Application of fuzzy logic for an enterprise production activity management

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Abstract. For knowledge representation and solving problems of qualitative nature, an applied calculus of fuzzy predicates of the first order has been developed. This theory and methods were used to create an expert system for scientific research in the field of molecular spectroscopy, as well as for a number of other subject areas. One of these areas is the planning and management of the enterprise production activities. A system of fuzzy predicates was developed to formalize basic knowledge of production and commercial activities related to solving the problems of managing production orders. The applied theoretical methods and practical approaches to solving problems of a qualitative nature are considered in the paper.

1. Introduction
To fulfil the company's order book, it is necessary to have operational (for the current day) and operational-calendar (with the layout for the next days) production and logistics plans. The key point in the planning and management of the enterprise production activity is the time of the next order adoption and the definition of its execution timing. In order to make the right decisions for a limited time, it is necessary to have all the completeness of the required information, which is characterized by a significant degree of vagueness and uncertainty. Making such a decision is a complex multifactorial intellectual task. Using the capabilities of fuzzy logic methods and information systems to solve it can have a large economic and organizational effect.

2. Main methods
There are various formal approaches to the presentation of knowledge and the solution of qualitative problems, including the problems of production management.

In computer and expert systems network, frame and production models, structurally combined by various methods (for example, in a hierarchical network) are often used for formalization of knowledge. At the same time, local knowledge has a logical character in the form of IF → THAT, i.e. product systems. For their formalization, Boolean algebra is used, or calculus of predicates of the first order.

The predicate is a propositional function \( P(x_1, x_2, ..., x_n) \), defined on individual variables \( x_1, x_2, ..., x_n \), the range of values of which is the true or false (1 or 0) statement. Fuzziness and uncertainty can be taken into account using the theory of fuzzy sets, which was proposed by L. Zade in 1965 [1]. The fundamental concept in the theory of fuzzy sets is the concept of the membership function. The specific form of the membership functions for each subject area is determined on the basis of various additional assumptions about the properties of these functions (piecewise linear approximation, exponential, quadratic, symmetric, monotone, etc.). A formal logical system was developed, which is an applied calculus of
fuzzy predicates [2, 3], combining the capabilities of the theory of fuzzy sets and calculus of first-order predicates.

The concept of a fuzzy predicate is introduced as a function defined on fuzzy variables, the range of values of which is constituted by statements the truth of which is estimated by the values from (0,1) interval. As in classical logic, \( F_1 \land F_2 \land \ldots \land F_n \) knowledge is considered as axiom systems, and problems are represented by G statements (theorems) that need to be proved or disproved. It is practically more convenient to determine the impracticability, rather than universality, therefore we will consider \( \neg((F_1 \land F_2 \land \ldots \land F_n) \Rightarrow G) \) formula, which is equivalent to \( F_1 \land F_2 \land \ldots \land \neg G \) formula, and its impracticability. There are a number of methods for proving theorems in the predicate calculus, the most famous of which are based on the principle of Robinson resolutions. Logical expressions (formulas) are reduced to a predetermined normal form (PNF), as a result we have a lot of clauses.

In order to obtain the proof, it is necessary to obtain an empty disjunction from a contradictory set of disjuncts using a substitution (resolving) procedure. In the applied calculus of fuzzy predicates, the substitution procedure is complicated, since it does not involve constants and variables, but fuzzy sets, which allows us to estimate the truth of the solution in the response clause.

Let two clauses \( C_1 \) and \( C_2 \), not having common variables, and their truth functions \( \mu_1 \) and \( \mu_2 \) be given. Then, for the truth function \( \mu_0 \) of the resolvent \( C_0 \) of the clauses \( C_1 \) and \( C_2 \), obtained by the substitution \( \alpha \), the inequality \( \mu_0 \geq \mu_1 \alpha \cdot \mu_2 \) is valid. If at least one of the truth functions is \( \mu_1 \alpha \geq 0.5 \) or \( \mu_2 \geq 0.5 \), then for the truth function \( \mu_0 \) of the resolvent \( C_0 \), the inequality \( \mu_0 \geq \min(\mu_1 \alpha, \mu_2) \) is true.

Other methods of fuzzy logic that differ from those proposed for consideration are also successfully used to develop expert and information systems [4-7].

3. Results

From the point of view of information support, we deal with input, reference, regulatory and output data or documents.

It is necessary to create and maintain the following reference and regulatory framework:

- reference book of production, details: cipher, name, unit of measurement, selling price, rate of output, list of necessary raw materials and materials, their number per unit of production;
- directory of commercial goods, details: code, name, unit of measurement, supplier code, purchase price, selling price;
- reference book of raw materials and materials, details: code, name, unit of measurement, supplier code, purchase price;
- supplier handbook, details: cipher, name, address, telephone, financial details, cipher of supplied products, type of delivery, assessment (reliability, efficiency, etc.);
- reference book of consumers, details: code, name, address, telephone, financial details, assessment.

Let us consider the system of fuzzy predicates describing the main production activities of the enterprise:

- PRODUCTION (code, number)
- GOODS (code, quantity)
- RAW-MATERIALS (cipher number)
- SUPPLY (code, supplier, quantity)
- TRANSPORT (type, code, quantity)
- PAYMENT (customer, type, amount, time)
Here the amount is a fuzzy function of time and in some cases of a cipher, the variable type describes the form of payment, the type ∈ {cs, cp, nc, clp}, cs - cash, cp - cash prepayment, nc - non-cash, clp - cashless prepayment.

Then the knowledge of production capabilities can be written as follows:
\( \land (\text{RAW-MATERIALS} (\text{cipher}_i, \text{quantity}_j(t_p)) \rightarrow \mu_{pr} \times \text{PRODUCTION} (\text{cipher}_i, \text{quantity}_j(t_p))) \)

Here, index i describes the list of used raw materials and materials necessary for the production of products of the type j, \( \{j\} \) - the range of products manufactured. We assume that the function amount \( (t_p) \) is stepwise linear, we can count the amount \( (t_p) = \text{amount}_0 t_p \) on linear sections, while amount \( t_0 \) is the consumption rate of raw materials and materials, amount \( t_0 \) is the output rate per unit time. The norms should be considered as fuzzy constants.

Expressions describing production capabilities should be understood as follows: if there is a necessary amount \( (t_p) \) of raw materials and materials of all types i, then the amount \( (t) \) of production \( j \) can be produced in time \( t \) with truth \( \mu_{pr} \). Here \( \mu_{pr} \) characterizes the degree of reliability of equipment, energy and heat supply, and similar factors.

Knowledge of inventory can be recorded as follows:
\( \lor (\mu_{sup} \times \text{SUPPLY} (\text{cipher}_i, \text{supplier}_i, \text{amount}_i(t_u))) \)
\( \land (\mu_{trans} \times \text{TRANSPORT} (\text{type}, \text{cipher}_i, \text{amount}_i(t_u))) \rightarrow \text{RAW-MATERIALS} (\text{cipher}_i, \text{amount}_i(t_u)) \)
\( \lor (\mu_{sup} \times \text{SUPPLY} (\text{cipher}_i, \text{supplier}_i, \text{amount}_i(t_u))) \)
\( \land (\mu_{trans} \times \text{TRANSPORT} (\text{type}, \text{cipher}_i, \text{amount}_i(t_u))) \rightarrow \text{GOODS} (\text{cipher}_i, \text{amount}_i(t_u)) \)

Here, index \( r \) describes possible suppliers with their \( \mu_{sup} \) reliability estimates, \( s \) index characterizes the transport possibilities and their \( \mu_{trans} \) assessment, \( k \) index is the list of raw materials, materials or goods of \( k \) type.

The considered expressions should be understood in the following way: if there is a need for raw materials, materials or goods of \( k \) type, then with the necessary transport available, the required quantity \( t_u(t_k) \) with truth \( \min(\mu_{sup} \times \mu_{trans}) \) can be received at the warehouse from one of \( r \) suppliers during \( t_k \) time.

Information about stocks in warehouse is formalized as follows:
\( \land \text{PRODUCTION}(\text{cipher}_i, \text{amount}_i(t_u)) \)
\( \land \text{RAW-MATERIALS} (\text{cipher}_i, \text{amount}_i(t_u)) \)
\( \land \text{GOODS} (\text{cipher}_i, \text{amount}_i(t_u)) \)

Each order can be described by the following expressions:
\( \land (\text{PRODUCTION} (\text{cipher}_i, \text{amount}_i(t_u))) \land \text{GOODS}(\text{cipher}_i, \text{amount}_i(t_u)) \land \mu_{tot} \times \text{PAYMENT}(\text{customer, type, sum, } t_0) \)

Here \( \mu_{tot} \) can have a different value from 1 only in the case of a non-cash type of payment and assesses the degree of confidence in the customer in the matter of timely payment.

From the point of view of calculating fuzzy predicates, formally an order is a qualitative problem, i.e. theorem; payment and transportation characterize the conditions for its solution, information about production capabilities, supplies and warehouse stocks - knowledge (axioms). To solve the problem, it is necessary to prove the impossibility of negating the logical expression describing the order.
\( \lor (\text{PRODUCTION} (\text{cipher}_i, \text{amount}_i(t_u))) \lor \neg (\text{GOODS}(\text{cipher}_i, \text{amount}_i(t_u))) \lor \mu_{tot} \times \text{PAYMENT}(\text{customer, type, sum, } t_0) \)

The task of fulfilling an order can be solved in one stage, if an empty disjunct is obtained when resolving the clauses of the order with information about the stocks in the warehouses. Otherwise,
information on production possibilities (stage 2) and supply (stage 3) may be included. At all stages, we obtain estimates of the truth of solutions, as the value of the membership functions of fuzzy sets.

The task of fulfilling an order can be attributed either to the type of interpretation tasks or to the type of forecasting. If the consumer needs to find out what time the order can be completed, that is, $t_z$ is a variable, then the task belongs to the class of forecasting tasks. If the consumer specifies a specific time of the order and wants to find out the possibility of its implementation, then we are dealing with the task of interpretation. If we are going to change the content or structure of knowledge, for example, to find out what should be the enterprise's material and technical supply capabilities to perform twice the expanded portfolio of orders, then this task can be assigned to the class of identification tasks.

Making decisions on the management of the enterprise activities consists not only in the timely issuance of production targets and provision of material and technical supply, but also in managing the order execution sequence. The possibilities of such a person without the application of formal methods and information systems are difficult to predict [8,9].

4. Conclusion

Formalisation model of basic knowledge about the enterprise production activity on the basis of applied calculus of fuzzy predicates is presented.

Examples of solving management problems and planning the execution of orders by the method of proving theorems with an assessment of the truth of the obtained results are considered.

The proposed approach to the formalization of knowledge and decision-making in the production and commercial activities of an enterprise provides additional opportunities, introduces meaningfulness in the management decision-making process and allows evaluating their results.

References

[1] Zadeh L A 1965 Fuzzy sets Information and Control 8(3) 338-53
[2] Serov V V 2012 Questions of formalization of fuzzy knowledge. Methods and practical applications (Sputnik+ Publishing House) pp 1-54
[3] Elyashberg M E, Serov V V and Gribov L A 1991 An expert system for molecular elucidation based on spectral data Computational and Theoretical Chemistry 230 191-203
[4] Kalkowska J 2016 Information and communication technologies supporting fuzzy knowledge management Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future 363-73
[5] Borisova L V, Nurutdinova I N and Dimitrov V P 2014 About the method of presenting fuzzy expert knowledge DSTU Vestnik 4(79)
[6] Miroshnik M A et al 2015 Designing artificial intelligence systems using fuzzy logic Radio Engineering 182 42-50
[7] Polkovnikova A N and Kureichik V M 2014 Development of a model of an expert system based on fuzzy logic Izvestiya SFU. Technical science 1(150)
[8] Gorbunova A Yu 2016 Logical incrementalism as a method of management of modern organizations Discussion 4(67)
[9] Stacho Z et al 2016 The organizational culture as a support of innovation processes management: a case study International Journal for Quality Research 10(4)