

Fuzzy Logic Decision Model for Robust Risk Management in ubiquitous environment- A Review

Dr. I. Jeena Jacob

Professor, GITAM University, Bangalore, India.

E-mail: jeni.neha@gmail.com

Abstract

Soft computing models are invaluable resources for solving addressing real-world issues. Soft computing is the process of solving difficult computer problems with imprecise yet practical results through the application of approximate computations. The method enables the resolution of issues that might be too difficult or time-consuming to handle with the technology available today. The term ‘computational intelligence’ is often used interchangeably with soft computing. This article will discuss various soft computing strategies, with a particular focus on the fuzzy logic approach. The study delves into risk management in the real world using fuzzy logic techniques across multiple fields, providing a comprehensive review and comparing performance analyses.

Keywords: Soft computing, Fuzzy logic, Risk management, computational

1. Introduction

Algorithms that generate approximations of solutions to intractable high-level computer science issues are referred to as soft computing. In order to solve issues, traditional hard-computing algorithms usually depend much on real data and mathematical models. The term "soft computing" first appeared in the last decade of the twentieth century. Soft computing offers tools to manage risk in the real world within the framework of AI and ML. Its techniques represent advancements over previous methods, resulting in improved

outcomes. Nowadays, integration of artificial intelligence with various computing techniques has resulted in hybrid intelligence systems. Soft computing expands the uses of artificial intelligence and produces reliable results. Key concepts include resolving ambiguity, adaptable learning, comprehending complex data, practical applications, and ethical considerations in artificial intelligence.

Soft computing began to emerge in the last decade of the 20th century. Fuzzy logic was first established by Lotfi Zadeh in 1965, and it provided the mathematical foundation for soft computing. Evolutionary computing, or the creation of genetic algorithms which imitated biological processes, started to take development in the 1960s and 1970s. These models paved the way for addressing uncertainty in various applications. Even though the 1940s and 1950s saw the beginning of neural network research, the 1980s saw a fresh need for this kind of study. It took time for researchers to create methods for pattern recognition. In order to swiftly tackle complex issues, hybrid intelligence systems that included fuzz logic, neural networks, as well as evolutionary computation were developed between the 1980s and 1990s. Models have been crucial and have an impact on many large data-handling sectors, such as engineering, health, the social sciences, and finance, since the 1990s [10].

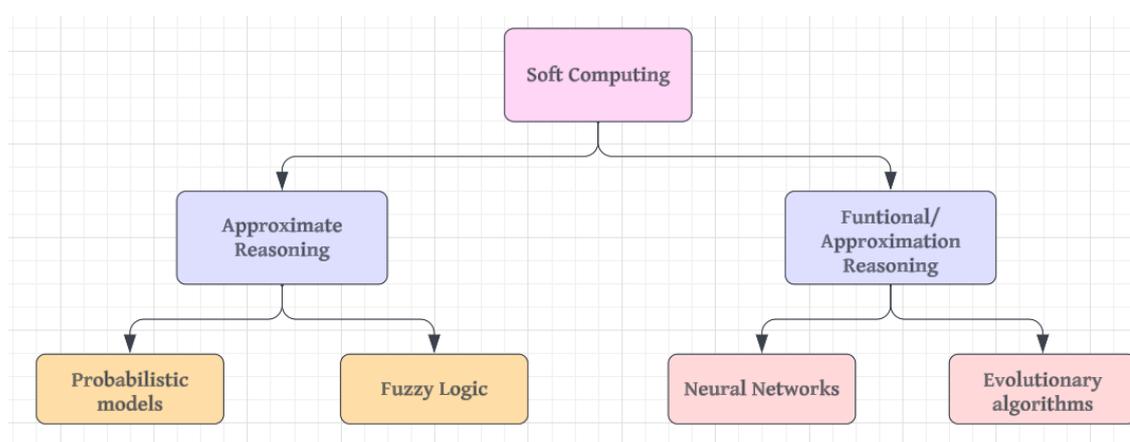


Figure 1. Different Types of Soft Computing

Soft computing comes in two varieties. They are functional reasoning and approximation reasoning.

Approximate Reasoning

The method or methods used to infer a potential imprecise conclusion from a set of imprecise premises are known as approximate reasoning. The main component of approximation reasoning is fuzzy logic. It is capable of handling many kinds of uncertainty [1].

Functional Reasoning

A particularly promising method for multi-variable, non-linear approximation of functions model and controller creation is the functional reasoning method [2]. As a result, each reasoning process produced unique soft computing strategies, which will be covered in the following sections. This article will include performance analysis comparisons while discussing various domains of risk management using fuzzy logic, a soft computing method

Techniques of Soft Computing

It is believed that conceptual intelligence is a developing discipline, and soft computing is one of its foundational elements. The recent developments to soft computing techniques include fuzzy logic (FL), evolutionary computation (EC) neural networks (NN), machine learning (ML), probabilistic reasoning (PR), and so on. Additionally, soft computing uses similar methods to handle any complicated issue. All of these components may be used to efficiently resolve any challenges. The three categories of methods that soft computing employs are as follows [11]:

- Fuzzy Logic
- Artificial Neural Networks
- Genetic Algorithm

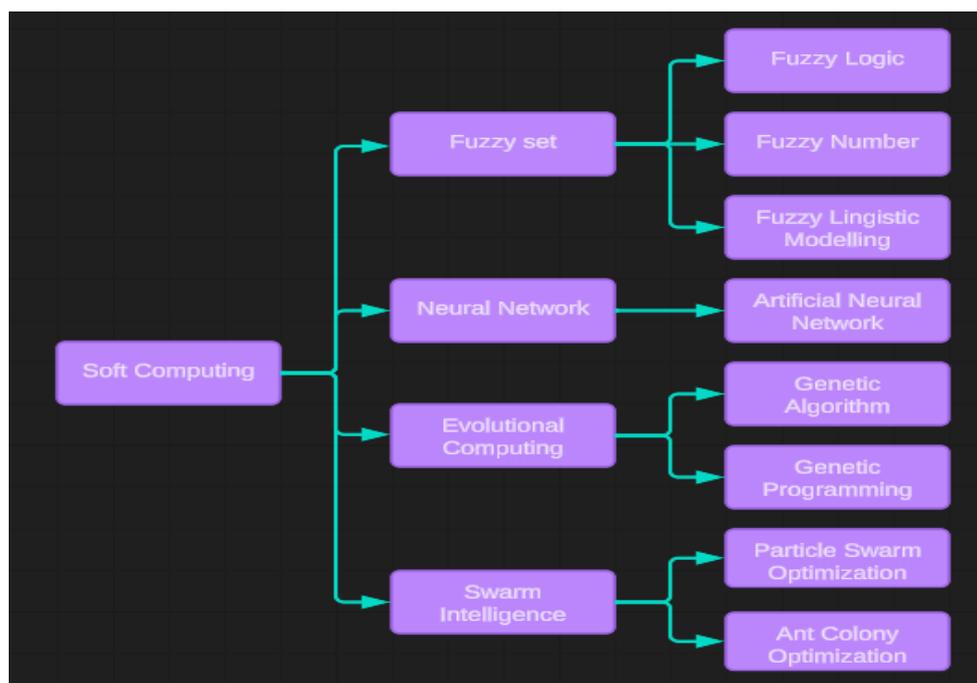


Figure 2. Different Techniques of Soft Computing

Fuzzy Logic

Basically, fuzzy logic is mathematical logic used to solve problems having an imprecise and open spectrum of information. It facilitates the acquisition of a variety of accurate judgements.

Fuzzy logic is primarily intended to find the most appropriate answer, given all the input data and knowledge together, to handle complicated problems. The fuzzy logic systems are greatest problem solvers. To get a definitive result, fuzzy logic may be applied in systems like microcontrollers, workstation-based systems, or big network-based systems. It may also be used in software or hardware.

Artificial Neural Networks (ANN)

The development of neural networks in the 1950s enabled soft computing to address real world problems that a computer could not resolve on its own. As we all know, a machine cannot accurately depict real-world situations, unlike human brain.

A computer capable of human-like thinking is referred to as an artificial neural network (ANN), which simulates the network of neurons that make up a human brain. In this way, a computer or other machine may learn things and become as intelligent as a human brain in

making decisions. Artificial Neural Networks (ANN) are computer programmes that mimic the communication patterns of brain cells. It is analogous to the neurological system of humans.

Genetic Algorithm (GA)

The definition of genetic algorithms is a class of computer optimisation method derived from the principles of selection and genetics. By imitating the process of evolution, it is used to solve complicated problems by iteratively improving a population of possible answers. The genetic algorithm derives inspiration from nature and is mostly based on it. They are not founded on search-based algorithms. Furthermore, a genetic algorithm is a subsection of a broad field of mathematics [12].

2. Literature survey

In this research [3], an innovative view of intuitionistic fuzzy sets within the extended context based on the Dempster–Shafer theory of evidence is further developed for monitoring safety-critical systems' performance. The suggested method is not only more efficient than the traditional Takagi-Sugeno fuzzy system, which considers that the rule (the information) is flawless, but it also considers fuzzy rules which deal with incomplete knowledge or information. Using fuzzy set theory and the conceptual probabilistic method for formal ship safety assessment, we offer an analytical solution to the practical and significant problem of uncertainties related to the dependability of the input data. Because the fuzzy mapping structure takes uncertainty and partial truth into account in the input–output mapping, it is possible to use it to analyse the overall security of the ship engine as an object of risk analysis. The suggested approach incorporates concrete proof of the discerning framework and is exemplified by means of allusions to instances where fuzzy set models provide useful insights. These straightforward examples show how to evaluate the conflicts of sensor information fusion for a vessel's adequate cooling power system in the face of harsh operating circumstances. It was discovered that propulsion engine safety systems are dynamic and sophisticated in addition to being a function of several environmental and operating variables.

This article [4] provides a thorough framework for developing and implementing controllers for autonomous drones that are based on fuzzy logic. The suggested framework consists of three main components: perception, decision-making, & control. The perception

module creates precise environment representations by processing sensor input, including depth and vision data. The decision-making module makes logical decisions for obstacle avoidance and navigation by interpreting the perceptual data and applying fuzzy logic techniques. The control module translates the decisions made by the fuzzy logic system into the appropriate control signals that the drone will obey. Additionally, resilient and adaptable to shifting environmental conditions and uncertainties, the fuzzy logic-based control system is suitable for real-time applications. Adopting this architecture opens up new possibilities for automated drone applications, including delivery services, surveillance, and search and rescue operations. Developing autonomous drone vehicles using fuzzy logic-based control systems is a feasible approach to delivering accurate and efficient drone navigation under difficult circumstances. This research contributes to the advancement of autonomous systems development by providing a comprehensive framework that integrates perception, decision-making, and control using fuzzy logic methodologies.

This article [5] was modified to provide an in-depth review of the most recent fuzzy logic techniques for collision-free planning of paths for serial manipulator robots operating in cluttered and complex workspaces. This will help researchers quickly and easily find relevant works on fuzzy-based solutions. Along with a thorough explanation of fuzzy hybridization, there is also a summary of various artificial intelligence approaches. Additionally, this article aims to summarise and visually represent all fundamental strategies that path-planning issues may include in the process of decision-making in order to provide the primary solutions. The report concludes by outlining some possible difficulties and investigating research questions for more effort.

In this research work [6], based on data fuzzification, inference, and defuzzification, a model of maintaining the stability of a geotechnical system using fuzzy logic techniques was created to avert accidents at mining firms. The primary guidelines were developed to help the mining sector identify the distinctive characteristics of hazardous production sites. The systematisation of uncontrolled (mining and geological) and controllable (technical and technological) characteristics, the presence or modification of which influences the stability of the rock massif or highways, was done in order to identify the input variables for the fuzzy logic model. It has been demonstrated that techniques like aggregation, implication, and defuzzification may be applied to process incoming signals. A fuzzy logic inference technique

was developed to regulate a geotechnical system's parameters. The capacity of the model to adjust to the particulars of managing the "support - rock massif" geotechnical system and to choose logical rules based on predetermined criteria sets it apart.

This article [7] uses the fuzzy-FMEA approach to analyse the risk level of the main engine. Eight fishing boats in Batam, Indonesia were directly observed in order to identify the system's components and the reasons for their failures. Using C-RPN analysis, the assessment produced a rating of the injectors (200.61), injection pumps (159.94), then fuel filter (95.09) as the three most important parts in order. By contrast, the injectors (454.80), injection pumps (358.42), & fuel tank (293.48) values of the key components changed as a result of the F-RPN study. Because the risk parameter scale of the assessment outcomes was used to evaluate the entered data, the F-RPN value in the examined analysis is more accurate. Because the fuzzy-FMEA model is accurate in determining the possible risk value on the C-FMEA when entering risk parameter indication data, it has the benefit of properly measuring the amount of component failure risk on fishing vessels' main engines. Utilising risk analysis on crucial parts of fishing boats' primary engines, the fuzzy-FMEA model advances our understanding of maintenance planning.

The usefulness of the Art-Risk 3.0 programme for historical building conservation research is covered in this article [8]. A brand-new, free programme that uses fuzzy logic makes it possible to monitor the preservation of historic structures over time and evaluate preventative conservation measures. In order to determine if restoration or preventative conservation is necessary, this artificial intelligence-based technology takes into account the fragility of buildings, their environs, and their management. A study of 500 theoretical case studies was conducted in order to verify Art-Risk 3.0. Additionally, modifications made after restoration were identified by examining a 14th-century Mudejar-Gothic-style church in Seville, Spain, both before and after it was restored. The above proof of concept shows how the Art-Risk 3.0 programme can evaluate the efficacy of restoration efforts and analyse the effects of the environment on a building's vulnerability, risk, & functional service life. This programme also determines which aspects are the most troublesome and whether repair is necessary.

In order to execute this investigation [9], 12 previously unexplored landslip conditioning factors with 10 *10 cell sizes were developed. Using their layer toolboxes, which comprise slope, aspect, elevation, curvature, and hill shadow. These variables were

immediately generated using a LiDAR (Light Detection and Ranging) and DEM (Digital Elevation Model). The spatial layers of slope, flow direction, and flow accumulation were used to generate the stream power index (SPI), topographic wetness index (TWI), and terrain roughness index (TRI). By digitising the land use/cover from the LiDAR picture and applying the Euclidean distance method in ArcGIS, shapefiles with the distances to lakes, roads, trees, and build-up were created. Expert opinion, prior landslip research, and the features of the study location were taken into consideration while choosing the parameters. Furthermore, this study employed multicriteria decision-making analysis to forecast the likelihood of a landslip. This analysis used the analytic hierarchy process (AHP) and fuzzy logic methodologies that were not applied before with a LiDAR DEM. The results were validated using the receiver operating characteristics (ROC). The ROC approach yielded area under the curve (AUC) values of 0.859 and 0.802 for the AHP and fuzzy, respectively. The ultimate susceptibility findings would be beneficial for sustainable landslip hazard mitigation as well as for Malaysian urban developers.

Table 1. Illustration of the Different Fuzzy Logic Approaches on the Different Field to Acquire the Solutions

Reference	Method	Applications	Result
[3]	Fuzzy set theory	Ship engine	Examine the ship engine's total security as a subject of risk analysis.
[4]	Fuzzy logic-based control systems	Drones	offering an extensive framework that uses fuzzy logic techniques to combine observation, decision-making, and control.

[5]	fuzzy logic techniques for serial manipulator robots	Robotics	All essential methods that path-planning problems might require in the decision-making process to offer its primary solutions
[6]	Geotechnical system using fuzzy logic	Mining Field	The model's ability to adapt the specifics of handling the "support - rock massif" geotechnical system & select rational rules according to present standards
[7]	Fuzzy-FMEA approach	Fishing boat engine	Advantages of accurately calculating the primary engine component failure risk for fishing vessels
[8]	Art-Risk 3.0 and fuzzy logic	Historical building conservation approach	To evaluate the success of restoration efforts and examine how the environment affects a building's risk, susceptibility, and functional service life.
[9]	AHP and fuzzy logic	Landslide approach	Beneficial for both Malaysian urban developers and sustainable landslip hazard mitigation

3. Performance Analysis

This section will address the performance of the aforementioned related works using the fuzzy logic approach. As a result, the accuracy of each method's fuzzy logic performance varies. The table 2 shows what the accuracies for every work.

Table 2. Accuracy for Each Method

Reference	Method	Accuracy
[3]	Ship engine	94.6
[4]	Drones	95
[5]	Robotics	92
[6]	Mining Field	90.8
[7]	Fishing boat engine	95.99
[8]	Historical building conservation approach	90
[9]	Landslide approach	85

Table 2 will be used to describe the diagrammatical technique, which aids in determining the accuracy range from high to low.

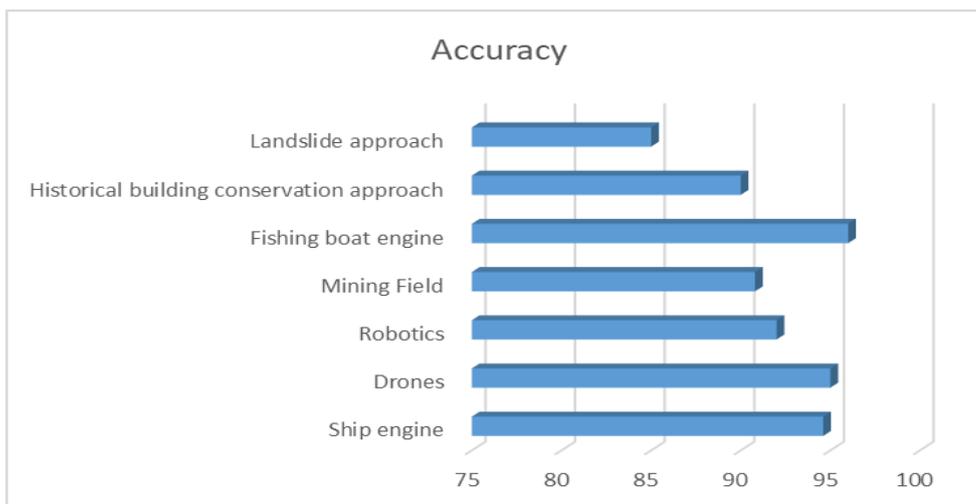


Figure 3. Graph Representation of Accuracy for Each Method

Thus, based on earlier studies, It was found that fuzzy logic plays a vital role in the decision making in various fields, in all the above applications fuzzy logic was used in combination with the advanced technological devices which helped in further enhancing the decision making in the time of risk by properly handling the uncertainties in the ubiquitous environment.

4. Conclusion

Numerous industries, including control systems engineering, robotics, consumer electronics, image processing, power engineering, industrial automation, and optimisation, have found success with fuzzy logic. In this article, using previous study methodology, we may determine the significance of fuzzy logic in all sectors and comparing the accuracy. The future scope of fuzzy logic is useful in circumstances where classic binary logic could be constrictive since it can handle imperfect information and ambiguity. Fuzzy logic is anticipated to become more crucial in the creation of intelligent systems and the resolution of challenging real-world issues as technology develops.

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