IMT Institute for Advanced Studies, Lucca

Lucca, Italy

Alternative Solutions to Traditional Approaches to Risk Analysis and Decision Making Using Fuzzy Logic

PhD Program in Computer Science and Engineering

XXIII Cycle

By

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2010

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IMT Institute for Advanced Studies, Lucca

2010

To my family

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Acknowledgements

It was like yesterday and it was like a century ago...

Three long-long years... thousands of kilometers far from my family, my country, my friends, I came to Lucca a beautiful charming Tuscan city without knowing a single Italian word, without knowing anyone...

Years of excitement, happiness, disappointments, endless deadlines, years of being homesick, years of falling in love with Italy, its fantastic cities, nature, architecture, food, people...

This thesis would not have been possible without people whom I would like to write my indebted thanks.

First and foremost I want to thank my advisor Beatrice Lazzerini. I appreciate her kind and maternal attitude towards me, all her contributions of time, ideas, encouragement.

I owe my sincere gratitude to my professor in Belgium Nuclear Research Center Da Ruan. I thank him for teaching me to be practical, to have more comprehensive view of my research, for giving me the opportunity to work in real life projects, for supporting me during all my stay in Belgium.

I would like to thank Professor Koen Vanhoof for hosting me in IMOB. It was very fruitful for me giving new ideas and new solutions.

I am grateful to all my Armenian friends who supported me even being far, who helped me to feel not far from Armenia. Special thanks to Tatevik Gyurjyan, Ani Hovian, Arman Sahakyan, Vahe Kesoyan, Diana Alexanyan, and Alina Margaryan.

Of course my friends that I got to know in Italy are the main witnesses of my PhD career. We shared common problems, common disappointments, common happiness and common dreams. Special thanks to my first friend in Italy and my best flatmate ever Irina Zviadadze with whom I have some of my best memories of Italy. Special thanks to my other russian friends Nadia Negovelova and Alexander Kuznetsov, my all colleagues of CSE XXIII, to Nicholas with whom I had my first publication, to Alessandro Ciaramella with whom I shared my academic troubles, to Farshad, Marzia, Manuela, Barbara, Adele, Ali for being always kind. My indebted thanks to Noel Gatt and Sam Moss for their encouragement and their belief on my success.

My very special thanks to Mercy Njima, Ahmed Nagi and Debora Furlan. Debora was the one with whom I did my first steps of learning italian language and who always will be for me a symbol of italian people. Mercy and Ahmed, my best friends, my neighbors in the dormitory, with whom I shared my best and worst days, who always supported me and whom I will miss always.

And finally, my last thanks to my family, my parents who were with me every single second even being always far, my brother and his family, my nephew Hovhannes and my niece Anahit who were always my inspiration for whatever achievements I have so far. And my very last thanks to Samuel, who was with me during the last stages of my PhD thesis and whose help is so much appreciated.

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2. L. Mkrtchyan, "Belief Degree Distributed Fuzzy Cognitive Maps for Energy Policy Evaluation," at *Belgian Nuclear Research Centre SCK•CEN*, Mol, Belgium, June 2010.
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Abstract

Fuzzy set theory (FST) and *Fuzzy logic* (FL) are one of the main components of *soft computing* which is a collection of techniques to handle hard problems in which the application of traditional approaches fails. The father of FST and FL stated that the dominant aim of SC is to exploit the *tolerance for imprecision and uncertainty* to achieve tractability, robustness, and low solution cost.

Since its establishment the theory of fuzzy sets and fuzzy logic became very popular and received much attention especially during the last decade being applied in many different fields. The wide use of fuzzy controllers in many mass-produced products resulted in the increase of research in fuzzy set theory and fuzzy logic.

In this thesis we use the techniques that are based on FL and FST for risk analysis and risk-based decision making.

There are several reasons for using FL and FST. Fuzzy logic is a true extension of conventional logic: thus anything that was built using conventional design techniques can be built with fuzzy logic. Another advantage is that it is close to human reasoning, and it is easy to understand for the users who do not have strong mathematical knowledge. A fuzzy system allows the user to use and to reason with words instead of crisp numbers. In addition, FL also offers a wide range of operators to perform efficient combinations of fuzzy predicates.

In this thesis we propose alternative solutions to the existing approaches that use FL and FST for risk analysis and risk-based decision making. We investigated the current approaches, and we actually found that there exists only a small

amount of researches that focus on risk analysis by using fuzzy logic. As far as we found, there are very few approaches that are generic and representative enough to be applied generally and to be used for complex problems. The existing approaches are very specific, targeting a particular area concentrating on specific types of risks.

In this thesis we propose several different frameworks and algorithms based on FST and FL.

First, we introduce two algorithms to rank the *generalized fuzzy numbers*. The main reason for developing a new ranking algorithm is that the existing ranking algorithms have some disadvantages that make them not suitable for risk assessment and decision making. We used our algorithms in risk-aware decision making related to the choice of alternatives.

Second, we introduce a *pessimistic approach* to assess the impact of risk factors on the overall risk. The methods that use the fuzzy weighted average often give a lower result than the real risk especially in the case of a large amount of input variables. Furthermore, the traditional approaches of using fuzzy inference systems may give the same result for different cases depending on the choice of the defuzzification method. For the pessimistic approach we used our developed algorithms of ranking generalized fuzzy numbers.

Next we propose the use of *Fuzzy Bayesian Networks* (FBNs) for risk assessment. While there is a considerable number of studies for Bayesian networks (BNs) for risk analysis and decision making, as far as we found there is not a study to make use of FBNs even though FBNs seem more appropriate and straightforward to use for risk analysis and risk assessment. In general, there is only a small amount of studies about FBNs, and not in many application fields.

The last approach discussed in this thesis is the use of *Fuzzy Cognitive Maps* (FCMs) for risk analysis and decision making.

We propose a new framework for group decision making in risk analysis using *Extended FCMs*. In addition we developed a new type of FCMs, *Belief Degree Distributed FCMs*, and we show its use for decision making.