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FUNCTIONAL STRUCTURE OF THE ADVISING EXPERT SYSTEM "DEFECT-CAUSE-ACTION"

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Abstract: *To solve some technological tasks, developers face a number of problems of formalization, modeling and management of production processes. Especially often difficulties arise when solving problems of detecting and eliminating defects. This is due to the fact that the same defects can appear for different reasons or for a set of reasons; one reason can lead to defects of different types; different values of the cause indicators can cause different defects; the complex of various causes that caused the appearance of certain defects can be eliminated by many combinations of actions taken in this case; the reasons for the appearance of defects can be so many that traditional deterministic modeling methods may be useless; in practice, the experience of a specialist who has worked for many years on the equipment of these technological processes can be very important and effective than complex software and technical complexes for automating the production of some product. The article considers the proposed method for detecting the causes of various manufacturing defects based on the use of fuzzy logic. The developed model and algorithms are implemented as part of a fuzzy expert system. The functional structure of the system with the description of subsystems is given. The proposed system is universal for solving problems of the type "Defect-Cause-Action".*

Keywords: *information environment, fuzzy logic, expert system, technology process, industry 4.0, knowledge base, defect.*

1. Introduction

We are currently living in the era of the Fourth industrial revolution (Industry 4.0), which should ensure the transition to fully automated digital production, controlled by intelligent systems in real time in constant interaction with the external environment, going beyond the borders of a single enterprise, with the prospect of combining into a global industrial network of Things and Services. This concept is becoming more and more relevant [1]. Many technologies are used in Industry 4.0, such as the Internet of things, Cyber-Physical systems, and Big data. These technologies have been used by companies to create smart factories. The developed methods such as Fuzzy Analytical Hierarchical Process (Fuzzy AHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) can help manufacturing companies transition to Industry 4.0 and increase productivity[2].

Competition in the manufacturing market has become indispensable with variable customer demand. As a result of increased competition, issues of productivity, sustainability, high technology, speed, quality and cost of production are becoming increasingly important. In this race, Industry 4.0 technologies give a great advantage to companies that connect the virtual world with the real world, create meaningful information from big data, and prevent time-wasting. [3]. Modern technology of production is a complex mechanical and physical-chemical process, the implementation of which is influenced by many different production conditions and factors. In the real conditions of the technological environment, it is not possible to take into account all these conditions, which is the reason for the appearance of blanks or finished products with various types of defects, the elimination of which leads to additional costs. When the production process consists of multiple stages , there are various factors that affect the quality of production. Moreover, the defects at each stage of production are summed up and, in the end, we can get a lot of defective products. Automation of such productions faces a number of problems of formalization, modeling and management.

This is largely due to the fact that different types of situations may occur in practice:

• the same defects may appear for different reasons or for a combination of reasons;

• one reason can lead to different types of defects;

• different values of the cause indicators can cause different defects (for example, temperature, pressure, concentration of the mixture, etc.), i.e. the range of values of the causes themselves is quite wide;

• the complex of various causes that caused the appearance of certain defects can be eliminated by a variety of combinations of actions taken in this case;

• there may be so many reasons for defects that traditional deterministic modeling methods may be useless;

• in practice, the experience of a specialist who has worked for many years on the equipment of these technological processes can be very important and effective than complex software and technical complexes for automating the production of a product.

All this leads to the assignment of the tasks of searching for reliable causes and actions to eliminate defects in the production of products to the class of difficult to formalize tasks. The use of fuzzy logic for solving production tasks is one of the most effective methods[4-6].

II. Purpose and method.

The purpose of the research is to develop the advising expert system that allows to determine the causes of defects in a relatively short time, as well as a set of actions that must be implemented to eliminate the defects.

The following requirements are set for the system:

- ability to accumulate initial data for the knowledge base creation;
- ability to use the knowledge of experts who have experience in this technological environment (process);
- ability to synthesize solutions from knowledge base components for the real production situation to determine the causes of defects and actions to eliminate them.

The system belongs to the class of systems with fuzzy logic, i.e. its mathematical basis is the theory of fuzzy sets. The mathematical model of the problem is reduced to the implementation of a fuzzy model of correspondences of the type "Situation-Cause-Action" and the corresponding algorithm.

Problem statement: 1) there are defects (possible defects) Z . We call each zi defect a sign of a situation. 2) there are causes a_i□□□ of these defects 3) there are certain actions c_i □□C, that we apply to eliminate these causes A. Need to find:

1) the causes of the situation S = {a1,a2,..... a_m}, consisting of defects that have occurred at the moment;

2) a set of actions that must be done to eliminate the causes of the defects.

The model and its algorithm are described in detail in the author's works [7,8]. Below we will show how to use the method for the "Defect-Cause-Action" case. The knowledge base reflects the intellectual activity of the technologist: reflections, conclusions, generalizations and abstractions, which are based on various knowledge-fundamental research, subjective, obtained as a result of practical activities and experience in the production.

The table form of the fuzzy model of correspondences "Defect-Cause-Action" is given in Table 1.

Table.1.

Fuzzy correspondence model "Defect-Cause-Action"

Defects				Causes	Actions			
z_1	z_2		z_n		s_1	s_2		s_m
μ^d_{11}	μ^d_{12}	.	μ^d_{1n}	a_1	μ^a_{11}	μ^a_{12}	.	μ^a_{1m}
μ^d_{21}	μ^d_{22}	.	μ^d_{2n}	a_2	μ^a_{21}	μ^a_{22}	.	μ^a_{2m}
μ^d_{31}	μ^d_{32}	.	μ^d_{3n}	a_3	μ^a_{31}	μ^a_{32}	.	μ^a_{3m}
μ^d_{41}	μ^d_{42}	.	μ^d_{4n}	a_4	μ^a_{41}	μ^a_{42}	.	μ^a_{4m}
μ^d_{51}	μ^d_{52}	.	μ^d_{5n}	a_5	μ^a_{51}	μ^a_{52}	.	μ^a_{5m}
μ^d_{61}	μ^d_{62}	.	μ^d_{6n}	a_6	μ^a_{61}	μ^a_{62}	.	μ^a_{6m}
				.	.	.	.	.
μ^d_{k1}	μ^d_{k2}	.	μ^d_{kn}	a_k	μ^a_{k1}	μ^a_{k2}	.	μ^a_{km}

μ^d_{ij} - membership function of z_j defect to a_i reason;. μ^a_{ij} - membership function of a_j cause to s_i action.

Let's consider the functional structure of the expert fuzzy system for solving the problems of enameled tableware production(Fig.1). We have divided the system into six subsystems, such as "User Interface" , "Creating the primary data base", "Knowledge base creation", "Explanation of decisions" , "Logical output of solutions", "Analysis". This division is conditional. Each subsystem performs its own specific function, but they are aimed at achieving the single goal: to identify the causes of defects and determine rational actions to eliminate defects. This allows you to effectively distribute the tasks of developing and managing the system.

1. The "User Interface" subsystem performs the functions of organizing the interaction of the User with the expert system. The User in this system is a technologist, worker directly engaged in the production of products.
2. The Subsystem "Creating the primary data base" is designed to form the database of primary information for the knowledge base. Knowledge Engineer collects and enters all possible types of z_i defects, causes a_j of defects, and what actions s_l can take to fix them.
3. The subsystem "Knowledge base creation". It is designed to organize, systematize and classify the knowledge received from experts. In addition, it performs the functions of formalization and testing of knowledge. The process of acquiring knowledge is carried out with the help of a Knowledge Engineer and experts - highly qualified specialists in the field of the production, most often working on this particular work site. Experts, with the help of an Engineer, give their estimates on the "Defect-Cause" and "Cause-Action" correspondences, i.e. give numeric values to the μ_i (membership functions) in the range from 0 to 1.
4. The "Explanation of decisions" Subsystem allows displaying intermediate and final decisions, as well as some fragments of the knowledge base along the "Defect - Cause - Action" chain. If there are doubts about the final solution, the subsystem generates several solutions - actions for the resulting defects for the user to choose from.
5. The "Logical output of solutions" Subsystem is designed to generate recommendations for the situation. It implements a strategy for selecting actions from the knowledge base based on specific product manufacturing defects. The main principle in decision-making is the degree of inclusion and establishment of appropriate priority coefficients for causes and actions.
6. The subsystem "Analysis" is intended to analyze the results, the introduction of updates to the knowledge base. The obtained statistical data on the use of the system's results (its "advices") are the initial information for introducing changes.

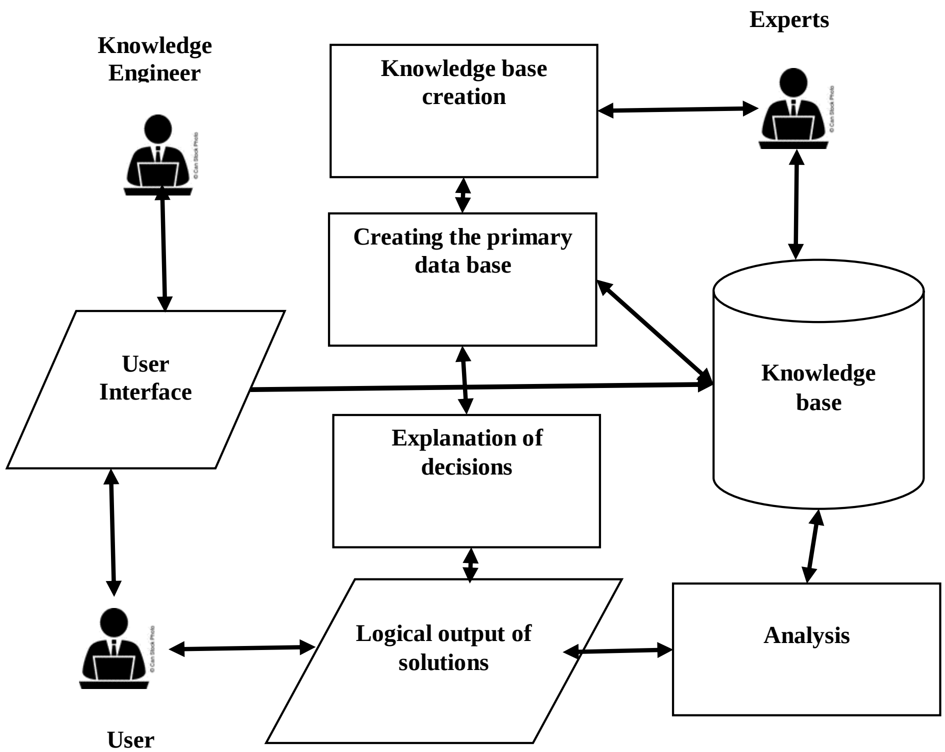

Fig. 1. ***Fuzzy expert system***.

Conclusion.

As the results of research and practical implementation of advising fuzzy systems in determining product defects and the causes of their elimination show is the most effective in the following cases:

- there is a complex multi-stage manufacturing process
- many parameters that affect the quality of the product
- the formalization of the technological process complicates and increases the cost of creating an automated system, and these efforts don't justify themselves
- there are highly qualified specialists who can give their knowledge to formalize it and create a knowledge base.

The expert system was tested to detect the causes of defects in the production of enamelware. Tests have shown that in practice, the most important thing is to provide the user with several solutions to eliminate defects. It is up to the user to choose which solutions are most appropriate for the given situation. Such systems are as effective as advising systems. The most time-consuming part of creating and implementing a consulting system is to collect and systematize knowledge about defects, causes, actions, and the degree of their compliance, i.e. the definition of membership functions. This is due to the following factors: psychological unpreparedness of experts to quantify (within the framework of expert assessments) parameters that affect the course of the technological process, organizational difficulties associated with the difficulty of attracting a large group of experts and the fact that it is necessary to distract (for quite a long time) experts from their main work.

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