Verification and Validation of Railway Control Systems Using an Expert System

Waldemar Nowakowski, Piotr Bojarczak(✉), and Zbigniew Łukasik

Faculty of Transport and Electrical Engineering,
Kazimierz Pulaski University of Technology and Humanities in Radom,
Malczewskiego 29, 26-600 Radom, Poland
{w.nowakowski,p.bojarczak,z.lukasik}@uthrad.pl

Abstract. A basic requirement which needs to be fulfilled by railway traffic control systems is to ensure a high level of safety. That is why, CENELEC (*European Committee for Electrotechnical Standardization*) norms include RAMS (*Reliability, Availability, Maintainability, Safety*) requirements for these systems. The process of designing, building and approving for exploitation the railway traffic control systems is finished with the assessment of correctness of each of the stages. Verification and validation of a railway traffic control system is a complicated process which requires a necessary experience by the people participating in this process. That is why it is rational to use a custom software, called the expert system. The authors of this article, on the basis of the Exsys Corvid environment, have built an expert system for the verification and validation of level crossing protection systems. The conducted research has proven both a great usefulness of this technology and, at the same time, the need to broaden the research on other kinds of railway traffic control systems.

Keywords: Railway traffic control systems · Verification · Validation
Expert system

1 Introduction

Railway traffic control systems are safety-related systems, thus it is necessary for them to ensure a high level of reliability and safety [1, 2]. Approving these systems for exploitation is related with running a verification and validation process, meaning both checking system conformity with project specification, and controlling customer satisfaction. A complicated procedure to assess system correctness is an activity in accordance with the verification and validation plan, thereby it is a repeatable action [3]. The authors of this article have proposed using an expert system in the evaluation of the railway traffic systems conformity. Expert systems belong to the most popular artificial intelligence tools which have practical applications [4–8]. The main advantage of these systems is that possessing expert knowledge in a chosen field they allow solving particular tasks without the later presence of the expert. What is more, one can aggregate knowledge of many specialists in such a system. Because the expert systems are tools ideal for automation of repeatable decisions, problems and tasks, the authors have conducted a research concerning the possibility to use the expert system in the

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verification and validation process of an example railway traffic control system, which is a level crossing protection system.

2 Expert Systems

The name ‘expert system’ comes from the word ‘expert’, signifying a person having qualified expertise in a given area and knowing how to use it to solve problems from this area.

Basic elements of an expert system are [9]:

- the knowledge base which contains knowledge necessary to solve a specific problem,
- the reasoning engine which determines facts resulting from the knowledge base and initial information,
- the user interface which allows querying,
- the knowledge base editor which allows modifying knowledge included in the system, allowing, at the same time, its expansion,
- the explanation subsystem which is a working memory, storing some facts introduced during a dialogue with the user.

The key element of an expert system is its knowledge base (Fig. 1). The most popular way of representing knowledge used in expert systems is representing knowledge with the help of rules [10]. A rule is a logic function whose arguments are conditions, and its value is a conclusion:

conclusion **IF** *list of conditions*

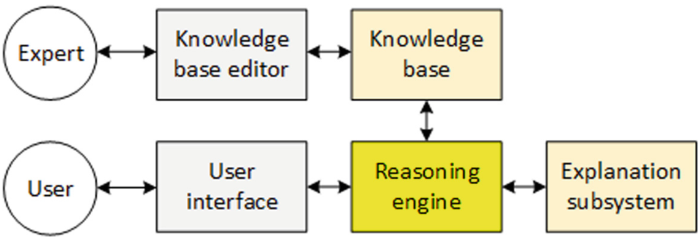

Fig. 1. Diagram of an expert system architecture [own study]

That is why a rule can be divided into two parts: conclusion and the condition part, where there can be an unlimited number of conditions but only one conclusion. Knowledge representation with the help of rules, regardless of its apparent simplicity, allows describing many complicated practical issues. Using such a way of knowledge representation allows gaining modularity of the knowledge base, facilitate its expansion, and to present qualified expertise in an intuitive way - clear, transparent and easy to verify. It is very important when building, updating and using the knowledge base, where domain experts usually are not system expert specialists. In such case, it is easier for them to define this knowledge and verify it. A very important trait of knowledge representation with the help of rules is a possibility to nest rules, which means using a conclusion of one rule as an argument of another. The possibility to nest rules allows for more clear and transparent expression of the expert knowledge.

As it has already been mentioned, an expert system, apart from the knowledge base, consists also of the reasoning mechanism. Basically, one can distinguish three basic kinds of reasoning [11]:

– forward chaining,
– backward chaining,
– mixed reasoning.

Forward chaining takes place when new facts are generated on the basis of available rules and facts, at the end it is possible to estimate those aspects of a problem the conditions allow to. Backward chaining consists in an opposite way of reasoning, meaning that knowing the target status one must define which conditions determine this status. On the basis of the premises, main hypothesis is proved. In case of the mixed reasoning the two, mentioned above, algorithms are used. It is thanks to metarules which contain indications regarding the choice of the reasoning type.

Practical realization of an expert system can be performed basing on:

– dedicated for this purpose programming languages Prolog or Lisp,
– available commercial packages allowing implementation of expert systems without the knowledge of the programming languages.

The authors have decided to use a commercial Exsys Corvid package. It allows saving executable code for a system in the HTML format. Thanks to this fact, it can be run on a random mobile device with an Internet browser installed.

3 Exsys Corvid

Exsys Corvid is an expert system shell containing all expert system elements, with an unfilled knowledge base. This software serves for a fast creation of expert systems on web pages [12]. Exsys Corvid uses defined by the user variables, logic blocks or action blocks and command blocks. Variables are the fundament of each expert system created in the Exsys Corvid environment. That is why, before starting building a system one has to plan the system functionality and resulting from this variables which will serve for creating rules. This software includes the following type of data [13]:

– *Static List* - a choice list which values are already known during creating an expert system,
– *Dynamic List* - a choice list in which values are defined during the system operation,
– *Numeric* - numerical value which can be used in formulas or conditional expressions,
– *String* - variable that will be assigned a value that is a text string,
– *Date* - variable that assigns a value that is a date,
– *Collection/Report* - the value is a list (collection) of text strings,
– *Confidence* - a variable to which a certainty level can be assigned.

Reasoning in the Exsys Corvid environment, similarly to other expert systems, is based on IF/THEN types of rules, organized in logic blocks. These rules describe respective steps which the expert needs to take into account when making a decision. As a result of such actions, the decision made is a combination of many, very complicated rules. It is illustrated by making decisions in real life. There are no defined rules of building logic blocks in the Exsys Corvid environment, this allows experts to develop any expert system building strategy. A logic block can be a single rule, but also a complicated decision tree. The whole system can have one or many logic blocks. It is assumed that the single logic block should contain all rules concerning a specific problem or a decision made. It allows for a better understanding of the logic in it. Managing variables and logic blocks is accomplished in the command block. Command blocks are responsible for, among others, initiating variables, calling logic blocks and resetting results. Thus Exsys Corvid needs to contain at least one command block [14].

4 Expert System for LCPS

Level Crossing Protections Systems (LCPS) serve for protecting roads for motor vehicles from dangers connected with railway traffic [15]. Thus they play an important role in ensuring safety, thereby approving these systems for exploitation requires running a detailed quality research [16]. An example verification and validation procedure of the B class level crossings where it comes to functionality control consists of the following stages:

- system reaction control for the occurrence of various operating conditions,
- system reaction control for disabling wheel sensors,
- checking system reaction correctness in case of a failure of activation points,
- checking system reaction correctness in case of a failure of deactivation points,
- checking system reaction correctness in case of a failure of road signals,
- operation correctness control of barriers,
- operation correctness control of warning shields,
- system reaction test for the occurrence of transmission errors,
- system reaction test for the occurrence of incorrect situations.

Because the authors' experimental research is in the preliminary stage, it includes only a chosen range of the control procedure, which is system reaction control for the occurrence of various operating conditions. The procedure consists of 113 control points for which decision rules in the Exsys Corvid expert system were developed. Building the expert system consisted in defining supporting variables (static list type), and variables in which there will be results of the action rules stored (confidence type). Next, for each of the control stages separate decision rules were created (Fig. 2).

The last stage of building an expert system for the LCPS was defining command blocks. Each of the control stages of the LCPS is connected to a separate command block. Actions accomplished in the command block consist in resetting variables, calling rules connected with a given control stage, and then checking reaction of the person performing the verification and validation procedure of the LCPS (Fig. 3).

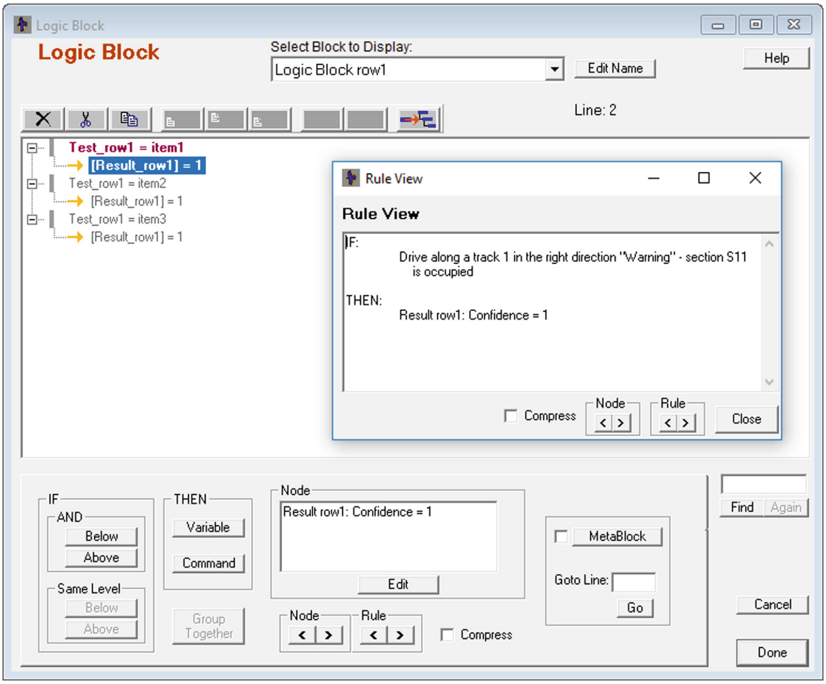

Fig. 2. Logic Block window with sample rules [own study]

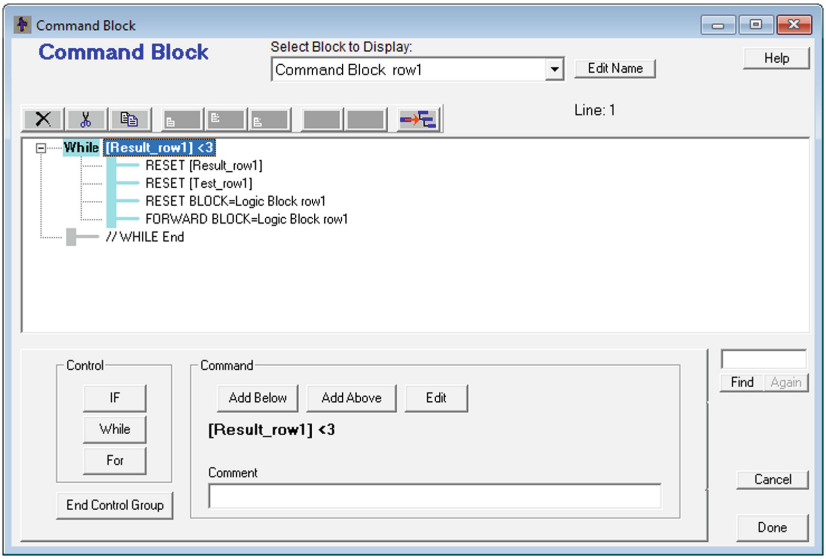

Fig. 3. Sample Command Block window [own study]

The person performing the LCPS control should conduct activities indicated by the expert system and then confirm their accomplishment. The operation of the expert system supporting the verification and validation process of the LCPS has been presented in the Fig. 4.

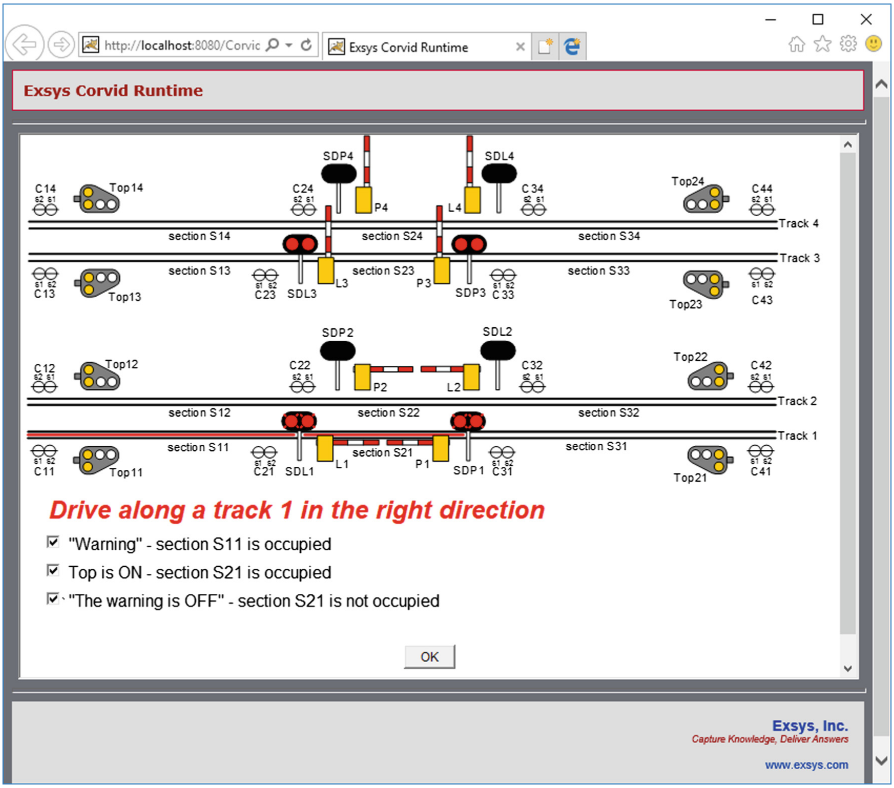

Fig. 4. Sample expert system question screen used in LCPS evaluation process [own study]

5 Conclusion

Changes in the railway industry are stimulated by many factors, e.g. increasing quality and technical requirements for the railway infrastructure, as well as by law regulations. A problem which is especially important is to ensure a high level of railway traffic safety. Realization of this goal can be accomplished by, among others, building reliable and safe railway traffic control systems. That is why the process of approving these systems for exploitation requires their verification and validation according to the established control plan. Because this activity is performed by people with considerable work experience and necessary competence, the authors of this article have proposed using an expert system as a tool supporting the assessment of system conformity of a railway traffic control system. The experimental research, conducted for a chosen system type, which is a level crossing protection system, has proved a great usefulness of this technology. That is why the authors of the paper are planning to develop the expert system through, e.g. taking into consideration other types of railway traffic control systems. It should both smoothen the process of correct operation of railway automation systems verification, and ensure the process's effectiveness and reliability.

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