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# METHODS FOR DECISION - MAKING AND RISK ASSESSMENT IN THE DESIGN OF TECHNOLOGICAL EQUIPMENT

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ABSTRACT
Designing is a sequence of procedures of decision – making in the condition of indefiniteness (probability, fuzz, or their combination). For the designer parameters of selection depend on parameters of the medium and this brings to accepting risk. Principles, criteria and methods for decision – making in the different conditions of indefiniteness in the design of technological equipment are thoroughly considered.
**Key words**: Optimization, risk, indefiniteness, fuzz, probability.

## INTRODUCTION

Main procedures in executing design works are assigning tasks, selecting criteria for optimal decisions, generating of variants and the decision – making. According to the conditions of work of the object of design two approaches for choosing of the optimal decision are possible:

- When the factors of the medium are stochastic and their probable characteristics are known, the choice is in the conditions of risk.
- When the factors of the medium are characterized with indefiniteness, contingent on the lack of reliable enough methods or technical means for measuring, confusing factors with unstable statistic characteristics, the choice is in the conditions of indefiniteness. The designer should decide very precisely in which one from the two categories are the factors of the medium in order to find a reasonable method for choosing the optimal variant.

**A. Decision – making in conditions of risk.**

A multiplicity of the criteria for optimality (productivity, exploitation outcome, reliability etc.), that are functions of many variable factors (argument) is formed. The numerical value of a criterion depends on two groups of factors. The first one depends on the human (the person, who makes the decision) and its bears the nomination elements of the decision. Most often the elements of the decision have strictly defined (determined) importance for the value of the criterion. These factors are the choice of determined technical parameters (for example the choice of the number of the transmissions, the choice of the transmission ratios of the transmissions and others in constructing a reduction gear). The second group of factors characterizes the conditions, in which the object of design functions (for example work rate, average ambient temperature in which the considered as an example reduction gear works). The person who makes the decisions cannot influence the values of these factors that represent casual processes, but it is necessary that this person have information about their probable distribution. Unless the person has this information, the decision is made in conditions of indefiniteness.

The decision – making in the conditions of risk means that the designer is forced to accept the expected value of the probable characteristics of the casual factors of the medium. Afterwards it is possible to turn out that the chosen by the designer values are not the real ones, in which the object of the designing functions. In this consists the choice, called choice in conditions of risk.

According to the general theory of the statistic decisions, various principles for decision – making exist. Principle for decision – making means the mathematical definition and the character of the criteria for decision – making. Two types of criteria exist:

- Criteria, which characterize the gain from the made choice of decision and the higher the value of the considered criterion, the better the decision (problem about the maximization of the criterion);
- Criteria, characterizing the expenses for the realization of the made decision. There is an evident necessity to achieve the lowest possible value (problem about the minimization of the criterion).

The next important point is the choosing of strategy, related to the behaviour of the medium. Several types of strategies for the choice exist:

- Principle of maxmin (minimax). It is also known as the principle of Valud. For criteria from the first type (gain) the optimal strategy is the strategy, in which the minimal gain is maximized. For criteria from the second type (expenses) the optimal strategy is the one, in which the maximal expenses are minimized.

The strategy of maxmin (minimax) is based on the supposition that the casual medium will realize the worst possible conditions (approach, based on an extreme pessimism). The indifferent in nature behaviour of the medium is changed with the behaviour of an ill-intentioned adversary. This strategy is reasonable when the designer wants to warrant maximally his or her decision.

More often it is reasonable to apply an intermediate strategy between the extreme pessimism and the unreasonable optimism. A weight coefficient $\alpha$, $0<\alpha<1$ for correction the strategy of maxmin (minimax), is initiated.

The Bernoulli's strategy of the insufficient reason is expressed in the supposition that all the factors of the medium are equally possible, e. g. dominating casual factors are lacking. Despite the fact that it is based on an ungrounded supposition, this strategy has its advantage – it is not based on extreme, but on average conditions.

**B. Decision – making in conditions of indefiniteness.**

This choice is based on a system of presumptive knowledge of the subject about the behaviour of the factors of the medium. In its nature the decision is subjective and thus the responsibility of the designer (the subject) increases. The methods of the fuzzy multitudes from the scientific direction artificial intellect are applied as a formal apparatus. Fuzzy relations about the quality values of the factors of the medium and of the purpose function (the criterion for optimality) are initiated more concretely. A fuzzy relation is characterized with a function of property, which is a subjective measure for the grade of execution (truthfulness) of the ratio factor – criteria. By the Belman-Zade's composition rule the fuzzy ratio is applied for calculating the value of the criterion for the values of the factors of the medium.

**C. Decision – making in conditions of risk and indefiniteness.**

Most often in the complicated objects and systems, characterized with substantial quantitative and qualitative particularities, the factors (arguments) of the choice of the designer are determined qualitative parameters (quantities) and the factors of the medium are casual or are evaluated by qualitative (linguistic) values.

As a result of the joint action of these two different factors the solution (the criterion) is many-valued, e. g. there are fuzzy (inaccurately determined) values. These values may be interpreted as qualitative (linguistic), logic or interval. A suitable apparatus for formal description of the criterion for optimality of the design decision is the many-valued logic probabilities and the many-valued logic fuzzy functions, respectively. They are based on the many--valued logic ($\kappa$ – symbol logic), $\kappa \geq 3$, generalization of the two – symbols logic. The Algebra, formed by the k – elementary multitude, along with all the operations in it, is called Algebra of the k – symbols logic. The operations (n – dimension operations) in the k – elementary multitude are called k – symbol logic functions with n variables.

Two circumstances are worth for paying attention to:

1. Many properties and results that are valid in the two symbol logic remain the same in the k – symbol logic systems;
2. In the k – symbol logic systems there are some particularities that differ in principle from the particularities of the two – symbol logic.
3. In spite of the numerous researches and interpretations, there are not any set generally accepted definitions for the nature of the logic values, accepted in the respective logic system.

Like all functions, the functions of the k – symbol logic f ($x_1$, .... $x_i$ ..., $x_n$), where $x_i$, $i = 1 \div n$, where each $x_i$ possesses $\kappa$ logic true values, can be represented in tables or analytically. Let $P_\kappa$ be the multitude of all the functions of a given k – symbol logic system. The number of the sets ($\alpha_1$,...., $\alpha_n$) of the values of the variables $x_i$ equals $\kappa^n$. This yields that the number of all the functions of the multitude $P_\kappa$, dependent on n variables $x_1$, ....., $x_n$, equals $k^{k^n}$. It is clear that in the multitude $P_\kappa$ when $\kappa \geq 3$ the difficulties increase greatly in comparison with the two-symbol logic as a possibility for an effective use of the table representation of the functions, as well as the possibilities for reviewing all the functions of n variables.

This often causes the representation of the functions $P_\kappa$, $\kappa \geq 3$, by means of algorithm for calculating the functions. Besides that, like in $P_2$, the concept for substantial and unsubstantial variables is initiated, as well as the concept equality of functions. Thus it is possible to observe the functions $P_\kappa$ with accuracy within fictitious (unsubstantial) changes.

"Elementary functions" are also initiated:

1. $\overline{x} = x + 1$ (mod k). Here $\overline{x}$ is a generalization of negation (cyclic change of values).
2. $Nx = \kappa - 1 - x$, often symbolized by $\sim x$ is another generalization of the negation of the value (negation of Lukashevitz).
3. min ($x_1$, $x_2$) – generalization of conjunction.
4. $x_1.x_2$ (mod k) – second generalization of conjunction.
5. max ($x_1$, $x_2$) – generalization of disjunction.
6. $x_1 + x_2$ (mod k).

The applied list of elementary functions reveals that functions of the algebra of the logic have several analogs in the k – symbol logic ($\kappa \geq 3$), each analog generalizing respective property of the function. The main properties of the elementary functions are the properties associating, commutation, distribution, rules for simplifying etc.

The briefly observed many0valued logic functions are used for description of non-linear chance dependencies when these dependencies are in the conditions of definiteness. When there are logic factors (variables $x_i$), that determine a multitude of possible values of the functions $P_\kappa$, the many-valied possible logic functions are initiated, respectively fuzzy logic functions are initiated, when some of the factors $x_i$ determine indefiniteness.

The many-valued logic probable function y= f ($x_1$, $x_2$, $W_1$, $W_2$), where $x_1$ and $x_2$ are quantitative factors (parameters) of the designer's choice and $W_1$ и $W_2$ are qualitative parameters of the medium, is presented as an example in Table 1. When there are m logic (qualitative) values of the function y ($y = y_s$, s = 1, 2, …, 5), e. g. m = 5, and when the factors $x_1$, $x_2$, $W_1$, $W_2$ – have three values $x_{11}$, $x_{12}$, $x_{13}$; $x_{21}$, $x_{22}$, $x_{23}$; $W_{11}$, $W_{12}$, $W_{13}$; $W_{21}$, $W_{22}$, $W_{23}$, e.g. к = 3, n = 4, the number of the different possible sets of the factors $x_1$, $x_2$, $W_1$, $W_2$ is $L = k^n = 3^4 = 81$. For each set of factors there are possible m = 5 logic (qualitative) values of the function y, and the total number of the values of the function y is $m.k^n = 5.3^4 = 405$. Each one of these values is characterized with defined probability $p\{y\}$, when the factors of the medium $W_1$ and $W_2$ are casual quantities or respectively with definite grade of property $\mu\{y\}$, when $W_1$ and $W_2$ are characterized with indefiniteness.

Table 1. y = f ($x_1$, $x_2$, $W_1$, $W_2$)

| Set | № | 1 | 2 | 3 | 4 | | | 81 |
|---|---|---|---|---|---|---|---|---|
| $x_1$ | | $x_{11}$ | $x_{12}$ | $x_{12}$ | … | … | … | $x_{13}$ |
| $x_2$ | | $x_{21}$ | $x_{21}$ | $x_{22}$ | … | … | … | $x_{23}$ |
| $W_1$ | | $W_{11}$ | $W_{11}$ | $W_{12}$ | … | … | … | $W_{13}$ |
| $W_2$ | | $W_{21}$ | $W_{21}$ | $W_{22}$ | … | … | … | $W_{23}$ |
| y | $y_1$ | $p_{11}$ | $p_{12}$ | $p_{13}$ | | | | $p_{181}$ |
| | $y_2$ | $p_{21}$ | $p_{22}$ | $p_{23}$ | | | | $p_{281}$ |
| | $y_3$ | $p_{31}$ | $p_{32}$ | $p_{33}$ | | | | $p_{381}$ |
| | $y_4$ | $p_{41}$ | $p_{42}$ | $p_{43}$ | | | | $p_{481}$ |
| | $y_5$ | $p_{51}$ | $p_{52}$ | $p_{53}$ | | | | $p_{581}$ |

The probability $p_{NS}$, respectively the grade of property $\mu_{NS}$, where N is the number of the set, S is the number of the logic value of y, is within $0 \le p_{NS} < 1$ ($0 \le \mu_{NS} < 1$). The sum of the probabilities is $\sum_{s=1}^{5} p_{NS} = 1$ for each N = 1, 2, 3, ....... , 81. This does not concern $\sum_{s=1}^{5} \mu_{NS}$ in the case of fuzzy values.

**D. Dialog systems for decision – making.**

Dialog is understood as iterative process of decision – making, which is based on a direct and sufficiently fast exchange of information between two subjects and on constant change of the roles (informer – informed subject). Unless this change of the roles exist, the process is unilateral and is characteristic for traditional information systems. In the examined case the concept dialog concerns also the contact between the user and the computer.

The main advantages of the dialog systems are:

- a possibility for applying knowledge of higher grade (semantic networks, dispersed data etc.);
- a possibility for detailed observation of the process of decision–making (a more thorough mechanism for explanation);
- a possibility for applying methods for non-monotonous logic conclusions.

In their nature these are possibilities for the application of new generation systems of artificial intelligence.

The dialog systems for decision–making are subject – oriented, which is a characteristic for contemporary artificial intelligence systems and are an actual task of the CAD/CIM systems.

## CONCLUSION

According to the theory of the statistic decisions the problem for decision–making in the conditions of risk and indefiniteness is systematized. Development of the theory by a new formal apparatus – the many-valued logic - is suggested.

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