Soft modeling and expert systems in modern science: development trends

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Abstract. The article examines the use of the potential of soft modeling and expert systems in modern science in the construction of mathematical models in various fields. In the scientific community, there is currently a growing understanding of the need to apply flexible and fairly soft mathematics based on information (expert) systems. As a rule, each model reflects the internal organization of a system (economic, social, legal, etc.), its essence, which is determined by the set goals. One of the first embodiments of the ideas of soft modeling was the creation of methods of fuzzy mathematics and fuzzy logic, which allow objectifying processes with a low level of formalization. Fuzzy set theory and fuzzy logic are the basis for creating fuzzy control systems and fuzzy decision-making systems (expert systems). The ideas of soft modeling can be applied in various fields, including legal, since soft models are mainly used in the description of crime. The article discusses the decision one of tasks based on the application of soft modelling and expert systems: definition of severity of punishment depending on the social danger of the act and the identity of the perpetrator.

Keywords: Scientific picture of the world, Soft modeling expert systems, Fuzzy mathematics, Fuzzy set theory.

1 Introduction

In recent years, modern science around the world is increasingly discussing the issues of modeling, formalization of various social processes, including their methodological foundations. In connection with the above, the topic related to the formalization of criteria for evaluating human activity, measurement of characteristics, classification of objects, etc. is relevant.

It should be noted that most of the solved problems and studies of modern scientific schools are related to the very nature of the objects of research in science, their specific features in the scientific picture of the world. The essence of the scientific picture of the world lies in its integrative function, in ensuring the synthesis of individual scientific knowledge. The scientific picture of the world introduces certain restrictions on the formation and nature of new scientific paradigms, directs the movement of thought and determines the way of seeing the world around us [1].

Constantly changing imaginative ideas about the dynamic world around us are sometimes difficult and almost impossible to express in the format of stable concepts, to classify them, etc. At the moment, in our opinion, it is a fuzzy concept and is built on the basis of their various models suitable for understanding and learning of complex volatile systems, and, no less, and perhaps even more than friends all have long rigorous models and concepts.

2 Materials and methods

The study used general theoretical methods of scientific knowledge: interdisciplinary analysis and synthesis of scientific, mathematical and methodological literature, as well as advanced scientific experience; comparative historical methods; methods of empirical research: expertise; modeling.

3 Results

Mathematics plays a special, significant role in creating conditions for the formation of such a modern scientific picture of the world, which is determined by its place in the system of sciences, the universality of methods and techniques that underlie a number of fundamental sciences. Representing a general scientific method of cognition of reality, today mathematics, its methods, technologies, applications create a kind of generalized, scientifically based system of general ideas, views on the world and its surrounding details, show the unity of the scientific picture.

Mathematics has been a strictly deterministic science since ancient Greece. However, in recent decades (the end of the XX – beginning of the XXI century), mathematical science, its methods, mathematical vision of the world are losing the certainty, the measure of absolute reliability and steadfastness that previously existed in science [2-3].

At the moment, there is a growing understanding in the scientific community of the need to introduce flexible and sufficiently soft mathematics. One of the most striking examples of this understanding was the research of the largest Russian mathematician V. I. Arnold, which later formed the basis for the adoption of the ideas of "soft modeling" by the modern mathematical community. He pointed out "the usefulness of soft models, in which there is uncertainty, ambiguity of development paths, and the danger of hard models, for which a single path of development is predetermined "[4]. The model, as you know, shows with some simplifications the internal structure of the system, its essence, which in turn is determined by certain goals. We emphasize that the ideas expressed by V. I. Arnold are mathematically justified and have great general philosophical significance.

In the last ten years in science, on the basis of the development of a synergetic worldview, discoveries in natural science, there have been changes in the entire style of scientific thinking (consciousness): the transformation to images (figures) of chaos took place; the mathematical theory of soft models becomes the basis for many new trends (directions of development) of modern mathematics (for example, the theory of bifurcations, fractal geometry, asymptotic mathematics, etc.) [5-6].

One of the first embodiments of the ideas of soft modeling was the creation of methods of fuzzy mathematics and fuzzy logic, which allow objectifying processes with a low level of formalization. For the first time, these methods were considered in the work of L. Zadeh called "Fuzzy sets", which was published in 1965. L. Zadeh tried to describe such phenomena and concepts that have a multi-valued and inaccurate nature. Vagueness, like uncertainty, is opposed to precision. Indistinctness does not imply consideration of the appearance of an event and refers only to the way the event itself is described [7].

The mathematical foundations of fuzzy logic, fuzzy sets and their practical application are considered in [8-9].

Here are the basic concepts of this theory. Fuzzy set A (subset of ground set U) is identified as set of pairs $\{\mu_A(x), x\}$,where $x \in U$, and function $\mu_A : U \to [0; 1]$ is identifed as membership function fuzzy set A.

Ordinary sets are a subclass of some class of fuzzy sets. Moreover, the membership function of an ordinary set takes only two values 0 or 1.

By the intersection of fuzzy sets, we mean such a maximal fuzzy set that is contained both in A and in B ($B \cup A$) , with the membership function

$$\mu_{A \cap B}(x) = \min\{\mu_A(x), \mu_B(x)\}, x \in U.$$

The union of fuzzy sets A and B ($B \cup A$) is understood as the smallest fuzzy set that contains both in A and in B, with the membership function

$$\mu_{A \cup B}(x) = \max\{\mu_A(x), \mu_B(x)\} \ x \in U.$$

Fuzzy logic is a multi-valued logic with special properties designed to model fuzziness and a number of natural language components.

Note that one of the main concepts of the theory of fuzzy logic is a linguistic variable $\langle \chi, T(\chi), U, G, M \rangle$, where χ is the variable name, $T(\chi)$ is the set of its meanings (language expressions), U is the universal set, G is a syntactic rule that can be used to form language expressions, M is a semantic rule by which each language expression is assigned its meaning, which will be a fuzzy set in U. Linguistic variables can be numeric and non-numeric, which is determined by the type of universal set. A numeric linguistic variable $U \subset (-\infty; \infty)$and the base variable is measurable.

Fuzzy set theory and fuzzy logic are the basis for creating fuzzy control systems and fuzzy decision-making systems. Currently, expert systems that can partially replace a specialist expert have gained steady recognition. One of the main advantages of expert systems is the ability to accumulate, update, and preserve knowledge for a long time. All this allows you to improve the skills of specialists working in a particular organization, using the best, proven solutions. Experts use expert systems to be confident in their knowledge and not forget anything. Expert systems are able to solve problems from a specific subject area using deductive methods. Such systems are also used to solve vaguely structured problems. Expert systems are particularly useful in cases where experts cannot arrive at a specific location to solve a problem. Expert systems allow you to spread the experience of experts and make it more accessible. Today, expert systems are used to diagnose diseases, to search for minerals, to buy goods through the Internet.

The main component of the expert system is the knowledge base (semantic model), which describes a specific subject area. Artificial intelligence systems are used in different fields, however, the scope of application of expert systems is limited, they can be used where the knowledge base exists in a natural form.

One of the types of expert systems is production expert systems, which are now most widely used, in which the knowledge base is presented in the form of a set of "if, then" rules. Such a knowledge base is formed in advance by an expert knowledge engineer (a generalist who knows the methods of knowledge representation). Production expert systems are convenient for programming, but quite expensive, due to the fact that they require a lot of time for programmers and knowledge engineers.

Through expert systems, it is possible to solve many topical problems of modern science, including, for example, in the legal field [10].

Further, for example, consider the problem of determining the severity of punishment depending on the public danger of the act and the public danger of the person responsible. In each of these two categories, it is important for experts to identify the most significant characteristics and evaluate them separately. For simplicity, in the example the first category we will evaluate in a consistent form, and secondly, highlight three characteristics: social danger of the person in the past, present and future. These qualities are evaluated by three experts (judges) independently of each other, putting any number in the range from 0 to 10, depending on the degree of public danger. This number is nothing more than a membership function multiplied by 10. The results of the evaluation are shown in Table 1.

With a large number of characteristics, it is more convenient to perform all the procedures in the MS Excel program (a variant of the expert system).

Table 1. The results of the evaluation.

Experts	Danger of the act	The danger of personality in the past	The danger of personality in the present	The danger of personality in the future	The severity of the punishment max (min)
A1	7	5	7	6	6
A2	5	6	7	7	
A3	6	4	6	5	
min (A1,A2,A3)	5	4	6	5	

After the experts fill in the table, you need to find the minimum value in each column and write it in the last line. The meaning of this operation is as follows. The opinion of each expert on each of the characteristics of the public danger of the crime and the identity of the perpetrator corresponds to a certain fuzzy set. To find the common part of these different sets, one must find their intersection, and the intersection of fuzzy sets forms the membership function. Thus, the value of this function is equal to the minimum of the values of the membership functions of all three sets.

Next, we need to find the optimal value of the membership function of the fuzzy set of the linguistic variable "severity of punishment". To do this, we need to find the union of fuzzy sets corresponding to each of the four characteristics. The value of the membership function of such a union is found as the maximum of the values of the membership functions of each of the four fuzzy sets corresponding to the four selected characteristics. In other words, you need to find the maximum value among the minimum values written in the last line. In this example, this number is 6, i.e. the desired value of the membership function is 0.6. Thus, the severity of the penalty is 0.6 on a scale from 0 to 1, i.e. "slightly above average". Note that the rule under consideration corresponds to the minimax principle, which is widely used in mathematical game theory.

4 Discussion

Questions of modeling and formalization of legal processes are related to the very nature of research objects in various fields of science, their specific features in the scientific picture of the world. The essence of the scientific picture of the world lies in its integrative function, in ensuring the synthesis of individual scientific knowledge. The scientific picture of the world introduces certain restrictions on the formation and nature of new scientific paradigms, directs the movement of thought and determines the way of seeing the world around us.

The problems put forward for research by the authors are related to the nature of the objects of research, including their specific features in the scientific picture of the world. The diversity of the surrounding world, the absence of clearly defined categories and strict boundaries in it, justifies the scientific acceptance of fuzzy concepts with an amorphous set of features (for example, the identity of a criminal, etc.). Non-strict (soft) representations show themselves to be a more effective means of understanding complex, unstable systems. Mathematics plays a special, significant role in creating conditions for the formation of a modern scientific paradigm, which is determined by the universality of its methods and techniques [11-14].

5 Conclusion

Expert systems today are able to solve problems from a specific area, using various methods and techniques. Such systems are also used to solve vaguely structured problems. Expert systems allow you to spread the experience of experts and make it more accessible.

Thus, using the ideas of soft modeling and using expert systems, it is possible to objectify processes with a low level of formalization, including, for example, the processes of determining the danger of crime. Fuzzy set theory and fuzzy logic are the basis for creating fuzzy control systems and fuzzy decision-making systems.

The undeniable advantages of fuzzy control systems in comparison with others are:

- The probability of operating with non-strict input data;
- Formalization of evaluation and comparison criteria based on fuzzy mathematics;
- Better evaluation of input and output data of research results;
- Conducting a comparative analysis with a given degree of accuracy, rapid modeling of complex dynamic systems [15].

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