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FUZZY LOGIC AND FUZZY SEMANTICS IN LINGUISTICS

The article is devoted to the fuzzy logic and fuzzy semantics in linguistics. The question of the fuzzy logic is a form of multivalued logic in which the truth value of the variables can be any real number between 0 and 1. The article reveals that it is used to handle the concept of partial truth, where the truth value can vary between completely true and completely false. It is found out that the process of fuzzy inference usually consists of several parts.

The article reveals that fuzzy logic originated in the context of fuzzy set theory, introduced by Lotfi Zadeh. It defines (a fuzzy set) defines the degree of membership of elements of the universe, usually a real number from the interval [0,1][0,1]. It is determined that fuzzy logic arises by assigning truth degrees to propositions.

It is observed that fuzzy logic is characterized as "logic based on real numbers." It is understood as logic in which truth rates are taken from the real line and the connectives are interpreted as functions on it.

The article also identifies and provides a list of determiners that express uncertainty, which is an indication of the importance of their use within the text.

In addition, the article also reveals that words, expressions, and idioms that express doubt and hesitation that are common in the English language.

It is determined that fuzzy logic is used to simulate real-life situations where true or false statements are rare.

It is found out that fuzzy algorithms are relatively simple to code, but they can require extensive verification and testing.

The article reveals that in practice, all of these constructs allow for partial values of the true condition. Instead of requiring all statements to be absolutely true or absolutely false, as in classical logic, truth values in fuzzy logic can be any value from zero to one. This allows algorithms to make decisions based on a range of data, as opposed to a single discrete data point.

It is found out that fuzzy logic is used in a wide range of applications: aerospace engineering, vehicle traffic control, business decision making, industrial processes, artificial intelligence, natural language analysis, etc.

Key words: *logic, linguistics, fuzzy, semantics, digital, meaning.*

Introduction. Fuzzy logic was first proposed by Lutfi Zadeh in an article he wrote for the journal Information and Control in 1965. In his article "Fuzzy Sets," L. Zadeh tried to reflect the type of data used in information processing and derived elementary logical rules for such sets [4, p. 154].

"Often, classes of objects encountered in the real physical world do not have well-defined membership criteria," explained L. Zadeh. "However, the fact remains that such poorly defined 'classes' play an important role in human thinking, especially in the areas of pattern recognition, information transfer, and abstraction" [12, p. 56].

Since then, fuzzy logic has been successfully applied in machine control systems, image processing, artificial intelligence, and other areas based on signals with unambiguous interpretation.

To understand fuzzy set theory in depth, it is first necessary to know the etymology of the term "fuzzy". R. Hodge's article states that "fuzzy logic arose from L. Zadeh's subtle understanding of the various logics inherent in human languages... his interest in studying the strengths and weaknesses of natural languages for scientific thinking". This scientist, who has extensive knowledge in the field of linguistics, uses the expression "fuzzy" as a category of language or thought, which has nothing to do with the essence of physical and mechanical phenomena. In his article written at the end of the 20th century, he put forward the flow of physical phenomena in terms of the description of fuzzy categories called the typology of boundary conditions, where he describes how people perceive and recognize each other based on their facial features.

The initial stage of the development of fuzzy logic was based on L. Zadeh's proof of the necessity of weakening the law of logic excluding the third and the law of logic of correspondence, which is dual

to it. Since the time of Aristotle, these laws have been considered stable in classical set theory. The new "post-Wiener" history has shown that in order to discover and develop new theories, it is necessary to abandon the traditional way of thinking. As a result, the scientific world was divided into two parts: supporters of classical approaches ("top-down") to achieve artificial intelligence and supporters of the ("bottom-up") path, advocating the creation of new thinking and approaches. In fact, by rejecting the main axiom of classical theory, L. Zadeh made this leap in 1965 by the path of upward development [12, p. 144].

Fuzzy logic is developed in its most basic sense through decision tree-type analysis. Thus, it forms the basis of artificial intelligence systems programmed with rule-based inferences on a larger scale.

In general, the term fuzzy refers to the many scenarios that can be developed in a decision tree-like system. Developing fuzzy logic protocols may require the integration of rule-based programming. These programming rules can also include fuzzy sets, as they are developed in accordance with the discretion of comprehensive models.

Fuzzy sets can also be more complex. In more complex programming analogies, programmers may have the ability to extend the rules used to determine the inclusion and exclusion of variables. This can result in a wider range of choices with less precise rule-based reasoning.

Discussion. *Fuzzy Semantics in Artificial Intelligence*

The concept of fuzzy logic and fuzzy semantics is a central component of programming artificial intelligence solutions. As the possibilities of programming from fuzzy logic also expand, artificial intelligence solutions and tools continue to expand in a number of sectors in the economy.

IBM's Watson is one of the most popular artificial intelligence systems that uses variations of fuzzy logic and fuzzy semantics. In particular, in financial services, fuzzy logic is used in technology systems that support machine learning and investment intelligence results. Integrating fuzzy logic mathematics into some advanced trading models can also be used to help analysts generate automated buy and sell signals. These systems help investors react to a wide range of market variables that affect their investments.

Fuzzy sets are a consistent tool that includes restrictions on linguistic information in the analysis of literary texts. K. Abdulla writes that when incomplete information is given about any action or event within the text, this reduces confidence in it. For example: the expression "probably" is stronger in meaning than the expression "probably". At this point, it is also necessary to keep in mind such determinants as "less", "much", "more". The scientist also notes that the information in the text is provided by the author based on his epistemological position based on his knowledge, observation or belief [1, p. 77].

It should be noted that the words expressing fuzzy meaning used in the texts differ greatly in terms of the meaning they carry, in terms of modality. For example, the words certainly and probably express meanings with differences in terms of modality. While *certainly* conveys certainty, the modal word probably conveys uncertainty. Therefore, it is necessary to be careful in choosing words with fuzzy meaning used in the texts.

K. Abdulla writes that in the text of "Kitabi-Dade Gorgud" it is sometimes easy and sometimes difficult to determine the degrees between the ordinary and the maximal. Let us describe a large ship in accordance with the linguistic potential of the text. The text of "Kitabi-Dade Gorgud" would easily express this image in the imagination as follows: "The water that plays with big wooden ships" [1, p. 78]. However, the ship in the imagination is not just big. It is incredibly large. The text tries to adapt the image in the imagination. Therefore, the text writes: "The water that plays with big wooden ships".

The expression "Big-big" here is an attempt to imagine the infinite size of greatness. This is where fuzzy logic comes into play. The double words in the language come to the rescue.

Fuzzy logic is used in natural language processing for tasks such as sentiment analysis and text classification. Natural language shows uncertainty in the meaning of text and makes decisions based on this uncertainty.

Knowing the logic of a natural language is like knowing its grammar. Just as one can speak and write grammatically correct sentences without being able to formulate the grammatical rules of a language, one can use and follow the logic of one's language without being able to formulate its logical rules and laws.

Fuzzy matching is vital in natural language processing tasks because it covers spelling variations, spelling errors, duplicate entries, abbreviations, etc. Humans think all the time. Whether the ability to think is innate or not, we teach our children to think better by identifying and correcting their mistakes. Moreover, all our reasoning is based on information we obtain from the social worlds we live in, or on ways of identifying and classifying information. We constantly reason with others, either reasoning with them to draw conclusions, or trying to convince or persuade them that certain conclusions or courses of

action are reasonable and others are unreasonable. So, in this sense, although each person reason individually, reasoning has a fundamental social dimension. While we can and do think privately, reasoning is in principle and often in practice social.

In our daily lives, we all encounter situations where we want to convince someone that a proposition is true or to persuade another person to do something. Sometimes we want to convince or persuade not just one person, but many. We may want to convince a potential employer to hire us, and in doing so, we want to convince him or her that we are an excellent candidate for the advertised job. We may want to convince a customer to buy a product we are selling, or as a customer, we may want to convince a seller to lower the asking price of a product we want to buy. We may want to convince our friends or family of the merits of a particular political party or candidate and persuade them to vote in a certain way. The occasion does not have to be significant. Perhaps we want to convince a friend or colleague to join us for a cup of tea or coffee, or to convince a family member to take an umbrella with them when they go outdoors. We can be on the same good side – just as someone else is trying to convince or persuade us. It is easy to generate vague examples of situations where someone wants to convince or persuade someone or others of something. Using fuzzy logic tools helps us in this case.

We can list the importance of using fuzzy logic as follows:

1) Fuzzy logic is conceptually easy to understand;
2) There are quite a lot of linguistic options in fuzzy logic;
3) Fuzzy logic is based on natural language rules, etc.

Fuzzy logic is perceived first of all as the logic of doubts and hesitations. It is also considered the logic of searches. This logic does not just appear. There are four main pillars of fuzzy logic: the general logic pillar; the fuzzy sets pillar; the epistemic pillar; the relations pillar [1, p. 13].

These pillars form fuzzy thinking based on a system of different relationships.

The "Logic Pillar" of fuzzy logic is a generalized form of polysemous logic. It basically creates a relationship between true and false.

Logic and fuzzy logic have been in the spotlight for many years. "Aristotle's Logic" is very famous. Aristotle developed a logic designed to describe what exists in the world. He suggests ten different ways to describe anything in the world. These categories include (1) matter, (2) quantity, (3) quality, (4) relationship, (5) where, (6) when, (7) being in a certain position, (8) having, (9) doing, or (10) being subjected to or affected by something. Aristotle did not believe that all claims (assumptions, reasoning) are related to words. However, words are a good way to start studying his logic. Logic is mainly about how we evaluate evidence. But arguments arise from statements, which in turn are made up of words. In Aristotle's logic, the most basic proposition is a proposition that asserts something, that is, a fully expressed sentence. Ideally, a proposition should consist of at least three words: a subject (a word that names the subject), a predicate (a word that names the attribute), and a linking verb, which logicians call a copula [6].

Logic is the study of valid reasoning. It includes both formal and informal logic. Formal logic is the study of deductively valid conclusions or logical truths. Regardless of the topic or content, conclusions can be determined solely by the structure of arguments. Informal logic is associated with informal fallacies, critical thinking, and argumentation theory. Informal logic examines arguments expressed in natural language, while formal logic uses formal language.

In generative grammar and related approaches, the logical form (LF) of a linguistic expression is the semantically interpreted version of its syntactic structure. It is distinct from the phonetic form, the structure that corresponds to the pronunciation of the sentence [7].

In logic, the logical form of an expression is the semantically well-defined version of that expression in a formal system. Informally, a logical form attempts to express a possible ambiguous expression with a clear, unambiguous logical interpretation with respect to the formal system. In an ideal formal language, the meaning of a logical form can be unambiguously determined only from the syntax. Logical forms are semantic, not syntactic constructs; therefore, in a given language, there may be more than one idea representing the same logical form.

Fuzzy logic is an approach to problem solving that proposes multiple truth variables that can be any real number between 1 and 0, as opposed to the binary version of truth, which can be either 1 or 0. Fuzzy logic is used as a decision-making strategy when using a machine learning framework or artificial intelligence. It can generally be expressed as the estimation of actual variable values between 0 and 1. Fuzzy logic is applied to represent real numbers between 0 and 1.

Fuzzy refers to anything that is highly uncertain. When a scenario is uncertain, a computer cannot

conclude True or False. According to Boolean logic, 1 represents True and 0 represents False. In contrast, fuzzy logic method takes into account all the uncertainties of the problem, where there can be more potential values than True and False. Fuzzy logic is used to achieve precise values, such as the solution to a problem. Fuzzy logic views human thinking as the most important data format for drawing precise conclusions.

The main advantage of fuzzy logic over formal Aristotelian logic is that it does not exclude the third, fourth, etc. between the two main poles. It does not limit human thought [8, p. 20].

K. Abdulla writes that the development of specific language units that use the principles of fuzzy logic in the language of the epic "Kitabi-Dade Gorgud" allows them to be analyzed [1, p. 35]. According to the scientist, the epic "Kitabi-Dade Gorgud" gives a lot of space to the principles of fuzzy logic in its linguistic space. The way of thinking hidden in the substratum of this ancient epic leads to the formation of specific logical schemes related to each of the four pillars of fuzzy logic. Thus, it becomes clear that the mentioned epic contains quite extensive linguistic materials on fuzzy logic. This also shows that our ancient ancestor preferred a broader and deeper approach in his view of the world. K. Abdulla writes that the epic "Kitabi-Dede Gorgud" reflects the democratic way of thinking, which perhaps manifested itself in the minds of our ancestors in an unconscious form and can be considered the deep moral-ideological basis of fuzzy logic [1, p. 36].

As mentioned above the Azerbaijani mathematician Lutfi Zade gave rise to the term by proposing fuzzy set theory. In addition, fuzzy logic was studied as infinite-valued logic by Lukasevich and Tarski in 1920 [8, p. 12]. The mentioned logic theory, more precisely fuzzy logic, is based on the observation that people make decisions based on imprecise and non-numerical information. Fuzzy models or fuzzy sets are mathematical tools that represent uncertainty and imprecise information. These models have the ability to recognize, represent, manipulate, interpret, and use uncertain information.

Fuzzy logic has been applied to many fields, from control theory to artificial intelligence.

The basic idea in fuzzy logic is that classical logic allows only true or false conclusions. However, judgments with variable answers are also observed here. In such cases, truth emerges as a result of the justification of imprecise or partial knowledge, where the sampled answers are mapped onto a spectrum [11, p. 342]. Here, both the degrees of truth and the probabilities vary between 0 and 1. Fuzzy logic uses degrees of truth as a mathematical model of uncertainty, and probability is a mathematical model of ignorance [2, p. 11].

Logic is considered a science of cognition. The Greek philosopher Aristotle has such a philosophical saying: "What a person says is either true or false." As it can be seen, Aristotle did not accept the intermediate degrees between categories such as falsehood and truth. However, for the first time in the world, Lotfi Zadeh proved that everything has degrees. According to his conviction, there is no such thing as absolutely white and absolutely black in the world. There are thousands of shades of change – intermediate nuances between these two concepts. Based on research, he discovered intermediate categories that exist in reality, and the essence of the theory observed in these intermediate categories was determined as tolerance. This theory introduced and restored the rights of shades that are not visible on the stage of the open, staying in the middle. It was concluded that the resolution of conflicts, the discovery of the truth, and the accuracy of calculations cannot be carried out without paying attention to the intermediate phases. If it were the opposite, they would have enough flaws. The Japanese were the first to dismantle the theory. They applied it to their economies. It is said that the vast majority of technical equipment currently produced in Japan is based on the theory of fuzzy logic. After the Japanese, the Americans applied this theory. When the issue of rebuilding America's air defense came up, a scientist named Kasko suggested applying this theory. They solved the problem with this theory, which had to be done at a cost of trillions of dollars. The theory brings China hundreds of billions of dollars in revenue per year [3, p. 11].

According to the unanimous opinion of scientists, the 19th–20th centuries were a period of great leaps in the development of science and technology, during which a large number of discoveries and inventions were made. It is no coincidence that the first, second and third industrial revolutions took place precisely in the two centuries in question. We are talking about the invention of the steam engine, the discovery of electricity and, of course, the introduction of computer technologies into our lives. It is believed that humanity is currently entering the fourth industrial revolution.

It is known that one of the great scientific discoveries that underpinned the transition from the 3rd industrial revolution to the 4th industrial revolution and stimulated this process is associated with the name of Lotfi Zadeh, known throughout the world as one of the most famous mathematicians, and his fuzzy theory.

As well as the mathematical side of the theory, there is also a philosophical side, and this helps ordinary citizens understand the essence of the theory in question. The philosophical side of the topic was explained in detail and clearly in the article "Logical-epistemological analysis of the theory of fuzzy sets" written by A. Mammadov and F. Gurbanov. According to the conclusion of these scientists, when ideas arising in human thinking are transformed into words, a process of approximation of fuzzy sets occurs through words. In other words, in fact, fuzzy sets are direct participants in human thinking and speech. This direction has already been sufficiently studied and mathematically modeled.

K. Abdulla and R. Aliyev's "Book of Dede Gorgud and Fuzzy Logic" writes: "When viewed from a philological-humanitarian perspective, the "logic" of fuzzy logic arises from the ideology of hesitations, doubts, assumptions, and sometimes even distrust" [1, p. 38]. To explain this idea, they write an example from H. Javid: "Doubt is the grandfather of every truth, Doubt is the father of the wise, Man has the right to doubt…". They write that this idea reflects the spirit of fuzzy logic. So, in fact, these verses can also be considered the anthem of the ideology of fuzzy logic. It is doubt that first manifests itself in any simple or complex case of fuzzy logic. It stands at the beginning of the path of fuzzy logic. It can be concluded that the "doubt" component is a constant indicator of fuzzy logic compositions. It can also be called this. If the main premise of Aristotelian logic (formal logic) is based on the ideology of "either...or", then the constant doubt aims to destroy this support.

Conclusion. Thus, fuzzy logic attempts to solve problems with an open, imprecise range of information that allows for a range of precise results. Fuzzy logic is designed to solve problems by taking into account all available information and making the best possible decision based on the information input. Fuzzy logic is based on the principles of set theory, which makes reasoning quite simple to understand. It serves as a highly effective solution to complex problems in all areas of our lives, as it mimics human thinking and decision-making.

Bibliography:

1. Abdulla, K., Aliyev R. "The Book of Dede Gorgud" and Fuzzy Logic. Baku: 525th Newspaper, 2022, 120 p.
2. Asli, Kaveh Hariri; Aliyev, Soltan Ali Ogli; Thomas, Sabu; Gopakumar, Deepu A. Handbook of Research for Fluid and Solid Mechanics: Theory, Simulation, and Experiment (English). CRC Press. 2017-11-23.
3. Babuška, Robert. Fuzzy Modeling for Control. Springer Science & Business Media. 1998.
4. Copi, I. M. Introduction to Logic. New York: MacMillan, 1954, 654 p.
5. Bellman, R. E., Zadeh, L. A. Decision-Making in a Fuzzy Environment. Management Science. Vol. 17, № 4., 1970, p. 141–164.
6. Hodge, R. Key Terms in Fuzzy Logic Deep Roots and New Understanding, University of Western Sydney, Australia, 2001.
7. Zadeh, L. A. Fuzzy Sets. Information and Control. Vol.8. 1965, p. 338–353.
8. Zadeh, L. A. Probability Measures of Fuzzy Events. Journal of Mathematical Analysis and Applications. Vol. 10., 1968, p. 421–427.
9. Zadeh, L. A. Similarity Relations and Fuzzy Orderings. Information Sciences. Vol. 3., 1971, p. 177–200.
10. Novák, V.; Perfilieva, I.; Močkoř, J. Mathematical principles of fuzzy logic. Dordrecht : Kluwer Academic, 1999.
11. Pelletier, Francis Jeffry. "Review of Metamathematics of fuzzy logics" (PDF). The Bulletin of Symbolic Logic. 6 (3). 2000: 342–46.
12. Walton, D. A Pragmatic Theory of Fallacy. Tuscaloosa and London: University of Alabama Press, 1995, 344 p.
13. Zadeh, L. A. "Fuzzy sets". *Information and Control*. 8(3). San Diego : 338–353, 1965.

Гурбанзада Ф. Н. НЕЧІТКА ЛОГІКА ТА НЕЧІТКА СЕМАНТИКА В ЛІНГВІСТИЦІ

Стаття присвячена нечіткій логіці та нечіткій семантиці в лінгвістиці. Питання нечіткої логіки є формою багатозначної логіки, у якій значення істинності змінних може бути будь-яким дійсним числом від 0 до 1. У статті показано, що воно використовується для обробки концепції часткової істинності, де значення істинності може варіюються між повністю істинним і повністю хибним. З'ясовано, що процес нечіткого висновку зазвичай складається з кількох частин.

У статті показано, що нечітка логіка виникла в контексті теорії нечітких множин, запровадженої Лотфі Заде. Він визначає (нечітка множина) визначає ступінь приналежності елементів всесвіту, як правило, дійсне число з інтервалу [0,1][0,1]. Визначено, що нечітка логіка виникає шляхом присвоєння пропозиціям ступенів істинності.

Відзначено, що нечітка логіка характеризується як «логіка, заснована на дійсних числах». Це розуміється як логіка, в якій показники істинності беруться з дійсної лінії, а зв'язки інтерпретуються як функції на ній.

У статті також визначено та наведено перелік визначників, які виражають невизначеність, що свідчить про важливість їх використання в тексті.

Крім того, стаття також розкриває, що слова, вирази та ідіоми, які виражають сумнів і вагання, поширені в англійській мові.

Визначено, що нечітка логіка використовується для моделювання ситуацій реального життя, де істинні чи хибні твердження зустрічаються рідко.

З'ясовано, що нечіткі алгоритми відносно прості для кодування, але вони можуть вимагати ретельної перевірки та тестування.

У статті показано, що на практиці всі ці конструкції допускають часткові значення істинної умови. Замість того, щоб вимагати, щоб усі твердження були абсолютно істинними або абсолютно хибними, як у класичній логіці, значення істинності в нечіткій логіці можуть бути будь-якими значеннями від нуля до одиниці. Це дозволяє алгоритмам приймати рішення на основі діапазону даних, на відміну від однієї дискретної точки даних.

З'ясовано, що нечітка логіка використовується в широкому діапазоні застосувань: аерокосмічна техніка, управління рухом транспортних засобів, прийняття бізнес-рішень, промислові процеси, штучний інтелект, аналіз природної мови тощо.

Ключові слова: *логіка, лінгвістика, нечіткість, семантика, цифровий, значення.*