Development of databases of intelligent expert systems for automatic control of product quality indicators

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Abstract. Currently existing methods of product quality assessment are far from perfect, since this assessment is carried out in the laboratories of enterprises. Successful solution of this problem is possible when implementing intelligent expert systems for monitoring and forecasting in the flow of product quality indicators using intelligent technologies in the production process. One of the most important components of the expert system is the database. The article deals with the methodological basis for creating databases for building an intelligent expert system for monitoring and forecasting product quality indicators in the production process. Distinctive features of databases are highlighted. The method of database development is investigated and proposed. The main stages of database development are investigated and analyzed. An integrated conceptual model of the domain database of the integrated expert system has been developed. Developed: a tree of database goals, the composition of the main elements of the database system of the intellectual expert system of product quality control. The main phases and stages of designing the database and expert system have been worked out. VAD data flow diagrams are presented. The description of the domain semantics is developed in the form of a system of functional and multi-valued dependencies between attributes of the conceptual model of the domain database. The database architecture has been developed. The developed specialized database of the integrated expert system for monitoring food quality indicators is a single information environment that provides information for automatic control of product quality indicators.

1. Introduction

At the present stage of economic development of the Russian Federation, the requirements for improving the quality and competitiveness of domestic food products are increasing [1]. The solution of these problems in modern conditions is possible only on the basis of using the latest scientific achievements in the field of engineering and technology, ensuring the stability of production processes, equipping production lines with modern means of continuous automatic control, regulation and management using high-performance intelligent technologies [2].
The difficulty of solving these problems is due to the fact that most of the prepared food products are complex and heterogeneous multi-component mixtures, the state of which depends on many factors [3]. All this causes frequent fluctuations in the parameters of the cooking processes of multi-component food masses and does not allow you to get a stable quality of the finished product [4]. Therefore, the problems of automation of control in the flow and forecasting the quality of food products, optimization of operating modes of the equipment used on the basis of taking into account changes in parameters that determine the course of these processes, are major theoretical and practical problems that require priority solutions [5].

To study the possibility of solving this problem, the most typical technological processes of confectionery, flour-milling, dairy and beer-non-alcoholic production of food products were selected, investigated and analyzed [6-8].

The most characteristic food industries were selected, representing large groups of a wide variety of food products. On the basis of comprehensive theoretical studies of the state of these production processes, a generalized scheme of the main stages of preparation of the analyzed processes for automation and implementation of intelligent technologies was developed. The most informative parameters of these processes are revealed [9].

To date, sufficient practical and theoretical information has been accumulated on the automation of technological processes of food production using modern information technologies, which were carried out by S. I. Apanasenko, V. K. Bityukov, A. B. Borzov, M. M. Blagoveshchenskaya, Yu. a. Ivashkin, A. ya. Krasinsky, A. E. Krasnov, and others [10-14 and others]. In this work, the experience of previous studies was taken into account and worked out, and the recommendations given by the authors of these works were used. Currently existing methods of assessing the quality of food products are far from perfect, since this assessment is carried out in the laboratories of enterprises and, most often, organoleptically. Organoleptic control is time-consuming and has many disadvantages [15]. Due to the absence of professional tasters, as well as due to non-compliance with the conditions of analysis at most food enterprises, such an assessment can often give unreliable and biased indications about the quality of the finished product [16]. There is a need to improve the objectivity of food quality control by introducing high-performance intelligent technologies in the production process and creating non-discontinuous automated control and management systems based on them. The successful solution of this problem is possible when integrated expert systems for monitoring and forecasting the flow of product quality indicators are introduced into the production process using modern intelligent technologies: artificial neural networks and computer vision systems. Creating and using intelligent expert systems is one of the conceptual stages in the development of food industry automation. The algorithm of the expert system is based on a neural network model, the functioning of which is based on the operation of artificial neural networks and computer vision systems. Creating such a system will allow you to: continuously monitor and forecast the quality of semi-finished products and finished products throughout the entire process; ensure the stability of food production; significantly reduce the level of marriage, reduce the loss of working time, raw materials and energy, and improve the quality of finished products [17].

The integrated expert system for monitoring product quality indicators solves the following tasks:
- real-time control of technological modes of organoleptic quality indicators of raw materials, semi-finished products and finished food products;
- identification of the current state of technological processes;
- forecasting the quality of finished food products;
- support for making management decisions in real time under conditions of uncertainty to regulate production processes.

The basis of an intelligent expert system for monitoring food quality indicators is made up of: a database, a knowledge base, and a decision support subsystem [18].
The integrated expert system for monitoring product quality indicators being developed uses the knowledge of specialists (experts) about a specific narrowly specialized subject area and within this area it is able to make decisions at the level of an expert professional.

The database is intended for temporary storage of facts or hypotheses that are intermediate solutions or the result of communication between the system and the external environment, which is usually an operator conducting a dialogue with the expert system.

A logical inference machine is a reasoning mechanism that operates on knowledge and data in order to obtain new data from knowledge and other data available in working memory. To do this, the intelligent expert system uses a programmatically implemented mechanism for finding a solution in a network of frames or a semantic network. The logical inference machine of the expert system implements reasoning in the form of: deductive inference (direct, reverse, mixed); probabilistic inference; unification; solution search with division into a sequence of subtasks; reasoning using the argumentation mechanism; associative search using neural networks.

The communication subsystem is used for conducting a dialogue with the user, during which the intelligent expert system asks the user for the necessary facts for the process under study, and also allows the user to control and correct the course of the expert system's reasoning to some extent.

The explanation subsystem is necessary in order to allow the user to control the course of reasoning and, perhaps, learn from an intelligent expert system.

The knowledge acquisition subsystem is used for updating and updating the knowledge base. In the simplest case, it is an intelligent knowledge base editor; in more complex expert systems, it is a tool for extracting knowledge from a database, unstructured text, and graphical information.

2. Experimental procedure

Figure 1 shows the main stages of developing a dynamic system for monitoring product quality indicators in the production process, which allows you to accumulate knowledge of service personnel and experts about the reasons for the deviation of quality indicators of semi-finished products and finished products at all stages of production.

One of the most important components of an intelligent expert system for monitoring product quality indicators is a database system, the process of building which has three main phases: the formulation of database requirements, design and implementation.

During the requirements formulation phase, a data model was developed: different data elements of the selected subject area (production of different products) were selected. In addition, the received data was subject to restrictions and rules, and the processing needs were determined.

The data structure of the subject area was designed, which is an information and logical model of the database.

An important stage in database development was the design phase. During the design phase, the data model was converted to tables and their relationships. Tables were created using the SQL language, which is the industry standard for processing tables. Foreign keys were used to represent relationships in tables. Constraint mechanisms, stored procedures, and triggers were designed.
Figure 1. Main stages of developing a dynamic intelligent expert control system

The next important stage was the implementation phase. In the implementation phase, tables and links were created for the subject area. To create tables, use the method using SQL tools. Data restrictions were also set using SQL tools. During implementation, stored procedures and triggers were tested. Then the databases were filled with the data obtained in the subject area and the system as a whole was tested.

Building a database and creating a single information model that allows you to store the data necessary for an intelligent expert system in an orderly manner meant experimentally searching for optimal values of organoleptic quality indicators for a specific product at all stages of production. At the same time, it was important to develop a block containing additional information about the optimal value of the color and taste of the studied products, which largely depend on the properties of raw materials, methods of obtaining products, modes of conducting technological processes, applied technological schemes, and other factors. It was also important to develop a block containing information about the color of the resulting semi-finished product and finished products. At the same time, these blocks combine the functional property of an intelligent expert system for monitoring product quality indicators.

At the first stage of design, the type of database management system was defined. From relational database management systems, the most common variant of bdForge Studio for MySQL was selected for our task. The advantages of this option include the presence of tools for centralized administration; tools for comparing databases; the presence of a visual query Profiler; the presence of a database designer that allows you to build visual charts, etc. with its help, you can easily automate routine work and save time.

The production process also provides for quality control of technological processes for the preparation of this product at all stages of its production. Thus, we get information about organoleptic, physico-chemical, and other indicators of product quality at each stage of production from the company's laboratories.

To collect this information in the database, the process "Collection of information on quality indicators determined by laboratory methods" was selected. Two types of data models are used in the
information structure of databases: hierarchical and relational. At the top level, the database has a hierarchical three-level structure with relationships between objects at neighboring levels of the "one to many" type, which gives the information system visibility and flexibility, the ability to include new types of parameters, types of automation equipment, etc.

At the lower level, the spreadsheet form corresponds to the relational information model. It includes two groups of fields - fixed fields that can't be changed, and variables where data can be updated. This model provides a quick search and sorting of data by various classification criteria. Properties of raw materials, semi-finished products and finished food products are presented in the database by reference tables containing their characteristics. For a systematic approach to the development of databases, structuring the list of the above-mentioned areas of work, and hierarchy of multi-level goals, a model has been developed – a tree of goals that allows you to organize and combine goals into a single complex (figure 2).

Figure 3 shows a VAD diagram of the data flow required for designing the database of an intelligent expert system for monitoring product quality indicators.

The goal of creating a database model is to provide the developer of an intelligent expert system with a conceptual database schema in the form of a single model or several local models that can be integrated relatively easily into any database. The developed integrated conceptual data model, which will be implemented in the database of the intelligent expert system for monitoring product quality indicators, is shown in the figure 4. When building an integrated conceptual model of the domain, all local conceptual models of the domain were used.

Figure 2. The objectives tree databases
The purpose of building such a model is to create a General scheme that integrates the views of different users of this system, while maintaining the semantics embedded in the local conceptual models of the subject area. The essence of the process of building an integrated conceptual model of the domain consists in combining local conceptual models into a common model, the entities of which contain attributes of each of the entities of the local conceptual models of the domain. When creating data models, the semantic modeling method was used, which is based on the meaning of structural components or characteristics of data, which contributes to their correct interpretation.
Various variants of entity-relationship — ERD diagrams are used as a semantic modeling tool. During the development of ER models, the subject area (various enterprises, factories) was examined and identified: entities that store data about these enterprises (represented as blocks); relationships between these entities (represented as lines connecting these blocks); properties of these entities (represented as attribute names in these blocks).

To create a database of intelligent expert system for monitoring product quality indicators, we used the results of our research of technological processes for the production of various products. The authors developed an ER-diagram of the image of the essence of the subject area under study and existing relationships, which allows automating data processing in the implementation of an intelligent expert system for monitoring product quality indicators.

The main functions and content of the database Application are: creating and processing a form; creating and transmitting queries; creating and processing reports; executing application logic; and managing the application. When the user fills out the form and sends the data back, the application determines which data tables need modification, and sends requests to the database management system to trigger the necessary modification.

If errors occur during this process, the Application receives an error message and generates a suitable message for the user or performs some other action.

In addition, the database management system contains a security system that is used to verify that only authorized users perform certain actions with the database: the database management system provides the ability to back up data from the database and restore it if necessary.

Figure 5 shows the overall architecture of the developed database in the form of a physical Erwin diagram, which was used to write code in SQL and implemented in bdForge Studio for MySQL.

![Figure 5. Database architecture of an intelligent expert system for monitoring product quality indicators](image-url)
The built database can function independently or be integrated into application programs for designing and monitoring food quality indicators.

3. Conclusion

The introduction of a single database that integrates disparate data into an intelligent expert system for monitoring product quality indicators will allow specialists to flexibly make changes to existing standard calculation methods, as well as make recommendations for monitoring the properties and characteristics of raw materials, semi-finished products and finished products in order to identify the reasons for the decline in the quality of manufactured products and the occurrence of defects in real time.

The developed specialized database of the intellectual expert system for monitoring product quality indicators is a single information environment that provides information for monitoring quality indicators of manufactured products.

There are three categories of users and their respective types of authorized access to information in databases:

1) software developers associated with the database-the data format is open, new information can be added to the database and old information can be deleted;
2) users using the database-you can add and delete data;
3) users of the database as an information search engine do not have the ability to change the contents of the database themselves.

The developed databases of the intelligent expert system allow you to store data about:
- classification of manufactured products in accordance with the technical documentation for these products, as well as depending on the method of manufacture (standard technological processes used) and finishing;
- range of finished products;
- types of raw materials used; indicators of the quality of these raw materials in accordance with existing GOST Standards;
- indicators of the quality of semi-finished products and finished products, indicating the possible range of changes in these indicators in accordance with GOST standards, passports of finished products;
- methods and means of quality control of raw materials, semi-finished products and finished products. Requirements for methods and technical means (TS) for determining quality indicators at all stages of the technological process of production of this product;
- causes of defects in the production of products, defects and conditions for their elimination;
- State standards for interstate and domestic production; in-plant quality certificates for the production of manufactured products and other documents of the enterprise.

The databases also include reference tables, regulatory materials, and graphical information about products manufactured by the industry. In addition, information is provided about industry terms, units of measurement, parameters, and symbols of elements in functional automation schemes. The databases also contain information about the functions of monitoring the state of technological processes of production, compliance with the technology of production processes, periodic inspection of the modes of equipment used and preparation of laboratory analyses of quality control indicators of manufactured products.

To register a product variety, fill in the passport of the raw material used, the requirements for the raw material used, and the passport of the finished product. The implementation of this function in databases is carried out by the process of "collecting information about the grades of manufactured products". For registration of state Standards in databases, information is filled in on interstate, intra-state, intra-factory quality certificates: finished products; raw materials; technical means used for the preparation of these products; methods used to check product quality indicators.
The implementation of this function in the database is carried out by the process of "collecting information about state standards". To register requirements for methods and technical means for determining the quality of raw materials, semi-finished products and finished food products, methods and methods for determining their definition are specified. The implementation of this function in the database is carried out by the process of "Collecting information about the requirements for methods and technical means for determining the quality of raw materials, semi-finished products and finished food products".

Developed a database of intellectual expert system of monitoring of quality parameters of products has the following advantages: openness, free access to data, supporting a variety of text and graphic data formats; the ability podklyucheniya data to application programs for the design and analysis of quality of raw materials, semi-finished and finished products industry.

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