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Module to Generate Rules for the Knowledge Base in a CAPCAST Expert System

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Abstract

The study presented here is related with one of the components of a hybrid decision support system called CAPCAST (Computer Aided Process - CAST), developed under a research project at the Faculty of Metals Engineering and Industrial Computer Science, AGH University of Science and Technology. This is a module for rule generation to serve the knowledge base operating in an expert system. The scope of the system operation involves the selection of technological parameters for the manufacture of machine parts from ductile iron. However, it can be extended to include other materials and technologies.

Keywords: Expert Systems, Knowledge Base, ADI

1. Introduction

Choosing the right materials in the design of machine elements requires a broad knowledge of technology, backed by scientific research, experience and capability of processing large amounts of information. Therefore, with the development of scientific and technological knowledge in such fields as metallurgy, foundry, and materials engineering, where the main aim is to raise the technical level and efficiency of the production of machinery, vehicles, tools and mechanical equipment, it is important to develop information systems to support production processes. The last decade has seen a growing interest of designers and manufacturers of machinery in systems for decision support in the selection of optimal (for a particular task) materials and technology. This refers to systems of the third and fourth generation, capable of automatic processing of knowledge made available to them in the form of certain representations. The most commonly used is the rule-based knowledge representation, saved and stored in the Rule-Based Knowledge Bases (RBKB). Each rule in a given area of the knowledge base is a true (proven) statement, built on a model of the implication, in which the conclusion is a simple (atomic) sentence. The quality and effectiveness of decision support systems, and of other systems based on knowledge, are strictly dependent on the quality of the knowledge base used by the system. This study presents an own solution to the problem of creating a knowledge base for the hybrid CAPCAST system (Computer Aided Process - CAST), developed as part of a research project executed at the Faculty of Metals Engineering and Industrial Computer Science, AGH University of Science and Technology, the essence of which consists in incorporating (into the system) a module for rule generation which will partially automate the creation and validation of the knowledge base.

2. Characteristics of the CAPCAST system

One of the main tasks of the system is to support decisions on the selection of technological parameters for the process of manufacturing various machine parts. Figure 1 shows a schematic diagram of the system with well visible details of its basic components. These are the following components: a database of material characteristics, a database of producer characteristics, a knowledge base, a programme for simulation of the cast iron heat treatment process, an interface, and other.

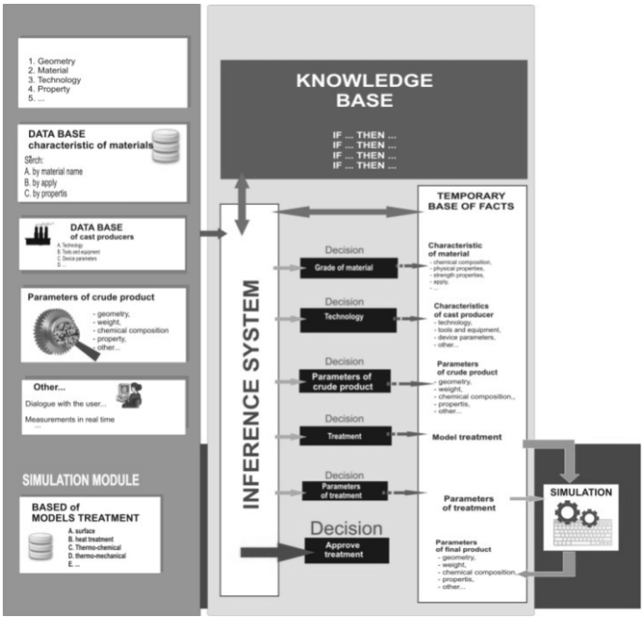

Fig. 1. General schema of the CAPCAST system

In the knowledge base of the designed system are set out rules for the process of manufacturing machine parts from ductile iron. The knowledge should be useful for designers of machine parts, and therefore it is focused on the task of isolating these specific product attributes that will have a decisive impact on future performance of the product. The proposed system architecture is open and can be expanded to numerous other materials.
Previous publications have described how to automatically generate rules using, e.g. the decision tables [1]. The developed CAPCAST expert system is also equipped with a module for "semi-automatic" generation of rules. Using appropriate tools, this module has the ability to export the developed rules to the knowledge base system.

3. Module to generate rules for the knowledge base system

A module to generate rules for the knowledge base of an expert system is a tool to assist the knowledge engineer in his task of completing the knowledge base with new rules. The defined rules (for both the premises and conclusions) may include pre-defined attributes (e.g. retrieved from a database of material characteristics, or from other databases), but there is also the possibility to define new variables that the user only intends to introduce. The, developed for this module and presented in this paper, user interface enables building in a simple manner a knowledge base, not requiring from the engineer any knowledge of the syntax of the programming language used.

3.1. Architecture of a module to generate rules

A module to generate rules for the knowledge base in a CAPCAST expert system is a web application, in which three layers can be distinguished:

- *database* + MySQL server is used to store the components of the rules, i.e. the constants, variables and relationships existing between them. Each record in the database is an individual ascertained case. The base can be filled with specific facts regardless of the system. Data recording in the form of a relational database enables automatisation of the process of creating rules that describe relationships between the individual database components,
- *application logic* - for the correct operation of the presented system (read and write, and rules validation) is responsible the PHP programming language used. To accelerate the operation of the application, part of the logic has been embedded in the user interface layer,
- *user interface* - the use of modern web technologies such as HTML5, CSS3 and JavaScript allows us to define rules in a user-friendly manner. The concept adopted here for the creation of rules is mainly based on the "drag & drop" mechanism.

  Figure 2 shows the architecture of the, discussed here, module to generate rules for the knowledge base, indicating its components on the client side and server side.

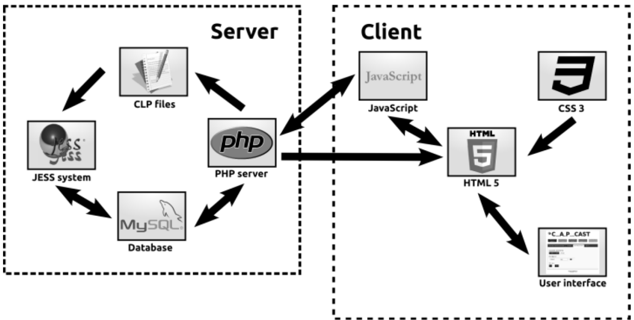

Fig. 2. Architecture of the rule generating module

3.2. Description of the process of technological knowledge transfer to a knowledge base system

The successive steps in the transfer process of the formalised technological knowledge (substantive, that is, useful in the design of machine components), i.e. the construction of rules with the possibility of carrying out reasoning on them, are presented in Figure 3.

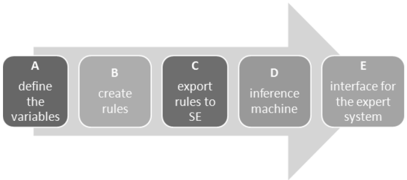

Fig. 3. The successive steps in a module generating rules for the knowledge base in an expert system

3.2.1. Defining the variables

The first step in the preparation of the knowledge that we want to transfer to the system consists in defining the basic variables, which will play an important role in the process of inference. Usually these are the parameters describing the process of producing a given item and its heat treatment, i.e. the parameters that affect the final properties of the material. Figure 4 shows a schematic decomposition of the attributes and data acquisition for the CAPCAST knowledge base system.

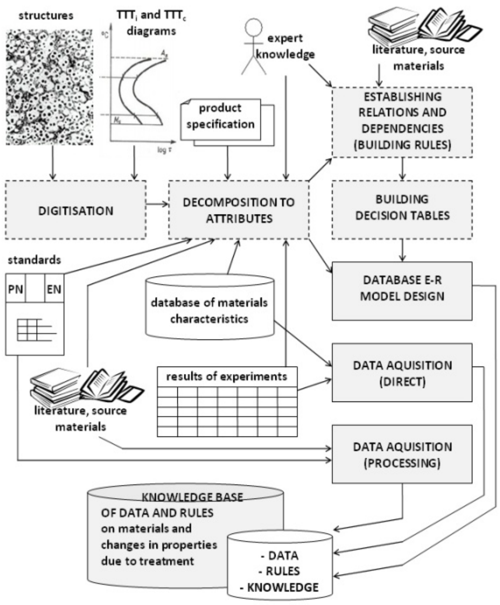

Fig. 4. Scheme of the decomposition of attributes and data acquisition for the CAPCAST knowledge base system

Defining a variable consists in defining:
◦ its name (e.g. temperature of charge),
◦ its type (BOOL, INT, FLOAT, ENUM),
◦ intervals for the occurrence of INT and FLOAT,
◦ a list of options for ENUM.

For example, for a variable called *structure*-component, the possibility was created to give definitions of the enumeration type *enum* and additions to the list of possible options, such as ferrite, austenite, etc. as shown in Figure 5. On the other hand, Figure 6 shows the interface window which enables defining the variables that occur in the knowledge base system.

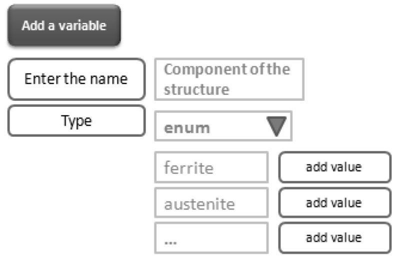

Fig. 5. Scheme to add a variable (parameter)

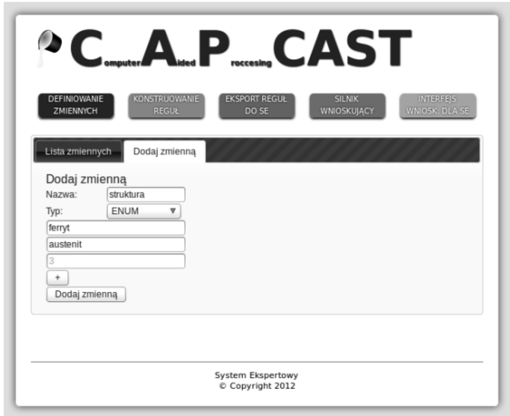

Fig. 6. Screenshot of the interface – defining a new variable

3.2.2. Construction of rules

The variables (process parameters) defined in the first stage are the basic components of rules containing knowledge about the linkages between different variables with the ranges of acceptable values, e.g. *if the tempering temperature* $<T_0$ *and the cooling medium = water then hardness =>* H_1 The user selects in the rule-generating module the available (previously defined) parameters of the process and by their application creates rules representing his own knowledge of the cause-and-effect relationships that exist between the parameters with certain predetermined values. The described module offers the possibility to generate direct rules (which in their conclusion have the parameter directly determining the value of a property) and the intermediate rules resulting from the following relationships: *Properties = f(microstructure); Microstructure = f(parameters of heat treatment); ParametersHT = f (MATERIAL parameters), etc.*

Figure 7 shows the scheme to create rules using the interface developed for this purpose, a dialogue box of which is shown in Figure 8.

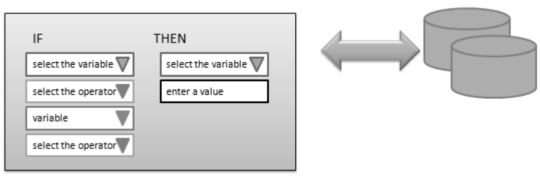

Fig. 7. Scheme for inference rule creation

The following steps were distinguished in the rule-defining procedure:

- selection of process parameter,
- selection of relational operator (>, ≤, ≥, <, =),
- determining the numerical value for relationship,
- possibly adding a composition for relationship,
- choice of the logical operator (¬, ∧, ∨) to build complex statements (logical expressions),
- possibly adding another composition,
- selecting a resultant variable. On the right side of the rule, that is, after the word THEN, there should be a conclusion (one only !). The conclusion should be an atomic formula, and therefore here in the choice of operators, relational operators (> <=, etc.) will be available and one logical operator¬, or possibly only conjunction / ∧ . / will be allowed. The conclusion may be, for example, a reference to another parameter in the process and giving its value (numerical or verbal).

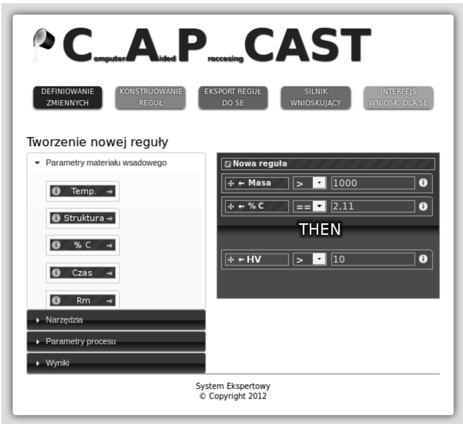

Fig. 8. Screenshot of the interface – defining a new rule

After saving the rule, it is subjected to a process of validation - initially at the level of the user interface to eliminate spelling mistakes (e.g. the text in the float, the lack of definition of the relationship). The second stage of validation is to verify the data integrity on the PHP server-side and re-validation of data (using the principle of limited trust in the user). The final stage of validation is to verify the logic of defined rules in terms of an expert system (e.g. too wide ranges, mutually exclusive rules). After this three-stage consecutive checking of the data, the rule is moved to a database and can be used in the task of defining new rules and in processes simulated by the system.

3.2.3. Export of rules to an expert system and starting the inference engine

Database - MySQL server is used to store the parameters of component rules and user-defined rules. To use them in the process of inference, the next step consists in exporting them to a text file, i.e. automatic generation of rules for the inference engine. As an inference engine, the JESS language has been selected (The Rule Engine for the Java Platform) and open source environment for the creation of expert systems with built-in forward and backward inference mechanisms, as illustrated in Figure 9.

Fig. 9. Schematic representation of the export process of rules from the database to a JESS inference engine

The subsequent rules are activated when the premises of these rules are true and are included in the database of facts. The result of the rule activation is a conclusion added to the database of facts. The conclusion from one rule may serve as a premise for another rule, and this is an indirect inference. The conclusion which answers the question posed is the final conclusion.

4. Summary

Creating a decision support system is a complex process. Analysing it in terms of the tasks it involves, groups of problems were isolated whose correct and efficient solution depends on the competences assigned to various, quite different, fields of knowledge. For example, the development of system architecture and its components requires programming skills (Figures 1 and 2), while providing a valid decomposition of attributes and data acquisition to knowledge base need an expert knowledge (scientific and technological) in the area in which the system is expected to operate (Figure 4). In the present study, attention has been focused on the execution of a task that requires both the basic knowledge of engineering materials and the skill in effective use of appropriately selected information resources and tools. An interface was created to speed up the construction of a rule-based knowledge base for the CAPCAST system, which is sufficiently versatile to be used in construction of knowledge bases with similar structures operating in other systems for processing of the knowledge comprised in different disciplines.

Acknowledgements

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