

Chapter 20

Recent Advancement in Fuzzy System: Full Type 2 Fuzziness

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ABSTRACT

Decision under uncertainty is an active interdisciplinary research field. A decision process is generally identified as the action of choosing an alternative that best suites our needs. This process generally includes several areas of research including but not limited to Economics, Psychology, Philosophy, Mathematics, Statistics, etc. In this chapter the authors attempt to create a framework for uncertainties which surrounds the environment where human decision making takes place. For this purpose, the authors discuss how one ought to handle uncertainties within Fuzzy Logic. Furthermore, they present recent advances in Type 2 fuzzy system studies.

INTRODUCTION

We are living in an uncertain environment. Knowledge is limited (or at best imperfect) and measurements are imprecise. Future events can only be predicted with certain confidence and in turn with some risk. As such decisions must be made in an uncertain environment. However uncertainty creates sub optimality, it is the central theme for the freedom of choice in decision making. It makes us free to choose. It lets us use our heuristics for everyday decisions. In some cases,

there may not be an optimal course of action while in some other cases there may not be a scientific method to find an optimal (or sub-optimal) action. Hence we generally make decisions under uncertainty. Generally, we are free to choose among a set of a rich optimal and at times sub-optimal criteria for decision making. Naturally, freedom is a product of uncertainty. Thus it is crucial to have the common understanding of uncertainty in order to understand the way human think and decide under uncertainty.

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Uncertainty has long been an important scientific research area. There is no commonly accepted single theory of uncertainty in the literature. However there are attempts to create taxonomy of uncertainty. But there is no common single taxonomy. There are also some attempts to construct uncertainty theories in mathematics (see for example, Liu, 2004, Liu 2010). Uncertainty theory is generally a subject of several theories and logics such as fuzzy logic (FL), crisp logic and probability theory (PT), complexity theory, etc. The views and thoughts about uncertainty are all related with the nature of problems in different fields. Hence in order to create a common ground for understanding, one should start with a brief summary about the research related to uncertainty. This is given in the next section.

Since the decision under uncertainty can be seen as the thinking process that result in choosing an action (Baron 2008), a study of thinking ought to be touched and briefly stated. This is another area that one can find a vast literature. However it is known that the way we think affects the decisions we make, this part is not covered and is well beyond the scope of this chapter. A very good reference that reader might want to see is Baron's book (2008). Instead we would like to state that thinking about decision making may lead us to discuss descriptive, prescriptive and normative models. From time to time, it would be appropriate to review the studies on decision making under either normative or descriptive approaches. The latter searches the answer of how people should decide in contrast to how people actually decide. In this sense it sounds as the normative models seek analytical framework to a reality (Baron, 2008). On the other hand, descriptive models seek an explanation of the reality. This process of explanation may or may not involve the mathematical rules. Hence decision theories that can be part of descriptive theories may include some mathematical/analytical modelling as well as heuristics.

Study of thinking is also related to the logic behind the thinking process. Thus theories so created are based on the rules associated with logics. Probability is the most commonly used theory that is based on the crisp logic where the sets have certain boundaries in $\{0,1\}$ lattice. However Fuzzy set theory is based on the logic where the boundaries of sets are in $[0,1]$ interval as a matter of degree.

In this chapter we would like to present a common understanding of uncertainty together with the recent advances in fuzzy theory. This includes:

1. The discussion of the term of uncertainty, and
2. Fuzzy Logic and the recent advances in Fuzzy theory.

UNCERTAINTY

At the beginning, more often one starts with a dictionary definition of uncertainty. Uncertainty is commonly referred to *the state of being uncertain*. Not known, not definite, not sure of something, not precise, fuzzy, vague, contradictory, etc. are among several meanings of the term *uncertain*. Think about the precision of some words, for example, *about*, *approximately*, *roughly*, *low*, *high* and *big*. They have no precise meanings although they are used frequently in daily life. Humans do understand them and communicate effectively using them. According to Parsons (2001), the meaning of the word *uncertain* falls into three categories. Something is uncertain because;

1. It hasn't been measured accurately enough,
2. Because it might change, and
3. The person who has the information is not confident.

There is no commonly accepted theory of uncertainty. There are several attempts to describe, explain and provide taxonomy about it. Walker's

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