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An Educational Knowledge-Based System For Civil Engineering Students In Cement Concrete Construction Problems

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Abstract

Civil engineering students study only few courses in highway engineering that involves only little information about pavement construction. After their graduation, they face many problems in construction site that they cannot control as they do not have sufficient information. Therefore, developing of an educational system in this domain that contains a knowledge base including descriptions, causes and solutions to these problems is an effective way to help civil engineering students learn about the problems that they may encounter. This paper describes the development and evaluation stages of unprecedented system including knowledge acquisition, knowledge representation, system building, and system testing.

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Keywords: Educational system; Knowledge-based; construction problems; pavement; cuases; solutions, system evelauation;

1. Introduction

Civil engineering students study only few courses in highway engineering. These courses involve only little information about asphalt pavement construction as the highway engineering includes many domains that cannot be covered in details during the study years depending on the traditional education way. After their graduation, they face many problems in the site of construction that they cannot control as they do not have sufficient information. Therefore, developing of an educational knowledge based system in this domain that contains a knowledge base including descriptions, causes, preventive actions, solutions to these problems and probable

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effects if these problems are not controlled is a very effective way to help civil engineering students and novice engineers learn about the problems that they may encounter.

When a cement concrete pavement is being constructed, numerous problems arise that civil engineers have to solve. Such problems can hinder the work and affect the overall quality of the construction. These problems can range from mildly troublesome to financially disastrous. Therefore, to ensure that a pavement is properly constructed, these problems must be solved immediately. Based on an expert's tacit knowledge, these problems can be easily treated [1]. On the other hand, the lack of experience makes novice engineers unable to prevent such problems from happening or even provide effective solutions. In the field of construction, the transfer of expertise is a difficult task [2]. Consequently, a system where experts are able to transfer their experiences to the novice engineers and civil engineering students is required. Without such a system as a method of expertise transfer, novice engineers are likely to repeat the mistakes of expert engineers that they spent a lot of time to dominate [2]. By recording, categorizing and computerizing the problems faced by experienced engineers, civil engineering students will be able to learn about the domain problems.

By utilizing tacit knowledge from various experts [3,4]), an intelligent system can solve problems that range from site assessment to engineering consultation [5]. The use of intelligent systems to solve complex problems, that require expertise, is now commonplace and many systems were created in miscellaneous domains [6]. Few systems have even been created in pavement industry. The RC-MMS is an example of such a system [7]. It is a prototype system that assists pavement designers in selection of the most economical materials. Deprizon, Amiruddin, and Atiq created a knowledge-based expert system that assists the designers in structural designs for asphalt pavement layers [8]. Syamsunur et al created an expert system to optimize the selection of the routes during road geometric designs stage [9]. Ismail et al implemented an extensive literature review in the area of pavement management and categorized the systems included in this area [10,11]. However, the review proved that no system was created in the area of pavement construction. Mosa et al created a knowledge-based system, based on written knowledge, to treat the problems arising at the construction sites of concrete pavements [12] [13]. Although all these systems were suitable to be employed as educational systems but the developers did not recommend using them as educational systems because these systems did not tested in an educational environment. On the other hand, the system developed in this study was evaluated in educational environment. The evaluation process was represented by testing the system by civil engineering students and teachers. The evaluation result proves the validity of the system as an educational system which makes it novel system in pavement industry. The other systems can be evaluated in same way to check their validity to be used as educational systems. Proper changes may be required to modify these systems according to the recommendations of the users.

The present study aims to build a knowledge-based educational system for civil engineering students and trainee civil engineers in cement concrete pavement construction projects to solve the probable problems. Such a system assists them to learn how to control these problems as they appear. This paper describes the development and evaluation stages of unprecedented system including knowledge acquisition, knowledge representation, system building, and system verification and validation. The initial knowledge is acquired by literature review. Then, expert knowledge is elicited through interviews and questionnaires. This knowledge is documented, analyzed, represented, and converted to computer software using the Visual Basic programming language. The system was verified and validated by extensive testing including unit testing, integration testing, and user satisfaction testing which performed by questionnaires. The system developed here provides expert knowledge about controlling ways for construction problems in cement concrete pavements using simple and flexible interface to simplify the training process for the users. The proposed system can be used repeatedly by the civil engineering students and novice engineers in learning process of the study domain.

2. Knowledge Elicitation And Categorization

In the building of an intelligent system, knowledge elicitation can be considered as a fundamental stage [14]. A knowledge-based system requires detailed analytical approaches [15], a process that is not only complex but time-consuming as well [3,16,17]. Knowledge acquisition represents the collection of knowledge from miscellaneous sources [18]. Books, manuals, guides and other written sources relating to the problem domain are usually reviewed first to prepare an initial knowledge engineering methodology. More knowledge, however, can be obtained from domain experts. The obtained knowledge can then be later combined and studied repeatedly if necessary [19].

In the current study, groundwork knowledge was obtained from comprehensive review of sources to understand the construction of a cement concrete pavement and the problems that are faced at different stages of its construction. This knowledge, which was analyzed and improved repeatedly, served as the foundation for the final knowledge base. The review covers the construction operation and related problems details including the descriptions, causes, solutions of various problems, and the probable effects of problems if they are not treated.

After preparing the groundwork knowledge base, the knowledge of domain experts was acquired by interviews and questionnaires. The experts gain knowledge related to their domain though their experience and education. Selecting the correct domain experts is an important process. Setting a criterion for selecting domain experts will guarantee the elicitation of the required expert knowledge. Two major criteria can be implemented for selecting domain experts. The first factor in the selection process is the work period in the specific domain as long experience greatly increases and improves an expert's analytical behaviour and judgment. The second factor is the ways that the expert gained the expertise (theoretical way, practical way, or both) [20]. Based on these two factors, a group of four experts was chosen for this study, for their expertise. These individuals possess extensive experience related to cement concrete pavements construction. They are renowned in this domain.

Throughout knowledge elicitation, the knowledge engineer can specify how the expert makes decisions. This can be done through qualitative research methods such as conducting interviews [16] or by watching the experts during their work to define implicit knowledge [15,16]. The proper method can be selected based on area of the study, amount of knowledge necessary, and effort limited to analyze the collected information. Regardless of what method used in knowledge elicitation, the knowledge engineer ensures to transfer the knowledge to the user (the student or trainee engineer) in simplest way.

The human expertise used in this study was acquired from the domain experts by unstructured interviews, structured interviews, questionnaires and focus interviews. Unstructured interviews were conducted for two primary reasons. The first was to build a comfortable relationship with the experts; a process that made expertise elicitation an easier task. The second was to obtain better understanding of the practical experiences of the experts related to domain problems they had faced. In the unstructured interviews, a few problems were discussed briefly while others were discussed in detail. The experts contributed and explained some of their practical experiences, the problems they faced with cement concrete pavement construction, and how they dealt with them. Though only a few brief questions were asked to each expert, the answers they gave were comprehensive. Upon the completion of each unstructured interview, the data collected was studied and then categorized. After updating the collected data, the questions that were to be used in the structured interviews were prepared. This process was a prerequisite step for expertise elicitation. To acquire accurate results from each structured interview, a particular aspect of the domain was focused on. Since these experts do not record their experiences, the amount of primary knowledge collected from expertise elicitation was substantially more than the amount of secondary knowledge obtained from the literatures.

The knowledge was, then, included in questionnaire forms which were submitted to three experts. The process of knowledge elicitation was simplified through the questionnaires because the experts were given time to sort out their answers. Using questionnaires to acquire the knowledge saves time, efforts and cost; particularly, in case that the knowledge engineer already specified the needed knowledge features [21,22]. Moreover, the questionnaire's design made it easier for the experts to separately review each problem. In the submitted questionnaires, blanks spaces were provided so that the experts could fill in their comments. Each expert added informative comments that greatly enhanced the knowledge base. After analyzing the replies, other interviews (focus interviews) were held with the experts. This step was done to clarify some of the comments they made in their questionnaire forms and to discuss their solutions to some of the outlined problems in details. The acquired knowledge was reanalyzed for the final categorization.

By reviewing and reanalyzing the knowledge, the domain problems were categorized based on their forms, locations, effects and other mutual features. In this way, the students and trainee engineers will be able to easily understand the problems and recognize them. Moreover, the reasons, precautionary measures, solutions and possible effects of various problems, were also specified to provide the students and trainee engineers with sufficient details about the domain problems. The pavement experts, chosen in this study, were also asked for their opinion in the repeated categorization stages. Three experts, during the focus interviews, evaluated and approved the final categorization. In addition, the final categorization form was approved by six experts in pavement engineering teaching (two assistance professors and two lecturers) who were selected to be involved in categorization and evaluation stages. Table 1 presents the problems in a categorized form.

Trainee engineers can diagnose the problem, visually or by tests, based on its properties to adopt the correct solution by assistance of the system. The system is capable to specify the causes of the problems. These include bad management, insufficiently skilled staff, poor mixture quality, faulty preparation of the base layer, bad weather conditions or inefficient equipment. Civil engineering student can learn how to diagnose and control these problems by repeated use of the system.

Table 1. Categorization of domain problems

Problems Observed Before the Concrete hardening	**Concreting under bad conditions**			Raining during construction Concreting during cold weather Concreting during dusty weather Machine stop during construction Contamination of Concrete by Sub-base Material Discontinuity of concrete feeding during construction Raw material changes.
	Problems of plastic concrete properties			Concrete temperature is out of the specifications Concrete density does not comply with the required Air content is too low or too high Variable air content/spacing factor Slump is out of specification Loss of workability/slump loss/early stiffening Mixture is sticky Bleeding Mixture segregates Mix sets early Delayed set
	Edge and Surface defects			Fibber balls appear in mix Concrete surface does not close behind paving machine Concrete tears through paving machine. Paving leaves vibrator trails Slab edge slump
	Cracking	*Cracking of plastic concrete*		Diagonal shallow cracks Craze cracks
Problems That Are Observed at	Cracking	*Hardened concrete cracking*	*Cracks within the bay*	Transverse and oblique cracks Longitudinal cracks Corner cracks

Some Time After Construction	*Cracking at or near joints*	Transverse and diagonal cracks Longitudinal cracks Joint intersection cracks
	Hardened Surface Defects	Honeycombed slab surface or edges Scaled surface Dusting along surface Concrete blisters Surface bumps and rough riding pavement 30. Surface is marred or mortar is worn away Improper surface texture
	Problems of Joints	Dowels are out of alignment Dislodgement of aggregate particles along groove sides Disruption of concrete around the wet formed groove Displacement or tilting of the forming strip Improper sealing of joint Ravelling along joints
		Spalling along joints.
	Structural properties deficiency	Strength gain is slow Strength is too low Pavement thickness is less than the required

3. System Building

The educational knowledge-based system that is outlined in this paper has been built to assist the user to learn how to detect domain problems. Representation of the acquired knowledge as rules is suitable for this type of systems. Therefore, this way was adopted in this study to create a rule-based system. An appropriate choice, to represent the knowledge in the rule-based expert system, is a data driven forward chaining inference engine as this way simulate the way of human expert in decision making [19]. In forward chaining, the facts contained within the knowledge base are utilized to reach the conclusion [23,14]**.** The inference starts from fed data, and then proceeds with that data to the results. This procedure based on IF-THEN relations; When an IF condition is found in a rule

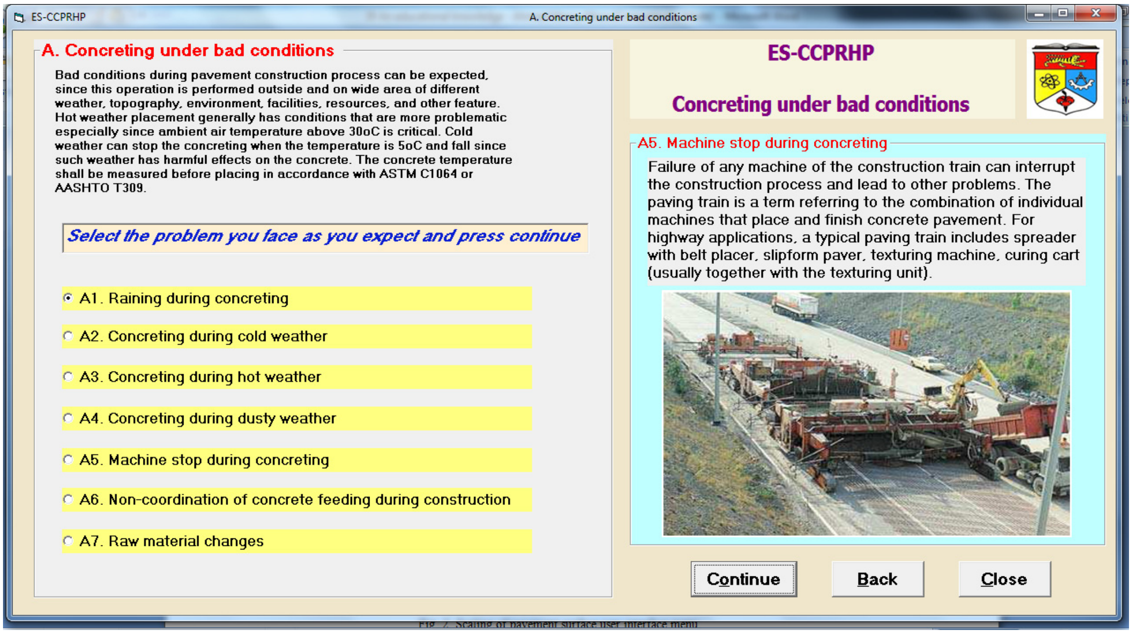

Fig. 1. Concreting under bad conditions problem user interface menu

within the knowledge base, the inference engine applies the action in its THEN element [24-25]. The KBS-DCPAP rules mimic the reasoning of human experts in study area.

In order to build the software, rules were created based on the categorized knowledge. The flexibility and effectiveness of the Microsoft Visual Basic programming language [12] in the Windows environment make it a suitable choice for the building the educational system. The responsibility of system building and updating based on software' source code is usually related to the knowledge engineer. For the civil engineering students and trainee engineers, who are designated as the end-users, an executable version was created. This executable version cannot be changed due to modification protection. Figure 1 and Figure 2 show examples of user interface from the executable version.

4. System Testing

Validation and verification of such systems are vital and difficult steps [26]. In order to verify that the right system is constructed, testing activities shall be performed. In this study, the proposed system was under integration and unit testing continuously during the process of system building. This approach enabled the knowledge engineer to verify that the elements of the system are functional and they run jointly. The evaluation of the system was done through the use of questionnaires. Likert scale is a useful measure in questionnaires evaluation [27,28]; therefore, it was adopted in this study. These questionnaires were designed for end-users in order to test their level of satisfaction when using the system. Six questionnaires were submitted to experts in civil engineering teaching (who were involved in categorization process), and twenty questionnaires

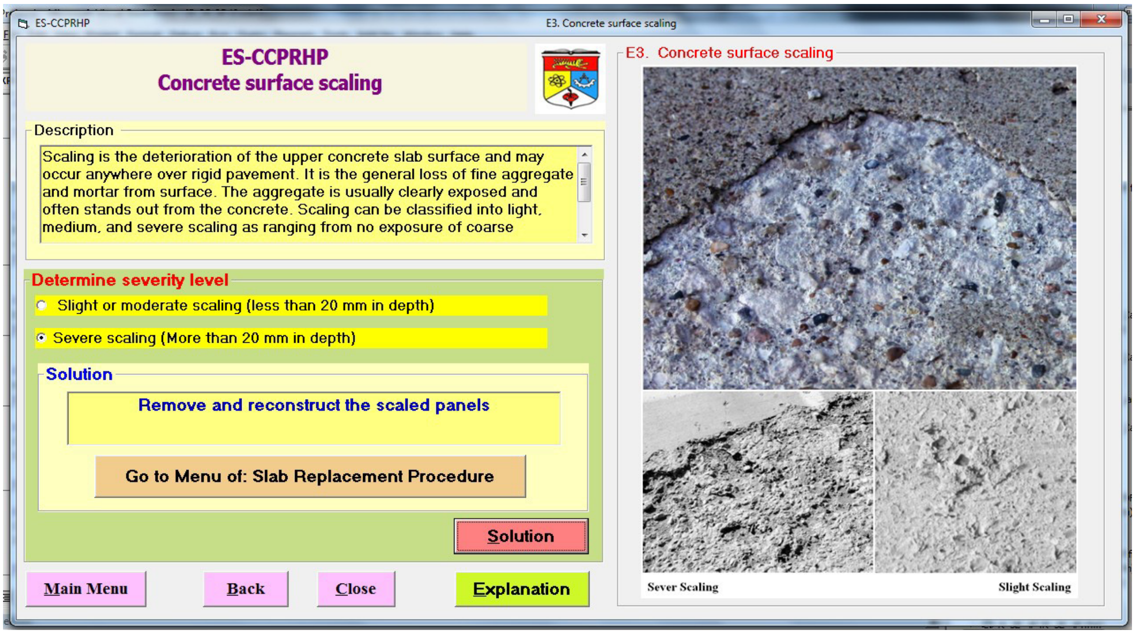

Fig. 2. Scaling of pavement surface user interface menu

were submitted to civil engineering students. After using the system with guidance of the knowledge engineer, the users evaluated the system. All the users were satisfy that the system is useful and effective in solving the domain problems, fast running, and user friendly as all the users gives evaluation values more than 3 which is the mid-value on Likert scale that consists of five values (from 1: strongly not satisfy to 5: strongly satisfy). Table 2 presents the results of evaluation. The questionnaire was statistically analyzed by calculating Cronbach's alpha and t-test. Cronbach's alpha value was (0.961) which shows high reliability and validity. The result of t-test shows no significant differences in mean values between the first group and the second group.

Table 2. System evaluation results tested by t-test

Number	Questions	Group 1		Group 2			
		Mean	SD	Mean	SD	t	p
Q1	The system is easy to use	3.833	0.687	4.200	0.678	1.159	0.257
Q2	The system runs quickly	5.000	0.000	5.000	0.000	-	-
Q3	The user interface is user friendly	4.167	0.687	4.450	0.670	0.903	0.376
Q4	Obtaining an explanation from the system is easy	3.670	0.471	3.650	0.477	0.090	0.929
Q5	The explanations are useful	3.670	0.471	3.600	0.490	0.309	0.760
Q6	Help facilities are effective	3.500	0.500	3.550	0.497	0.216	0.831
Q7	The questions are helpful	3.500	0.500	3.550	0.497	0.216	0.831
Q8	The questions are clear	3.500	0.500	3.650	0.477	0.669	0.510
Q9	The terms are clear	3.500	0.500	3.600	0.490	0.437	0.666
Q10	Presentation of results is clear	3.833	0.687	4.100	0.436	1.150	0.262
Q11	Presentation of results is complete	3.833	0.687	4.050	0.497	0.860	0.398
Q12	The system is helpful to provide solutions	3.670	0.471	4.200	0.678	1.778	0.088
Q13	The system is helpful to specify the causes of problems	3.670	0.471	4.200	0.678	1.778	0.088
Q14	The system is helpful to adopt preventive actions	3.670	0.471	4.200	0.678	1.778	0.088
Q15	The system is helpful to specify effects of problems	3.670	0.471	4.200	0.678	1.778	0.088
Q16	Generally, I am satisfied with the system	3.500	0.500	3.700	0.458	0.920	0.367

5. Conclusion

This paper presents the building and evaluation of a novel educational knowledge based system in the domain of cement concrete pavement construction problems. The system can be used by civil engineering students and trainee civil engineers to learn how to diagnose and solve domain problems. The knowledge base of the system is based primarily on human expertise and secondarily on a literature review. The knowledge base includes the problems encountered in the domain, their causes, precautionary measures, solutions, and their effects in a categorized form. This knowledge is represented in the form of rules and coded in software. The system is verified and validated by extensive testing. The results of testing proved that the system is built correctly and can efficiently teach the students and trainee engineers how to solve problems and simulate human expert reasoning by repeated using of the system. It also has a flexible and friendly user interface. The system has been verified and validated and can be used confidently by end users. In addition, it can be used as a database to archive the problems encountered in the domain and to share engineers' experiences and transfer expertise to successive generations of engineers. Moreover, the system can be used as a foundation to build other systems in the domain of pavement construction. Updating the system to include new experiences is a very simple operation as the system includes help facilities within its source code. A knowledge engineer or any competent user of Visual Basic can update the system under supervision by a civil engineer.

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