CONCEPTUAL MODEL OF DECISION SUPPORT SYSTEM IN A MANUFACTURING ENTERPRISE

Monika Piróg-Mazur, Galina Setlak

Abstract: *The article presents a concept of advisory system supporting decision-making processes in a manufacturing enterprise operating in the glass industry. The purpose of the system is to support operators and production line managers in recognising defects of finished products (bottles) and to propose methods of eliminating these defects. Basic purposes and assumptions regarding the development of this system as well as a description of its operation have been presented. The knowledge has been recorded in a knowledge base and is represented by rules and facts. The structure of the knowledge base and the reasoning process have been presented.*

Keywords*: decision support systems, knowledge base, knowledge representation, reasoning process.*

ACM Classification Keywords*: I. Computing Methodologies, I.2.1 Applications and Expert Systems, J. Computer Applications,*

Introduction

The use of proper tools which support decision making on all stages of a production system operation is indispensable for managing a modern enterprise [Setlak, 2002].

In the recent years a great number of enterprises have made large investments in developing modern tools of computer support of production. These tools were to compete with expensive and complicated systems available on the market. However, these works did not bring satisfactory results. The main drawback of majority of solutions was oversimplified modelling of objects and processes using these objects [Euwe, 1997]. Thus, what was necessary was a fundamental change of approach to the systems solving complex problems of modern production. Systems should not only process data and information but first of all they should be based on an expert's knowledge.

A decision-making process is an organised set of activities, realized on the basis of an algorithm, whose function is to precisely determine conditions and limitations of a decision-making situation and choose the optimal variant. Efficiency and effectiveness of decision making is a key factor of success of every undertaking. Intelligent decision-making systems in the form of expert systems play an important role in supporting decision-making processes [Buchalski, 2006, Zieliński, 2000].

The advantage of advisory systems based on expert systems is simplicity of their usage, which comes down to sessions of questions and answers between the computer programme and the user. Sessions can be repeated any number of times by changing input data, which allows to examine a lot of solutions (results) and gives the system features of a simulation program [Piróg-Mazur, 2010].

The structure and essence of an expert system operation

An expert system is a computer program using knowledge and reasoning procedures to solve problems that require human experience (of an expert), which has been acquired in the course of long-term activity in a given field.

In general, the idea of operation of expert systems consists in transferring specialized knowledge of an expert to a knowledge base, designing an inference engine on the basis of information possessed and adding user's interface, which is the tool of communication [Rutkowski, 2009].

The structure of an expert system can be very varied. Basically, it is dependent of a field of application. A schema of an expert system is shown in Fig. 1. It is assumed that every such a system should consist of at least three modules presented below [Mulawka, 1997]:

- knowledge base – a collection of knowledge within a given field arranged according to a selected method of its representation;

- reasoning mechanism – it searches the knowledge base and determines the order of analysing elements of knowledge which will be applied to formulate an answer given by the system;

- interface – it enables the user to communicate with the system in dialogue mode; the way of conducting this dialogue corresponds to the way of solving a problem by an expert.

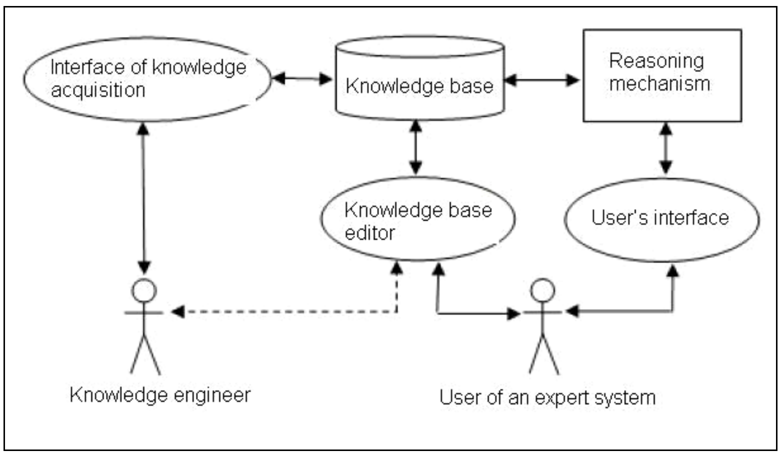

Figure 1. The structure of an expert system

Basic purposes and tasks of individual elements:

- **User's interface:**
    - accepting a task,
    - generating messages prompting the user to give additional information concerning the task,
    - modifying a task description formulated by the user according to the internal format,
    - generating explanations and answers addressed to the user, managing the dialogue with the user while solving a problem.
- **Reasoning mechanism:**
    - searching for a solution using the knowledge stored in the knowledge base,
    - sending messages on the state of a task,
- **Explaining module:**
    - accepting the user's questions (through the user's interface),
    - searching for answers to the user's questions,
    - preparing the answer.

- **Knowledge base:**
  - permanent knowledge (terms, permanent facts, definitions, interpretations, photos),
  - changeable knowledge, corresponding to the current task,
  - a set of reasoning rules [Białko, 2005, Stefanowicz, 2003].

The concept of developing a decision support system

Designing decision support systems for manufacturing enterprises is methodologically very complex (it concerns the issues of modelling and synthesis of technological knowledge, techniques of data processing and supporting decisions). This issue is quite difficult to sort out in academic conditions. Therefore, the elaboration on conceptual model of decision support system on the basis of technological documentation of a manufacturing enterprise operating in the glass industry has been prepared. It will be possible to test in practice and apply the results of the work in this enterprise, limiting the scope of research to supporting the process of quality control of finished products.

The purpose of development of a decision-making system is to create an interactive tool supporting the decision-making process while trying to eliminate defects of finished products (here bottles). Making a decision during emergency state in the manufacturing enterprise is connected with serious consequences because of a large number of finished products, high temperature and high pressure in the equipment used in this production process.

The assumptions underlying the system development include:

- the system should identify problems occurring during the manufacturing process (production) on the basis of causes of occurrence of these problems,
- the system should propose solutions within a particular scope - providing support in solving decision-making problems related to the process of quality control of finished products, i.e. classification of products (here: bottles) defects as well as analysis and a choice of a proper technique of their elimination, which will allow to improve the technological process,
- the system should provide expert opinions and advice in emergency situations in the scope of reasons for their occurrence,
- the system should be friendly for the end-user, who is not necessarily an expert in a given field; the interface will be based on questions and answers in a natural language,
- the system should provide access to texts, drawings, possibly simulations - data bases in the form of text and graphic files, which contain additional or more complete explanations.

The assumptions presented above and the fact that domain knowledge is often organised in the form of tables (engineering guides, data from measuring points, analyses) and partly algorithmised, for example, a choice of a method of defect elimination, allowed to create the concept of the expert system development and its actual implementation.

An advisory system should enable to create the classification of product defects and to choose a suitable (the most advantageous) method of their elimination. The system should support an operator and a production line manager in a comparable way as a highly-qualified specialist (expert) does.

In the result of dialogue, on the basis of data entered by the user and data from measuring points the advisory system will realize the process consisting of:

Step 1: Recognising a defect of a product (here: a bottle) and classifying it into a suitable group (e.g. Group 0 - critical defect - leaking bottle finish, bottle finish/collar overblown, cracks in a bottle finish/collar),

Step 2: Recognising and determining the reason for the defect occurrence (failure of the moulding process, the equipment, machine configuration),

Step 3: Determining ways of methods of eliminating the defect,

Step 4: A selection (of the optimal solution out of the ways or methods determined earlier).

On the basis of the process presented above the system will propose a method of eliminating product defects occurring on the production line. The user can accept, modify or reject the variant proposed by the system.

Advisory systems, having access to the recorded knowledge of a specialist in a selected field, can use it effectively many times. Simultaneously, it allows an adviser (an expert) to free themselves of repeating similar expert opinions and focus on more creative tasks. A special advantage of such systems is a possibility of solving certain tasks without direct participation of a specialist as well as a possibility of accumulating knowledge of a numerous group of specialists in one system [Cholewa, 2002].

The enterprise for whose needs the system is being developed specialises in glass packaging production. In total, 14 production lines are operated in the Glassworks. Production in the enterprise is realized in the three-shift system seven days a week. During one shift one production line is able to produce 200 000 items of finished product.

Acquisition and representation of knowledge

Acquisition of data and knowledge for decision support systems are realized using both traditional and formal methods [Pondel, 2003]. Data on materials, the means of production are acquired from standards, catalogues, literature, documentation of the enterprise and data bases which already exist in the enterprise. The traditional method of knowledge acquisition consists in observing a production engineer and having talks with him. A knowledge engineer plays a key role in this method. This is a person who observes an expert solving a problem, analyses his or her knowledge on the basis of given instructions and real tasks solved and accumulates the knowledge using analogy. Then, the knowledge engineer selects and arranges the knowledge communicated by specialists so that it can be stored and effectively applied using a computer [Zieliński, 2000].

Technological knowledge is a collection of information on a technological process performed in the precisely defined realities of a given enterprise. Technological knowledge is a dynamic collection, i.e. it changes in time as parameters of the technological process change. It is assumed that technological knowledge can be processed in a way typical of phases of an advisory system development. This process consists of the following phases:

- acquiring technological knowledge,
- preparing models of technological knowledge representation,
- storing the knowledge in the technological knowledge base of the system.

Participation of the expert in building the advisory system is necessary as using his or her experience concerning both the tasks solved in the past as well as the ways of solving particular tasks and the way of selecting suitable methods of solving them, is indispensable.

The knowledge engineer takes into account the following sources of knowledge:

- information necessary to carry out work (materials from non-serial and serial publications),
- information on all processes realized in the production system (materials collected in the Glassworks, consultations with Plant Manager of O-I Poland, consultations with employees specialising in different phases of technological process – an expert's knowledge),

- methods of quality assessment of finished products (ideal standard and permissible standard),
- allowable variants of development (purchase of new machines, modernization of current machines, new technologies, new materials, etc.),
- assessment criteria of the system development variants.

Development and application of expert systems are strictly connected with the process of knowledge processing. The purpose of this process is to acquire resources of knowledge and experience corresponding to the range of tasks within a particular field of application from identified sources of knowledge and to record them in the knowledge base in a way that enables to effectively support human activities while solving problems within this field [Knosala, 2007].

We distinguish two basic types of symbolic knowledge representation: procedural and declarative representation. Procedural representation consists in determining a set of procedures whose operations reflect the knowledge about a particular field whereas declarative representation consists in defining a set of facts, statements and rules specific for the field considered. The advantage of procedural representation is high effectiveness of representation of processes; however, declarative representation is easier to describe and formalize. Thus, these two methods are very often combined within one method of knowledge representation [Knosala, 2007].

Development environments for building advisory systems usually offer a collection of forms of knowledge representation: rules, semantic networks, frameworks, scenarios and others. Currently, availability of many forms of knowledge representation within one development environment for building advisory systems has become a standard.

Different ways of knowledge representation allow to present the reality of a particular problem in many ways. Some methods allow to describe the existing relationships more precisely, others allow to express an expert's knowledge easier and more concisely.

Out of the methods listed above knowledge representation in the form of rules (they link relationships between objects and their properties) is the most popular because of its effectiveness and intuitiveness. It uses the rules of the type:

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IF the_list_of_conditions THEN the_conclusion
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Conditions are usually connected with the logical operator "AND". Some systems also allow to use the operator "OR"; however, it decreases readability of the knowledge base and does not increase the system capabilities because it can be easily replaced by adding the second rule with another list of conditions [Michalik, 1998].

One of the most frequent forms of knowledge representation are rules. They consist of two elements: a premise and a conclusion.

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IF <the premise> is true
THEN <the conclusion> is true
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A very important feature of knowledge representation based on rules is the possibility of nesting rules, i.e. using a conclusion of one rule as a premise for the next one. The possibility of nesting rules allows to express knowledge more clearly and in a more readable manner.

IF the defect occurs in a continuous cycle

AND a number of defect occurrences in the second measuring point is similar

AND there is the cold kier in the area of moulding the finish

AND the cooling pipe touches the internal edge of finish

THEN the invert arms open too fast.

The sample rule presented above shows that in view of the expert first it should be checked if the defect occurs in a continuous cycle, than the results should be compared with the results obtained in the second measuring point and then the position of the kier and the cooling pipe should be checked.

All the collected and pre-formalized knowledge using the knowledge obtained from the plant expert, expressed in the form of a model, was recorded in the knowledge base. In order to create the base of rules within this scope the expert was asked to provide key information and domain knowledge. Domain knowledge are facts, theories, heuristics within a particular field of a system application, strictly adjusted to the realities of a particular enterprise.

The knowledge base of a decision-making system contains the base of facts and the base of rules. The base of facts contains names of defects, basic quantities and technical parameters prepared by production engineers. The base of rules contains information necessary for operation of the reasoning mechanism.

Facts, called premises, are expressed in the form of questions which can be answered by two to several answers. Below there are several examples of facts, possible answers to the questions are in brackets:

- Does the defect belong to the group of critical defects {yes, no}?
- Was a number of the defect occurrences checked? {yes, periodically, systematically, no}
- Was the mould number localized on the automatic machine? {yes, no}

The rules consist of one or several premises with answers to the asked questions and the final information about the order of actions to be carried out to eliminate a defect. The final information is also called a conclusion. Below there are some examples of rules included in the base.

- Defect: vertical cracks in the bottle finish

  Is the time of the kier contact sufficient? {yes, no}

  Is the pressing pressure correct? {yes, no}

  Is there the cold kier within the area of the finish moulding? {yes, no}

  Does the cooling pipe touch the internal edge of the finish? {yes, no}

- Defect: glass adhered

  Is the design of takeout tongs suitable? {yes, no}

  Is the design of the side guide of sweep-off gear suitable? {yes, no}

  Do the takeout tongs slide out entirely on time? {yes, no}

  Do the bottles contact each other on the pusher rail? {yes, no}

Reasoning process

In the advisory system being created progressive reasoning strategy (forward) will be applied. A block diagram of the algorithm is shown in Fig. 2 [Mulawka, 1996, Buchalski, 2008].

The algorithm of reasoning forward begins with placing a hypothesis on the task stack. Then, the system searches the list of facts in the knowledge base checking if there is an answer for the hypothesis formulated. If the fact which can be adjusted to the hypothesis is already in the knowledge base, the system ends the process of reasoning and generates a suitable message, which contains an order of actions to be carried out to eliminate the defect. In the case when after searching the base of facts the system is unable to give an answer to the hypothesis formulated, some steps are undertaken, which result in generating new facts. The rules whose premises are true are enabled. The system determines a set of rules which can be applied in a particular phase of reasoning. One of the rules is selected and activated. The process of reasoning is continued as long as the purpose is achieved or more rules cannot be activated [Buchalski, 2008, Mulawka, 1996].

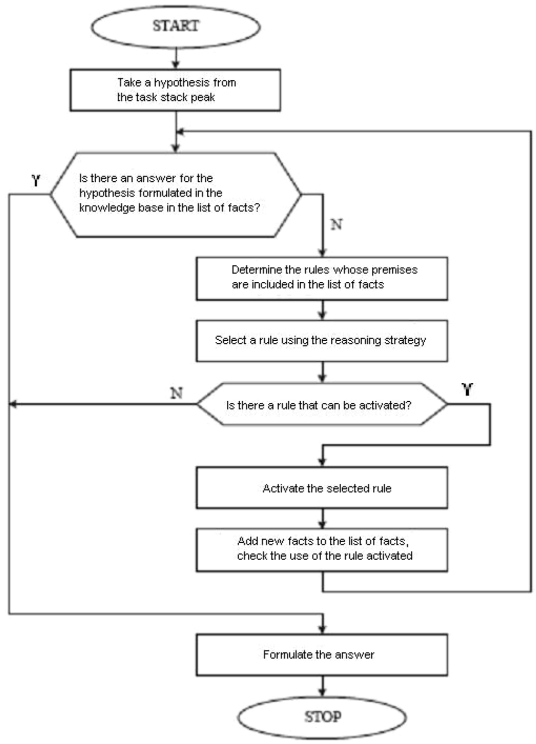

Figure 2. The algorithm of reasoning forward

The example of reasoning for a moulding process failure resulting in a critical defect - vertical cracks in the finish:

- Defect:

  vertical cracks in the finish
- Possible failure:

  kier mechanism
- Questions asked by the system:

  Is the time of the kier contact sufficient? (check in technical specification)

  Is the pressing pressure correct? (check in technical specification)

  Is there the cold kier within the area of the finish moulding? (check a position of the kier)

  Does the cooling pipe touch the internal finish edge? (check a position of the finish edge)
- The method of the defect elimination:

  Correct the kier mechanism - it is not set up correctly
- Additional information:

  Open vertical cracking which runs through the finish wall, from the sealing surface towards the neck. This defect can be detected by catching a reflection of strong source of light while turning a bottle. The defect should be removed immediately as the use of a bottle with the defect may cause a customer's injury.

The example of reasoning for failures occurring in the moulding part resulting in a critical defect – glass adhered:

- Defect:

  glass adhered

- Possible failure:

  takeout tongs

- Questions asked by the system:

  Is the design of takeout tongs suitable? (check in technical specification)

  Is the design of the side guide of sweep-off gear suitable? (check in technical specification)

  Do the takeout tongs slide out entirely on time? (check visually)

  Do the bottles contact each other on the pusher rail? (check visually)

- The method of the defect elimination:

  Replace inserts in takeout tongs - they are broken

- Additional information:

This is a piece of glass, usually a very sharp one, adhered to the external wall of a product. This is one of the most critical defects. All measures must be undertaken to avoid this defect. If because of any reasons we deal with such a defect, we cannot let such products reach the annealing furnace. We should also inform the Cold End section about a number of the mould which can cause problems so that they can prepare and reject faulty products. The defect should be removed immediately as the use of a bottle with the defect may cause a customer's injury.

The steps of reasoning presented above are a form of generalization of the procedure.

Conclusion

Computer systems are computer programs designed to solve specialized problems that require professional expertise. Application of expert systems allows to improve the quality of products, achieve substantial savings and increase productivity [Mulawka, 1996].

Using the Decision Support System by the Glassworks in the production process will enable to solve complex problems occurring within the production system faster and more effectively and to make necessary decisions in a much shorter time than now, which may be of a great importance for the innovation and improvement of their competitiveness.

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