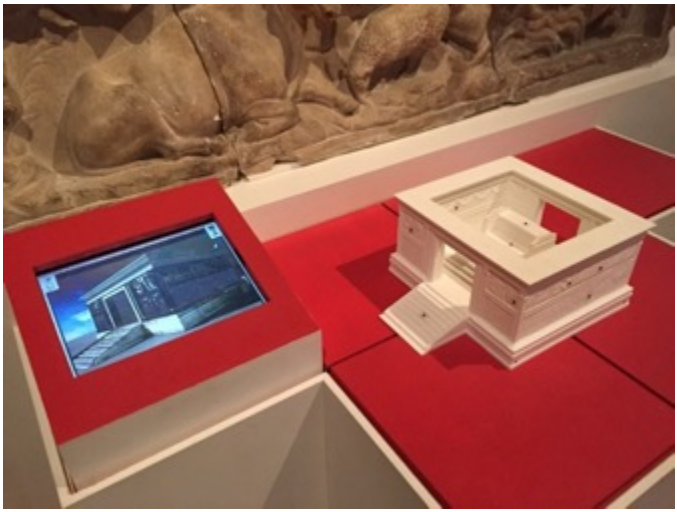


Figure 129 The Ara Pacis installation (source: the author).

Figure 130 A plaster copy of the Ara Pacis panel is exhibited behind the interactive (source: the author).

References

Capurro, C. (2014). Tangible Interfaces in Digital Museum Applications. Visual Dimensions bvba, Belgium. (http://bmuseums.net/wp-content/uploads/2014/11/141029-tangible_interfaces.pdf).

video: https://www.youtube.com/watch?v=nQbdn2NVlls

7. VIRTEX (Augustus of Prima Porta) Allard Pierson Museum, Amsterdam

Virtex is a presentation method that enables visitors not only to hold an untouchable object as a replica and feels all details of it but also to explore the meaning of the object through sounds, images, and video. In this implementation (Figure 131), VIRTEX consists of a small replica of the Augustus of Prima Porta statue (
Figure 132) embedded with orientation and touch sensors (push buttons) placed in specific areas of the replica, and a small screen visualizing a 3D coloured model of the statue. The 3D model on the screen is visualized replicating the orientation of the small replica in the hands of the visitors (Figure 133). Pushing specific sensors, the virtual model of the statue is oriented and zoomed to show the specific area of interest and information are provided. A coloured plaster copy of a bas-relief of the Ara Pacis that is part of the museum collection is placed behind the exhibition.

Date: 2014
Location: Keys to Rome Exhibition, Allard Pierson Museum, Amsterdam
Designers/Developers/Researchers: Daniel Pletinck

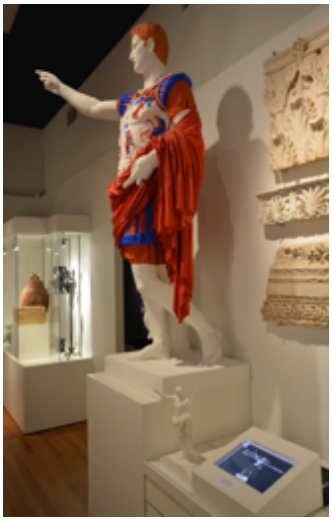


Figure 131 The Augustus of Prima Porta Installation (Capurro, 2014).

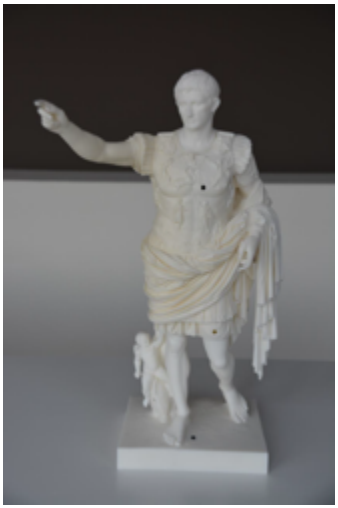


Figure 132 The sensorized model of the Augustus statue (source: Capurro, 2014)

Figure 133 A visitor interacting with the small replica of the statue (source: https://www.youtube.com/watch?v=nQbdn2NVlls).

References

Capurro, C. (2014). Tangible Interfaces in Digital Museum Applications. Visual Dimensions bvba, Belgium. (http://bmuseums.net/wp-content/uploads/2014/11/141029-tangible_interfaces.pdf).

video: https://www.youtube.com/watch?v=nQbdn2NVlls

8. Open House: If These Walls Could Talk

The exhibition 'Open House: If These Walls Could Talk' in the Minnesota History Center in St. Paul tells the stories of the families who lived in an ordinary house in the "Railroad Island" neighbourhood on St. Paul's East Side, from 1888 to the present (Figure 134). The exhibition is structured as a house made up of several rooms (Figure 135), related to different times and furnished accordingly. Moving inside the rooms or making actions with objects, the visitors can uncover the stories of families or cluster of families who lived in the house, "from the first German immigrants through the Italians, African-Americans and Hmong" (Filene, 2011). In this exhibition, even though they are present, "'historic objects were not essential: our artefact – our vehicles for authentic connection to the past – were stories" (Filene, 2011). One of the messages the exhibition aims to convey is that even ordinary people make history.
One example of installation is an interactive dining table (Figure 136). The action of sitting at the table triggers stories of family dinners during the house's Italian era. The stories are told through images projected on the surface of the plates and audio stories.
Touching an illuminated silver dollar in the 1960s bedroom launches home movies and the Krismers' recounting of how they saved coins for their families' vacations across Minnesota (Figure 137). The story is told through audio and a video on the video projected in the mirror in front of the coin.
Date: 2006
Location: Minnesota History Center, St. Paul
Designers/Developers/Researchers:

Figure 134 A historical picture of the house in the "Railroad Island" neighbourhood on St. Paul's East Side (Filene, 2011).

Figure 135 The exhibition appears as a house from outside (source: Minnesota Historical Society, n.d.b).

Figure 136 The dining table installation (source: Filene, 2011).

Figure 137 The coin installation in the bedroom (source: https://www.youtube.com/watch?v=xnp9AkqxhnM).

References

Filene, B. (2011). Make Yourself at Home - Welcoming Voices in Open House: If These Walls Could Talk. In A. Bill, B. Filene, & L. Koloski (Eds.), Letting Go? Sharing Historical Authority in a User-Generated World. Philadelphia, PA: Pew Center for Arts & Heritage.

Minnesota Historical Society. (n.d.a). *MNHS.ORG | Exhibits: Open House.* Retrieved 2015, from Minnesota Historical Society: http://www.mnhs.org/exhibits/openhouse/exhibit.php

Minnesota Historical Society. (n.d.b). *Open House | Minnesota History Center.* Retrieved 2015, from Minnesota Historical Society:

Videos:
https://www.youtube.com/watch?v=3hkz3KYUiI4
https://www.youtube.com/watch?v=xnp9AkqxhnM
https://www.youtube.com/watch?v=JPev2bx-Wxw

9. The "Interactive Artifact Exploration Cabinet"

The "Interactive Artifact Exploration Cabinet" at Dohaland's Knowledge Enrichment Center (KEC) in Doha is an interactive made up of drawers containing objects, an interactive tabletop and a screen (Figure 138). Visitors are asked to open drawers, take and place artefacts on the interactive tabletop. As a result, information in the form of explanatory text, videos and images is displayed on the screen (Figure 139).

Date: 2010
Location: Dohaland's Knowledge Enrichment Center (KEC) in Doha
Designers/Developers/Researchers: AV&C (http://www.av-controls.com/wordpress)

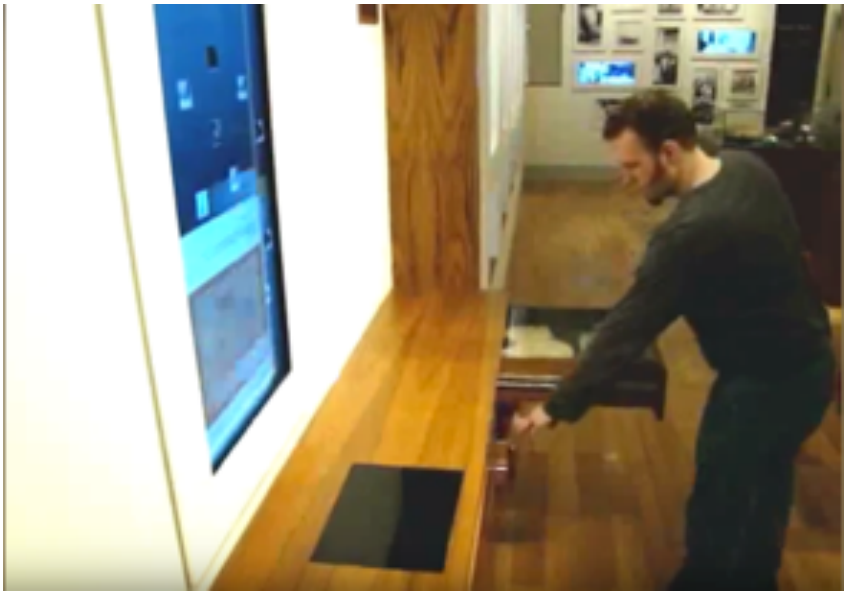


Figure 138 The Interactive Artifact Exploration Cabinet (source: https://www.youtube.com/watch?v=3SgKcR1EQXI).

Figure 139 A visitor interacting with the installation (source: https://www.youtube.com/watch?v=3SgKcR1EQXI).

References

video: https://www.youtube.com/watch?v=3SgKcR1EQXI

10. Le cabinet des Fables

It is an installation proposed for the "Musée des Arts Décoratifs" in Paris, where a whole part of the Museum, "Le Cabinet des Fables", is augmented through digital audio content related to the history of the place, some fables, or the description of the museographic context.
The content is activated according to the position of the visitor in the rooms where different visual markers are provided on the floor corresponding to different points of view (Figure 140).

Date: 2011
Location: "Musée des Arts Décoratifs", Paris
Designers/Developers/Researchers: Erasme (centre of technological innovation), Lyon, France (http://www.erasme.org/)

Figure 140 Visitor interacting with the installation placing themselves on visual markers provided on the floor (source: ERASME, 2011).

References

ERASME. (2011, December 7). *Strat*. Retrieved 2015, from ERASME: http://www.erasme.org/Strat

video: https://youtu.be/kqMYdF2yLyc

11. Winnipeg Art Gallery's interactive case

This interactive consists of an interactive case embedded into a wall and containing a sculpture (Figure 141). In front of the display, a replica of the sculpture is placed. When no visitors are near the interactive an animation is overlapped on the exhibit attracting the visitors to go closer. As the visitor goes closer, basic object information is shown that are aligned according to the gaze of the visitor. More information can be obtained by touching the different parts of the replica. Finally, using a mobile application the visitors can publish hand drawings on the exhibit that are shown for short time.

Date: 2014
Location: generic
Designers/Developers/Researchers: Hincapié-ramos, Juan David, Xiang Guo, and Pourang Irani.

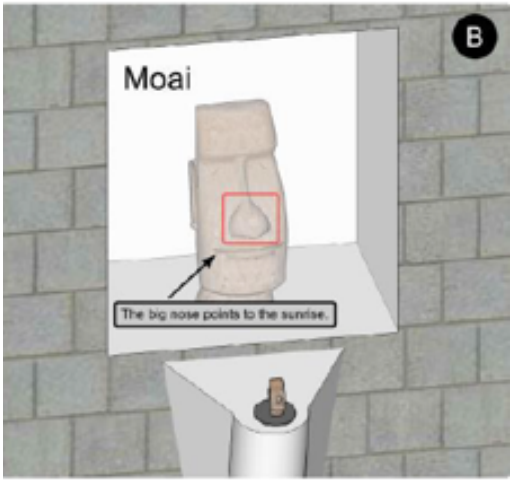


Figure 141 Winnipeg Art Gallery interactive case (source: Hincapié-Ramos et al., 2014).

References

Hincapié-Ramos, J., Guo, X., & Irani, P. (2014). Designing Interactive Transparent Exhibition Cases. *Proceedings of the third international ACM Workshop on Personalized access to cultural heritage (PATCH '14)*. Haifa, Israel: ACM.

12. The Hague and the Atlantik Wall

The Atlantic Wall was a system of defence built by the Germans along the European coast of the Atlantic Ocean and the North Sea during the Second World War. The exhibition in the Dutch Museum "Museon", aimed to describe the impact that the construction of the Atlantic Wall had on the life of the people living in The Hague. The exhibition was organized in several showcases distributed on a space that reproduced the physical map of the city and containing objects, documents, along with traditional information labels. In order to allow visitors to access also to another layer of information made of personal stories of the people living in The Hague at that time, interactive technology was employed. This consisted of physical smart replicas of objects (Figure 142) each representing a specific perspective on the events in The Hague (civilians, officials and Germans), chosen for their ability to represent specific perspectives. The original objects which replicas are based on are also displayed in a case at the beginning of the exhibition (Figure 144). At the start visitors can choose and pick up a replica to carry with them during the visit. Placing the replica on a hotspot near specific glass cases present in the exhibition, the visitor can activate audio and video contents related to the story of the Atlantik Wall that are told in first person from the specific perspective associated to the replica (Figure 143). Audio content is provided through an audio earpiece while the video is projected directly on the display case. This mechanism was chosen instead of buttons hoping that it would provide a stronger curiosity and involvement of the visitor with the story compared to standard buttons.

Date: 2015
Location: Museon, The Hague
Designers/Developers/Researchers: European meSch project

Figure 142 Tangible smart replicas (source: Marshall et al., 2016).

Figure 143 The original objects on which smart replicas are based exhibited in a case (source: Marshall et al., 2016).

Figure 144 A visitor activating an audio content at a display case by placing the replica of a mug on the hotspot (source: https://www.youtube.com/watch?v=sK3AdQU9kkc).

References

Marshall, M., Dulake, N., Ciolfi, L., Duranti, D., Kockelkorn, H., & Petrelli, D. (2016). Using Tangible Smart Replicas as Controls for an Interactive Museum Exhibition. *Proceedings of the Tenth Anniversary Conference on Tangible Embedded and Embodied Interaction, TEI '16* (pp. 159-167). New York, NY, USA: ACM.

Kockelkorn, H. (2015, April 2). *meSch - Why do we use smart replicas in museums?* Retrieved 2015, from meSch: http://www.mesch-project.eu/why-we-are-using-smart-replicas/

Video: https://www.youtube.com/watch?v=sK3AdQU9kkc

13. Nottingham Castle Installation

This installation was created at Nottingham Castle in 2002. Its aim was to allow the visitors to understand the different events that took place in the history of the castle, often in locations and buildings that are no longer visible today, and to help them to connect displays, locations and historical events. The visitor experience takes the form of a "history hunt". Upon arrival, the visitors are given a set of (electronically tagged) paper clues each associated to a particular historical figure and a location in the castle that featured in the history of that figure (even though sometimes the appearance of the places has changed). The clues lead the visitors to these specific locations, where they are asked to record information (e.g., symbols, bridges etc.) for example by adding drawings on the paper cues (Figure 145). Inside the museum, the visitors can use their completed paper clues to interact with a number of interactive installations that give them further information about the historical events. In designing the interactive installations, desktop multimedia interaction techniques are rejected in favour of innovative techniques "which were idiomatic for the site and the clue-seeking activity" (Fraser et al., 2003).
The first installation takes the form of a storytent in order to create a more intimate and personal space (Figure 146). Placing the paper clues on a turntable inside the tent, visitors could activate a 3D historical reconstruction of the castle at the time of the character on one site (and change the viewpoint by turning the turntable), and an image depicting the figure at the specific location on the other side. The second installation is the sandpit (Figure 147), an interactive floor projection of simulated sand. After putting the paper clue in a sandbox nearby, the visitors can dig for other images related to it (same location or same time), pointing a flashlight onto the display.

Date: 2002
Location: Nottingham Castle
Designers/Developers/Researchers: European SHAPE project

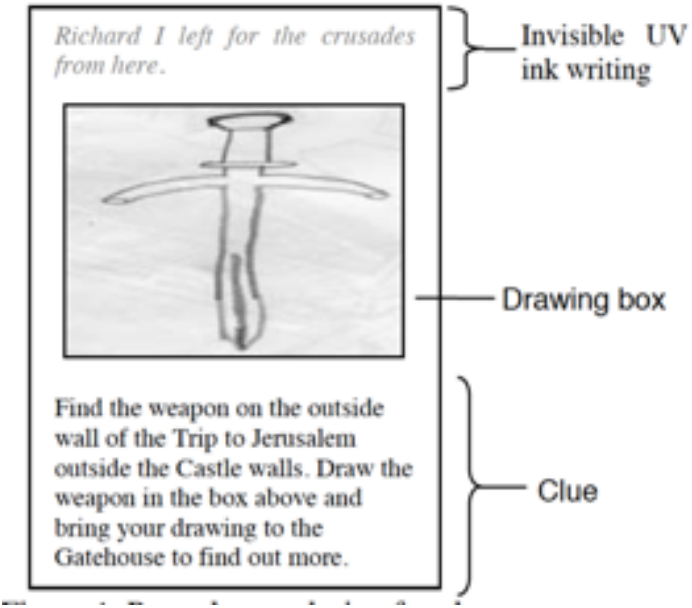


Figure 145 Example of a paper clue (source: Fraser et al., 2003).


Figure 146 The storytent installation (source: Fraser et al., 2003)

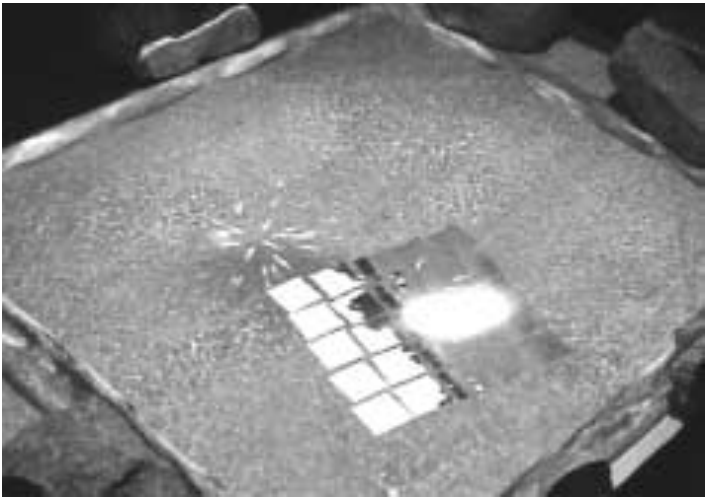


Figure 147 The sandpit installation (source: Fraser et al., 2003).

References

Fraser, M., Stanton, D., Ng, K., Benford, S., O'Malley, S., Bowers, J., . . . Hindmarsh, J. (2003). Assembling history: Achieving Coherent Experiences with Diverse Technologies. *Proc. of European Conference on Computer Supported Cooperative Work (ECSCW)* (pp. 179-198). Oulu University Press.

14. Kurio

Kurio is a tangible guide system to support families and groups of people during a museum visit by promoting social interaction and learning. It consists of a tangible pointer, reader, listener, finder (Figure 148) and a PDA and require family members to take part in a game.

In this game, the family members play the role of time travellers stuck in this time because their time map is broken. In order to fix the map, the family members have to collect historical information about objects in the museums. The missions are received on a PDA by one family member acting as coordinator and assigning the challenges to each family member. Once received the challenges, the family members can use tangible to collect information around in the museum (Figure 149). The pointer, similar to a flashlight, is used to select specific objects; the reader reminiscent of a magnifying glass can be used to collect text from labels; and the listener, resembling a walkie-talkie can be used to listen to audio file in various point of the exhibition. A button on the tangible interfaces can be pressed to make the selection and a colour feedback or vibration is provided to confirm the selection. The PDA application is used to monitor the progress of each family members and to assign new challenges (Figure 150). Finally, a tabletop display can be used by families to see and assess their progress in missions and challenges, and to receive reward videos or information at the end of the missions that can guide the learning process.

Date: 2009
Location: Surrey Museum, Surrey, Canada
Designers/Developers/Researchers: Ron Wakkary, Marek Hatala, Kevin Muise, Karen Tanenbaum, Greg Corness, Bardia Mohabbati, and Jim Budd

Figure 148 The pointer, the reader, the listener and the finder (source: Wakkary et al., 2009).

Figure 149 The family members use tangible interfaces to collect information (source: Wakkary et al., 2009).

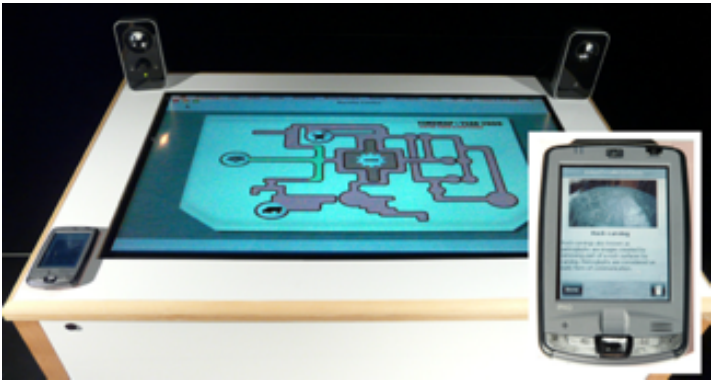


Figure 150 The PDA and the tabletop display (source: Wakkary et al., 2009).

References

Wakkary, R., Hatala, M., Muise, K., Tanenbaum, K., Corness, G., Mohabbati, B., & Budd, J. (2009). Kurio: a museum guide for families. *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction (TEI '09)* (pp. 215-222). New York, NY, USA: ACM.

video: https://www.youtube.com/watch?v=2rifr_UTnr8

15. The visitor as virtual archaeologists

"The visitor as virtual archaeologists" is a concept that was developed but never implemented for the Hunt Museum of Limerick, consisting in placing hybrid physical-digital artefacts, replicas of ancient artefacts, in a sandbox simulating archaeology digs in museums (Figure 151). Visitors are asked to unearth the artefacts and bring them to specific artefacts in the museum collections, where, combined with objects other visitors have uncovered, interactive installations reveal information about the artefacts in the real collection.

Date: 2001
Location: Hunt Museum, Limerick (Ireland)
Designers/Developers/Researchers: Tony Hall, Luigina Ciolfi, Liam Bannon, Mike Fraser, Steve Benford, John Bowers, Chris Greenhalgh, Sten-Olof Hellström, Shahram Izadi, Holger Schnädelbach, Martin Flintham

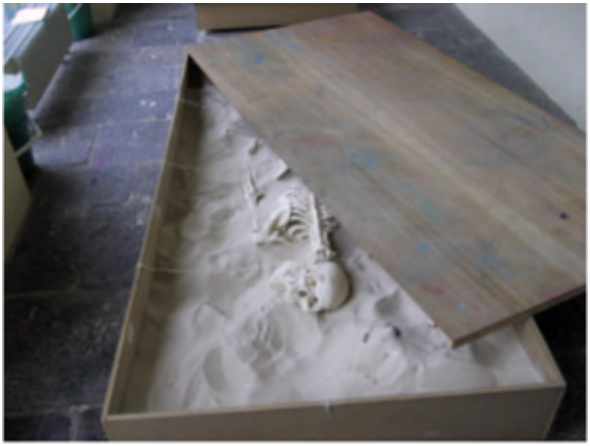


Figure 151 The sandbox for simulating archaeology digs in museums (source: Hall et al., 2001).

References

Hall, T., Ciolfi, L., Bannon, L., Fraser, M., Benford, S., Bowers, J., . . . Flintham, M. (2001). The Visitor as Virtual Archaeologist: Explorations in Mixed Reality Technology to Enhance Educational and Social Interaction in the Museum. *Proceedings of the 2001 conference on Virtual Reality, archaeology and cultural heritage.* New York, USA: ACM.

16. "Reminisce"

Reminisce is an installation designed for enhancing the visit of "Bunratty Folk Park" in Ireland. The park is an open-air museum exhibiting "32 historic dwellings that have been relocated there from different regions of Ireland and furnished appropriately to the period and context" (Ciolfi et al., 2002) and also featuring "hands-on activities, landscapes and livestock from wild deer to farmyard animals" (Ciolfi et al., 2002). Traditionally information about the site is provided to visitors by the animators since only limited textual information is present in the site and provides only spatial guidance.
In Reminisce the technology was deployed in such a way not to distract visitors from the physical experience of the place and also to allow them to enrich the site through the generation of personal content. At specific houses a QR code is placed that allow visitors to access reminiscences of a chosen fictional character by scanning them with a mobile phone. The memories can be listened through a handset. At the same locations, visitors can also record their comments (Figure 152).
In addition, tangible tokens in "the form of small packs of keepsakes containing a physical asset that was associated to the specific site, like recipes, pieces of turf, wool" (Ciolfi et al., 2002) can be found and picked inside the different houses (Figure 153). These tokens can be interpreted as clues that lead visitors to other places where they can get other memories.
The same tokens are also used to interact with the interactive desk in the Folk Park house at the end of the trail, in order to listen to recordings that other people left at the various houses during the trail (Figure 154). Placed on the desk were books with embedded RFID tags, each of them relating to one of the characters that visitors could collect memories from. A book holder and a basket were also placed on the desk. When one of the books was placed on the holder and one of the tangible tokens was placed inside the basket, the recordings left by other visitors were played back. These recordings were of the site where the tangible token was collected.

Date: 2011
Location: Bunratty Folk Park
Designers/Developers/Researchers: Luigina Ciolfi and Marc McLoughling (Interaction design Centre, Dept of CSIS, University of Limerick, Ireland)

Figure 152 Visitor scanning a QR code at a location in the park in order to listen to a memory and to record personal thoughts (source: Ciolfi et al., 2002).

Figure 153 Tangible tokens present inside the different houses in the park (source: Ciolfi et al., 2002).

Figure 154 The interactive desk in the Folk Park house (source: Ciolfi et al., 2002).

References

Ciolfi, L., & Bannon, L. (2002). Designing interactive museum exhibits: enhancing visitor curiosity through augmented artifacts. *Proceedings of the European Conference on Cognitive Ergonomics (ECCE11).* Catania.

Ciolfi, L., & MacLoughlin, M. (2011). Physical Keys to Digital Memories: Reflecting on the role of tangible artefacts n "Reminisce". In J. Trant, & Bearman (Ed.), *Museum and the Web 2011: Proceedings.* Toronto: Museum and Archives Informatics.

17. Virtual Conductor

In "the virtual conductor" installation in the House of Music in Vienna the visitor can lead a video projection of the Vienna Philharmonic Orchestra using a replica of a conducting baton (Figure 155). According to how fast the baton is moved, and how intensive and expansive the movements are the performance changes, as well as the mood of the musicians. If the visitor totally lacks talent, the musicians are not amused and leave.

Date: 2001
Location: House of Music, Vienna
Designers/Developers/Researchers: CheckpointMedia GMBH (http://www.checkpointmedia.com/en/projects/haus_der_musik)

Figure 155 The virtual conductor installation (source: https://www.wien.info/en/music-stage-shows/city-of-music/house-music).

References

checkpointmedia. (n.d.). *checkpointmedia | Haus der Musik.* Retrieved 2015, from checkpointmedia: http://www.checkpointmedia.com/en/projects/haus_der_musik

Wiener Tourismusverband. (n.d.). *House of Music - VIENNA - Now. Forever.* Retrieved 2015, from The online travel guide for Vienna - VIENNA - Now. Forever: https://www.wien.info/en/music-stage-shows/city-of-music/house-music

video:
https://www.youtube.com/watch?v=n884FffJZbc
https://www.youtube.com/watch?v=c6bUxW-8WQU
https://www.youtube.com/watch?v=Ue5QZJyny4A

18. Drinking Symposium

The drinking symposium was a drinking session that used to happen in Ancient Greece after a meal with people reclined on couches in a U-shape.
The installation consists of a large wall projection representing virtual characters taking part to the ritual, a 3D printed replica of a Greek drinking bowl (kylix) from the collection of the Allard Pierson Museum and a reproduction of a Greek daybed placed on the opposite wall that seems to complete the virtual scene in the real world (Figure 156). Both the kylikes and the daybeds are embedded with sensors. On the pedestal the text "Picks me up" is shown that invites the visitor to take the kylix. When no actions are performed, the installation is in the idle state and individuals gently move. When the visitor picks up the kylix removing it from the pedestal, one of the animate figures lifts his kylix, toasts and drink wine. When the kylix is placed back on its place, an animated woman in the corner plays the flute and is applauded by one of the others. When the visitor sits down on the daybed, one of the animated figures shoots a drop of wine from his cup toward a stand in the middle of the room, a game which was popular in ancient Greece (kottabos game).

Date: 2015
Location: Allard Pierson Museum
Designers/Developers/Researchers: European meSch project

Figure 156 The Drinking Symposium Installation (source: the author).

References

video: https://vimeo.com/146224161

19. Interantarctica

"Interantarctica" is a tangible aiming to communicate how human activities impact on the climate change (with positive or negative consequences). It is made up of a table, tangible tokens and three screens showing videos about Antarctica (Figure 157). Tangible representations of objects that have a positive impact on the environment (like a tree, and an energy saver light-globe) and a negative impact (like a chain-saw, or standard light globe) are provided on a table (Figure 158). Picking up these objects and moving them in the environment the visitor both modifies a graphical representation (a pie-chart) on the table representing the CO2 emissions of a house, and a music composition is generated in real time in the environment.

Date: 2009
Location: exhibition at the University of Sydney
Designers/Developers/Researchers: designed by DronacloV and developed by an interdisciplinary team of researchers and students from the University of Sydney.

Figure 157 Interantarctica installation (source: De Berigny, 2010).

Figure 158 Tangible representations of objects that have an impact on the environment (source: De Berigny, 2010).

References

De Berigny Wall, C. (2010). InterANTARCTICA: An interactive environmental installation. *IEEE International Conference on Multimedia and Expo (ICME)*, (pp. 1629-2634). Singapore.

Video: https://vimeo.com/16268443

20. "Yongzheng emperor's interactive tabletop", National Palace Museum

"Yongzheng emperor's interactive tabletop" was developed for the exhibition "Harmony and Integrity: The Yongzheng emperor and His Times" at the National Palace Museum in Taiwan. The interactive consists of a tabletop and a series of physical artefacts each representing concepts that the installation allows to explore (Yongzheng's places, his times, his relation with high officials). A tangible figurine for each representative place has been developed (e.g. Yongzheng figurine holding an imperial vase for the Imperial Workshop) (Figure 159). A tangible object based on a rare calendar clock belonging to Yongzheng era has been created to represent the "abstract times of the emperor" (Figure 160). Finally, a figurine of the Emperor in court dress has been designed to interact with the figurine of a high official to explain the process of writing of memories (submitting, reviewing and returning) that was carried out by the emperor and his officials (Figure 161). By interacting (placing and rotating) with the tangible interfaces on the tabletop the visitors can explore the Yongzheng Emperor's stories connected to the specific concepts as well as manipulate images of artefacts that are in the exhibition (Figure 162).

Date: 2010
Location: National Palace Museum, Taiwan
Designers/Developers/Researchers: Hsieh, C.-K.; Liu, I.-L.; Yu, N.-H.; Chiang, Y.-H.; Wu, H.-T.; Chen, Y.-J. & Hung, Y.-P.

Figure 159 Tangible figurines developed for each representative place (source: Hsiez et al., 2010).

Figure 160 Tangible object used to represent the times of the emperor (source: Hsiez et al., 2010).

Figure 161 Images and other information shown placing the figurines on the tabletop (source: Hsiez et al., 2010).

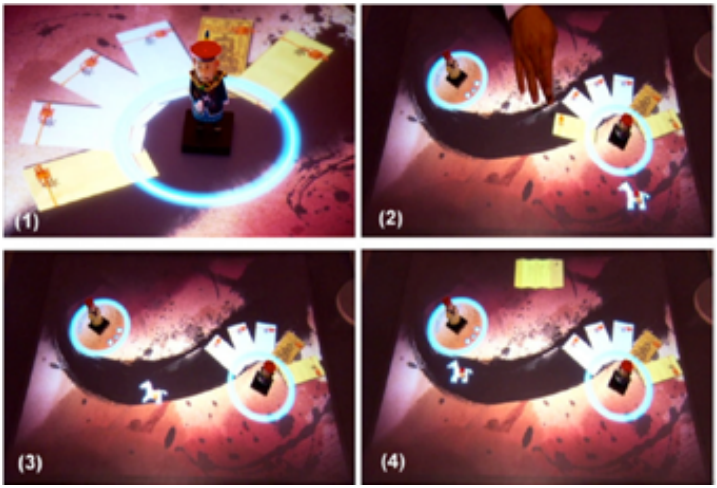


Figure 162 The process of writing of memories explained through TUIs (source: Hsiez et al., 2010).

References

Hsieh, C., Liu, I., Yu, N., Chiang, Y.H., Wu, H., . . . Hung, Y. P. (2010). Yongzheng emperor's interactive tabletop: seamless multimedia system in a museum context. In A. Del Bimbo, S.-F. Chang, & A. Smeulders (Eds.), *ACM Multimedia* (pp. 1453-1456). ACM.

21. Companion Novel (Sheffield General Cemetery)

The "Companion Novel" is a tangible interactive installation which was designed with the purpose of supporting and enhance the visit at Sheffield General Cemetery (England), an important site both from a historical and natural point of view (Figure 163). The Companion Novel consists of an interactive book (Figure 164) that the visitors can carry with them during the exploration of the cemetery and a set of Bluetooth speakers placed in specific points of interest in the site (Figure 165). The visitor can select their favourite narrative theme by placing a bookmark on a page of the book (Figure 166). The different themes are: "Nature in the city" related to the natural richness of the site; "This is my story" telling the stories of the people who were buries in the cemetery; "Weird and Wonderful" regarding anecdotes in the history of the Cemetery; and "Favourite Spots" regarding favourite places chosen by the volunteers and past visitors.
When, exploring the Cemetery, visitors approach a point of interest a sound is played to attract the visitor to go closer. At that point, a specific audio content is played (according to the selected theme). The use that is made of tangible interaction in the Companion novel allows to respond to specific challenges regarding the use of technologies in cultural heritage that are: design a technological solution that don't distract the visitor from the heritage, bridging the gap between heritage and digital content; considering the social dimension of the visit rather than isolating visitors.

Date: 2013
Location: Sheffield General Cemetery, Sheffield (UK)
Designers/Developers/Researchers: European meSch project

Figure 163 Sheffield General Cemetery (source: Ciolfi et al., 2013).

Figure 164 The interactive book (source: Ciolfi et al., 2013).

Figure 165 A visitor carrying the book with him when exploring the park (source: https://www.youtube.com/watch?v=GP0wAPO84Qo)

Figure 166 Selection of a favourite theme inserting a bookmark in the book (source: https://www.youtube.com/watch?v=GP0wAPO84Qo).

References

Ciolfi, L., Petrelli, D., Goldberg, R., Dulake, N., Willox, M., Marshall, M., & Caparrelli, F. (2013). Exploring historical, social and natural heritage: challenges for tangible interaction design at Sheffield General Cemetery. *NODEM 2013 : Beyond control - the collaborative museum and its challenges*. Stockholm, Sweden.

video: https://www.youtube.com/watch?v=GP0wAPO84Qo

22. Companion Novel ("Voices from the Trenches")

The installation "Voices from the Trenches" is a readjustment of the Companion Novel concept (see previous project) for the visit to another cultural heritage site, the Trenches of Nagià Grom in the north of Italy. In this case a wearable device is used consisting of a belt inspired by World War I army clothing equipped with a specific pocket where the visitor could place a card according to the specific theme he is interested to listen to (Figure 167). The different themes are: "Order of the day" providing factual information structured as a military order; "My dear wife" based on the diaries and letters of soldiers; "Women in the war" reporting stories about the life of women during the war; "Poems from WWI" telling poems from WWI like Brothers from Ungaretti.
When, exploring the site, visitors approach a point of interest a sound is played to attract the visitor to go closer. At that point, a specific audio content is played (according to the selected theme).

Date: 2015
Location: Trenches of Nagià Grom (Trentino, Italy)
Designers/Developers/Researchers: European meSch project

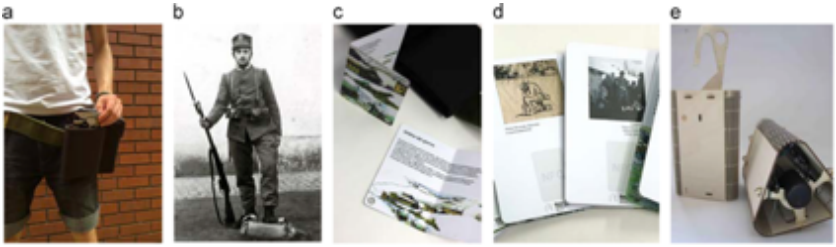


Figure 167 The components of the installation "Voice from the Trenches" (source: Marshall et al., 2015).

References

Marshall, M., Petrelli, D., Dulake, N., Not, E., Marchesoni, M., Trenti, E., & Pisetti, A. (2015). Audio-Based Narratives for the Trenches of World War I: Intertwining Stories, Places, and Interaction for an Evocative Experience. *International Journal of Human-Computer Studies, 85*(4), 27-39.

23. Magic Worlds

Magic Worlds is an exhibition about magic designed for children and presented with variations in various British museums in 2013 and 2014 starting from Victoria and Albert Museum.
The version of the exhibition that took place at the Great North Museum: Hancock in Newcastle upon Tyne is divided in three rooms: the fantasy room containing objects regarding fairy tales and fantasy literature, the illusion room exhibiting the history of magicians and exhibiting optical devices and trickery, and the enchantment room related to magical creatures. Three interactive installations were created and placed in specific points of the exhibition in order to foster the emergence of spontaneous storytelling and play possibilities. These are two magic mirrors and a magic cauldron.
The "delay magic mirror" is in the "Fantasy" area (Figure 168). The installation encourages children to try fairy-tale costumes and see their reflections in the mirror. The "delay magic mirror" looks like a normal mirror, a framed surface hang on the wall reflecting the image of the visitor. But at times a subtle surreality is observed as the mirror starts to manipulate the temporality of the reflection as the camera feed is time-shifted or reversed or overlaid to previous camera feeds.
The "Kaleidoscope" mirror is located in the illusion room because connected thematically to the other objects in the rooms like optical illusions devices and trickeries. Looking into the mirror the visitor sees his reflection manipulated in different ways: reflections dissected and shown like the spirals of the kaleidoscope, images bisected and reflected making them appear as Cyclops or with two heads.
The magic cauldron (Figure 169) is located in a small dark room dedicated to the witchcraft topic, near the enchantment space and consist of a witch's cauldron and a series of items (some of them inspired to those present in the museum) to be thrown inside. In the "Magic cauldron" flat LED light panels are hidden under a translucent panel that registers the weights of the items thrown in. A "bubbling and burbling" lighting is used to give an eerie personality to the cauldron as well as mouth sounds like "chewing, swallowing, gulping and groaning" are used. The sounds and lights increase in volume or intensity as objects are thrown into the cauldron by the visitors while playing at spell-casting. To stimulate the imagination of children in formulating spell casts, a macabre collection of taxidermy animals and fossils is displayed in a glass case, as well as one wall of the room is decorated with a text inspired to Macbeth text.

Date: 2013/2014
Location: Great North Museum: Hancock in Newcastle upon Tyne

Designers/Developers/Researchers: Robyn Taylor, John Bowers, Bettina Nissen, Gavin Wood, Qasim Chaudhry, Peter Wright, Lindsey Bruce, Sarah Glynn, Helen Mallinson, and Roy Bearpark.

Figure 168 The delay magic mirror (source: Taylor et al., 2015).

Figure 169 The magic cauldron (source: Taylor et al., 2015).

References

Taylor, R., Bowers, J., Nissen, B., Wood, G., Chaudhry, Q., Wright, P., . . . Bearpark, R. (2015). Making Magic: Designing for Open Interactions in Museum Settings. *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition (C&C '15)* (pp. 313-322). New York, USA: ACM.

24. "Whispering Table", Jewish Museum of Berlin

The "Whispering Table" is an interactive commissioned by the Jewish Museum of Berlin on the theme of the symbolic meanings of food within different rituals of different cultures: the Jewish Seder, the Moroccan Mimouna, the Persian Norooz, and the Buddhist hungry ghost festival. It consists of a table populated by empty ceramic dishes, bowls and jugs (Figure 170). The visitors can sit down at the table and congregate. Picking up an object and holding it to the ear, the visitor can listen to stories about the meaning of a food in a ceremony from a first person perspective. An object (corresponding to a specific narrator) will tell stories related to a different culture depending on where it is placed on the table. In addition, the stories being told (e.g. stories of similarities or differences) will depend on the position of the specific object with respect to the others (Figure 171).

Date: 2009
Location: Jewish Museum of Berlin
Designers/Developers/Researchers: Studio TheGreenEyl

Figure 170 The Whispering table installation
(source: http://www.thegreeneyl.com/whispering-table).

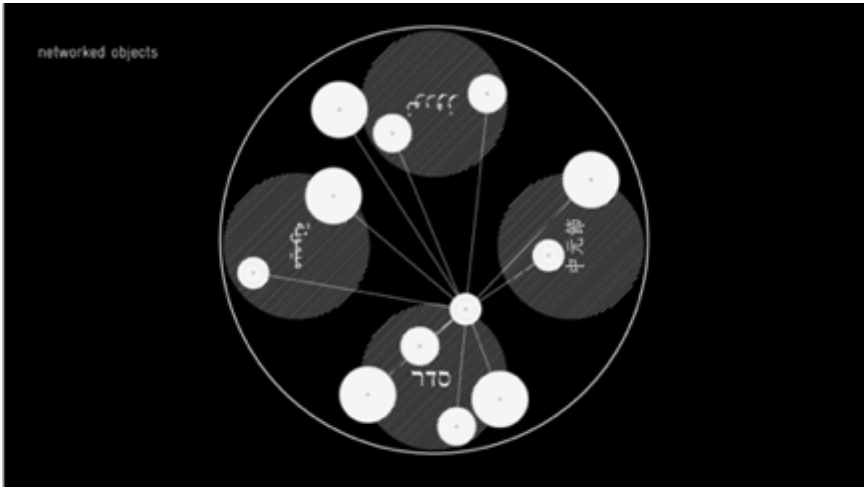


Figure 171 the story being told depends on the position of the object on the table and with respect to the others (source: http://www.thegreeneyl.com/whispering-table).

References:

Studio TheGreenEyl. (n.d.). *Whispering Table | Studio TheGreenEyl.* Retrieved 2015, from Studio TheGreenEyl: http://www.thegreeneyl.com/whispering-table

25. Frammenti di memoria

Objects belonging to the farming traditions are distributed inside the inner space of an almost ruined building in an suggestive way with illuminations and sounds "magically" evoking the atmosphere of past times (Figure 172; Figure 173). By touching the objects light effects are created and the objects start to tell the related stories of farmers.

Date: 2005
Location: San Martino di Sorli in Val Barbera (Alessandria)
Designers/Developers/Researchers: *idea e realizzazione:* Gabriel Rapetti (idea e realizzazione); Daniele Ferrarazzo (contributi audio); Alessandro Ferrari (collaborazione)

Figure 172 Particular of an object that is part of the installation (source: Repetti, 2005).

Figure 173 “Frammenti di Memoria” installation (source: Repetti, 2005).

References

Repetti, G. (3, October 2005). *Frammenti di memoria - Gabriel Rapetti.* Tratto il giorno January 2017, 25 da Gabriel Rapetti - Progettazione e realizzazione di sistemi multimediali interattivi per mostre, stand e musei: https://gabrielrapetti.com/frammenti-di-memoria/

26. Nonlinear stories told by cups and saucers. Smart replicas with responsive 3D Audio

This installation consists of an exhibition space in which porcelain replicas of seven teacups and saucers that are part of the collection of Museum Boijmans Van Beuninginen in Rotterdam are placed. Audio clips and information about specific items are conveyed to the visitors using headphones according to their positions and actions.
When exploring the exhibition, a spatialized audio is triggered depending on user location/viewing angle (proximity to specific object) attracting him to go closer. Going closer to the specific items, an audio story can be heard informing about the role of the specific cup and saucer (Figure 174). Picking up one of the objects, specific audio information is triggered. The visitor can listen this information while turning and exploring the object.

Date: 2013
Location: Museum Boijmans Van Beuninginen in Rotterdam
Designers/Developers/Researchers: Lotte de Reus

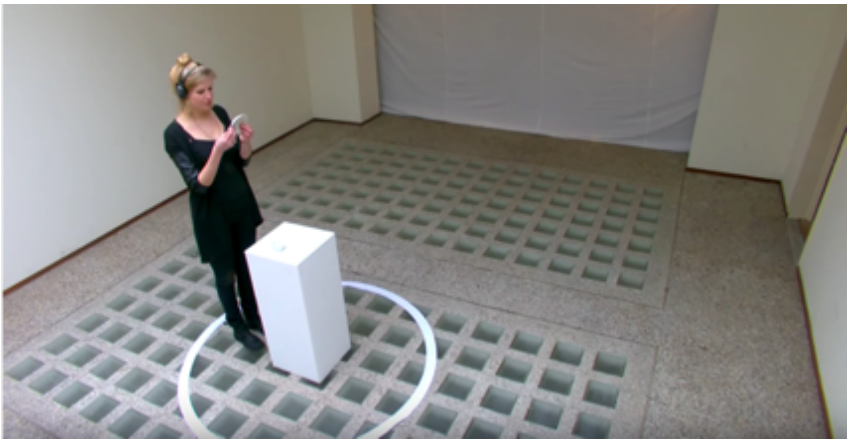


Figure 174 A visitor interacting with an object in the installation and listening to information (source: https://www.youtube.com/watch?v=enR1Ggbuf_8) .

References

De Reus, Verlinder, J. C., & Roozenburg, M. (2013). Nonlinear stories told by cups and saucers. Smart replicas with responsive 3D Audio. *Ar[t], 3*.

De Reus, L. (2013). Smart replicas. Design of an experience with responsive 3D audio, augmented to replias of seven porcelain cups and saucers. Delft University of Technology, Industrial Design Engineering. Delft University of Technology.

video: https://www.youtube.com/watch?v=enR1Ggbuf_8

27. The meSch Loupe (Allard Pierson Museum, Amsterdam)

The meSch Loupe, developed by Waag Society for the meSch project, is a sort of magnifying glass providing information on the object it is pointed to (like images, animations and texts) and also guiding the visitor through thematic tours in the exhibition (Figure 175). It has been used in Allard Pierson Museum (Amsterdam) in the context of the exhibition about Ancient Greek. The visitor is offered the device at the beginning of the visit. When held upright, it shows the outline of an object that is present in the exhibition. Matching the right object with the outline that is shown in the Loupe, content related to the object is provided. The content can be explored in depth by tilting the loupe right or left to more forward or backward in it. At the end of this interaction, the outline of another object is shown, representing the next object in the thematic tour.

Date: 2013
Location: Allard Pierson
Designers/Developers/Researchers: Dick van Dijk, Karien Vermeulen (concept development); Mickael Boulay (design); Lodewijk Loos (developer); Esther v.d. Bijl-Wind (project manager)

Figure 175 A visitor interacting with the Loupe in the Greek Gallery of Allard Pierson Museum (source: meSch project, 2015).

References

Petrelli, D., Not, D., Damala, A., van Dijk, D., & Lechner, M. (2014). meSch - Material Encounters with Digital Cultural Heritage. In *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection* (Vol. 8740, pp. 536-545). Springer International Publishing.

Damala, A., Hornecker, E., van der Vaart, M., van Dick, D., & Ruthven, I. (2016). The Loupe: Tangible Augmented Reality for Learning to Look at Ancient Greek Art. *Mediterranean Archeology and Archaeometry, XVI*(5).

meSch project. (2015, 10 29). *meSch - Smart Object Enhanced Museum Exhibition: Atlantik Wall at the Museon*. Retrieved 2015, from meSch - Material Encounters with Digital Cultural Heritage: http://www.mesch-project.eu/smart-object-enhanced-museum-exhibition-atlantik-wall-at-the-museon/

Video: https://vimeo.com/88233719

28. The meSch Loupe, Seal Hunting in the Museum (Museon, The Hague)

The meSch Loupe is an interactive magnifying glass developed by the Waag Society for the meSch project. It consists of a smartphone that is hidden in it. It has been used in the museum Museon (The Hague), in the context of an exhibition for children about the Inuit of Greenland, both to facilitate wayfinding and to provide information about the objects. Several markers were distributed on the floor of the exhibition, some of them closer to the objects (
Figure 177). The markers far from the objects were used to guide the visitors to the objects. Holding the loupe on one of these markers, a virtual guide (a polar bear or a seal) is visualized in the loupe (
Figure 176), showing the right direction to reach the next object in the story line. Two different story lines are associated to the two different guides but both regards hunting in Greenland as a means of subsistence. Holding the loupe on a market that is close to an object, information about the object are provided.

Date: 2013
Location: Museon, The Hague
Designers/Developers/Researchers: Waag Society

Figure 176 The Loupe a Museum, The Hague (source: http://mesch-project.eu/seal-hunting-in-the-museum-testing-a-mesch-prototype/).

Figure 177 Visitors interacting with the Loupe in Museum, The Hague (source: http://mesch-project.eu/seal-hunting-in-the-museum-testing-a-mesch-prototype/).

References

Kockelkorn, H. (2013, September 5). *meSch - Seal hunting in the museum, testing a meSch prototype.* Retrieved 2015, from meSch: http://www.mesch-project.eu/seal-hunting-in-the-museum-testing-a-mesch-prototype/

29. The meSch Loupe, Hunt Museum, Limerick

The meSch Loupe, first tested in the Museon museum and in the Allard Pierson museum (see projects 27 and 28), has then been repurposed for the Hunt museum to make the exploration of the collection more interactive. In the Hunt museum the loupe is given a different shape and appeal (Figure 178) and it is used to offer already existing tours ("History of Ireland in 10 objects" and "Architecture in the Hunt Museum"), originally provided through brochures or told by staff, in a more innovative way (Figure 179). The solution was developed through the collaboration between the Hunt museum and the Interaction Design Center of the University of Limerick.

Date: 2015
Location: Hunt Museum, Limerick
Designers/Developers/Researchers: Hunt museum,

Figure 178 The new shape of the meSch Loupe in the Hunt Museum (source: http://mesch-project.eu/the-loupe-strikes-again-revealing-narratives-in-a-museum-in-ireland/).

Figure 179 A visitor interacting with the Loupe (source: http://mesch-project.eu/the-loupe-strikes-again-revealing-narratives-in-a-museum-in-ireland/).

References

Maye, L. (2016, January 11). *meSch - The Loupe strikes again at the Hunt Museum in Ireland.* Retrieved from meSch: http://www.mesch-project.eu/the-loupe-strikes-again-revealing-narratives-in-a-museum-in-ireland/

30. Historical Orchestra

The "Historical Orchestra" installation is an interactive designed to enhance the experience of a 16th century Turkish Manuscript documenting through illustrations an arts and crafts festival organized by the Sultan Murad III for the circumcision celebration of his son. It is made up of three tangible musical interfaces that replicate the musical instruments represented in the illustration, and a screen displaying an animation inspired to the illustrations contained in the manuscript with a two-pages layout (Figure 180). Using the tangible musical interfaces, the visitor can impersonate the role of players and make a projected animation goes on (the players move forward; the audience increases in number of people; the Sultan appears on the Palace window when all the players arrive there) (Figure 181).

Date: 2011
Location: Topkapi Palace Museum in Istanbul, Turkey
Designers/Developers/Researchers: Ferhat Şen and Lily Diaz

Figure 180 The historical orchestra installation (source: Farhat et al., 2011).

Figure 181 Scheme representing the functioning of the installation (how he animation progress according to the interactions of visitors) (source: Farhat et al., 2011).

References

Ferhat, S., & Diaz, L. (2011). Historical Orchestra: An Interactive Audio/visual Cultural Experience. In L. Ciolfi, K. Scott, & S. Barbieri (Ed.), *Proceedings of the International Conference "Re-thinking technology in Museums 2011: Emerging Experiences"*. Ireland: University of Limerick.

Sen, F., & Dişçioğlu, S. (2011). Design of an Interactive Cultural Heritage Experience: the Historical Orchestra. *Proceedings of 17th International Symposium on Electronic Art.* Instambul, Turkey.

Video: https://vimeo.com/18720674

31. "Interactive ceramic figurines", Hunt Museum, Limerick

It represents one of the first prototypes (low-fi) of tangible interaction designed for a museum context (Hunt Museum, Limerick) (Figure 182). Two RFID tagged ceramic figurines are placed in a drawer. The visitor can open the drawer, pick up the objects and placing them on the place on top of the drawer. Different visual descriptions and sounds background are provided near the object according to which figurine the visitor places on top of the drawer.

Date: 2002
Location: Hunt Museum, Limerick
Designers/Developers/Researchers: L. Ciolfi, and L. Bannon

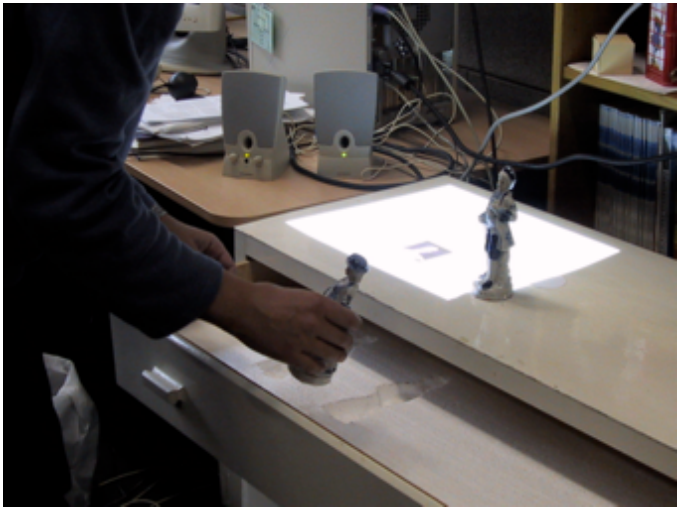


Figure 182 The interactive ceramic figurines prototype (source: Ciolfi et al., 2002).

References

Ciolfi, L., & Bannon, L. (2002). Designing interactive museum exhibits: enhancing visitor curiosity through augmented artifacts. *Proceedings of the European Conference on Cognitive Ergonomics (ECCE11)*. Catania.

32. ec(h)o: Situated Play in a Tangible and Audio Museum Guide

ec(h)o is a museum guide prototype that integrates a tangible interface, audio display and adaptive modelling. At the beginning visitors choose three cards from a set of a cards on table and give them to an attendant. These cards represent different topics related to the exhibition The attendant gives the visitors a tangible interface consisting of a wooden cube with three coloured sides (Figure 183), and a pair of headphones connected to a small bag the visitor must carry with them containing a device for position tracking and audio receiving. While the visitor moves through the exhibition, he can hear immersive ambient sounds providing a context for the nearby objects (
Figure 184). As he goes closer to a objects display, the soundscape fades and three audio prefaces are presented coming from different directions (left, centre, right). Rotating the cube so that the selected side faces upward, the visitor can hear more in-depth pieces of information that are linked to a specific audio prefaces (Figure 185). Then, the visitor is provided again with three audio prefaces (a new preface substitutes the previously selected one). The audio prefaces and in-depth information are automatically selected by the systems on the basis of the visitor's movement in the exhibition, the audio files previously listened and the visitor's topic preferences. The audio contents consist of the voices of natural historians and scientists providing informal comments related to the objects on display. In many cases, the prefaces consist of puns, riddles and words plays.

Date: 2007
Location: Canadian Museum of Nature in Ottawa
Designers/Developers/Researchers: Ron Wakkary and Marek Hatala

Figure 183 The wooden cube tangible interface (source: Wakkary et al., 2007).

Figure 184 The visitor hears ambient sounds as he moves in the exhibition connected to the nearby cases (source: Wakkary et al., 2007).

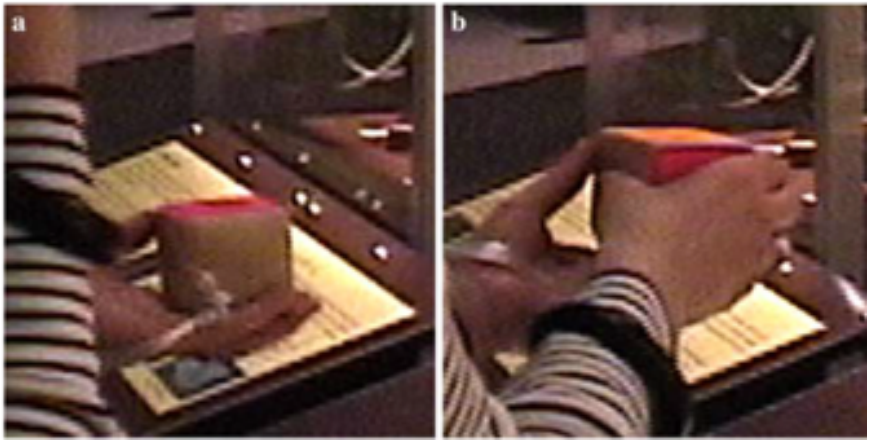


Figure 185 The visitor rotates the cube to select different audio options (source: Wakkary et al., 2007).

References

Wakkary, R., & Hatala, M. (2007). Situated play in a tangible interface and adaptive audio museum guide. *Personal Ubiquitous Computing, 11*(3), 171-191.

33. Philharmonic Museum, "waltz-dice-game"

In “Waltz-dice-game” people can experience a modern version of the dice game “The Instant Minuet and Polonaise Composer” invented by the German violist and composer J.P. Kirnberger, consisting in throwing dice for generating complete music compositions from pre-composed options.
The game is quite simple. Two dice (with the symbols flute and cello) are alternately rolled onto two tables (Figure 186). A special software interprets the results and converts the data into pre-determined melodic elements. After eight rolls of the dice, these melodic elements are combined into two parts and augmented with waltz accompaniment.

Date: 2003
Location: Philharmonic Museum, Vienna
Designers/Developers/Researchers: CheckpointMedia GMBH (http://www.checkpointmedia.com/en/projects/haus_der_musik)

Figure 186 Waltz dice game at the Philharmonic Museum, Vienna (source: checkpointmedia, n.d.).

References

WIENER PHILHARMONIKER. (2003, January 1). *Compose Your Own Waltz at the Vienna Philharmonic Museum*. Retrieved 2015, from Vienna Philarmonic Orchestra: https://www.wienerphilharmoniker.at/orchestra/philharmonic-journal/year/2003/month/1/blogitemid/505

checkpointmedia. (n.d.). *checkpointmedia | Haus der Musik.* Retrieved 2015, from checkpointmedia: http://www.checkpointmedia.com/en/projects/haus_der_musik

34. Rfid card, Allard Pierson Museum, keys to Rome

In the "Keys to Rome" exhibition at Allard Pierson Museum, RFID cards are used for personalization of the contents in digital installation placed near objects.
At the beginning of the exhibition, the visitor can take a card and associate to it (through a touch screen station at the beginning), one of the three possible perspectives (Egyptian, Roman, Lowland) regarding the objects exhibited. Then, this card can be used as a key to access digital content (text, images, 3D) in the various technological installations according to the chosen perspective (Figure 187). Technological stations are placed in front the main objects in the exhibition.

Date: 2014
Location: keys to Rome exhibition, Allard Pierson Museum, Amsterdam
Designers/Developers/Researchers: [Allard Pierson Museum]

Figure 187 A visitor interacting with an interacting station using a card
(source: http://keys2rome.eu/downloads/CatalogK2R.pdf).

References

Pescarin, S., & al., e. (Eds.). (n.d.). *Keys to Rome. Roman Culture, Virtual Museums.* Retrieved 2015, from KEYS2ROME | Keys2Rome is a unique international exhibition on Roman culture: http://keys2rome.eu/downloads/CatalogK2R.pdf

35. Engaging Constable: Revealing Art with New Technology, Tate Britain

In "Engaging Constable" walking towards an interactive replica of Constable's "Salisbury Cathedral from the Meadows" painting people can explore the underlying x-rays layers and analyse the artist's pentimenti, "the underlying images beneath overpainted alterations" (Figure 188). The underlying layers are displayed more or less in correspondence of the silhouette of the visitor.

Date: 2006
Location: Tate Britain
Designers/Developers/Researchers: Dirk vom Lehn, Jon Hindmarsh, Paul Luff & Christian Heath

Figure 188 A visitor interacting with the interactive replica of Constables' painting (source: http://www.mickeystretton.com/portfolio/tate-britain/).

References

Lehn, D. V., Hindmarsh, J., Luff, P., & Heath, C. (2007). Engaging Constable: revealing Art with New Technology. *CHI CONFERENCE*, 2, pp. 1485-1494.

http://allofus.com/work/tate-britain/constable-exhibition/

Mickey Stretton. (n.d.). *Mickey Stretton | Creative Direction for Experiencial and digital Projects >> Tate Britain.* Retrieved 2015, from Mickey Stretton | Creative Direction for Experiencial and digital Projects: http://www.mickeystretton.com/portfolio/tate-britain/

36. Tangible interfaces to explain Gaudı's use of ruled-surface geometries: Interactive systems design for haptic, nonverbal learning

A tangible interface is designed to make the modelling methods used by Gaudi to build the "rectangular" double helix columns in the Sagrada Familia easier to understand compared to a verbal description or complex geometric representation. The procedure used by Gaudi consists in counter rotating two rectangles around the common centre point and simultaneously translating them along the z-axis (Figure 189).
The tangible interface proposed in this installation consists of a desktop turntable on which two bi-dimensional profiles are presented (Figure 190). When the user rotates one profile, the other profile is automatically counter rotated. At the same time a computer screen shows the generated column segment.

Date: a2002
Location:
Designers/Developers/Researchers: T. Fischer, C. Herr, M. Burry, and J. Frazer.

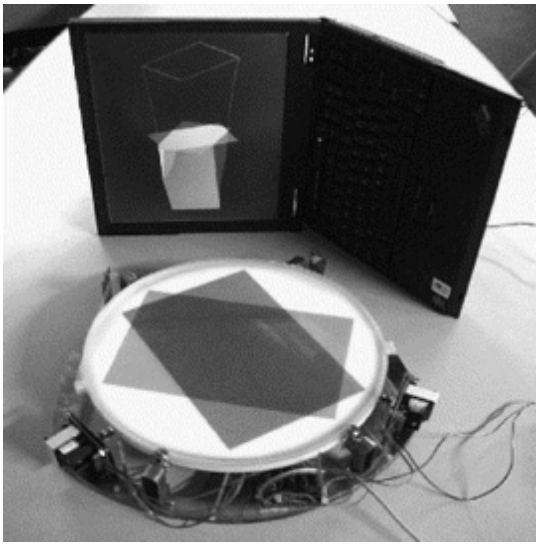


Figure 189 The components of the installation (source: Fischer et al., 2002).

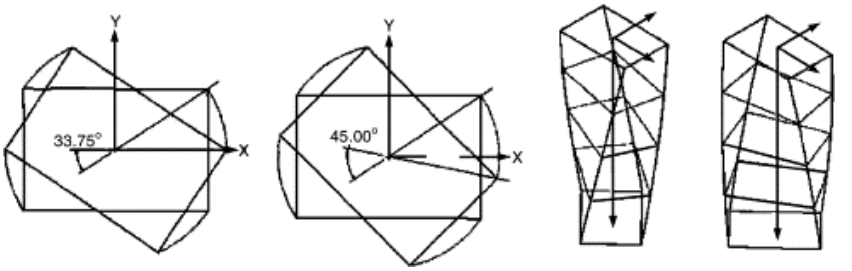


Figure 190 The procedure used by Gaudi to build the "rectangular" double helix columns in the Sagrada Familia (source: Fischer et al., 2002).

References

Fischer, T., Herr, C., Burry, M., & Frazer, J. (2002). Tangible Interfaces to Explain Gaudi's Use of Ruled-Surface Geometries: Interactive Systems Design for Haptc, Non-Verbal Learning. *Automation in Construction, 12*, 467-471.

37. Diplomacy and Sevres Porcelain, Prestige and the French art of living in the 18th century

In the exhibition "Diplomacy and Sevres Porcelain", developed by LOUVRE – DNP Museum Lab, visitors can see items of Sévres porcelains made in France in 18th century, learn the technique to make them and the customs of court table etiquette. Different separated interactive installations have been created for this installation.
Among these, there is one that combines tangible interaction (interactive pamphlets) and spatial augmented reality. The installation consists of a multimedia table display, and a series of folding paper pamphlets on the side of the table, each corresponding to different types of objects (Figure 191). When a pamphlet is picked and put on the table, the systems recognize the pamphlet, the page it is opened to, and further information is projected onto the table or onto the pamphlet itself. Turning the page allow to go to the next layer of information (Figure 192). The purpose of the installation is to facilitate the access to the information, immediately understanding the structure and amount of information available.

Date: 2011
Location: Museum Lab gallery at Gotanda, Tokyo, for the seventh exhibition of the Louvre–DNP Museum Lab
Designers/Developers/Researchers: Ueda T., Hanai A., and Kamei K

Figure 191 The interactive installation consisting of a multimedia table display, and a series of folding paper pamphlets on the side of the table (source: http://www.museumlab.eu/exhibition/movie/movie07.html).

Figure 192 Interacting with a pamphlet on the table, the visitor gets information (source: http://www.museumlab.eu/exhibition/movie/movie07.html).

References

Ueda, T., Hanai, A., & Kamei, K. (2011). Intuitively Interactive Pamphlets. Using Augmented Reality. *ACM International Conference Proceeding Series.* ACM.

Seventh presentation Thematic approaches | Current presentation | Louvre - DNP Museum Lab. (n.d.). Retrieved 2015, from Louvre - DNP Museum Lab: http://www.museumlab.eu/exhibition/07/development.html

video: http://www.museumlab.eu/exhibition/movie/movie07.html

38. The Reading Glove: Designing Interactions for Object-Based Tangible Storytelling

It is a prototype of a tangible interactive narrative system consisting of a wearable RFID based glove and a set of RFID tagged objects (Figure 193). The glove allows the user to extract fragments of a stories in the form of audio narration from the object just grasping and holding them. Some objects have multiple story fragments associated with them that can be revealed through repetitive interactions. Each story fragment has a direct reference to the associated object. In addition, to help the reader to reconstruct the overall story, the various story fragments contain "conceptual hyperlinks" that can be used as a guide in the exploration and reconstruction of the story. The story being told is about a spy that has to escape because he has been betrayed by his own agency for political reason.

Date: 2010
Location: research laboratory
Designers/Developers/Researchers: Tanenbaum J., Tanenbaum K., and Antle A.

Figure 193 The reading glove installation (source: https://www.youtube.com/watch?v=xUiBgPgvTNU).

References

Tanenbaum, J., Tanenbaum, K., & Antle, A. (2010). The Reading Glove: Designing Interactions for Object Based Tangible Storytelling. *ACM International Conference Proceedings Series.* ACM.

video: https://www.youtube.com/watch?v=xUiBgPgvTNU

39. "The painting, a material object"

This installation (Figure 194) is part of the exhibition "El nino azul, Goya and the Spanish painting" developed by LOUVRE – DNP Museum Lab and aims to allow the visitor to explore the materiality of the painting. This includes the possibility of learning about the structure of the painting (i.e. the various layers that compose it), but also about how external factors (e.g. time, humidity, light) can affect the appearance of the painting. It is made up a series of eight tangible tokens, a screen and a hotspot where tangible tokens can be placed. Four tokens represent a specific layer of the painting (while the others represent the external conditions. Each token is shaped in such a way to recall the concept they aim to represent.
The visitor can get a visual representation about each layer that composes the painting by placing the related token (and combination of tokens) on the hotpot, accompanying by a textual description (Figure 195). By placing a token representing external factors, a visual representation and textual description of how the painting is affected is shown on the screen (Figure 196). The rotation of the tokens on the hotspot allows for the change of the language used.

Date: 2002
Location: Museum Lab gallery at Gotanda, Tokyo, for the ninth exhibition of the Louvre–DNP Museum Lab
Designers/Developers/Researchers: LOUVRE – DNP Museum Lab

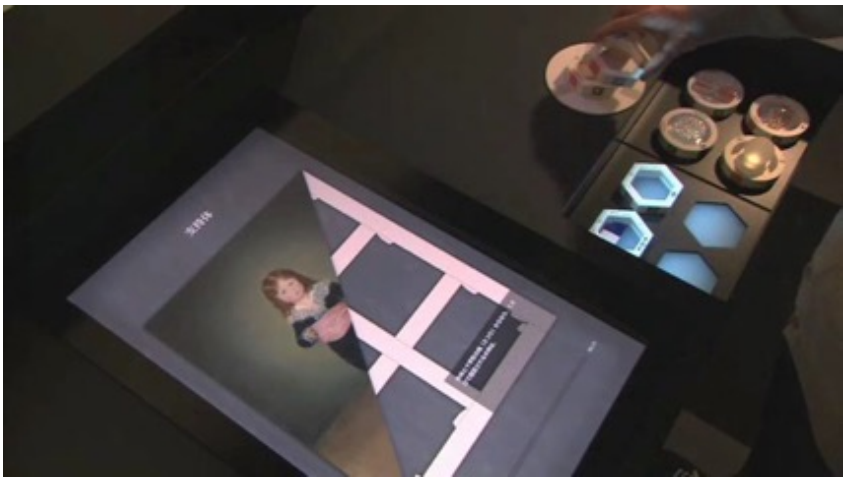


Figure 194 "The painting, a material object" installation (source: http://www.museumlab.eu/exhibition/movie/movie09.html).

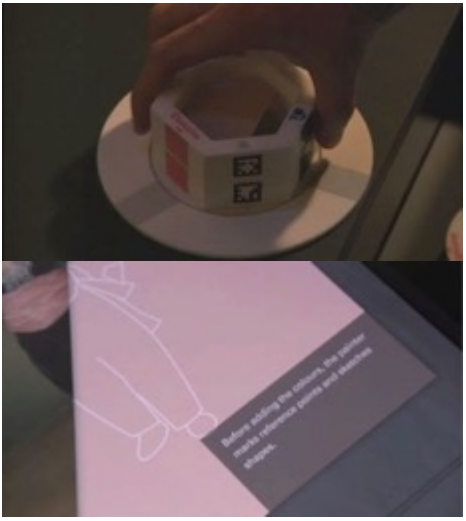


Figure 195 combining specific tokens the visitor can see the different layers that make the painting (source: http://www.museumlab.eu/exhibition/movie/movie09.html).

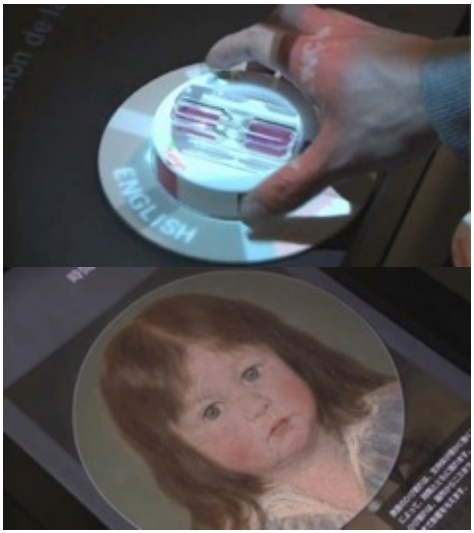


Figure 196 By placing a token representing external factors, a visual representation and textual description of how the painting is affected is shown on the screen (source: http://www.museumlab.eu/exhibition/movie/movie09.html).

References

Ninth Presentation Thematic approaches | Louvre - DNP Museum Lab. (n.d.). Retrieved 2015, from Louvre - DNP Museum Lab: http://www.museumlab.eu/exhibition/09/development.html

video: http://www.museumlab.eu/exhibition/movie/movie09.html

40. Musical drawers, The Fryderyk Chopin Museum

The "musical drawers" interactive (Figure 197) at "The Fryderyk Chopin Museum" in Warsaw consists of a set of drawers containing some Chopin's original scores, and a tabletop surface with speakers where projections are visualized. Opening a drawer, the visitor can observe some scores, listen to associated music and see projections of score details on the tabletop.

Date: 2010
Location: The Fryderyk Chopin Museum in Warsaw
Designers/Developers/Researchers: Andy Wheatcroft Producer

Figure 197 "Musical drawers" interactive at the Chopin Museum in Warsaw (https://www.designboom.com/design/chopin-museum/).

References

Andy Wheatcroft. (n.d.). *The Fryderyk Chopin Museum*. Retrieved 2015, from Andy Wheatcroft's Portfolio: https://web.archive.org/web/20150501212340/http://andywheatcroft.co.uk/96300/773024/projects/the-fryderyk-chopin-museum

Chin, A. (2010, March 28). *chopin museum*. Retrieved 2015, from designboom magazine | your first source for architecture, design & art news: https://www.designboom.com/design/chopin-museum/

videos:
https://www.youtube.com/watch?v=4-QNopPug90
https://www.youtube.com/watch?v=jynDJIAcfZg

41. Retracing the past: mixing realities in museum settings, SHAPE project

The exhibition "Re-Tracing the Past: exploring objects, stories, mysteries" took place in 2003 at the Hunt Museum (Limerick), a museum hosting the collection of artworks that belonged to the Hunt family. The aim of the exhibition was to add value to some mysterious objects existing in the Museum, and to encourage the personal interpretation by the visitors. Since John Hunt, the assembler of the collection, had a study room, it was decided to create a two rooms exhibition, one of which was indeed the Study Room while the other was the Room of Opinion. Ubiquitous computing was used instead of desktop computing to integrate the interactive installations in a seamless way into the setting. The Study Room (Figure 198), whose purpose was to support the exploration of the objects from multiple points of view and in a playful way, was populated with pieces of antique furniture (like a trunk, a desk, a radio) that were made interactive (Figure 199; Figure 200; Figure 201; Figure 202). Placing keycards (Figure 203) each representing one object (that were taken by the visitors at the entrance) at specific interactive installation, and interacting with specific controls, visitors could trigger various information about the specific object. The Room of Opinion, instead, allows the visitors to handle physical replicas of the objects and also to record a personal opinion and interpretation about the mysterious objects (Figure 204). These recordings contribute to the exhibition, as they can be listened by the later visitors through the radio installation in the Study Room.

Date: 2003
Location: Hunt Museum, Limerick
Designers/Developers/Researchers: Fraser, Mike and Bowers, John and Brundell, Pat and O'Malley, Claire and Reeves, Stuart and Benford, Steve and Ciolfi, Luigina and Ferris, Kieran and Gallagher, Paul and Hall, Tony and Bannon, Liam and Taxén, Gustav and Hellström, Sten Olof

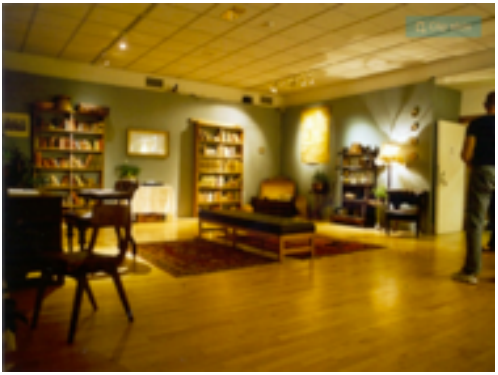


Figure 198 The study Room (source: Fraser et al., 2004)

Figure 199 the interactive trunk (source: Fraser et al., 2004).

Figure 200 the virtual touch machine (source: Fraser et al.,2004).

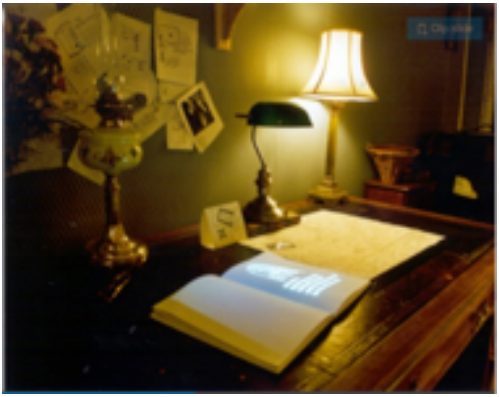


Figure 201 the interactive desk (source: Fraser et al., 2004).

Figure 202 the interactive radio (source: Fraser et al., 2004).

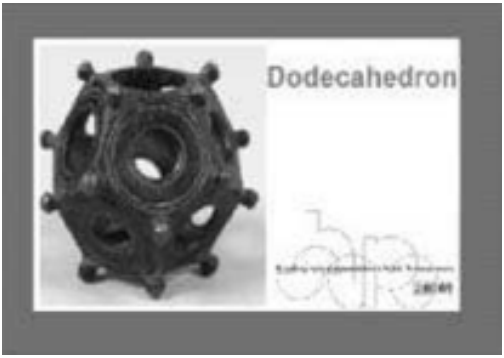


Figure 203 keycards representing objects (source: Fraser et al., 2004).

Figure 204 a visitor recording personal opinions about an object in the room of opinions (source: Fraser et al., 2004).

References

Fraser, M., Bowers, J., Brundell, P., O'Malley, C., Reeves, S., Benford, S., . . . Hellström, S. O. (2004). Re-Tracing the Past: Mixing Realities in Museum Settings. *Conference on Advances in Computer Entertainement (ACE)*. Singapore.

42. Interactive histories

This project was developed to inspire the plans for rearranging the Museum of Islamic Art in Berlin. It allows visitors to be guided in thematic tours in the museum, to explore individual objects (their meaning, context and biography) and understand the connections between the different objects in the tour.
The technology makes use of physical tokens (storytellers) and fixed capacitive screens disseminated around the exhibition in correspondence with most of the artefacts. Storytellers are abstract representations of some historic objects that are present in the museums (Figure 205). They offer different thematic tours through the objects of the exhibition and allow to access information about them at specific screens.
At the entrance a welcoming station is provided along with a series of different storytellers (Figure 206). Here a screen provides the visitor with an overview of different thematic tours and allow him to filter the specific level of background knowledge and age (Figure 207). Placing a storyteller on the screen an introduction about the specific thematic tour is provided (Figure 208). Then a map is displayed showing the location of the various objects in the tour and highlighting the location of the next object (Figure 209). When the visitor reaches the object indicated in the map a nearby screen displays the position of the object in a timeline and geographical map (Figure 210). As the visitor places the storyteller on the screen information about it or a question are provided. Rotating the storyteller clockwise deeper level of information are provided. Going on with the thematic tour, for each object seen in the tour an icon is shown in the screen so that the visitor can understand the relations between objects (Figure 211). The objects can be browsed again placing the storytellers on the timeline. When the visitor reaches the object corresponding to that represented by the storyteller a representation of the object is provided (Figure 212). Placing the token on it, the area below is shown enlarged and different questions are visualized. After the visit, the storyteller can be taken home (Figure 213) and be used to access information using a tablet (Figure 214).

Date: 2013
Location: Museum of Islamic Art in Berlin
Designers/Developers/Researchers: Marlene (Umeå University)

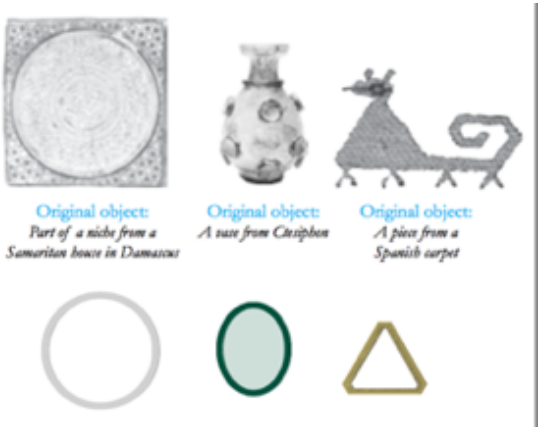


Figure 205 The physical token (storytellers) and the original object they represent (source: Kettner et al., 2013).

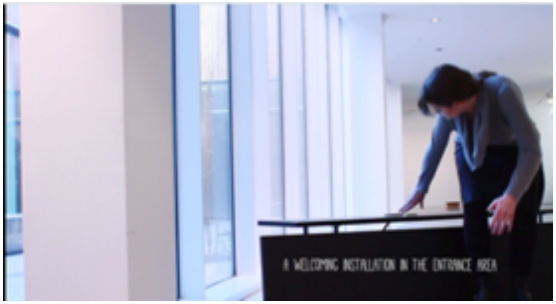


Figure 206 Welcoming station at the entrance (source: https://vimeo.com/67016141)

Figure 207 The welcoming station allow to filter specific level of background knowledge and age
(source: https://vimeo.com/67016141)

Figure 208 An introduction to the thematic tour associated to the specific token is provided
(source: https://vimeo.com/67016141)

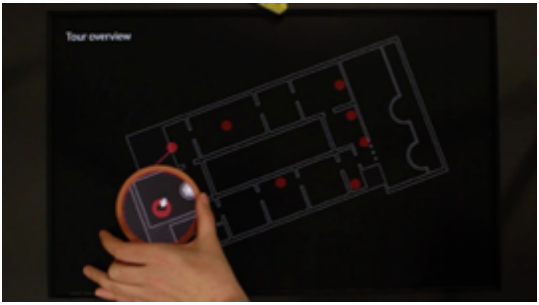


Figure 209 Map showing the location of the objects in the thematic tour (source: https://vimeo.com/67016141)

Figure 210 The screen (placed nearby an object on display) shows the position of the object in a timeline and geographical map). The tangible token allows to access deeper information. (source: https://vimeo.com/67016141)

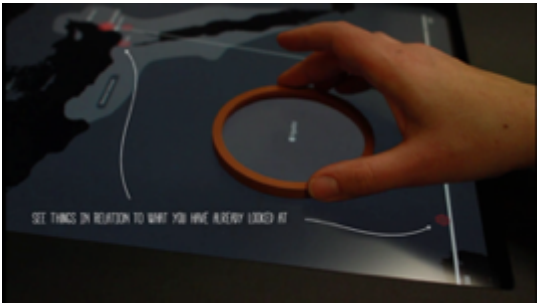


Figure 211 The previously seen objects are shown in the timeline and map (source: https://vimeo.com/67016141)

Figure 212 The installation referred to the object the storyteller is representation of
(source: https://vimeo.com/67016141)

Figure 213 The tangible storyteller can be taken home (source: https://vimeo.com/67016141)

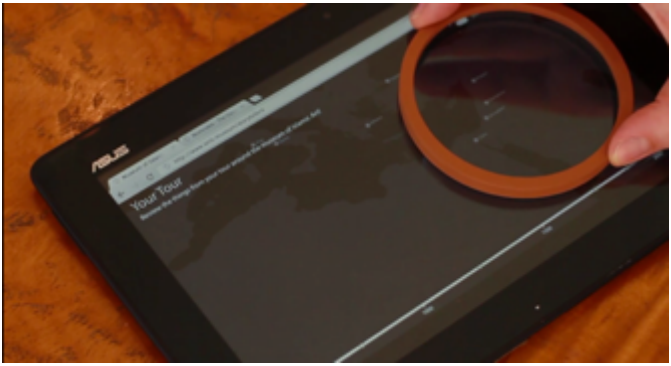


Figure 214 Storytellers can be used at home together with a tablet (source: https://vimeo.com/67016141)

References

Kettner, M. (2013). Interactive histories: How might interactive exhibtion elements improve the understanding of Islamicate history?.Umeå Institute of Design| Umeå University (Master's Dissertation).
http://umu.diva-portal.org/smash/get/diva2:629607/FULLTEXT01.pdf

video: https://vimeo.com/67016141

43. Supportare l'esperienza di visita ai musei attraverso oggetti interattivi e interfacce tangibili. Il caso studio del museo delle culture di Lugano

This installation has been developed for the Museo delle Culture di Lugano, an anthropological museum exhibiting objects and photos related to ethnic art of the "Mari del sud". The visit represents a trip from India to Polynesia, with each room representing a different region or ethnicity. The installation consists of a series of monitors placed in the various rooms and a mobile tangible object –a ball- with three different symbols on its surface representing a specific visit profile (Figure 215). Through this object the visitor can select a specific profile in front of the monitors and get information accordingly. The three profiles are: nomad, providing curiosities; anthropologists providing scientific information; explorer, providing geographical information (Figure 216).

Date: 2010
Location: Museo delle Culture di Lugano
Designers/Developers/Researchers: Elisabetta Bacconi

Figure 215 Tangible interactive consisting of a monitor, webcam and a tangible object shaped as a ball (source: Bacconi, 2011, August 26)

Figure 216 The three different profiles ant the related icons (source: Bacconi, 2011, August 26)

References

Bacconi, E. (2011, September 5). *TANGIBLE FOR MUSEUM Thesis project II | Elisabetta Bacconi*. Retrieved 2015, from Elisabetta Bacconi | Portfolio: https://web.archive.org/web/20150810062955/http://bettybacconi.info/tangible-for-museum-2/

Bacconi, E. (2011, August 26). Supportare l'esperienza di visita ai musei attraverso oggetti interattivi e interfacce tangibili. Il caso studio del museo delle culture di Lugano. Retrieved 2015, from Share and Discover Knowledge on Linkedin Slideshare: https://www.slideshare.net/bettybacconi/supportare-lesperienza-di-visita-ai-musei-attraverso-oggetti-interattivi-e-interfacce-tangibili-il-caso-studio-del-museo-delle-culture-di-lugano-9019820

44. Challenging Visitors to Move from Memory to Action at the United States Holocaust Memorial Museum

This installation at the Holocaust Memorial Museum consists of a series of desks visitors can sit at to write a hand written pledge about how to face the problem of genocide today (Figure 217). The pieces of paper are then deposited in a glass vitrine, while the same text appears in a big pledge wall projection (Figure 218). "The accumulation of pledges makes a visual statement and encourages the participation of individuals who together form a community of conscience".

Date: 2009
Location: United States Holocaust Memorial Museum
Designers/Developers/Researchers:

Figure 217 Visitor interacting with the installations at the Holocaust Memorial Museum (Conley-Zilkic et al., 2011).

Figure 218 Glass vitrine containing pledges hand written by visitors (Conley-Zilkic et al., 2011).

References

Simon, N. (2009, May 26). *Museum 2.0: Mixing Digital and Physical: The Holocaust Museum's Handwritten Pledge Wall.* Retrieved 2015, from Museum 2.0: http://museumtwo.blogspot.it/2009/05/making-promises-with-mixed-media.html

Simon, N. (2010). *The participatory museum.* Santa Cruz, CA: Museum 2.0.

Conley-Zilkic, B., & Gillette, N. (2011). Challenging Visitors to Move from Memory to Action at the Unite States Holocaust Memorial Museum. *EXHIBITIONIST FALL '11*, pp. 34-38. https://static1.squarespace.com/static/58fa260a725e25c4f30020f3/t/594bd66c29687f4662be43b5/1498142341355/8+EXH_fall11_Challenging+visitors+to+move+from+memory+to+action_zillkic_gillette.pdf

45. Interactive stela, Manchester Museum

The installation (Figure 219), at the Manchester Museum, consists of a nylon replica of the limestone Stela of Hesysunebef that is endowed with touch sensors so that visitors can touch the different symbols, objects or characters engraved in the stela and in so doing trigger images, texts and audio contents played on a nearby screen (Figure 220). The original object is present in the museum in another floor.

Date: 2012
Location: Manchester Museum
Designers/Developers/Researchers: Professor John Tyrer (Loughborough University) and Manchester Museum

Figure 219 Interactive stele installation at the Manchester Museum (source: the author).

Figure 220 The screen providing information (source: the author).

References

Sportun, S. (2014). The Future Landscape of 3D in Museums. In N. Levent, & A. Pascual-Leone (Eds.), *The Multisensory Museum. Crossing Disciplinary Perspective on Touch, Sound, Smell, Memory and Space.* Rowman & Littlefield.

Ancient hieroglyphics meet cutting-edge technology at Loughborough University. (2012, November 12). Retrieved 2014, from Loughborough University: http://www.lboro.ac.uk/departments/mechman/news/hieroglyphics.html

46. Social Activities with offline tangibles at an interactive painting exhibit in a children's cultural centre

In "Social Activities with offline tangibles at an interactive" a tangible interactive system is developed to make children (3-6 years old) understand the topic of biodiversity, how people's actions affect other living organisms as well as how different species affect the larger ecosystem. The installation requires children to colour various animals that then become part of an overall picture having a butterfly shape.
It consists of a screen projection, an interactive touch screen and a physical paintbrush, 10 paint pots, tangible wooden cards with inscribed drawings of animals, a card slot and an ambient audio track (Figure 221). When inserted in the card slot, the card is recognized and the outline of the animal to be painted is shown both on the small and the big screen. Painting is done using the brush on the small screen, and placing the brush in a different pot to change colour. When the card is removed from the slot, it becomes part of a giant butterfly image projected on the big screen.

Date: 2012
Location: Ark, a cultural centre for children in Dublin, Ireland
Designers/Developers/Researchers: Loraine Clarke, and Eva Hornecker.

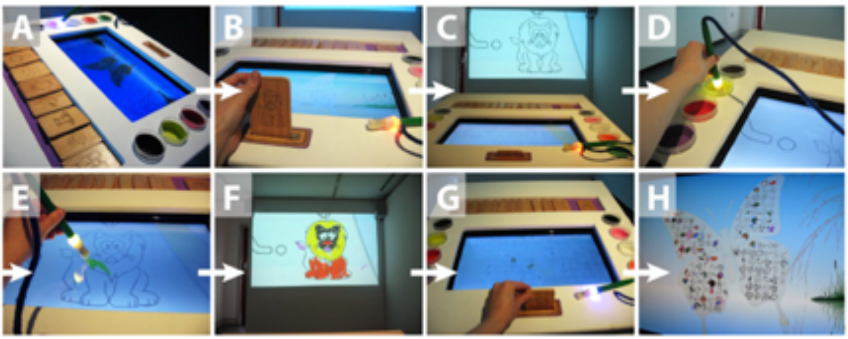


Figure 221 The tangible interactive systems and the various steps of interaction with it (source: Clarke et al., 2015).

References

Clarke, L., & Hornecker, E. (2015). Social Activitis with offline tangibles at an interactive painting exhibit in a children's cultural centre. *Proceedings of the 2015 British HCI Conference.* Lincoln, Lincolnshire, United Kingdom.

47. Wonder Objects

Date: 2005
Location:
Designers/Developers/Researchers: Rawat, T. J.

"Wonder Objects" refers to interactive interfaces designed in the context of a "Museum of Information Technology" exhibiting past writing and calculation machines developed by the Olivetti company in Italy.
Different separate tangible interactives have been designed and prototyped with the purpose of fostering learning through discovery and wonder.

The "Magic Mirror" (Figure 222) interactive consists of a typewriter place on a pedestal, and a large mirror a little distance ahead. In the idle state the visitor can hear sounds of tapping, and the object is spotlit. As the viewer goes closer to the object, the intensity of the light varies according to his proximity, and the sounds of tapping stop. The mirror reflects the typewriter, but as the viewer goes closer it stops being a reflecting surface and turn into a backlit display, showing different content according to the sensors activated on the floor by the visitor.

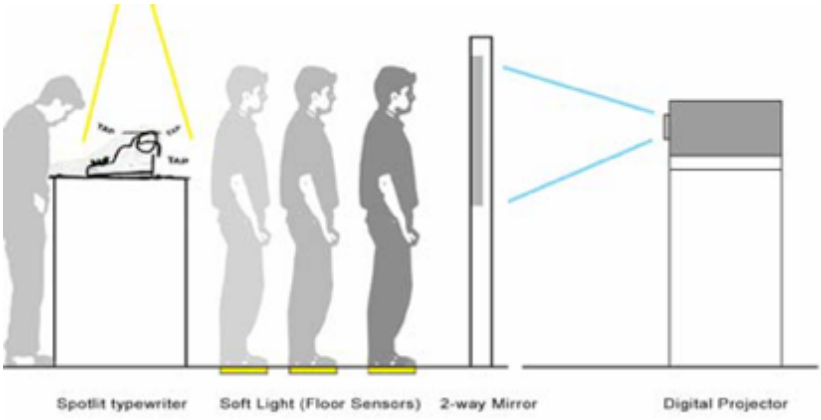


Figure 222 The Magic Mirror interactive (source: Rawat, 2005).

The "Whispering Table Installation" (Figure 223) is table with small peep-holes on it, each containing artefacts and a small digital screen, and a viewing lens held by the viewer. In the idle state, a flicker of

lights and a murmur of sounds emanates from the table. These effects stop as the viewer goes closer to the table, leaving the peep-holes only dimly illuminated. When the visitor places a viewing lens upon one of the peep-holes, the specific peep-hole bright up and audio/video content is triggered.

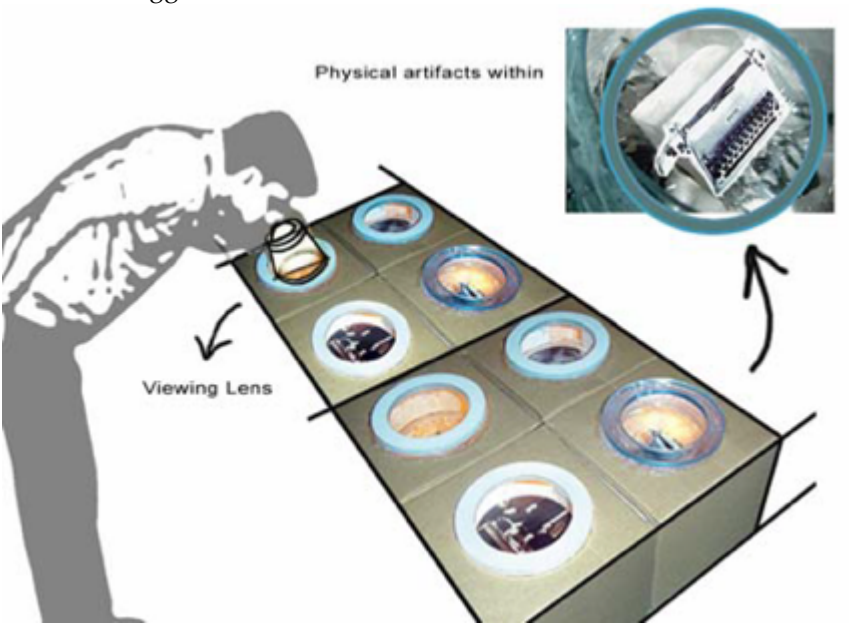


Figure 223 The whispering table installation (source: Rawat, 2005).

"The interactive book" (Figure 224) consists of a typewriter placed on a pedestal with a book in front of it, and a fragmented projection screen behind, consisting of papers suspended from the ceiling. The video provides information about the object in the form of text and images. Flipping some pages of the book, some video projections take place on the screen. The papers that made up the screen "are placed at varying distances from one another, creating an illusion of depth and producing a fragmented image of the whole. When viewed from the front, the viewer sees the whole image, but when viewed from any other angle, these floating papers appear like illuminated windows, animating the space in the periphery of the key exhibit. This fragmentation is suggestive of different ways of looking at the key object on display, as well creating an atmosphere of drama around it".

Figure 224 the interactive book installation (source: Rawat, 2005).

"Wonder Objects" (Figure 225) consists of a typewriter placed on a pedestal. In the idle state, the visitor sees and hears hands typing on the machine's keyboard; but as the viewer goes closer another video is triggered showing a set of instructions to interact with it. Pressing specific hotkeys on the typewriter, video content is projected on the typewriter's sheet of paper animating the object.

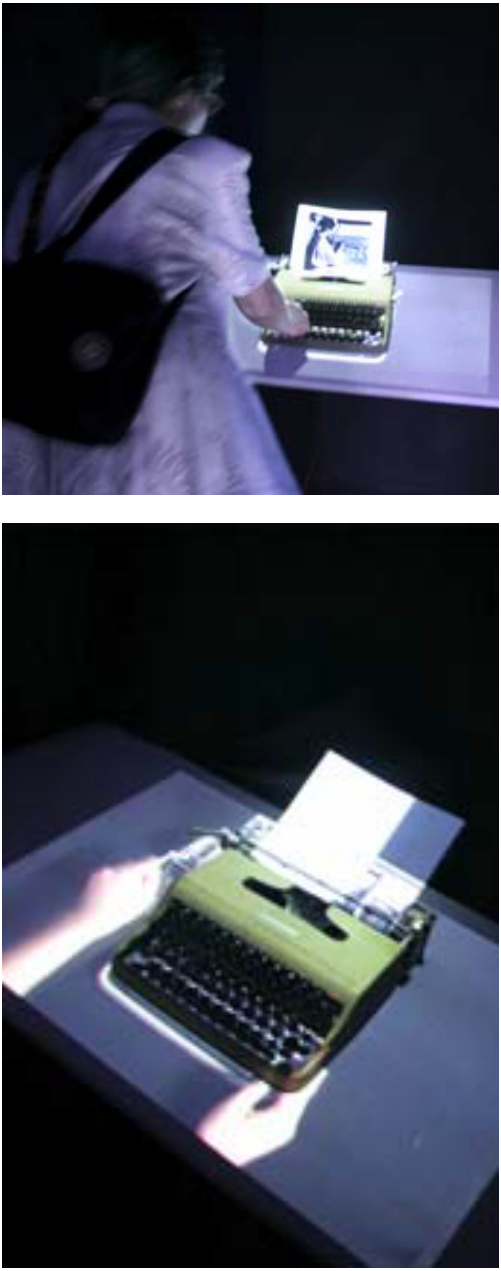


Figure 225 Wonder Objects installation (source: Rawat, 2005).

References

Rawat, T. (2005). Wonder Objects - Magic and Interactive Storytelling. *COGNITIVE SCIENCE RESEARCH PAPER - UNIVERSITY OF SUSSEX CSRP*, *577*, 91-96.

48. ʔeləẃkʷ- Belongings: A Tangible Interface for Intangible Cultural Heritage

ʔ eləẃkʷ - Belongings is an interactive installation developed for an exhibition at the Museum of Anthropology (MOA) at the University of British Columbia in Vancouver, Canada. The exhibition is about *ćəsnaʔəm*, a Musqueam's ancient village site on which part of Vancouver was built.

The aim of the interactive is to show how the past Musqueam's culture and traditional knowledge continues today. The interactive is made of a tangible tabletop with two activator rings on top, a belongings cart made of six replicas of ancient belongings excavated from ćəsnaʔ əm (net weight, celt, slate blade, harpoon, a decorated fragment, as well as a piece of cedar bark), and six contemporary everyday items (ice cube, keys, status card, tide chart, quarters, and a Coke can) (Figure 226). Three screens are placed on the walls around the table and the belongings cart.

The table shows a top down view of a fish-cutting table with various items represented on top and supplies for fishing and fish preservation represented around (Figure 227).

When a visitor places a belonging in one of the rings on the table, basic information about that belonging and its use appears on the table (Figure 228). Additional images of similar belongings from the LOA collections database appear on the nearby monitor so visitors can see other examples of this type of belonging.

Visitors can connect a belonging to its related area of the fish-cutting image (Figure 229). When the correct section of the image is located, information about the belonging's use and place in Musqueam culture appears.

Visitors can further explore the belongings by connecting an ancient belonging to its contemporary match to learn about the continuity of Musqueam culture from the past to present day, learning what has changed and what has remained (Figure 230). When visitors connect two seemingly unrelated belongings from the past and present day, a series of texts, contemporary images, historical documents, and quotes from community members appear on the table.

Once a visitor has fully explored a belonging though these interactions and activities, they gain access to a short video of a Musqueam community member sharing their own lived experiences, often relating important moments of learning about history and culture.

ʔeləẃkʷ – Belongings encourages interactions between visitors, the sharing of information, and the informal discussion of the intangible knowledge being shared about Musqueam belongings.

Date: 2015
Location: Museum of Anthropology (MOA) at the University of British Columbia in Vancouver, Canada
Designers/Developers/Researchers: Muntean, R., Hennessy, K., Antle, A., Rowley, S., Wilson, J., Matkin, B., .& Wakkary, R.

Figure 226 Tangible replicas of ćəsnaʔəm's "belongings", both from the past and present (source: Muntean et al., 2016).

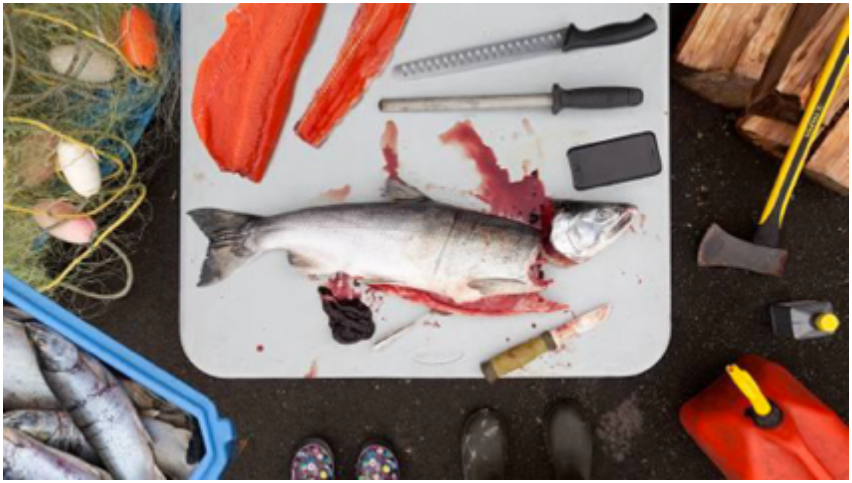


Figure 227 The fish-cutting table represented on the tabletop (source: Muntean et al., 2016)

Figure 228 Basic information shown when a belonging is placed in one ring on the table.
(source: https://vimeo.com/132751190).

Figure 229 Visitors can connect a belonging to its related area of the fish-cutting image getting information about its use in Musqueam's culture.
(source: https://vimeo.com/132751190).

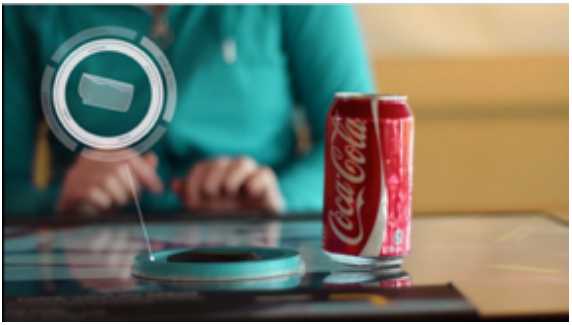


Figure 230 Visitors can match two belongings one from the past, the other from present days, and learn about the continuity of past Musqueam's culture in the present. (source: https://vimeo.com/132751190).

References

Muntean, R., Hennessy, K., Antle, A., Rowley, S., Wilson, J., Matkin, B., . . . Wakkary, R. (2015). ʔeləw̓kʷ- Belongings: A Tangible Interface for Intangible Cultural Heritage. *Electronic Visualisation and the Arts (EVA 2015)*. London, UK. (http://ewic.bcs.org/content/ConWebDoc/54933)

video: https://vimeo.com/132751190

49. The revealing flashlight (oscillum)

The "Revealing Flashlight" (Figure 231) is an application of tangible interaction that allows visitors to reveal the original colour of the object. According to the direction the visitor's finger is pointing at, a specific area of the artefact is augmented through a projection of the original colour. This kind of technology was used in Amsterdam to augment an "oscillum", a decorative object used in Roman houses.

Date: 2014
Location: Allard Pierson Museum (keys to Rome exhibition)
Designers/Developers/Researchers: Software: INRIA: Patrick Reuter; ArcheoTransfer. Models and text: CNR ITABC; Visual Dimension: Daniel Pletinckx, San Nollet

Figure 231 The revealing flashlight installation (oscillum) at Allard Pierson (source: https://vimeo.com/109284410)

References

Ridel, B., Reuter, P., Laviole, J., Mellado, N., Granier, X., & Couture, N. (2013). La Lampe torche magique: Une interface tangible pour l'inspection geometrique d'objets en realirt augmetée spatiale. *25ème conference francophone sur l'Interaction Homme-Machine, IHM'13.* Bordeaux, France: ACM. (https://hal.inria.fr/hal-00852053/file/lampe_torche_magique.pdf)

Ridel, B., Reuter, P., Laviole, J., Mellado, N., Couture, N., & Granier, X. (2014). The Revealing Flashlight: Interactive spatial augmented reality for detail exploration of cultural heritage artifacts. *Journal on Computing and Cultural Heritage2014, 7*(2), 1-18.

Pescarin, S., & al. (Eds.). (n.d.). *Keys to Rome. Roman Culture, Virtual Museums.* Retrieved 2015, from KEYS2ROME | Keys2Rome is a unique international exhibition on Roman culture: http://keys2rome.eu/downloads/CatalogK2R.pdf

video: https://vimeo.com/109284410

50. The Revealing Flashlight – marble slabs (Rome)

The "Revealing Flashlight" (Figure 232) is an application of tangible interaction that allows visitors to reveal the original colour of the object. According to the direction the visitor's finger is pointing at, a specific area of the artefact is augmented through a projection of the original colour. This kind of technology was used at the Fori Imperiali Museum (Rome) to show the original colours of the remains of marble slabs that once decorated the wall behind the statue of Augustus.

Date: 2014
Location: Allard Pierson Museum (keys to Rome exhibition)
Designers/Developers/Researchers: Software: INRIA: Patrick Reuter; ArcheoTransfer. Models and text: CNR ITABC; Visual Dimension: Daniel Pletinckx, San Nollet

Figure 232 The "Revealing Flashlight" allows to show the original colours of the remains of marble slabs that once decorated the wall behind the statue of Augustus. source: http://keys2rome.eu/downloads/CatalogK2R.pdf).

References:

Pescarin, S., & al. (Eds.). (n.d.). *Keys to Rome. Roman Culture, Virtual Museums.* Retrieved 2015, from KEYS2ROME | Keys2Rome is a unique international exhibition on Roman culture: http://keys2rome.eu/downloads/CatalogK2R.pdf

51. The revealing flashlight - head of Caesarion (Alexandria)

The "Revealing Flashlight" (Figure 233) is an application of tangible interaction that allows visitors to project a digital reconstruction on the head of Caesarion (Figure 234), that is preserved in the Bibliotheca Alexandrina. The head was originally part of a 5 metres-high statue that remained underwater for 1600 years as a result of a tsunami in 365 AD and that, for this reason, suffered erosion and damage.

Date: 2014
Location: Allard Pierson Museum (keys to Rome exhibition)
Designers/Developers/Researchers: Software: INRIA: Patrick Reuter; ArcheoTransfer. Models and text: CNR ITABC/ Cultnat; Visual Dimension: Daniel Pletinckx, San Nollet

Figure 233 "The bust in the Antiquities Museum in Alexandria" (source: http://keys2rome.eu/downloads/CatalogK2R.pdf).

Figure 234 Digital reconstruction on the head of Caesarion (source: http://keys2rome.eu/downloads/CatalogK2R.pdf).

References

Pescarin, S., & al. (Eds.). (n.d.). *Keys to Rome. Roman Culture, Virtual Museums.* Retrieved 2015, from KEYS2ROME | Keys2Rome is a unique international exhibition on Roman culture: http://keys2rome.eu/downloads/CatalogK2R.pdf

52. "Strike the Pose: Gallery One"

As part of the Gallery One interactive exhibition at the "Cleveland Museum of Art" the exhibition "Strike the Pose" was present (Figure 235). The visitor interacts with its body in front of a screen trying to match with his body the pose of a sculpture. Then the interactive gives feedback about the accuracy of the pose.

Date: 2012
Location: Gallery One, Cleveland Museum of Art
Designers/Developers/Researchers: [Cleveland Museum of Art]

Figure 235 Strike the pose installation (source: https://vimeo.com/60866008).

References:

Cleveland Museum of Art. (2015). *Interactives | Cleveland Museum of Art.* Retrieved from Cleveland Museum of Art: http://www.clevelandart.org/gallery-one/interactives

Alexander, J., Barton, J., & Goeser, C. (2013). Transforming the Art Museum Experience: Gallery One. In N. Proctor, & R. Cherry (Ed.), *Museums and the Web 2013.*

https://vimeo.com/60866008

53. Interactive sensory object for access to cultural heritage

"Interactive Sensory Objects for and by People with Learning Disabilities" is a three-year (2012-15) research project funded by the UK Arts and Humanities Research Council. The aims of the projects are: "to engage people with learning disabilities as co-researchers in the design of interactive multisensory objects that replicate or respond to museum collections[;] to explore what improvements to access and engagement with heritage and museum displays can be achieved for people with learning disabilities, through the use of multisensory objects[;] to explore to what extent the experiences of people with learning disabilities can influence the provision of multisensory objects and interactive technologies in museums and heritage sites for the general public" (Hollinworth et al., 2014).
Through a series of co-creation workshops that brought together artists, technology experts, experts in multimedia advocacy, and people with learning disabilities, different multisensory objects were built to augment existing artefacts or create new ones in various sites in the UK (Speke Hall; the Museum of English Rural Life; a museum of the University of Reading; the British Museum).
Examples of objects include:

- "sensory boxes" built after the visit of Speke Hall to send to people who have never visited the site, to share with them their sensory interpretation of the visit. They are built of various materials combined with digital media triggered by electronics (Figure 236).
- A series of multisensory objects for the Museum of English Rural life, related to the English rural life, built using buckets, boots and baskets.
    - A wellington boot covered in faux cowhide, making the sound of a cow mooing when it was stroked or squeezed (Figure 237).
    - A chicken in a basket which clucks and flaps its wings when an observer moves close to it
    - Grass-covered boot that plays rural sounds when picked up, pressed or moved around
    - A range of buckets containing various interpretation of pigs and others of pigs, other farm animals, and even a golf course.
    - a portable "herb in a boot garden" that visitors could smell and taste in the museum

Date: 2012-15
Location: various
Designers/Developers/Researchers: Interactive Sensory Objects for and by People with Learning Disabilities" research project

Figure 236 An example of "sensory box" (source: Hollinworth et al., 2014).

Figure 237 Interactive boot (source: Hollinworth et al., 2014).

References

Hollingworth, N., Allen, K., Kwiatkowska, G., Minnion, A., & Hwang, F. (2014). Interactive Sensory Objects for and by People with Learning Disabilities. *ACM SIGACCESS Accessibility and Computing, 109*, 11-20.

Sensory Objects - Project Website. (n.d.). Retrieved 2015, from http://sensoryobject.wpengine.com/

54. Etruscanning (Vaticans Museum and Allard Pierson Museum)

The Installation presents a virtual reconstruction of a still existing Etruscan tomb in Cerveteri (Regolini- Galassi tomb) including the funerary goods that since the discovery where removed from their original location (Figure 238) and are now part of the Vatican Museum collection. The real tomb is today completely empty and generally not accessible to the public.
Through gesture-based interaction, the visitor can explore the virtual tomb in every direction and select objects in order to hear a story. The visitor is first of all required to select a modality (like free-exploration or selection) by moving to specific hotspots on the ground. After that he can make gestures with his arms in order to move inside the tomb or select objects. The grammar of gestures defined for this application is illustrated in (Figure 239).

Date: 2013 (last version)
Location: last version at the Vatican Museums and Allard Pierson Museum (Amsterdam)
Designers/Developers/Researchers: [Etruscanning 3D project]

Figure 238 A visitor interacting with the Etruscanning installation (source: Pietroni et al., 2013).

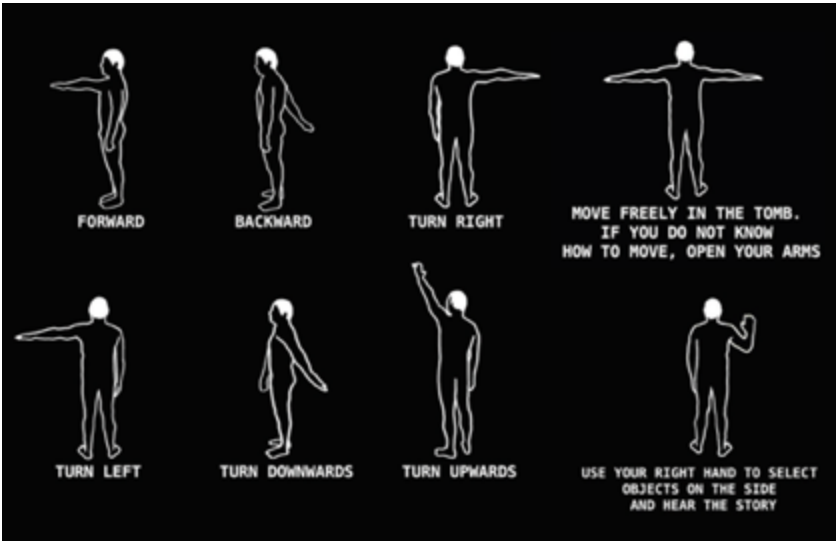


Figure 239 The grammar of gestures to interact with Etruscanning installation (source: Pietroni et al., 2013).

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55. The Really Simple Object Recognition Interactive Anglo-Saxon Table

The Really Simple Object Recognition Anglo-Saxon Table is an interactive installation consisting of a modern kitchen/breakfast table on which a rear projection plexiglas screen is embedded, and a plate and a set of contemporary objects are placed (Figure 240). Placing an object on the plate, information related to Anglo-Saxon counterparts that are part of the museum collection are presented on the screen accompanied by audio (Figure 241).

Date: 2014
Location: Maidstone Museum and Bentlif Art Gallery
Designers/Developers/Researchers: MGH Consultants (www.mghconsultants.com)

Figure 240 The Really Simple Object Recognition Anglo-Saxon table (source: https://www.youtube.com/watch?v=tUBVwJzFHn8).

Figure 241 Example of interaction with the interactive table. Placing a modern glass on the table a description of a glass Anglo-Saxon object is provided. (source: https://www.youtube.com/watch?v=tUBVwJzFHn8).

References

Video:
https://www.youtube.com/watch?v=tUBVwJzFHn8

56. Sculpture lens gallery one

Sculpture lens is part of the Gallery One interactive exhibition at the Cleveland Museum of Art (Figure 242). By performing facial expressions in front of a screen, the visitors can get a visualization of portraits from the museum collection that better match the facial expression.

Date: 2012
Location: Gallery One, Cleveland Museum of Art
Designers/Developers/Researchers: [Cleveland Museum of Art]

Figure 242 Sculpture lens in Gallery One (source: Alexander et al., 2013)

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Color illustrations

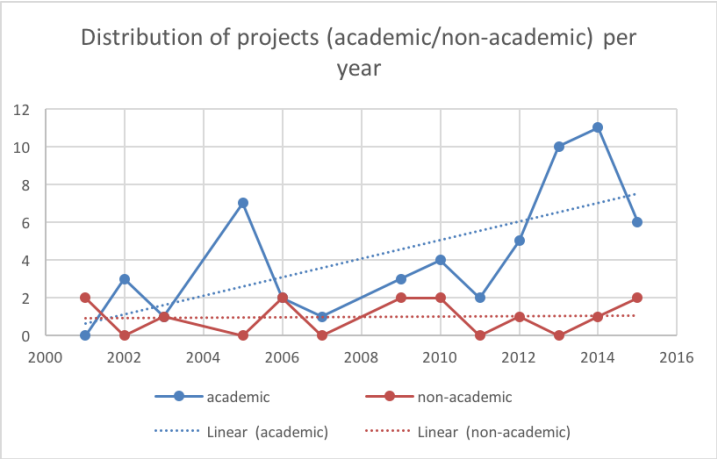


Figure 31 Distribution per year of academic and non-academic projects

Figure 32 Map showing the geographic locations where the academic and non-academic projects were installed.

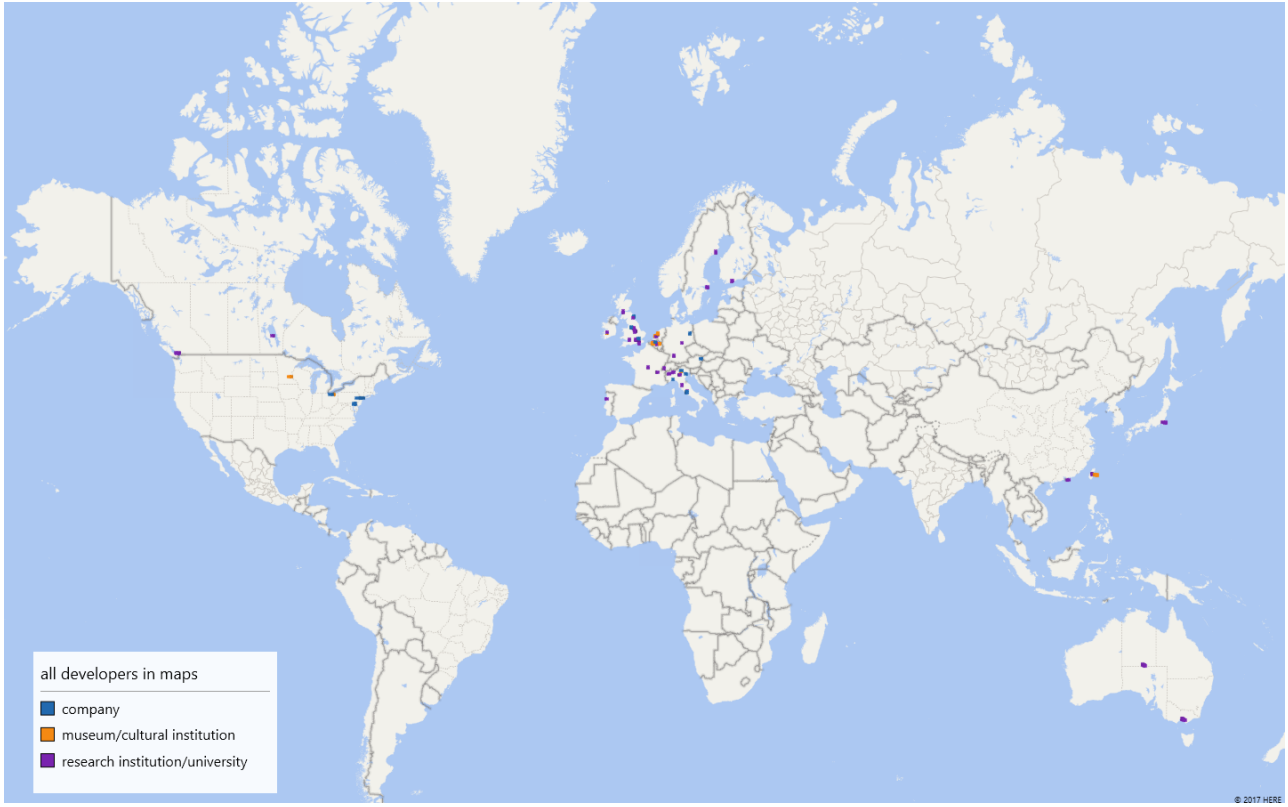


Figure 33 Map showing the geographic locations of developers of all the projects.

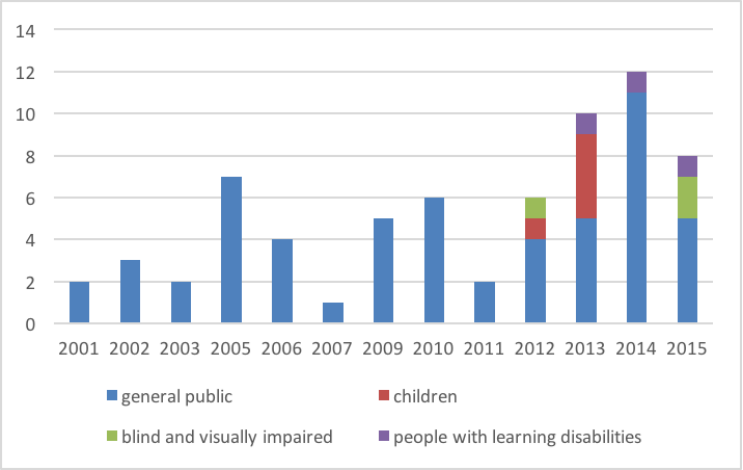


Figure 38 Distribution per year of different targeted installations.

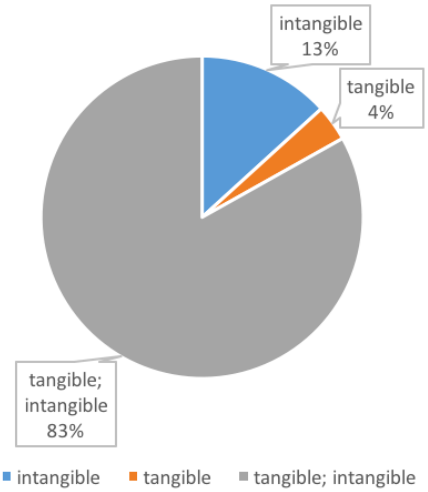
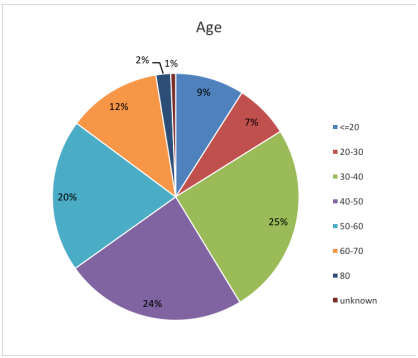
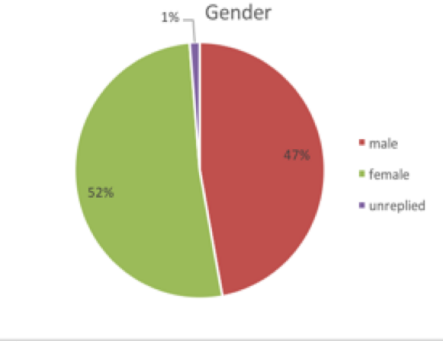


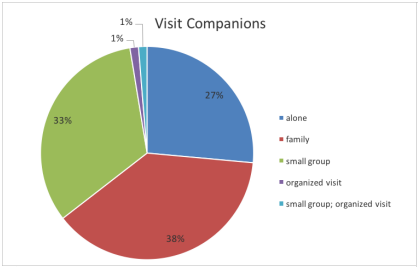
Figure 41 Types of CH assets referred by the installations.



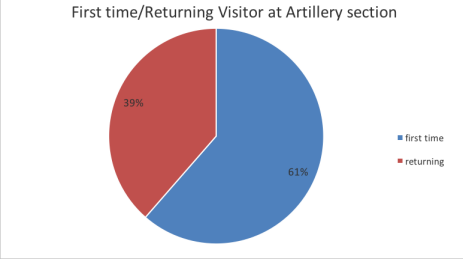
a)



b)



c)



d)

Figure 110 a) distribution of visitors by age; b) distribution of visitors by gender; c) distribution of visitors on the basis of typology of visit (alone, with family, small group, organized visit); d) percentages of First Time and Return Visitor at the Artillery Section of the MdG.

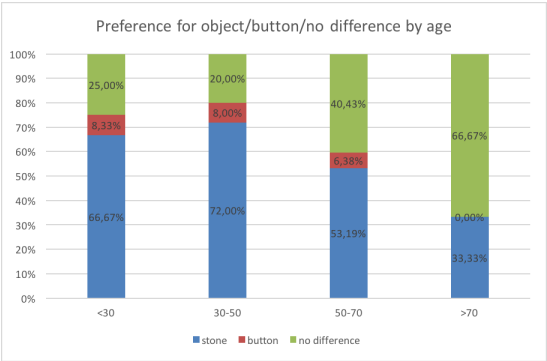


Figure 114 "If you could choose whether activating the contents using the activating object or a button, which method would you choose?". Distribution of the answers by age.

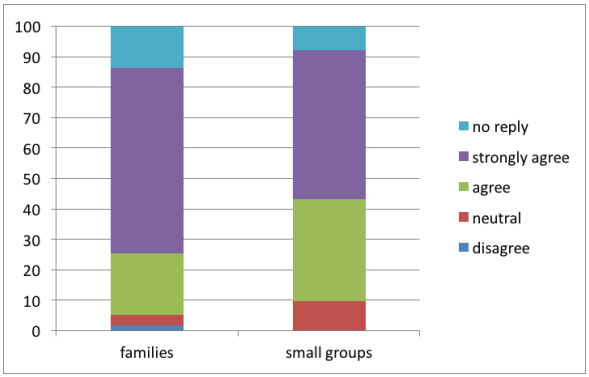


Figure 115 "I feel I have shared the experience with my group". Distribution of the answers both for families and small groups