DATABASE AND KNOWLEDGE BASE AS INTEGRAL PART OF THE INTELLIGENT DECISION SUPPORT SYSTEM, CREATED FOR MANUFACTURING COMPANIES

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Abstract: *The paper presents the structure of a database and a knowledge base which are the integral part of the Intelligent Decision Support System, being developed for a manufacturing company operating in the glass industry. Both modules will be used in the advisory system, whose functions will be classification of defects of products (here: glass packaging, e.g. bottles, jars) and selection of an appropriate (the most beneficial) method of elimination of defects arising in the manufacturing process.*

Keywords*: intelligent 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

In a manufacturing company making decisions in the scope of production preparation processes is a basic and key element of the whole manufacturing process.

It is essential for manufacturing companies to obtain information necessary to make an appropriate decision as soon as possible. They employ a lot of experts and specialists to react appropriately at every moment and to make suitable decisions. Decision-making processes are also supported by integrated computer systems, which continuously gather data and analyse different areas of the manufacturing process.

Decision support systems using artificial intelligence techniques are the systems which combine the potential for gathering and processing enormous amounts of data, using increasingly diversified models and intelligent utilizing data and knowledge gathered. The main purpose of development of an intelligent decision support system is to reflect experts' knowledge and experience, which are indispensable for solving problems by the system. Integration of intelligent methods allows to create better and more precise methods which can be applied in this field. In intelligent systems reasoning plays the most important role. The indicator of a system's "intelligence" is the ability to make decisions (through the reasoning process) and the ability to learn and acquire knowledge [Rojek, 2010].

Intelligent Decision Support Systems (IDSS) are the systems which have the potential for gathering and processing huge amounts of decision-making information, conducting analyses of the information and using diversified models, data and knowledge gathered to solve complex decision-making problems. The essential parts of an intelligent decision support system are a database and a knowledge base [Zieliński, 2000].

A database is one of the most important sources of decision-making information for a knowledge base in an IDSS. A database plays a basic role when developing a knowledge base in order to support the technological process, including the quality control process. The purpose of this paper is to present the issues concerning the development of these two component parts of the advisory system being developed.

Characteristics of the selected object of research.

The design of the intelligent decision support system, which is presented in this paper, is being realized for the Glassworks, a company operating in the sector of large companies. In total, the glassworks has 14 production lines, which work in a three-shift system; the capacity of one production line per one shift is 200,000 items of finished product. To illustrate it better – an automatic machine works with the speed of 275 drops (gobs of molten glass) per minute.

The concept to develop an intelligent decision support system arose after analysing the literature on the subject and numerous visits in the Glassworks. It was found that there was no algorithm to be applied in the case of discovering a defect of a product (here: glass packaging, e.g. bottles, jars) and for selection of an appropriate (the most beneficial) method of elimination of defects which occur during the production process.

The intelligent decision support system being designed should allow to classify product defects and to select an appropriate (the most beneficial) method for their elimination. The system being developed should support a line operator and a production line manager to a degree which is comparable with the support provided by a specialist (an expert) with high qualifications. Effects of the operation of the advisory system operation will allow operators and line managers to make appropriate decisions to eliminate production defects, and in consequence, to improve the technological process [Piróg-Mazur, 2010].

Before setting about working on the expert system being discussed initial assumptions and a method of the system development have been defined:

- the system should suggest solutions within the defined range – supporting a user in solving decision-making problems in the process of finished product quality control, i.e. classification of defects of products (bottles) as well as analysis and selection of an appropriate method of defect elimination, which will also allow to improve the technological process,
- the system should be user-friendly, a user is not required to be an expert in the field, the user interface will be based on questions and answers in the natural language,
- the system should provide texts, drawings and possibly simulations - databases in the form of text and graphic files, which contain additional or more complete information,
- the system can be developed in any programming language.

The technological process in the Glassworks precisely defines the process of converting a raw material (semi-finished product) into a finished product, which is compliant with requirements specified in a project. Development of technological processes is a very important phase of production preparation. However, its automation is very difficult due to large contribution of the experience of process engineers to the designing process. Traditional designing of technological processes is dominated by the activities which to a large degree are based on the experience, skills and intuition of a process engineer. Technological processes and their costs are dependent on a process engineer's experience.

When designing a technological process information from different sources is used. Technological processes are influenced by different kinds of information and limitations: information on a product, limitations related to technological capabilities of a manufacturing company and output, requirements concerning a product manufacturing, competences of a process engineer (professional experience, creativity), methods and resources used in technological planning and data gathered previously (technological databases and knowledge bases) [Rojek, 2010].

According to the definition, a technological process is a quantitatively and qualitatively structured set of actions that change physical properties (shape, size), the form or chemical properties of a specific substance (material). Technological process, together with support actions (transfer of material), constitutes a production process that results in a final product. The process of glass production comprises 9 main actions, connected with transforming raw materials and materials into ready products (for the purpose of an external recipient).

- Glass batch preparation – accurately weighed out and mixed raw materials constitute the so called batch. Glass cullet is a very important raw material. Even 80% of natural resources can be replaced with it.

- Melting – the batch is transported to the foundry furnace, namely the glass melting furnace and melts in the temperature of 1500*C. Such a high temperature is provided by gas fire burners, situated on both sides of the glass melting furnace. Molten glass is pushed by a new portion of batch.
- Forming process – a stream of molten glass is cut into sections – drops of glass (known as gobs) of a weight that corresponds to the weight of the container being formed. Gobs are transferred to forming machines. The compressed air shapes, in the initial phase, a glass bubble that falls into the moulds where it takes on its final shape.
- Hot refinement – bottles or jars are transferred to a tunnel-chamber where the compound of tin is sprayed. It penetrates the glass surface and results in higher mechanical resistance of wares and gives them shine.
- Tempering – Wares are moved slowly on a conveyor belt inside a tunnel-lehr and solidify under control. It protects bottles against future cracking.
- Cold refinement – cooled glass wares are subject to a process that makes them still more shining and flexible.
- Quality check and sorting – it is automatically checked whether wares have flaws. If yes, the machine immediately eliminates defective wares.
- Packaging an lamination – once the wares have bee checked, they are conveyed to an automatic machine – palletizes, which arranges them in layers on pallets and protects them with a heat-shrinkable film. Packed wares are transferred to warehouses.
- Storage and shipping – prepared to client's order wares wait in the warehouse to be shipped [Stowarzyszenie Opakowań Szklanych, 2010].

In the case of such an extended production process the probability of occurrence of defects is very high. Optimization of the technological process is essential for the company.

Characteristics of database

A database development process comes down to defining objects in individual objects/tables and their attributes.

When designing the database the following questions have been asked:

- what data are we interested in?
- what format will they have?
- how are they related to each other?

Large production lines, which consist of several dozen machines linked to each other, have measurement points. Currently, in the glassworks data from measurement points are collected by PIC - Production Information Computer. Controlling the software (setting parameters which should be checked: glass wall thickness, profiled body, bottle neck, bottom, setting sensitivity – permissible norm and ideal norm) is indispensable for maintaining desired parameter values on a constant level. These parameters are adjusted every time when a product range (a product) is being changed. Control and measurement apparatus adjusts sensitivity. Sensitivity to critical defects is set to 100%. The higher sensitivity (expressed numbers) the larger number of rejects.

PIC software provides the following information:

- summary of losses on a specific production line,
- summary of losses in the whole glassworks,
- summary of rejects on a measurement point (cold end),
- losses on a selected production line,

- losses on a selected production line (detailed report),
- rejects per specific defects (percentage value),
- rejects per specific defects (number of items),
- machine downtime report,
- summary of results on all production lines,
- switching to another production line.

Dynamic data are related to the defects being monitored - a number of defects in time intervals: in 10 min., in an hour, in one shift and in 24 hours. Table 1 contains real data from one production line. There are 5 measurement points (FP1, ..., FP5) situated along the line, which record quality and quantity of defect occurrences. The table presents numbers of defects, their abbreviated names, percentage values in individual measurement points (FP) and their totals.

Table 1 . Data extracted from measurement points one production line. Source:: System PIC

DETECTOR ID	FP1 %	FP2 %	FP3 %	FP4 %	FP5 %	TOTAL %
L1 SPEK.101	0.05	0.11	0.08	0.19	0.16	0.11
L2 SPEK.101	0.09	0.05	0.19	0.35	0.00	0.15
L3 SPEK.119	0.00	0.00	0.00	0.00	0.00	0.00
L4 PECH. W GL.	0.34	0.43	0.24	0.44	0.92	0.39
L5 SPEK.102	0.03	0.01	0.03	0.30	0.05	0.08
L6 SPEK.121	0.40	0.25	0.59	0.27	0.48	0.39
L7 NIEROWNLOGLY	0.83	0.56	0.38	0.34	0.98	0.56
L9 KRZYWY	0.26	0.20	0.44	0.37	0.59	0.33
L10 OOR-CMG	0.02	0.15	0.02	0.14	0.04	0.07
L11 SPEK.119	0.43	0.25	0.15	0.56	0.17	0.32
L12 SWA	0.57	0.48	0.43	0.40	0.58	0.48
L13 OOR-IPS	0.01	0.00	0.00	0.00	0.00	0.00
L14 SPEK.DNO	0.01	0.05	0.20	0.16	0.03	0.10
L16 FTA	1.81	1.98	1.72	1.94	1.71	1.85
L17 CID	0.45	0.52	0.36	0.36	0.67	0.44
L18 ROZDMUCHANA	0.00	0.00	0.01	0.00	0.00	0.00
L19 CIENKI GORA	0.09	0.14	0.08	0.03	0.27	0.10
L20 CIENKI DOL	1.26	0.89	0.95	0.57	0.82	0.93
L21 SSG1	0.00	0.00	0.00	0.00	0.00	0.00
L22 SSG2	0.00	0.00	0.00	0.00	0.00	0.00
L23 SSG3	0.00	0.00	0.00	0.00	0.00	0.00
L24 BHA	0.73	0.58	0.61	0.97	0.73	0.71
% REJECTED	6.22	5.58	5.42	5.86	6.84	5.82
INSPECTED	152638	144079	150891	115036	30026	592670

One of the first phases of the database designing process is development of a conceptual data model, which is of key importance for usefulness and quality of a database being designed. It is created independently of solutions characteristic for any logical models and database management systems. The conceptual model will allow to present the technological process described above in a formalized way. The main purpose of database conceptual modelling is to create a design which reflects the fragment of reality being analyzed, which is free of details that would locate it among models of a specific class (object, relational or others) and which is independent of a programming platform. The final effect of the conceptual designing process is a design containing three kinds of elements [Put, 2009]:

- facts, i.e. objects and events, which are to be stored in a database,
- attributes which describe individual facts,
- types of relationships between facts.

A design is typically presented graphically in a form of an entity-relationship diagram, which is supplemented with a detailed text description of information which it contains. In the diagram, facts are usually denoted with rectangles, attributes are denoted with ellipses and relationships between facts are denoted with lines linking rectangles and with symbols near lines which describe a type of relationship (Fig. 1).

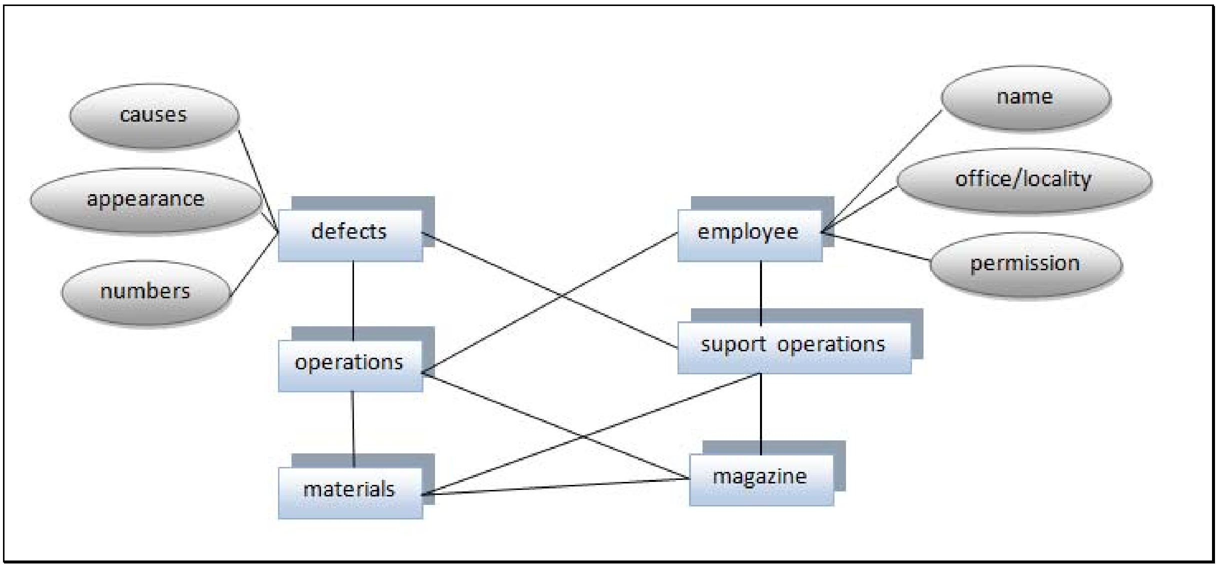

Fig. 1 Example of conceptual design - *graphic form (fragment/episode). Source: own work*

Selection of the relational model as a data storage method means that it is necessary to translate a universal conceptual design into a design in which data about facts is stored in tables, and attributes - according to the assumptions of the relational model – are atomic, which sometimes means the need to create additional tables and relationships between them. The logical design, presented in the form of a diagram, in the further phase of the process will be a basis for creation of a physical design and its implementation in a selected relational DBMS [Put, 2009].

Fig. 2 presents the relational database design developed on the basis of the conceptual design.

A database conceptual design, which is the final effect of the designing process participated by a future user, is the basis for creation of a logical design, which takes into account the specifics of a system in which the database will be implemented. The universal character of the conceptual model and its independence of the logical model allow to design databases not taking into account details of a particular model type.

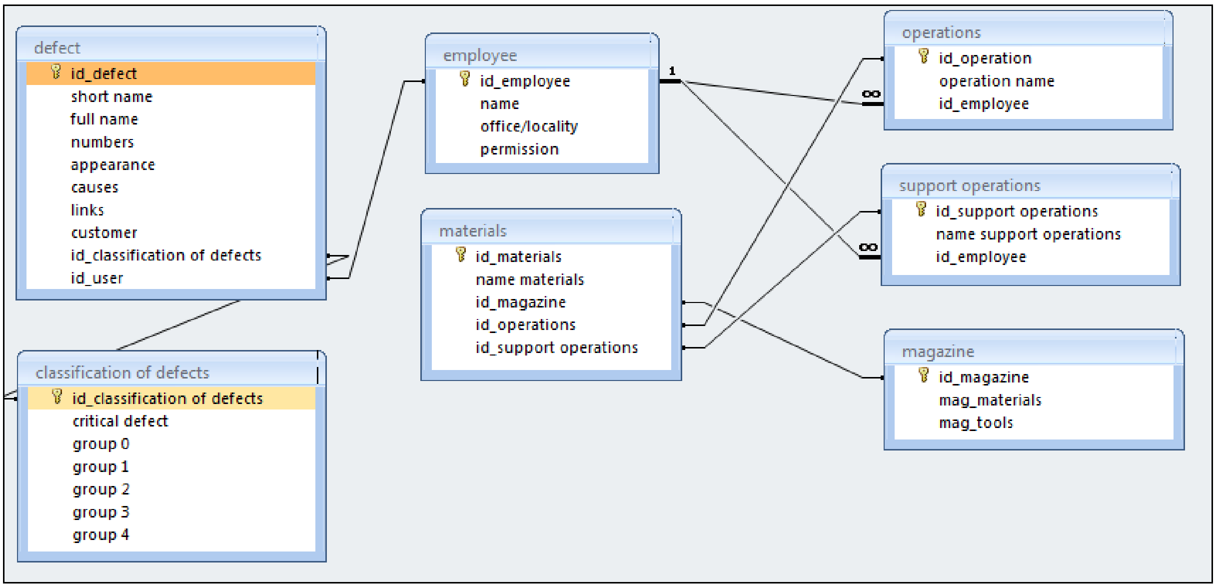

Fig. 2. Relationship database *Source: own work*

The following tables have been included in the relational database model:

- Products table - contains information on a product manufactured (product card, finished product specification),
- Materials table - contains information on materials (semi-finished products) used,
- Operations table - contains a list of operations carried out subsequently (technological operations),
- Auxiliary Operations table - contains a list of auxiliary operations to be carried out in the case of specific products (additional operations),
- Defects table - contains detailed information on individual defects.

The database contains vocabulary data and dynamic data and operates in real time. Vocabulary data concerns subject-matter objects and it changes much slower; however, it is also updated if objects are changed. As far as dynamic data is concerned, the database is archived periodically due to fast growth of data and a huge number of records. Dynamic data is related to gathering measurements from measurement points (FP), which read instantaneous measurements. This data will be used in the knowledge acquisition system as teaching files. The database structure is still being developed.

In the current phase, the largest collection of data is data containing classification of defects and complementary data containing a list of defects, defect descriptions, photos, reasons for occurrence of defects and methods of their elimination.

Measurement data indicates correlations between defects. A few correlations between defects are presented below:

- If the defect "melted bottom" occurs, the defect "deformed bottle lip" in a similar quantity can also be expected; in this case there is a lack of glass needed to form a bottle lip,
- uneven bottle – uneven bottle lip,
- thin bottom – thin glass walls – thin product.

Defects which are classified as critical are defects which may cause hazardous conditions for a product user (every defect which may result in glass inside a bottle). Products with such defects should not get into the annealing furnace. If they get into the annealing furnace, this fact should be reported to the cold end and these products should be rejected before they reach the end of the annealing furnace. It should be remembered that any of these defects may cause injury to a customer or a consumer.

Technological knowledge base in a company

Technological knowledge plays a very important role in a manufacturing company. Systems supporting the design of technological processes, currently being developed, allow to make different methods of data presentation available, transform and exchange data.

Knowledge acquisition is a process of defining knowledge, on the basis of which an expert system will provide answers in the form of an expertise. Defining knowledge consists in acquiring knowledge from an expert in a form which allows formalizing it. An expert in a given field is responsible for the content of knowledge, whereas a knowledge engineer is responsible for its form.

Technological knowledge is a collection of information on a technological process realized in specific conditions of a given enterprise. The contribution of an expert and a knowledge engineer are described in the reference titles [Rojek, 2007]. Technological knowledge is a dynamic collection, i.e. it changes in time along with changes of a technological process. Additionally, it is assumed that technological knowledge may be processed in the way specific to the phases of an advisory system development. The following phases of the process are distinguished:

- acquisition of technological knowledge,
- development of technological knowledge representation models,
- recording knowledge in a system's technological knowledge base.

A knowledge engineer uses the following information for assessment of knowledge sources:

- information necessary to carry out work (materials from non-serial and serial publications),
- information concerning all processes realised in the production system (materials collected in the Glassworks, consultations with the plant manager of O-I Produkcja Polska, consultations with specialists having expertise knowledge on different phases of the technological process - an expert's knowledge),
- methods of finished product quality assessment (ideal norm and permissible norm),
- possible variants of modernisation (purchase of new machines, modernisation of existing machines, new technologies, new materials etc.),
- criteria for assessment of variants of the system development.

As a result of a dialogue, on the basis of data entered by a user and data from measurement points the expert system will perform a process consisting of:

- recognition of a defect of a product (here: bottles) and its classification into one of the groups (e.g. Group 0 - critical defect - leaky bottle lip, overblown bottle lip/collar, scratches in a bottle lip/collar),
- recognition of the cause of a defect (a mechanical defect, a defect of a form etc.),
- determining ways or methods of elimination of a defect,
- selection of an optimal solution out of previously determined methods.

On the basis of the process presented above the system suggests a method of elimination of product defects occurring on the production line.

Artificial intelligence package SPHINX by AITECH will be used for development of the intelligent decision support system. The following software tools will be used for the implementation of the system: PC-Shell – expert system shell – for development of basic modules of the system, CAKE – for presentation of knowledge elements and explanation how they are used and DeTreex – to acquire knowledge, decision-making rules from the database.

PC-Shell shell system is a hybrid system with the blackboard architecture, so it may use different sources of knowledge for solving problems. PC-Shell 4.5 supports the following sources of knowledge: expert knowledge bases, applications based on neural networks and databases with text explanations.

A knowledge base in the PC-Shell system is divided into five blocks: the block of knowledge sources description, blocks of facets, rules, facts description and the block of control. A knowledge base in PC-Shell may contain the following elements:

- descriptions, or in other words, facts, which are indicative sentences. A fact may be represented in the form of a relationship between certain objects and have different features (attributes),
- rules, which are indispensable for solving a problem in a given field,
- relationships,
- procedures.

The general format of description of rules in PC-Shell is presented below:

[number_of_rule :]   conclusion1 if

condition_1 & condition_2 &...& condition_n.

Example:

[Rule No.1:] <misadjustment of plunger and guide ring> if
<uncentred plunger cylinder>&<plunger cylinder is not aligned with invert>
& <too low plunger cylinder> & <glass reaches plunger>

All rules are numbered and express logical associations between elements of knowledge in a given field or they contain a description of certain actions. Facts, expressed in the form of indicative sentences, represent elements of knowledge and they are treated as statements or conclusions. There are clear semantic associations between rules and facts [Piróg-Mazur, 2011, Buchalski, 2005].

Conclusion

Manufacturing companies currently operating in the market collect more and more data on production processes, delivery processes, customers and their requirements, products' susceptibility to failure and control processes. The decision-making process is a process consisting in processing information. Classical methods of acquiring and analyzing information often fail, and additionally, they often refer to legacy data.

The paper presents the characteristics of the selected object of research, the conceptual data model, formalization of knowledge and the information collected during visits in the manufacturing company for which the intelligent decision support system is being developed.

The need for development of an intelligent decision support system arose from the practice and numerous meetings with a production line manager. It was realized that there was a lack of algorithms of action in the case of finding a defect of a product (here: glass packaging, e.g. bottles, jars) and for selection of an appropriate (the most beneficial) method of elimination of defects.

The system being designed, which is based on integration of selected tools of artificial intelligence and a knowledge base will allow to solve complex problems occurring in the production system faster and more effectively, using experience and intuition of a manager as an expert [Piróg-Mazur, 2011].

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