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An Insight into Fuzzy Logic Computation Technology and Its Applications in Agriculture and Meteorology

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Abstract

Speaking of recent advances, many computing technologies have been applied to several domains and have proved to provide more approximate and acceptable results. Fuzzy logic being one of them has been very useful in solving many real-world problems that are inherent for their uncertainty, complexity, impreciseness and a high degree of randomness. Soft computing aims to mimic human thinking and thus solve problems as a human does. The systems embedded with one or more soft computing technologies tend to make decisions quicker (reducing the processing timeframe) and more accurate in the light of uncertain and indefinite data. This paper aims at an extensive review of fuzzy logic also unraveling some of the applications of the same in the field of agricultural science and meteorology.

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Keywords

Artificial Intelligence;
Computation Technology;
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Introduction

Artificial Intelligence, Augmented Reality, Virtual Reality, Soft computing have become one of the top buzzwords of the decade and we can't deny the future being chiseled by these technologies. Human reasoning is unimaginable and unmatched to date. We, humans tend to make decisions ac-cording to the situation and do not follow any rules for doing so. Human reasoning is approximate and is capable of making decisions in the light of uncertain situations and imprecise data. For ex-ample, when we cross a road, we do not use the speed, distance, time formula and then decide to cross the road. We just cross the road if we think the car is coming slow. This ability to think like a human is being incorporated into machines. Soft computing as a whole is defined as an approach to building computationally intelligent systems that can mimic human thinking and can adapt and learn to a changing environment at a lower cost. It encompasses several methodologies for doing so. It includes fuzzy logic, neural networks, and genetic algorithms, etc.,. When they are used in com-bination it is called a hybrid system and hybrid systems have more Machine Intelligent Quotient (MIQ) than any methodology used alone. Fuzzy logic was first introduced by Lotfi A Zadeh at the University

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of California, Berkely. Though there are a lot of papers citing that Fuzzy logic was in-troduced in 1965, history is a little different. In 1964, Lotfi A Zadeh came up with the idea of fuzzy sets as an extension of the traditional Boolean / crisp sets. His paper was published in 1965. Later in his 1974 paper, 'Fuzzy logic and Approximation.' the term fuzzy logic was used first used by Lotfi A Zadeh. The concept was developed as a means to deal with uncertainty, impreciseness, and the vagueness associated with real-world problems. In the crisp sets, an object can belong to or not belong to a set. However, in the fuzzy set, an object can belong to a set to a certain degree. This degree of membership allows an object to belong to two sets at the same time.

This paper deals with an extensive review of the use of Fuzzy Logic in agricultural sciences with special reference to meteorology.

Methodology

Databases like ProQuest, Science Direct, Elsevier have been used. Search results for fuzzy logic (AND) agriculture, fuzzy logic (AND) meteorology has yielded results of 2,065 and 720 respective-ly in the ProQuest database. Around 25 papers from 1995 to 2020 have been used for the review.

Agricultural Science

Agriculture extensively deals with the natural data known for their uncertainty and vagueness. Fuzzy logic has been applied in the agricultural and biological systems to get more accurate and reliable results. The application domains include a wide array from agro-engineering applications to clinical diagnosis. Some of the literature citing applications in agriculture are given below:

Mariman and Mushthofa (2013) have summarized the uses of fuzzy logic and fuzzy inference systems in the areas of agricultural engineering and technology. They have reviewed studies relating to fuzzy logic applications for finding suitable land, predicting weather conditions, managing pests and weeds, and product quality management. Fuzzy logic combined with computer vision tech-niques prove to be an added advantage.

Roseline *et al*., (2015) have reviewed some of the applications of fuzzy logic combined with an expert system used in the field of agriculture. Disease management, pest management, weed management, soil studies, expert systems for various crops were some of the areas that were reviewed. The paper emphasized the growing use of expert systems and other technologies in agriculture and elu-cidated the modern methods that can be combined with the traditional methods thereby benefiting the farmers as a whole.

Luydmila *et al*., (2017) have applied fuzzy set theory for yield estimation by using agro-meteorological models. The approach was proved to be a tool for ranking farming territories ac-cording to their weather conditions and viability to grow crops.

Pandey *et al*., (2018) have acknowledged and developed a model for agriculture disease diagnosis and forecasting support system.

Vema *et al*., (2019) have used Fuzzy Inference Systems for evaluating suitable sites to establish water harvesting structures.They applied the developed model to Kondepi watershed in Andhra Pra-desh.

Fuzzy Logic in Meteorology

Soft computing techniques have opened many opportunities to deal with the complexity and ambi-guity that comes with meteorology. A word cloud (Fig.1) that was generated based the articles col-lected for review revealed the following. This word cloud shows that fuzzy logic is widely applied for weather prediction and forecasting studies in meteorology.

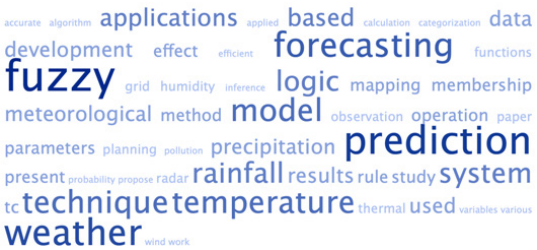

Fig. 1: Word cloud on the reviews collected

Numerical weather forecasting has its genesis in 1922 when Lewis Fry Richardson made an elemental approach to forecast weather conditions using his hand calculator. The initial forecast was six hour long. After the world wars, in 1950 when the computer and information technology began to flourish, Jule Charney and his group made the

first successful numerical weather prediction using ENIAC (first computer) at Princeton. Since then, many developments have been made from statistical models to soft computing models. These soft computing and hybrid climate models will allow for real time data collection and prediction with improved accuracy, less ambiguity, and the ability to deal with vague and noisy environment.

Rainfall Prediction

Fuzzy Logic helps in accurate prediction of rainfall conditions precisely in terms of wind speed and temperature variables. Short-term load forecasting has also proved to be explicit with rainfall pre-dictions using fuzzy logic systems (Singla *et al*. 2019). Accurate or near -accurate rain prediction admits for formulating better strategies for managing excess water, predicting drought and flood conditions in the future. It has been proved that Fuzzy artificial neural networks (Fuzzy ANN) gives a more reliable prediction on rainfall than the traditional artificial neural networks(ANN) (Lu *et al*., 2014). Based on their study, a new model was proposed for error-free weather predictions called, Neuro Fuzzy Inference Systems - Weather prediction Model or NFIS - WPM. Fuzzy logic can be used to develop a model to predict rainfall using the temperature of that location (Jimoh *et al*. 2013). Models that are built on fuzzy logic and fuzzy inference systems have proved to be more au-thentic and definitive (Jantakoon, 2016). The author has evaluated the validity of fuzzy model with two types of error namely, Prediction error and Root Mean Square Error. Evidently, either of these errors were comparatively less than the actual data, further proposing fuzzy logic is highly capable of dealing with scattered data. Fuzzy Membership approach for predicting pre-monsoon weather conditions in Kolkata, India has demonstrated more accuracy and reliability than the traditional used statistical method, Linear Discriminant Analysis (Chatterjee *et al*., 2011). A precipitation probability grid developed with fuzzy logic to improve radar precipitation maps gives improved correlation results, transforming location-based variables to probabilities (Silver *et al*., 2020).

The accuracy rate of rainfall predictions made using fuzzy inference system in Malaysia is about 72 per cent (Safar *et al*., 2019). Anurag *et al*. (2020) have proposed that co-active neuro fuzzy inference system (CANFIS) gave better results in terms of reliability and accuracy in predicting standardized precipitation index (SPI). The CANFIS was validated with an artificial intelligence model and a regression model enumerating the performance evaluation metrics like root mean square error, Nash-Sutcliffe efficiency etc. Results of the study revealed CANFIS was a more preferable model and that it can aid in building a more resilient and valid expert intelligent system. This expert system can be used in or predicting drought conditions across various time periods. Fuzzy logic is an inevitable and an effective technique for correctly predicting rainfall (Das and Tripathy, 2017).

Atmospheric Temperature

Fuzzy set theory was used in forecasting atmospheric temperature for different cities in India. The variable used here for prediction was rainfall (Ghosh *et al*., 2014). To develop the fuzzy knowledge base, they used a sequence containing 19,140 sets of daily observations of Temperature, Rainfall over a period of one year. Fuzzy systems are highly flexible and could also be applied for other me-soscale situations like stratus formation and dissipation, (non-frontal) thunderstorm development, snow squall situations and ice crystal formation. Fuzzy Inference System was used to forecast at-mospheric temperature in the Indian coastal cities (Patel and Christian 2012). The variables used were, Mean Sea level Pressure, Relative Humidity and Temperature. The proposed fuzzy logic pre-diction model established higher accuracy in predicting the temperature. The results were validated with Root Mean Square Error which proved to be low for the study. Fuzzy genetic system was used in creating a model for long-term air temperature prediction based on geographical information (Sadeghi-Niaraki *et al*. 2020).

Radiation Fog

Jim Murtha (1995) hadutilized fuzzy logic technique to forecastthe probability of formation of radi-ation fog in operational meteorology.

Pollution Concentrations

A fuzzy weather forecast was developed to forecast pollution concentrations. Data were collected for weather forecasts, meteorological situations and pollution concentrations. They have investi-gated the fuzzy logic approach in predicting pollution concentrations in the atmosphere using vari-ous parameters (Domanska and Wojtylak, 2010)

Cyclone Forecasting

Most tropical cyclone(TC) forecasts depend on forecasts like wind radius and velocity. Irawan *et al*., 2019 have developed and validated a TC simulation prediction model that has proved to have lesser error terms.The accuracy of the results with Fuzzy logic algorithms were at 75%.

Besides the aforementioned arenas, fuzzy logic is also used in measuring solar energy/ sunshine duration, load forecasting using weather data, thermal maps, sea-breeze events detection, wind generation forecasting etc., Soft computing and hybrid systems have proven to be an established method for more complex and ambiguous data. Meteorology is innate to vague, inaccurate, and uncertain large data accompanied by subjective human conclusions. In such circumstances, fuzzy logic mani-fests to be the solution to accurate and authentic results for better forecasting and prediction.

Conclusion

Several soft computing technologies have found prominent applications in life sciences and social sciences. It is evident that these technologies are proving to be of great use in terms of accuracy and swiftness. Though fuzzy logic had been almost half a century old, it is of recent times that it is being applied to agriculture and Meteorology. The results have been great and promising for the future. Lotfi A Zadeh had formed the basis for computing with words and making machines think and decide more like humans which is what we call artificial intelligence today. Fuzzy logic was and is continued to be a basic system of Artificial Intelligence. This paper discussed some of the research-ers using fuzzy logic in agriculture and Meteorology but its applications are still wide and have room for further exploration. Its ability to deal with uncertainty and its compatibility to deal with natural language has been the concrete idea behind using it for agriculture and Meteorology where there are a large number of human decision factors. The literature reviews have shown to prove the same. Studies are also done by incorporating fuzzy logic into various Multiple-criteria decision-making (MCDM) approaches for better results. Its ease of blending with other tools provides an added advantage. Some of the examples are fuzzy-ISM, fuzzy-MOORA, fuzzy-AHP, etc., Fuzzy Logic is a great tool that is under-utilized in many areas. Its advantages are plenty and is an easy tool for use. Further applications can be attempted in profound areas of Agriculture and Meteorology.

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Conflict of Interest

The authors do not have any conflict of interest.

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