Number 3 Volume 10 September 2004 Journal of Engineering

SELECTION AND MANAGEMENT OF EARTH-MOVING EQUIPMENT BY EXPERT SYSTEM

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ABSTRUCT

This study involves the development of expert systems software to present the necessary experience covering the various cases of the earth-moving plant selection and management. These parts of information have been inserted to the system are from experts' experience, previous researches and literatures related to the policy of earthmoving plant.

The designed expert system allows storing new experiences and equipment easily, it has high degree of flexibility and modification. As a result, this system helps the engineer at the construction site to take decision by him self. It can be used as a training tool for young civil engineering students to justify their equipment selection. Also, the system provided with visualization component to help inexperience engineers to grasp complicated concepts and visualize a construction method without visiting construction sites. The video effects of various types of earthmoving equipment during earthmoving operation were integrated to the system.

الخلاصة

تم في هذا البحث بناء نظام إداري لانتخاب المعدات الإنشائية الخاصة بالأعمال الترابية تلبية للحاجة المتزايدة إلى تغذية المشاريع الإنشائية بالمعارف الاستشارية عن طريق الحاسب الإلكتروني. استخدمت في هذا البحث إحدى تقنيات الذكاء الصناعي وهي بالتحديد تقنية النظام الخبير التي تهدف إلى تقديم الخبرات التخصصية في مجال إدارة الآليات الترابية وذلك بأقل وقت وكلفة و إيجاد أفضل البدائل.

إن النظام المقترح علاوة على كونه أداة فعاله لمساعدة المهندس في الحقل الإنشائي على اتخاذ القرار ، يعتبر نظام تعليمي و تدريبي لطلبة الهندسة المدنية والمهندسين الجدد يعرض للمستخدمين كيفية اختيار و إدارة آليات الأعمال الترابية وفق ظروف و متطلبات محددة و توضيح عمل الآليات في الحقل الإنشائي من خلال المؤثرات الصورية المتحركة التي زود بها النظام ليتسنى للمبتدئين مشاهدة التفاصيل من دون زيارة الموقع الإنشائي.

KEY WORDS

Earth-moving, equipment, management, expert, systems, plant, excavation.

INTRODUCTION

Earthmoving equipment selection, one of the most important aspects in construction projects. The selection depends on many considerations ،such as material type, excavation depth, and hauling distance, etc. For example, dozers and scrapers are suitable for the task of moving materials with a

shallow depth and wide area. Scrapers seem to be more popular than dozers in this task because scrapers can transport and spread material more easily than dozers. Loader shovels are suitable for moving material which is above machine level, like a stockpile.
Back-hoes are suitable for various kinds of tasks such as moving material which is above or below machine level or in a deep trench. While, clamshells are more suitable than excavators when excavating at very deep trench. Draglines can dig above or below machine level and also underwater materials but they are not suitable for precise position work [Chanthawarange 1998].

THE RESEARCH'S JUSTIFICATIONS

The construction projects of irrigation, highways, dams and embankments etc., that adopted, involve one of the major bid items namely the earthmoving operation. Sometimes during the construction, many earthmoving activities are delayed due to inappropriate selection of equipment. In-particular, these projects that deal with various types of materials, terrain, and activities making it difficult for inexperienced engineers to select the optimal equipment, then the delay due to inappropriate equipment selection will cause time and cost overruns. The experience in these project shows an urgent need for inexperienced engineers to be thoroughly trained to make appropriate equipment selection. One approach to meet this need is to exploit knowledge on construction methods and equipment selection which is abundant but not readily accessible in the context of regular training sessions, books, or manuals. Such knowledge can be gained mainly from individuals who have years of on-site experience. However, much of this knowledge has been neglected or lost with the passing of individuals.
Inexperienced engineers can use quantitative analysis as a tool to decide which type of equipment performs most economically. By determining cost per unit of material, which equals the cost per hour of equipment divided by its production per hour, they can easily decide which equipment performs most economically. However, this analysis may result in impractical choices because it is sometimes impossible to exactly predict the equipment's production, which varies from site to site. Therefore, engineers usually make their selection based on their experience.

EXPERT SYSTEMS

Artificial Intelligence (AI) is a computer system that imitates human abilities like: thinking, seeing, hearing, and speaking. An expert system is one application of AI that imitates a human's thinking and understanding by using a reasoning process to solve problems [Clive 1991]. One approach to solve equipment selection problems is to develop an expert system. Experts' experience was gathered to create a knowledge base that contains knowledge and expertise of the experts in order to feed the designed system.

KNOWLEDGE BASE

There are four processes involved in creating a knowledge base. The first process is knowledge acquisition. The second process is knowledge representation. After being recorded or noted, this knowledge will be transformed into a standard format which helps knowledge engineers to more easily group them together or create the decision tree diagrams which represent the structure of the knowledge base. The third process is to develop the user interface. This process is an important part of the knowledge base in that it helps users to easily use and understand the program and to modify the system efficiently. The last process is knowledge validation and evaluation. This process validates and confirms all knowledge before the users use it [Chanthawarange 1998].

Knowledge acquisition

In this process, the knowledge engineers are the key individuals to collect the knowledge and expertise for creating the reliable and practical expert systems. The quality of knowledge often determines the success of an expert system [Parsaye 1988]. To gather knowledge, there are three basic approaches: observation, literature review, and interview. Of these three methods, interviewing and literature reviews are adopted to create specific knowledge base that feeds the designed system later.

The interviewing and the development of a questionnaire

There are two alternatives for developing the questionnaire. The first alternative is to list each question in multiple choice form with full explanation so those experts can quickly check and indicate the choice to be considered. The second alternative is to ask the experts to create the hypotheses and then list the choices or the factors, which are considered to be significant. This alternative, which was selected for this study, can free the experts' thinking and can obtain more information.

There are three main questions in this questionnaire (interview) as follows:

1- The first question asks the experts to list the most common types and models of equipment used in earthmoving operations in Iraq. The purpose of this question is to develop the scope of this study.

2- The second question requests the experts to describe the suitable conditions and limitations for using equipment which is specified in the previous question.

3- The third question consists of three points as follows ;

a- Asks the experts to list the factors which are significant in selecting the types of earthmoving equipment .

b- For each factor that the experts list, they are asked to list the sub-factors that affect the choice of equipment .

c- Finally, for each sub-factor that is specified, the experts are requested to indicate their preference on a particular scale and for each equipment.

The expressions (terms) of this scale that to be indicated by the experts are; Excellent, Very Good, Good, Rather Poor, Poor and Impossible, where Excellent is the most commonly used equipment (for certain sub-factor) while Impossible is used to indicate that the equipment can not work with particular sub-factor [AL-Jumaily 2002].

To convert these expressions to mathematical means, let the scale vary from (1) to (5) where (1) represents the term (poor) and (5) represents the term (excellent) and so on for the others. For example, when an equipment has preference value 'very good ' which can be represented also by number (4) that means the percent (%) for this equipment will be $(4/5) \times 100 = 80$ % .

Multiple domain experts

Some authors have noted that the knowledge engineer need not be particularity concerned about multiple experts. Using a rule base cloned from an expert, then building a prototype expert system and then letting the other cloning experts critique the results [Surko 1989]. In this study a similar approach was followed when dealing with multiple domain experts. The researchers selected one domain expert as the individual from whom as the key expert, the rules were to be acquired. Then the researchers presented the prototypes to the remaining experts for a critique. From the suggestions, comments and criticisms received from the other experts, the researchers as a knowledge engineer then attempted to identify those that seemed to be both constructive and important. The researchers then presented these to the key expert for his comments to specify the final format sheet of the approved knowledge base.

An example to illustrate how the system's engine works

Excavated material, size of excavation, excavation depth, and hauling distance are considered as the factors in earthmoving activities. Suppose that these factors have the following properties respectively (as sub-factors);

1- muddy clay
2- large area
3- deep excavation
4- hauling distance < 25 meters

Table (A) illustrates the preference value for each equipment in respect for each sub-factor indicated from experiences of experts and literature review ;

Table (A)

Sub-factors / Equipment types	Muddy Clay	Large Area	Deep Excavation	Hauling distance
Motorized Scraper	impossible	excellent	impossible	impossible
Backhoe Excavator	very good	excellent	excellent	very good
Loader Shovel	poor	very good	impossible	rather poor
Bulldozer	very good	good	rather poor	excellent

To find the preference value for each equipment, the terms should be converted to the equivalent numeric values as stated in **Table (B)** below:

Table (B)

Sub-factors / Equipment types	Muddy Clay	Large Area	Deep Exca.	Hauling distance	Total preference	(%) preference
Motorized Scraper	0	5	0	0	0	0 %
Backhoe Excavator	4	5	5	4	18	90 %
Loader Shovel	1	4	0	2	0	0 %
Bulldozer	4	3	2	5	14	70 %

Form the information in **Table (B)**, hydraulic excavator (backhoe) gets maximum preference value (90 %).

So a production rule can be generated as in the following statement;

IF Material is muddy clay
AND Size of excavation is large
AND Excavation depth is deep
AND Hauling distance < 25 meters.
THEN Hydraulic excavator (backhoe crawler type) is the most suitable equipment for moving muddy clay in large area , deep excavation and hauling distance less than (25) meter with (90 %) preference.

The selection above is experience-based selection related to a certain condition. However, there is another important consideration in the selection of equipment namely the economic consideration, or in other words, the minimum unit cost of production material.

In this research, the relation between the quantitative analysis (minimum unit cost of the materials to be moved) and the experience based selection (preference value) was considered and combined

This combination is represented by a weight percent for quantitative analysis and the remaining of the percent for experience based selection. This weight can be modified or changed according to certain case studies.

If the quantitative analysis gives for example, fifty percent (as a weight consideration) and the remaining fifty percent for experience base selection, the results that offered by system shows that the best selection is for the bulldozer with size equal to (8 yd³ or 6.11³m) and maximum combination value equals (68 %).

Briefly, the best selection of equipment that the system offer can be reached from more than one approach as follow ;

a-The best selection according to maximum weight that the equipment gets for certain conditions.

b-The best selection according to economical factors (minimum unit cost of production materials).

c-The selection can be reached according to the combination of the two factors above with certain weight percent for the first, and the remaining of the percent is for the other. This weight can be changed according to the project requirement.

To justify these three point above and for more details the reader can cheek chapter eight Ref. [Al-Jumaily 2002]

Visualization component

Providing the visualization component (video effects) can not only help users to grasp complex knowledge but also to visualize the method of construction. Animations of various types of equipment during earthmoving operation were gathered from various heavy equipment companies such as VOLVO, O&K, CASE-POCLAIN, HYUINDAY, LIEBHERR and others [Al-Jumaily 2002].

Validation of the designed system

If there are errors in the knowledge from which a knowledge base is built, then there will usually be errors in the performance of the expert system. There are several ways that the Knowledge Base can come to represent incorrect knowledge;

a-The expert(s) provide incomplete or incorrect knowledge.

b-The knowledge engineer fails to correctly understand or code the expert's knowledge.

c-Errors were introduced in maintenance.

This process validates and confirms all knowledge of the designed system before the users use them. To achieve this feature the researchers compared the results that the designed system provided with a real project results (Al-Jadriah Lake Project) near Baghdad University. When applied the system, the results that the system suggested was compatible with the actual plan by about (80 %) as commitment by the project manager, beginning from the best selection, number of equipment and dump trucks needed and ending with estimated costs and out-put.

Evaluation of the Designed Expert System

Ten site experts and academic personnel were selected to evaluate the designed expert system . Their answers are represented in **Table (C)**. The numbers in the first raw in table (C) represent the questions below respectively;

1- Is the system user-friendly and do you accept the system?
(excellent), (very good), (good), (rather poor), (poor).

2- Does the system give "correct" results ?
(excellent), (very good), (good), (rather poor), (poor).

3- Is the logic of the system correct?
(excellent), (very good), (good), (rather poor), (poor).

4-Does the expert system offer an improvement over the practices?
(excellent), (very good), (good), (rather poor), (poor).

5-Is the system easy to learn and can the user become proficient in it?

(excellent), (very good), (good), (rather poor), (poor).

6- Is the system useful as a training tool?
(excellent), (very good), (good), (rather poor), (poor).

7- Is the system in fact maintainable by users other than the developers?
(excellent), (very good), (good), (rather poor), (poor).

8- Can the system be used in the intended work environment?
(excellent), (very good), (good), (rather poor), (poor).

9- Is there time saving through using of the system?
(excellent), (very good), (good), (rather poor), (poor).

10- Is there cost saving through using of the system?
(excellent), (very good), (good), (rather poor), (poor).

11-Indicate your evaluation of the whole system as a preference value if the scale is between (1 to 10); (10) is being the highest assessment .

The experts should select the appropriate choice under each question.

Note ; excellent = E, very good = V.G, good = G, rather poor = R.P, poor = P

From analyzing the answers which are represented in the evaluation Table the following points have been concluded;

1- All answers to the first ten questions about the system are positives.

2- To question number eleven, six experts give (9) preference value while only one gives (10) preference value and the remaining three expert give (8). The total summation will be (88) which mean (88 %).

CONCLUSIONS

The research has resulted in the following specific conclusions relating to both earthmoving planning and expert system technique:

1- The uncertain nature of the information available, the rule of thumb, and the large amount of data required make the equipment selection seem ideally suited to an expert system.

2- Almost the engineers at the construction companies depend on their experience in selection and management of earthmoving equipment. There is no clear scientific and management tool to do that, but their on-site experience.

3- The designed Expert System has a high degree of modification in simplest way because of its high intelligence user interface.

4-The system gives alternative solutions and prints all input conditions and output results in format sheets to be documented.

5- The best selection of equipment that the system offer can be reached from more than one approach as follows ;

a-The best selection according to maximum weight that the equipment gets for certain conditions.

b-The best selection according to economical factors (minimum unit cost of production materials).

c-The selection can be reached according to the combination of the two factors above with certain weight percent for the first, and the remaining of the percent is for the other. This weight can be changed according to the project requirement.

6-When the system was applied to a real construction project (AL-Jadriah Lake Project) near Baghdad University, the results that the system suggested was compatible with the actual plan by about (80 %) as commitment by the project manager, beginning from the best selection, number of equipment and dump trucks needed and ending with estimated costs and out-put.

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