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Fuzzyfication of the Decision Making Process - Theoretical and Conceptual Antecedents

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ABSTRACT

Fuzzy logic has seen tremendous advancements in the last few decades and is now widely used in a variety of real-world contexts, including control systems, pattern recognition, data mining, and classification, among other fields. Entrepreneurs face significant hurdles in juggling ambiguity and risk while making decisions, making it difficult for them to make the optimal choice. Forecasting business choices and operations is becoming increasingly challenging due to the growing complexity and complexities of corporate environments. Fuzzification is the process of using the data in the knowledge base to transform a crisp input value into a fuzzy value. This study looked at the decision-making process' fuzzification from theoretical and conceptual angles. When information is scarce and of low quality, fuzzy logic provide a natural method for solving multidimensional and difficult problems.

Keywords: Fuzzy logic, Membership functions, Decision, Fuzzy Set, Entrepreneur

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1. INTRODUCTION

Researchers and academics have been particularly interested in entrepreneurship for a long time, drawing their attention to the social and economic issues it faces. 2017; Khefacha, Belkacem, and Mansouri, 2014; Laviolette and Brunel, 2012; Norrman, Bager-Sjögren, and 2010, Gürol and Atsan, 2006; Acs and Audretsch, 2003; Garcia-Rodriguez, Desiderio, and Inés. Making decisions is an essential part of every successful business. On the other hand, decisions made on the basis of flawed logic, emotionalism, or insufficient information can swiftly drive a business out of business. Decisions made on the basis of knowledge and solid reasoning can lead a company into long-term profitability. Business success is ultimately determined by the caliber of decisions made and carried out. Sound judgments translate into profitable business.

1.1 What is fuzzy logic?

Due to the bivalent nature of classical logics, any representation of a proposition can be categorized as either true (T) or false (F). Human decision-making in real-world situations is limited to options between T and F. Nevertheless, fuzzy logic was developed to simulate such inaccurate human thinking processes since classical logic is unable to handle ambiguous information expressed in natural languages. It makes perfect sense to say that a statement's reality depends on how realistically it is decided. The basis for approximate thinking is laid by fuzzy logic, wherein the rules of inference and the values of "truth" are approximate rather than precise (Carlucci, Renna, Materi, Schiuma, 2020; Dzitac, Filip, Manolescu, 2017).

What follows are the Steps of Fuzzy Logic

1. Fuzzification : Processing crisp input into fuzzy input in the form of membership function
2. Rule Evaluation : Stages of use of rules to determine what control actions to perform in response to inputs.
3. Defuzzification : The last stage after rule evaluation is defuzzification. In defuzzification, all significant fuzzy outputs will be combined into specific output variables. One commonly used defuzzyfication technique is the Center of Gravity (COG) method.

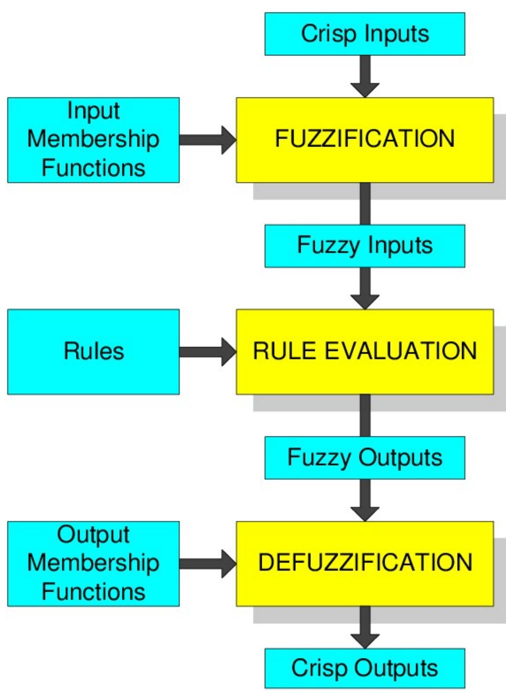

Fig 1; Steps in the Fuzzification Process
https://www.researchgate.net/figure/Steps-of-Fuzzy-Logic-1-Fuzzification-Processing-crisp-input-into-fuzzy-input-in-the_fig2_329838479

The idea of making decisions has a long history since life has always involved making choices amongst options. However, it has only been in recent years that corporate decision making has received consistent study attention. Current developments in the discipline include advancements in procedural and technical aids, problem identification, problem solutions, and legitimation processes, as well as the context of the problem. Certain problems in the fields of sociology, economics, the environment, engineering, medicine, and other sciences cannot be solved by using traditional approaches because of the inherent uncertainties in these areas of study. Since its initial proposal by Zadeh in 1965, fuzzy set theory has grown to be a crucial tool for resolving issues of this nature and offers a suitable framework for describing ill-defined ideas by permitting partial membership.

Over time, fuzzy logic, fuzzy automata, fuzzy decision making, fuzzy control systems, fuzzy topology, and fuzzy logic have all emerged as applications of fuzzy set theory, which has been researched by mathematicians and computer scientists alike. To be an entrepreneur is to have unrestricted access to opinions and judgments regarding the course of a business (Foss and Klein, 2007). As we've seen, an entrepreneur is an explorer who must be prepared to accept the possibility that his or her assessments of the situation may be incorrect (Casson, 2005).

In order to address complicated issues and unexpected opportunities, risk management calls for adaptation, which is defined as trying out new concepts and whole new technologies (Bhidé, 2000). In order to address the complexity inherent in making decisions by entrepreneurs, this study suggests a nature-based strategy for decision making called the fuzzy inference model.

2. THEORETICAL BACKGROUND OF FUZZY LOGIC AND FUZZY DECISION MAKING SYSTEM

The foundation of this essay is fuzzy logic, a subset of soft computing, an approach influenced by nature. To set this research work in context, this section will briefly discuss the fuzzy set theory idea. Fuzzy logic is a more useful modeling technique when a system is more complex (Oderanti, 2010). Approximate interpolation between input and output scenarios is possible with fuzzy logic (FL) (Keshwani, Jones, Meyer and Brand, 2008). FL offers a conceptual framework that seeks to establish a natural method of handling situations where the lack of well-defined class membership criteria, as opposed to the existence of random variables, is the cause of imprecision (Zadeh 1965).

Lotfi Zadeh developed this method of problem solving in 1965 to address ambiguous or imprecise situations (De Wilde 2004; DeWilde 2002; Dweiri and Kablan 2006; Kandel and Zhang 1998). FL is used to simulate human knowledge and reasoning that lack clear boundaries. Fuzzy sets, linguistic variables (Hajjaji and Rachid, 1995), possibility distributions (membership functions), and fuzzy if-then rules (Dweiri and Kablan 2006) are the four basic principles of fuzzy logic, despite its broad scope of theories and methods. A fuzzy set describes the values of a linguistic variable quantitatively. By assigning a linguistic variable to a fuzzy set, one can impose constraints on its value, known as possibility distributions or membership functions. A functional mapping between antecedents and consequents is described by fuzzy if-then rules, which are knowledge representation schemes (Oderanti, 2010).

Without using exact quantitative analysis, a fuzzy inference system (FIS) can simulate the qualitative components of human knowledge and reasoning processes using fuzzy if-then rules (Oderanti, 2010). Since fuzzy if-then rules with membership functions provide the information in these systems, FIS are typically intelligible (Anderson and Hall 1999). FIS can be combined with words to compute.

3. CONCEPTUAL ANTECEDENTS

It is necessary to model the system that would support decision making holistically in order to address the complicated conceptual issues in decision making. Fuzzy logic can take into account every potential limitation that could influence an organization's decision-making process in order to accomplish this. The idea of making decisions has a long history since life has always involved making choices amongst options. However, it has only been in recent years that corporate decision making has received consistent study attention. Current developments in the field include advancements in procedural and technical aids, problem solving, problem identification, and legitimation processes, as well as the context of the problem and its context for decision making. Problems are the basis for all decisions, and they influence context on three different levels. The macro setting highlights national concerns (the cultural inclinations toward decision-making processes of various countries), global issues (current currency rates, for example), and national laws and cultures at the provincial and state levels.

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The organizational cultures and structures are taken care of in the micro-context. The organization's staff, board, or office—the immediate decision environment—is covered by the micro-context. Every organization has a different decision-making process. But when a decision needs to be made, all businesses must take these three context levels into account. A key challenge in decision making is waiting until one is too near to the decision point, when options and information are severely constrained. Most organizations operate in a "reactive" manner, with problems "found" only after they have started to negatively affect the company's operations.

However, environmental scanning and strategic planning procedures are intended to carry out problem reconnaissance, thereby warning firm executives about issues that may require attention in the future. While it necessitates a decision intelligence process lacking in many businesses, proactivity can be a major asset in decision making. The Fuzzy Inference System is useful in this situation. Furthermore, if the company takes a long time to acknowledge or address the issue, problem identification is not very helpful. After an issue has been located, details regarding the precise nature of the issue and possible solutions (decision(s)) must be obtained. The field of operations research has expanded to include decision-making in business, which involves creating mathematical and computational tools to assist decision-makers in their subjective assessment of performance criteria (Zavadskas, Turskis, and Kildienė, 2014). Numerous studies have been conducted to create intelligent models that aid in organizational decision-making (Zavadskas & Turskis, 2010). Analytically speaking, the organization of the business and the entrepreneur's concept are intertwined. According to Foss et al. (2007), having residual decision rights to opinions or judgments regarding the future course of a firm entails being an entrepreneur. Researchers have also observed that an entrepreneur is an explorer who must be able to manage multiple risks, including the possibility that their judgment may be incorrect (Casson, 2005).

In order to address complicated issues and unexpected opportunities, risk management calls for adaptation, which is defined as trying out new concepts and whole new technologies (Bhidé, 2000). It is not that entrepreneurs saw less risk; rather, they framed venture hazards in terms of their own ideals. Additionally, they felt more assured about their capacity to impact the venture's future growth. Entrepreneurs suffer from an illusion of control, according to research done in 2000 by Simon, Houghton, and Aquino. This means that they feel their competence will improve performance even in circumstances when it actually cannot or if it is obvious that results are heavily dependent on chance. Similarly, entrepreneurs are more inclined to be overconfident and to draw conclusions from small, random samples, according to Busenitz and Barney's 1997 theory.

4. SOFT COMPUTING IN DECISION MAKING

Additionally, a number of earlier studies have used various soft computing approaches to assist decision-making within an organization in order to address a problem or problems related to corporate growth and sustainability (Şengül et al, 2015). These are: Applied Software Computing (Roszkowska and Wachowicz, 2015); inclusion-based TOPSIS approach with interval-valued intuitionistic fuzzy sets for multiple criteria group decision making. An enhancement of the quantitative strategic planning matrix with fuzzy numbers and many criteria decision making. Production management and applied soft computing (Rabbani, Zamani, Yazdani-Chamzini, and Zavadskas, 2014) opined that decision-aiding process cannot be completed step-by-step by following a single, distinct, and well-defined technique. Aggregation is a significant problem when working with things that can only be compared and characterized using a number of qualities.

It attempts to achieve a goal like selecting the item with the highest degree of membership in a particular issue space by operating a synthesis of the objects' typically contradicting attributes. (Marchant, Bouyssou, Vincke, Tsoukias, and Pirlot, 2006). The Fuzzy Inference System was not fully utilized in any of the studies or methodologies used, meaning that not all of the limitations in entrepreneur decision making were covered by the precise fuzzy rules that were used. The purpose of this work is to present a model that, by employing the Mamdani Fuzzy Inference System technique, will carefully choose fuzzy rules in the entrepreneur issue space and be able to facilitate efficient decision-making inside an organization.

Fuzzy Inference Systems in Decision making

The intelligence behind FIS is its application of widely accepted rules in a system to simulate the rule-driven system. As a result, a comprehensive system that can be utilized to simulate the difficulties associated with decision-making is created. The process of designing a FIS for an entrepreneur issue space will be covered in detail in this section. The FIS is an intelligent system designed to correctly respond to both known and unknown inputs. When the common traits or general laws of the system are understood, FIS are good at simulating real-world issues.

Computational Intelligence and Fuzzy Logic

Computational intelligence (CI) allows for the creation of intelligent systems that mimic several facets of human behavior, including learning, perception, reasoning, evolution, and adaptability. These systems can be developed using intelligent methodologies, some of which are inspired by nature (Engelbrech, 2007).

Some examples of Computational Intelligence techniques are: Artificial Neural Networks, biological neuron-inspired technique (Anagnostopoulos and Maglogiannis, 2006), (Aruna, Rajagopalan and Nandakishore 2011). Evolutionary Computation, inspired by biological evolution (Mohamed, Hegazy and Badr, 2011); Expert Systems, inspired by inference process (Anagnostopoulos , Anagnostopoulos , Vergados, Rouskas and Kormentzas, 2006); and Fuzzy Logic, inspired by language processing. As a formal technique for troubleshooting, fuzzy systems theory attempts to address modeling, representation, reasoning, and the faulty information procedure (Dubois and Prade, 1983). Established in 1965 (Zadeh, 1965), fuzzy set theory was developed by fusing the ideas of classical logic and groupings, which define degrees of relevance (Lukasiewicz, 1970). It serves as a tool for modeling the imprecision and ambiguity that emerge in complex systems (Zadeh, 1965 and Zadeh 1979). The main idea behind the model put forward in this study is fuzzy logic. In contrast to a traditional set, a fuzzy set gives each element a value inside the unit interval [0, 1]. A fuzzy set is specifically defined as a function A of a set x, often known as the universe of discourse, to [0, 1].

The value A (x) indicates the degree of relevance, or compatibility, of the element x with the concept represented by the entire fuzzy set. The function A is known as a membership function. Thus, the fuzzy logic proposed by Zadeh (Zadeh, 1965, Zadeh, 1971) provides a mathematical model for the processing of inaccurate or vague information and concepts, intending to make computers carry out inferences as people. The fuzzy processing is generally composed of: Rules Base (provided by specialists or extracted from numerical data); Fuzzification Stage (activates the rules from a set of precise entries); Inference Stage (determines how rules are enabled); Defuzzification Stage (provides precise output, generating a fuzzy set of output).

5. WHY FUZZY INFERENCE APPROACH

According to Yilmaz and Ayan (2013), the fuzzy logic method was chosen over existing mathematical models because it could model obscurity in the relevant problem space, operate with lower costs and easier application, have a higher mechanical intelligence level, be flexible in its structure, be compatible with solving poorly defined problems, and use intuitive methods rather than specific algorithms to solve new problems. Fuzzy logic was chosen above other systems because it operates with reliable data and produces accurate results. Other systems do not have a flexible framework.

Fuzzy Systems

Lofti A. Zadeh established the fuzzy sets theory in 1965. The reason fuzzy systems are so important in soft computing is that human thinking is not precise and allows for degrees. The fundamental idea of fuzzy systems is that values on the range [0, 1], where 0 denotes absolute falseness and 1 denotes absolute truth, are used to represent truth values (in fuzzy logic) or membership values (in fuzzy sets). Fuzzy logic (FL) is the foundation of fuzzy systems. Fuzzy logic deals with approximate reasoning as opposed to fixed and accurate thinking; it is a type of many-valued logic or probabilistic logic. Using fuzzy logic, control problems are solved by applying a straightforward rule-based IF X AND Y THEN Z method, as opposed to trying to mathematically model the system. FL offers a straightforward method for drawing a firm conclusion from imprecise, noisy, unclear, or missing input data. One benefit of fuzzy logic is that it can translate a problem's solution into language that human operators can comprehend, allowing their expertise to be incorporated into the system's design. This facilitates If-Then Rules (Fuzzy Logic) mechanization of jobs that are currently successfully completed by humans.

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Fuzzy Inference System

In order to effectively map inputs to outputs, a Fuzzy Inference design must create the right rules within a specified problem space. Accurately and sufficiently identifying the inputs and outputs is the main challenge. The degree of membership of the identified membership functions is also a key contributing factor to the ultimate output of the proposed system. Rules are the driving forces behind the fuzzy inference system.

The amount of fuzzy sets connected to a linguistic phrase is one of the design criteria for a fuzzy inference system. As a soft computing technique, fuzzy inference system imitates how the human mind uses language to carry out cognitive reasoning tasks in natural situations. The process of creating a fuzzy logic map from provided input(s) to output(s) is known as fuzzy inference. This mapping offers a foundation upon which judgments can be rendered or trends identified. Several industries, including medicine, robotics, automatic control, data categorization, decision analysis, expert systems, and pattern recognition, have effectively used FIS in several applications. A nonlinear mapping from input space to output space is implemented by a fuzzy inference system with crisp inputs and outputs.

Many fuzzy if-then rules, each of which characterizes the mapping's local behavior, are used to perform this mapping. Specifically, a rule's consequent specifies the output in the fuzzy region, whereas the antecedent defines a fuzzy zone in the input space. Models of fuzzy logic can be created using process input-output data or expert knowledge. In the first scenario, expert process knowledge can be used to extract fuzzy models. Linguistics is one way that the expert knowledge can be expressed, although it can be inaccurate at times and the model needs to be adjusted. As a result, understanding the processes is crucial to the design that makes use of domain-specific expert knowledge. Determining the fuzzy model type and establishing the model input linguistic variables are necessary steps in this procedure.

In general, the main steps performed in the FIS are as follows:

- The fuzzification stage transforms each crisp input variable into a membership grade based on the membership functions defined in the problem space.
- The inference engine then conducts the fuzzy reasoning process by applying the appropriate fuzzy operators in order to obtain the fuzzy set to be accumulated based on their firing strength in the output variable.
- The defuzzifier transforms the fuzzy output into a crisp output by applying a specific defuzzification method.

The Mamdani and Sugeno methods are the two forms of fuzzy inference techniques that are most frequently employed (Negnevitsky, 2001). The formulation of the consequent component is where these two fuzzy inference approaches diverge. Consequences in the Mamdani method (Mamdani & Assilian, 1975) are fuzzy sets, and the Mamdani method's final crisp output is dependent on defuzzification of the overall fuzzy output through a variety of defuzzification techniques. This essay strongly suggests the Mamdani approach since making decisions as an entrepreneur necessitates taking into account a wide range of factors. The Mamdani fuzzy inference process includes four steps (Negnevitsky, 2001) (Naaz and Ranjit, 2011).
These are:

Step 1: Fuzzification -In fuzzification process the crisp input values are transformed into the grades of membership function (MF) for linguistic values of fuzzy sets. The membership function provides a grade for each linguistic value.

Step 2: Rule Evaluation - After successfully defining the input and output variables, and the corresponding MFs, it is necessary to design the rule-base of the fuzzy knowledge-base. The rule-base of FIS design is composed of IF < antecedents >THEN < conclusion > rules. These rules are then transformed from an input to an output, based on MFs that inform the projected outcomes. The total number of rules is dependent on the total number of linguistic variables and MFs. In Mamdani, the AND operator is applied on each rule for rule evaluation.

Step 3: Aggregate output(s) - After evaluating all the rules, the rules need to be bundled together in a particular approach to make a decision. Aggregation method is used to bundle the output fuzzy set after the evaluation of the rules. In Mamdani, the OR operator is used to aggregate the output fuzzy sets. After aggregation, the final output is a single fuzzy set.

Step 4: Defuzzification – This stage comes up after all others of the fuzzy inference process. A crisp number is generated from the single output fuzzy set that is found from aggregating the rules in Step 3. Figure 1 shows the diagrammatical presentation of an FIS.

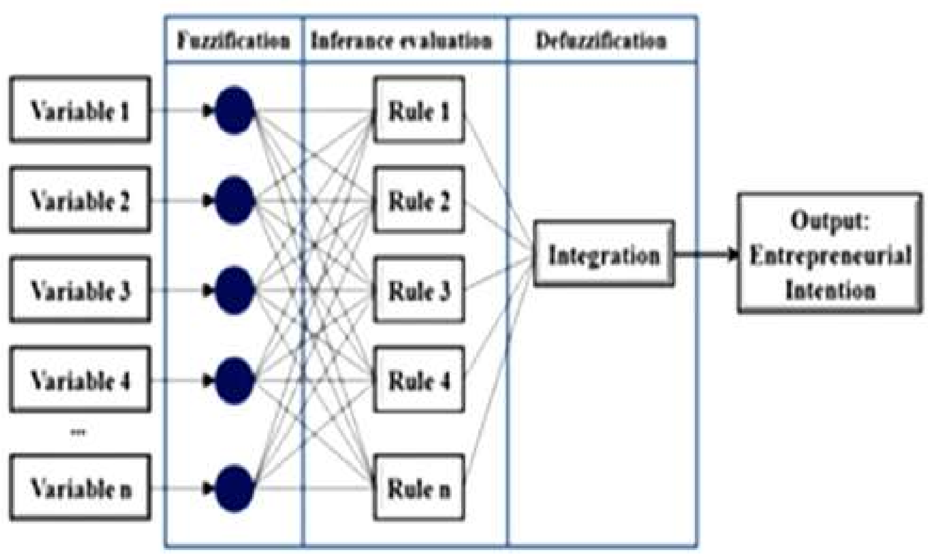

Figure 2: The Structure of Fuzzy Inference Systems for entrepreneurs. Source: Khefacha, Islem; Belkacem, Lotfi (2015)

6. CONCLUSION

Numerous studies on entrepreneurship have been conducted recently, in both academic and practical contexts. Various modeling strategies have been proposed in theories and applications, and several appropriate ways have been given for modeling decision. The decision-making process depends on a number of factors, including time, organization regulations, available information, and the individuals participating in it. These factors include the problem solution strategy and the model. The ability of the FIS approach to handle issues characterized by several competing interests, taking into account their varying degrees, is by far its greatest asset.

This essay specifically addressed the need to investigate the possibilities of fuzzy logic, or soft computing, in decision-making. Fuzzy logic may manage the variables involved in decision making in an integrated manner. The successful development of these efforts may be facilitated by a deeper comprehension of the variables influencing attitudes toward entrepreneurship and entrepreneurial intent. This study primarily addressed the primary obstacles that impact entrepreneurial decision-making, which will significantly reduce the challenges experienced by entrepreneurs while making decisions.

Fuzzy logic has found its way into many practical applications in many facets of human life, including artificial intelligence, control systems, and decision-making procedures. Fuzzufication is useful in scenarios where traditional binary logic might be constrained since it can handle imprecise information and uncertainty. Fuzzy logic is expected to become more crucial as technology develops for creating intelligent systems and resolving challenging real-world issues.

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