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Review

Soft Computing for Decision-Making in Fuzzy Environments: A Tribute to Professor Ioan Dzitac

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Abstract: This paper is dedicated to Professor Ioan Dzitac (1953–2021). Therefore, his life has been briefly presented as well as a comprehensive overview of his major contributions in the domain of soft computing methods in a fuzzy environment. This paper is part of a special reverential volume, dedicated to the Centenary of the Birth of Lotfi A. Zadeh, whom Ioan Dzitac considered to be is his mentor, and to whom he showed his gratitude many times and in innumerable ways, including by being the Guest Editor of this Special Issue. Professor Ioan Dzitac had many important achievements throughout his career: he was co-founder and Editor-in-Chief of an ISI Expanded quoted journal, International Journal of Computers Communications & Control; together with L.A. Zadeh, D. Tufis and F.G. Filip he edited the volume "From Natural Language to Soft Computing: New Paradigms in Artificial Intelligence"; his scientific interest focused on different sub-fields: fuzzy logic applications, soft computing in a fuzzy environment, artificial intelligence, learning platform, distributed systems in internet. He had the most important contributions in soft computing in a fuzzy environment. Some of them will be presented in this paper. Finally, some future trends are discussed.

Keywords: soft computing; decision-making; fuzzy sets; fuzzy environment; Dzitac

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1. Introduction

This paper is dedicated to Professor Ioan Dzitac (14 February 1953–6 February 2021). Therefore the paper begins with a short presentation of his life and work.

Ioan Dzitac was born in the village of Poienile de sub Munte, in the County of Maramures, Transylvania, Romania. He graduated from the Faculty of Mathematics of Babeş-Bolyai University of Cluj-Napoca in 1977 and continued as a high school math teacher in Bihor (Aleşd and Oradea), Romania. In 2002, Prof. Dzitac obtained his PhD Thesis at Babeş-Bolyai University of Cluj-Napoca and in the next few years he published several works in field of distributed and information systems.

In 2007, Dzitac had the great privilege of meeting the world-renowned scientist Lotfi A. Zadeh and since then, up to the end of his career, his scientific interest focused on different sub-fields:

1. Fuzzy logic applications. For major achievement see: [1,2] etc.
2. Soft computing in a fuzzy environment. See: [3–8] etc.
3. Artificial intelligence: [9,10] etc.
4. E-learning platform: [11,12] etc.
5. Distributed systems in internet: [9,13] etc.

He had the most important contributions in soft computing in a fuzzy environment. Some of them will be presented in this paper.

His collaboration with Lotfi A. Zadeh started in 2008. Zadeh was invited as speaker at the International Conference on Computers Communications and Control (ICCCC) (see Figure 1), an ISI indexed conference, founded and chaired by Dzitac.

Figure 1. Ioan Dzitac and Lotfi A. Zadeh at ICCCC 2008.

Just a week before passing away, I. Dzitac remembered: "I waited for him (Lofti A. Zadeh) at the airport in Budapest. At 87 years old, he was traveling unattended from San Francisco, where he lived and was the active director of the research institute BISC at the University of California, Berkeley (position that he held until his death in 2017, at 96 years old). He took a nap in the car. However, when he woke up, he started to tell me about his first visit in Romania and the encouragements offered by Grigore C. Moisil, in 1967, two years later, with great courage, he published "Fuzzy Sets". He really needed those pats on the back because many mathematicians, logicians and engineers met his theories with skepticism and sometimes even with mockery [14]".

L.A. Zadeh had a major influence on Ioan Dzitac's career, because, after their encounter, Ioan Dzitac had a very prosperous period from a scientific point of view, as he published many articles in well-known journals, either as a unique author or in cooperation with: F.G. Filip, M.J. Manolescu, S. Negulescu, A.E. Lascu, C. Butaci, S. Dzitac, G. Bologa, D. Benta, S. Nadaban, B. Barbat, I. Moisil, I. Felea, T. Vesselenyi, C. Secui, V. Lupse and abroad: B. Stanojevic (Serbia), H. Liu (China), S. Gao (China), R. Andonie (USA), A.M. Brasoveanu (Austria), Y. Shi (China), G. Kou (China), F. Cordova (Chile), H. Lee (Korea), etc.

One volume, very dear to Professor I. Dzitac, cannot be omitted. It is "From Natural Language to Soft Computing: New Paradigms in Artificial Intelligence", volume co-edited by L.A. Zadeh (University of California), D. Tufis (Romanian Academy), F.G. Filip (Romanian Academy), I. Dzitac (Agora University), Romanian Academy Ed. House, 2008 [15].

The recognition of his results appeared very soon, his papers being quoted by authors from Romania, Chile, India, USA, Iran, Malaysia, Serbia, Canada, France, Russia, Turkey, Australia, Hungary, Lithuania, Morocco, Spain, Tunisia, Algeria, Czech Republic, in some prestigious journals.

To highlight the impact of his research it should be mentioned that Ioan Dzitac has in Web of Science h-index = 11 and 472 citations, of which 64 in the first 5 months of 2021. The paper [6] has 10 citations in the period January 2021–May 2021, while the paper [2] has 16 citations in the same period. The last citations from May 2021 are:

1. Liang, H.; Cai, R. A new correlation coefficient of BPA based on generalized information quality. *Int. J. Intell. Syst.* **2021**, doi:10.1002/int.22490 [16];
2. Roszkowska, E.; Kusterka-Jefmanska, M.; Jefmanski, B. Intuitionistic Fuzzy TOPSIS as a Method for Assessing Socioeconomic Phenomena on the Basis of Survey Data. *Entropy* **2021**, *23*, 563, doi:10.3390/e23050563 [17];

3. Hamzelou, N.; Ashtiani, M; Sadeghi, R. A propagation trust model in social networks based on the A* algorithm and multi-criteria decision-making. *Computing* **2021**, *103*, 827–867, doi:10.1007/s00607-021-00918-w [18].

I. Dzitac was co-founder and Editor-in-Chief of an ISI Expanded quoted journal, *International Journal of Computers Communications & Control* (nominee by Elsevier for Journal Excellence Award - Scopus Awards Romania 2015) and member in Editorial Board of 12 scientific journals. Additionally, he is co-founder and General Chair of International Conference on Computers Communications and Control. He was member of the Program Committee of more than 80 international conferences.

He was Senior Member IEEE (since 2011). He was invited speaker and/or invited special sessions's organizer and chair in China (2013: Beijing, Suzhou, Chengdu, 2015: Dalian, 2016: Beijing), India (2014: Madurai, 2017: Delhi), Russia (2014: Moscow), Brazil (2015: Rio), Lithuania (2015: Druskininkai), South Korea (2016: Asan), USA (2018: Nebraska).

He was included among 100 Romanian computer scientists from all over the past 100 years in the volume "One Hundred Romanian Scientists in Theoretical Computer Science", Romanian Academy Publishing House, 2018.

I. Dzitac was full professor at Aurel Vlaicu University of Arad (since 2009), professor at Agora University of Oradea (since 2017) and Rector at Agora University of Oradea (2012–2020). He was an Adjunct Professor at University of Chinese Academy of Sciences—Beijing, China (2013–2016) and since 2016 he was in Advisory Board Member at Graduate School of Management of Technology, Hoseo University, South Korea.

In 2019 he defended his Habilitation Thesis "Soft Computing for Decision-Making" at "Alexandru Ioan Cuza" University of Iasi, which conferred him the right to conduct doctorates. Thus, he became PhD supervisor at University of Craiova, Romania.

In all those years, I. Dzitac did not cease to show his gratitude towards the one who considered to be his mentor: Lofti A. Zadeh. Thus, in 2011, he edited a Special Issue of IJCCC at 90th Zadeh's birthday and another in 2015 at 50th Fuzzy Sets anniversary. In 2017, at Zadeh's death, I. Dzitac published a survey about his life and his famous contributions in scientific world [2]. In January 2021, just a month before his death, I. Dzitac edited another Special Issue of IJCCC dedicated to the centenary of the birth of Lotfi A. Zadeh (1921–2017).

As already mentioned, beginning with 2007, Ioan Dzitac's interest was in soft computing methods in fuzzy environments. Starting from here, the structure of the paper will continue as follows: Section 2 will present some general considerations regarding soft computing methods, highlighting the fundamental differences between soft computing and hard computing; considering that soft computing methods are numerous, in Section 3 we will resume to presenting some fundamental ideas of fuzzy logic, which is the most used Soft Computing method in a variety of decision-making problems; in Section 4 we will present a survey on I. Dzitac's contributions to this domain. Finally, in Section 5 we will have some conclusions but mostly some future trends will be discussed.

2. Soft Computing Methods

Hard computing (HC) is the conventional calculation and it needs an analytical model well defined and many times a log time for calculating. Many analytical models are valid only in ideal cases. The problems of the real world exist within a non-ideal frame. Thus, many complex systems that are found in engineering, biology, medicine, economy remain unsolved to HC.

Soft computing is a concept introduced for the first time by L.A. Zadeh [19]. According to Zadeh's definition, Soft computing (SC) methods are opposed to HC techniques, consisting of computational techniques in Informatics, machine learning and certain engineering subjects that study, shape and analyze a very complex reality for which the traditional methods prove ineffective. Soft computing can work with ambiguous data, and it is tolerant to vagueness, uncertainty, partial truth and approximation. The model for SC is human mind.

Lotfi A. Zadeh said about Natural Language (NL) Computation: "NL-Computation is of intrinsic importance because much of human knowledge is described in natural language. This is particularly true in such fields as economics, data mining, systems engineering, risk assessment and emergency management. It is safe to predict that as we move further into the age of machine intelligence and mechanized decision-making, NL-Computation will grow in visibility and importance. Computation with information described in natural language cannot be dealt with using machinery of natural language processing. The problem is semantic imprecision of natural languages. More specifically, a natural language is basically a system for describing perceptions. Perceptions are intrinsically imprecise, reflecting the bounded ability of sensory organs, and ultimately the brain, to resolve detail and store information. Semantic imprecision of natural languages is a concomitant of imprecision of perceptions. Our approach to NL-Computation centers on what is referred to as generalized-constraint-based computation, or GC-Computation for short. A fundamental thesis which underlies NL-Computation is that information may be interpreted as a generalized constraint." [20].

Soft Computing includes: (1) Fuzzy Logic; (2) Neural Computing: Perceptions, Artificial Neural Networks, Neuro-Fuzzy Systems; (3) Evolutionary Computation: Genetic Algorithms (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Artificial Life(AL); (4) Machine Learning: Intelligent Agents, Expert Systems, Data Mining; (5) Probabilistic Reasoning: Bayesian Networks, Markov Networks, Belief Networks.

To discuss all these methods would exceed the space for an article. Therefore, the next section will be limited to the presentation of only a few fundamental ideas of fuzzy logic, which is the most used Soft Computing method in a variety of decision-making problems.

The next table (see Table 1) is adapted from [9] and it presents the conclusions of the HC paradigm versus SC paradigm.

Table 1. Hard Computing vs. Soft Computing.

Hard Computing	Soft Computing
Well-posed problem solving	*Ill-posed problem* solving
Bivalent logic-based (tertium non datur)	*Fuzzy logic*-based (tertium included)
Deterministic environment (closed, static, known)	*Nondeterministic* environment (open, dynamic, uncertain)
Well-defined *problem* (quantity, precision, certainty)	Fuzzy-defined *Situation* (quality, imprecision, uncertainty)
Solving accurately problems (imperative, firm, reliable)	*Managing* "Just In Time" situations (descriptive, flexible, robust)
Optimal, lasting, *solution* (algorithmic, apodictic, general)	Suboptimal, temporary, *answer* (non-algorithmic, revisable, local)
Technocentric design	*Anthropocentric* design
Software entity: *PROGRAM* (*object devised as tool*)	Software entity: *AGENT* (*process devised as interactant*)
Client-Server paradigm (object-oriented, sequential)	*"Computing as Interaction"* paradigm (agent-oriented, parallel)

3. Fuzzy Logic in Decision-Making

In classical logic the sentences are bivalent, this meaning that all sentences that describe the state of an event are either true or false. With this bivalent logic computers were endowed, they can make massive computations, which are very difficult for people. On the other hand, computers cannot imitate the intuitive human mind and this because people can operate with vague linguistic information. It is difficult though for these to be modelled in classical logic. At the same time, in many real-world situations there are uncertainties and vague information.

To be able to deal with these uncertainties and ambiguities, L. A. Zadeh [21] introduced in 1965 the concept of fuzzy sets.

If X is an arbitrary set. A fuzzy set in X is a function $\mu : X \to [0,1]$. The function μ is called the membership function and $\mu(x)$ represents the value of truth as x belongs to the fuzzy set.

In 1975, L.A. Zadeh [22] introduced the concept of linguistic variable. This is a variable whose values are words or sentences. For example, an important criterion in location problems is "accessibility". This is a linguistic variable. It can take values linguistic terms. For the linguistic variable "accessibility" the linguistic terms set is

$$T(\text{"}accessibility\text{"}) = \{Very\ good, Good, Medium, Poor, Very\ poor\}.$$

The structure of a fuzzy logic system is presented in Figure 2. We notice that a fuzzy logic system is made of four components: fuzzyfication, fuzzy rules, inference engine, defuzzification.

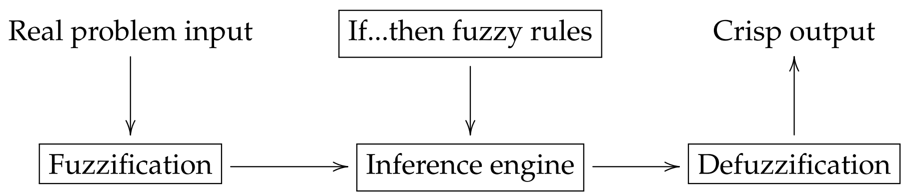

Figure 2. The structure of a fuzzy logic system.

3.1. Fuzzification

At this stage , first, each linguistic input A is mapped to the linguistic terms set $T(A) = \{T_A^1, T_A^2, \cdots, T_A^k\}$, and then, the meaning of each linguistic term $T_A^j (j = \overline{1,k})$ is represented by the membership function $\mu_A^j (j = \overline{1,k})$.

According to the needs, considering the computational efficiency, different types of membership functions can be used. The most used are *fuzzy numbers* (FNs).

By a FN we understand a mapping $f : \mathbb{R} \to [0,1]$, such that:

1. $f(y) \geq \min\{f(x), f(z)\}$, for $x \leq y \leq z$;
2. $(\exists)x_0 \in \mathbb{R} \ : \ f(x_0) = 1$;
3. f is upper semicontinuous, i.e.

$$(\forall)x \in \mathbb{R}, (\forall)\alpha \in (0,1] \ : \ f(x) < \alpha, (\exists)\delta > 0 \text{ such that } |y - x| < \delta \Rightarrow f(y) < \alpha \,.$$

Among the various types of fuzzy sets or their generalizations, the most common (see [6,23,24]) are:

(1) *Triangular FNs* which have membership function

$$f(x) = \begin{cases} 0 & \text{if} \quad x < a \\ \frac{x-a}{b-a} & \text{if} \quad a \leq x < b \\ \frac{c-x}{c-b} & \text{if} \quad b \leq x < c \\ 0 & \text{if} \quad x > c \end{cases} \text{, where } a \leq b \leq c \,,$$

and they are denoted by $\tilde{f} = (a,b,c)$.

(2) *Trapezoidal FNs* defined by membership function

$$f(x) = \begin{cases} 0 & \text{if} \quad x < a \\ \frac{x-a}{b-a} & \text{if} \quad a \leq x \leq b \\ 1 & \text{if} \quad b < x < c \\ \frac{d-x}{d-c} & \text{if} \quad c \leq x \leq d \\ 0 & \text{if} \quad x > d \end{cases} \text{, where } a \leq b \leq c \leq d \,,$$

and expressed as $\tilde{f} = (a, b, c, d)$.

(3) *Gaussian FNs* defined by $f(x) = e^{-\frac{(x-m)^2}{2\sigma^2}}$.

(4) *Interval-valued fuzzy sets*, defined by the membership mapping $f : X \to \mathcal{I}([0,1])$, where $\mathcal{I}([0,1])$ represents the set of all closed subintervals of $[0,1]$.

(5) *Intuitionistic fuzzy sets*, defined by a membership function f and also by a non-membership function g such that $0 \leq f(x) + g(x) \leq 1, (\forall) x \in X$.

(6) *Interval-valued intuitionistic fuzzy sets*, defined by two functions $f, g : X \to \mathcal{I}([0,1])$ such that $0 \leq \sup_{x \in X} f(x) + \sup_{x \in X} g(x) \leq 1$.

Our basic references for interval-valued fuzzy sets, intuitionistic fuzzy sets and interval-valued intuitionistic fuzzy sets are [25–32].

(7) F. Smarandache [33] proposed in 1999 the concept of neutrosophic set. A *Neutrosophic set* in X is defined as

$$A = \{< x, T_A(x), I_A(x), F_A(x) >: x \in X\}$$

where $T_A(x), I_A(x), F_A(x)$ are subsets of $]0^-, 1^+[$ and represent the truth-membership function, indeterminacy-membership function and falsity-membership function such that

$$0^- \leq \sup_{x \in X} T_A(x) + \sup_{x \in X} I_A(x) + \sup_{x \in X} F_A(x) \leq 3^+,$$

where

$$a^- = \{a - \epsilon \ : \ \epsilon \in \mathbb{R}^*, \epsilon \text{ is infinitesimal}\}$$

$$b^+ = \{b + \epsilon \ : \ \epsilon \in \mathbb{R}^*, \epsilon \text{ is infinitesimal}\}.$$

For applications we can consider that $T_A(x), I_A(x), F_A(x)$ are subsets of $[0,1]$.

(8) *Pythagorean fuzzy sets* were proposed by R.R. Yager in 2013 [34]. A *Pythagorean fuzzy set* is defined by the functions $f, g : X \to [0,1]$ which give us the degree of membership and degree of non-membership, respectively such that

$$0 \leq (f(x))^2 + (g(x))^2 \leq 1, (\forall) x \in X .$$

The function $h : X \to [0,1]$ defined by

$$h(x) = \sqrt{1 - [(f(x))^2 + (g(x))^2]}$$

is called the degree of indeterminacy.

3.2. Fuzzy Rules

Fuzzy rules allow the logic fuzzy system to take rational decisions. Fuzzy rules offer a frame in which human knowledge is integrated. In the fuzzy process the relation between input variables and output variables are described through schemes like: "If ... then". Generally we have a number N of fuzzy rules, each of them with the form [24,35]:

If A_1 is $T^j_{A_1}$ and A_2 is $T^j_{A_2}$, then B_0 is $T^j_{B_0}$, where B_0 is the consequent (output) linguistic variable of the rule.

3.3. Inference Engine

The mission of the inference engine is to obtain output variables from input variables, based on fuzzy logic rules.

For example, let us assume there are two rules:

If A_1 is $T^1_{A_1}$ and A_2 is $T^1_{A_2}$, then B_0 is $T^1_{B_0}$,

If A_1 is $T^2_{A_1}$ and A_2 is $T^2_{A_2}$, then B_0 is $T^2_{B_0}$.

The firing strengths of the two rules are: $f_1 = \mu^1_{A_1} \wedge \mu^1_{A_2}$ and $f_2 = \mu^2_{A_1} \wedge \mu^2_{A_2}$, where $\wedge$ represents AND operation in fuzzy logic, this being the minimum most often, namely

$\mu^1_{A_1} \wedge \mu^1_{A_2} = \min\{\mu^1_{A_1}, \mu^1_{A_2}\}$ and $\mu^2_{A_1} \wedge \mu^2_{A_2} = \min\{\mu^2_{A_1}, \mu^2_{A_2}\}$, but there can be used other t-norms as well.

We also consider $\hat{\mu}^1_{B_0}$ and $\hat{\mu}^2_{B_0}$ defined by: $\hat{\mu}^1_{B_0} = f_1 \wedge \mu^1_{B_0}$ and $\hat{\mu}^2_{B_0} = f_2 \wedge \mu^2_{B_0}$.

Finally, the membership degree of the output is obtained using OR operation (denoted $\vee$), namely $\mu = \hat{\mu}^1_{B_0} \vee \hat{\mu}^2_{B_0}$.

For OR operation most often we meet: $\hat{\mu}^1_{B_0} \vee \hat{\mu}^2_{B_0} = \max\{\hat{\mu}^1_{B_0}, \hat{\mu}^2_{B_0}\}$, but other t-conorms can be used.

3.4. Defuzzification

In this phase the fuzzy sets obtained of the inference engine are defuzzied into crisp outputs.

There are several methods that can be used. Center of gravity is a method used in many studies. Let us assume that the result is the membership function $\mu : \mathbb{R} \to [0,1]$ with the support the interval $[t_0, t_k]$. We consider an equidistant division $\Delta = \{t_0, t_1, t_2, \cdots, t_{k-1}, t_k\}$ of this interval. The crisp value is obtained by

$$\hat{t}_j = \frac{\sum\limits_i t_i \mu(t_i)}{\sum\limits_i \mu(t_i)}.$$

Other defuzzification methods are: max membership principle, weighted average method, mean max membership method, center of largest area etc.

4. On Some Results Obtained by Ioan Dzitac

4.1. Fuzzy Method for Multiple Criteria Fractional Programming

In paper [8], B. Stanojević, I. Dzitac and S. Dzitac proposed a new method of solving a full fuzzy linear fractional programming (FFLFP) problems using α-cut representations for the triangular fuzzy coefficients involved in both the objective function and constraints. The decision variables were considered fuzzy valued, but their shapes were determined a posteriori.

The authors first discussed the issues arising when a ratio of fuzzy numbers had to be evaluated: (i) the error induced by approximating the exact membership function of the ratio with the membership function of the triangular fuzzy number that had the same support and the same value with maximal amplitude as the exact (non-triangular) fuzzy number representing the ratio; (ii) the misleading computation of the ratio of two functions of fuzzy numbers, in the case that the same fuzzy number appeared on both numerator and denominator of the ratio, and in the global α-cut evaluation distinct endpoints of the α-cut were used for that same fuzzy number on numerator and denominator respectively. The authors established the formula for computing the area between the graphic representations of the exact membership function of the ratio of fuzzy numbers and its above-mentioned approximation. The difference between the correct and a misleading evaluation of a rational function of one triangular fuzzy number valued variable, and the effect of the translation of the triangular fuzzy numbers on the rational function correctly evaluated were both illustrated in the paper.

Further on, the authors introduced a new methodology to solve the FFLFP problems by making use of two models to yield the left and the right endpoints of an arbitrary α-cut. Their approach properly handled the multiple occurrences of variables in the fractional objective function and in constraints as well. Discrete representations of the inverses of the exact membership functions of the products and ratios of fuzzy numbers were used to derive the fuzzy solutions expressed by (non-triangular) fuzzy numbers. The main advantage of the solution approach was in its ability to work with the exact membership functions of the ratios, and to avoid the usage of any special definition for fuzzy inequality evaluation.

By their approach, the authors disclosed a direction that can be useful in managing decision-making processes involving fractional objective functions under uncertainty. The illustrative example provided in the paper analyzed and solved a decision-making problem in production planning.

4.2. Prudent Decision to Estimate the Risk in Insurance

In paper [3], the authors investigated the issue of capital allocation with risk exposure starting from the regulations of the new solvency system "Solvency II" built by European Commission to regulate all insurance activities in European Union member countries.

As stated in the Solvency II Directive, 101 Article, the allocation of capital in insurance is done either using a standard formula or by developing an internal model taking into account the particularities of the insurance company.

Making prudent risk assessment decisions to which the insurance company is exposed ultimately means a capital allocation that better corresponds to the company's risk exposure. The risk measure advanced by the new Solvency II system under the standard formula is Value-at-Risk (VaR) or Tail Value-at-Risk (TVaR). The authors proposed for determination of VaR or TVaR, the use of the theory of extreme values. This decision proves more prudent in the sense of correlating the values of VaR and TVaR with the amplitude of risk exposure.

To argue quantitatively the usefulness of applying the theory of extreme events to set the level of prudence regarding the determination of the solvency capital requirement (SCR), the authors built a hypothetical portfolio composed of shares and bonds. Although the standard formula in the Solvency II system was built on the assumption of the normal distribution of the risk to which the company was exposed, this hypothesis was verified too few times, especially when it came to the occurrence of rare events. Under these conditions, the use of distributions better adapted to the company's risk exposure may prove to be a more prudent decision.

In the case of the built-up portfolio, compared with the use of normal law, the authors proved that more prudent decisions had been shown to be the use of specific distribution laws for determination of extreme quantiles such as: Chi2 (from the attraction domain of Fréchet—laws with heavy tails); Exponential, Gamma and Weibull (from the attraction domain of Gumbel—laws with exponential decreasing tails).

4.3. Decision Support Model for Production Disturbance Estimation

There are several models in the literature for the study of disturbance in manufacturing systems to optimize them. Unfortunately, these models do not give us a dynamic evaluation of multiple consequences of the disturbance. Many production bottlenecks have the effect of severe economic consequences, and they are caused by disturbances in technological lines. A good estimate of disturbance dynamics is needed to reduce losses.

In paper [4] the authors introduced a model which allows a dynamic evaluation of consequences of disturbance. The model used several indicators: time, energy and costs. Model testing was done using MATLAB.

4.4. Manufacture System Control Using ANN Software

In paper [5] the authors presented a technique for improving the autonomy of the flexible manufacturing systems. The paper presented a system capable of monitoring the tool flank and widening the manufacturing system whiteout input from the users.

The entire structure of the proposed system was presented as well as the different connections between the system itself and other components of the flexible manufacturing systems. The concept behind the system was the continuous monitoring of tools in the machine tool storage systems. From the hardware point of view the paper presented an experimental system designed to acquire the tool flank images.

The paper also presented the software component. The first step taken by the authors was the realization of an application able to extract significant data from the pictures obtained. All the steps taken were presented in the paper. Several parameters were identified and compared to determine their efficiency in determining the tool ware.

An alternative decisional process regarding the tool ware is based on artificial neural networks. The paper presented the realization and setting of such a network realized in MATLAB and performed an in-depth analysis of the network. Methods of Image Classification Using One-Hidden-Layer ANN on Image Data and Image Classification with Autoencoders on Image Data were presented.

The conclusion section of the paper makes an exhaustive presentation of the results for each method of image classification using ANN, a comparative network training parameters table is presented. Als the paper includes the statistical data for misclassification of images.

The paper offers significant theoretical and experimental data on the hardware component of the system, and it is also focusing on the software component. Several methods for image classification are presented and the results are compared to determine optimal solutions both from accuracy and computational time.

4.5. Ant Colony Optimization for a Practical Economic Problem

The source of inspiration for ant colony optimization (ACO) algorithm is the behavior of ants in search of food, which is a problem of optimization, more precisely of determining the optimal path between food and nest.

Several theoretical aspects of artificial ants were presented in papers [10,36].

In paper [7] the authors presented an algorithm based on Ant Colony Optimization (ACO) applied in a practical economic problem, more precisely, in finding an optimal solution in an electricity distribution network. A nonlinear function was used in the mathematical model of optimization. The mathematical model contains both equality constraints and inequality constraints. The results are validated on a network with 35 nodes.

5. Conclusions and Future Trends

We wrote this paper for a Special Issue dedicated to the centenary of birth of Lotfi A. Zadeh published by Mathematics. Therefore, this paper is an homage to Lofti A. Zadeh as a sign of respect for his great contributions to scientific knowledge. At the same time, this paper is dedicated to I. Dzitac, who passed away on 6 February 2021 as he stood out as one of the followers of Zadeh's work by publishing, between 2007 and 2020, tens of articles in the domain of soft computing.

I. Dzitac's most important contributions have just been presented, wishing and hoping that either his former partners or other researchers will continue his work.

We will finish with some challenges and future research directions, because the rapid development of the economy and of the modern industrial systems make the process of decision-making more complicated, leading to difficulties in dealing with vague information. In this environment, soft computing methods have been successfully applied. Nevertheless, as the human thinking process is very complex, raised attention and new research are necessary for the applications of soft computing methods in intelligent decision-making. We will raise a few problems, more general and larger, but that deserve the attention of researchers.

1. In Section 3.1 various types of fuzzy sets used for the representation of the linguistic terms are presented. The development of new types of fuzzy sets deserves to be solved in order to obtain better results in problems of decision-making. Thus, it is necessary to develop new algorithms for generalized fuzzy sets. Choosing membership functions has an important role in fuzzification process. To increase the accuracy of soft computing methods, membership functions must be improved to finally reach a better representation of linguistic variables.
2. Because of the complexity of the economic problems and of the modern industries, we must operate with cu massive input items. In such a situation the number of fuzzy rules increases exponentially as related to the number of input items [37]. As a result, some fuzzy rules can become incomplete or unsubstantial and there can appear conflicts among these numerous rules. There are only a few studies in this direction

and it is necessary that in the future more attention to be granted and greater efforts to be made.

3. Fuzzy inference methods are largely used to model the experts' behavior. Despite this, fuzzy inference methods need standard procedures for a quantity analyze and to optimize the process of transformation of experience and experts' knowledge (see [24]). The development of artificial intelligence can be of great help as fuzzy inference systems can be combined with mining techniques.
4. Another great challenge is to improve the linguistic operators and to increase in this way, the flexibility outcomes as a result of the defuzzification process.
5. Consensus reaching is a subject of great importance in the group decision-making field. The obtaining of a high level of consensus or agreement among decision-makers is of crucial importance in any group decision-making problem (see [38,39]). This consensus can be obtained by integrating the opinions of decision-makers according to some rules, because it is natural and normal for the decision-makers to have different point of views upon the same issue. Therefore, making adequate rules to solve conflicts in a group is a subject that still needs to be studied.
   In the literature of genre can be found many models of consensus with linguistic information. Nevertheless, some questions remain open: the development of new models of consensus that include feedback mechanisms, the creation of new technologies to implement consensus models etc.

In conclusion, as the problems of decision-making become more and more difficult when vague linguistic information interferes, soft computing methods have gained more attention and a great interest in the latest years. In this paper, a comprehensive review upon some of I. Dzitac's results has been realized. The structure of a fuzzy system has been presented and its components have been analyzed. Finally, some challenges and future trends have been presented.

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