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A KNOWLEDGE-BASED EXPERT SYSTEM FOR EIA USING BLACKBOARD APPROACH

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ABSTRACT

Expert systems and knowledge-based systems are widely used in engineering applications and in problem-solving. Rapid development today has brought with it environmental problems that cause loss or destruction of natural resources. Environmental impact assessment (EIA) has been acknowledged as a powerful planning and decision-making tool to assess new development projects. It requires qualified personnel with special expertise and responsibility in their domain. Knowledge-based EIA systems incorporate expert's knowledge and act as a device-giving system. The development of an expert system to produce environmental impact assessment reports using an intelligent blackboard co-operative approach is presented. The system has an advantage over human experts and can significantly reduce the complexity of a planning task like EIA.

Keywords: ***Expert systems, EIA, Blackboard architecture, CLIPS, Knowledge engineering, Problem-solving***

1.0 INTRODUCTION

Rapid development today has given rise to environmental problems that cause loss or destruction of natural resources. Decisions on environmental issues and on sustainable development is about the better management and decision-making from a higher authority, for the current environmental impact assessment (EIA) activity in harmony with the environment [1]. EIA can be defined as a systematic activity designed to identify, predict and evaluate the environmental impacts of a particular action [2]. It interprets and communicate information about these impacts, and details out the mitigating measure prior to approval and implementation [3, 4].

The process of EIA seeks to avoid costly mistakes in project implementation, either of environmental damage or of subsequent modifications in order to make the project environmentally acceptable. It involves the collection, analysis, interpretation and review of an extensive amount of information. EIA is then needed as a powerful tool to aid decision-makers and to quantify the impacts prior to any new development for better problem-solving. Most experts from international institutions such as UNEP (United Nation Environmental Program), national environmental agencies as well as academics, agree that EIA still needs promotion and improvement [5].

One of the problems of EIA in developing countries is the lack of information exchange. Information and knowledge in EIA reports has been shared between various reports [6]. Mostly, this information was shared in the existing environment and potential impacts of the ongoing projects. Based on a review of that recent literature, there is no computerised system to produce EIA reports. The Department of Environment Malaysia (DOE) has acknowledged EIA as a useful planning tool in making decisions prior to the implementation of new development projects. Based on data analysed by the DOE between 1988-1992, eighty three per cent of EIA reports submitted were not in accordance to the project planning schedules recommended in the EIA guidelines [7]. Therefore, it would be useful to have an expert system on the preparation of EIA reports.

Knowledge-based expert systems have been growing rapidly over the last decade in the new information technology age [8]. Information is a vital resource for many endeavours in technology development [9]. Expert systems have been designed for application in the field of technology and they process advantages over human experts [10, 11]. This article describes an expert system developed to facilitate the EIA report preparation process. This expert system is in the form of a shell that incorporates relevant expert knowledge, data and common information that used in preparing EIA reports. The structure of early expert systems shifts from search-based to knowledge-based problem-solving and from knowledge transfer to knowledge modelling [12, 13]. Primarily, the structure of an expert system model consists of two major traits: the expert's knowledge and reasoning of facts with the domain knowledge.

One of the most intelligent features of expert system structure is the implementation of knowledge modelling. Knowledge based systems may reduce significantly the complexity of a planning task such as EIA. This task requires qualified personnel with special expertise and responsibility to be involved in decision-making within their domain [14]. The development of an expert system for such applications can incorporate the expert's knowledge and act as a device-giving system. The challenge of dealing with real problems in an EIA, requires more flexibility in its domain. Knowledge sources and the solution space are usually structured hierarchically as they would be in a human expert [15]. A co-operative blackboard approach was implemented in the development of the expert system. In this approach, various sources of expert knowledge in EIA can participate in forming and modifying the emerging solution. Expert knowledge from different domains is shared in the system to infer an adequate information and accurate decision, and provide a powerful explanation facility “WHY” and “HOW” to the end-user.

2.0 EIA PROCEDURE AND STRUCTURE

Results from an EIA study should be presented in a form that is readily understood and can be utilised in project planning and implementation. Under the EIA Act [16], nineteen categories of activities are prescribed and these include those related to agriculture, airport, drainage and irrigation, land reclamation, fisheries, forestry, housing, industry, infrastructure, ports, mining, petroleum, power generation, quarries, railways, transportation, resort and recreational development, waste treatment and disposal, and water supply. In order to conduct an effective EIA study, three major steps should be taken. The preliminary assessment stage should be initiated at the pre-feasibility stage of the development of an activity. Project options and any significant residual impacts are identified at this stage. A detailed assessment is undertaken for those projects for which significant residual environmental impacts have been predicted in the preliminary assessment. The review stage of EIA is carried out internally by the DOE for preliminary assessment reports and by the ad hoc Review Panel for detailed assessment reports. Recommendations arising out of the review are transmitted to the relevant project approving authorities for consideration in making a decision on the project. The outcomes of the EIA reports and format are divided into chapters and sections. These chapters include the Introduction, Title of the Project, Project Initiator, Statement of Need, Project Descriptions, Project Options, Description of The Existing Environment, Potential Significant Impacts, Mitigation and Abatement Measures, Residual Impacts, Summary of Conclusions, Data Sources and List of References. This paper discusses on expert system developed to produce EIA reports according to the chapters mentioned. The system is able to organise all information in each chapter to produce a complete reports.

3.0 SYSTEM OBJECTIVE

Currently, EIA approval is mandatory for most of the development projects to be undertaken in Malaysia. However, there are no standard procedures to follow by the consultants in preparing the EIA reports. The Department of Environment (DOE) encounters problems in evaluating (to approve, reject or approve with conditions) the EIA reports. If a report is approved, the DOE also faces problems of verifying that the developer or the project manager is actually complying with the approved guidelines. For these reasons, the development of a comprehensive expert system to aid in preparing EIA reports as well as for decision-making will be helpful.

4.0 SYSTEM COMPONENTS

At the development stage of the expert system, four major components were constructed. The generic system includes the domain knowledge, the expert system kernel, solution methods and strategies and the user interface. Fig. 1 shows the general components of the expert system structure.

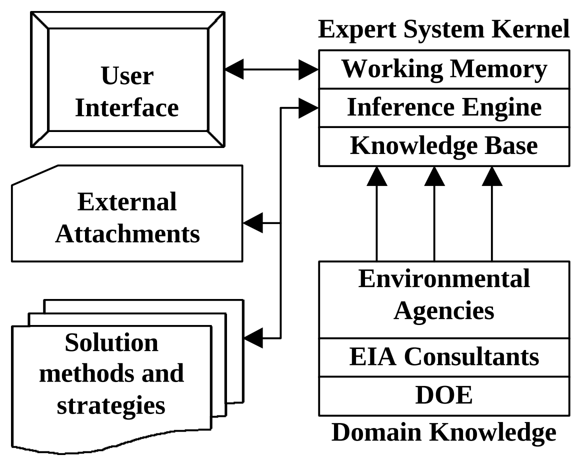


Fig. 1: General Components of the Expert System Structure

The inference engine invokes external modules and attachments that can be used to estimate project parameters and mitigate the impacts of the significant values. The knowledge base was modularly structured to separate knowledge from control. The EIA knowledge was acquired from different resources such as the DOE, EIA consultants and environmental agencies. EIA parameters and knowledge were used to develop the knowledge base unit in a rule form knowledge representation. In addition, two other components were added to the system - the category selector for all prescribed activities as recommended by the DOE, and the Editor tool and summary report generator that summarises and evaluates the impact assessment and provides a hardcopy report.

4.1 The System Domain Knowledge

Knowledge is the key to expert systems functionality. One of the most difficult tasks in developing expert systems involves information gathering and knowledge extraction. The system domain knowledge was acquired from various disciplines. The main source was the DOE through the approved EIA reports and the EIA experts and consultants. To maintain knowledge in the expert system, a knowledge acquisition unit was developed. A database system was also attached to the expert system developed in FoxPro. Data was gathered from sources such as environmental agencies, the literature, interviewing experts in their domain and subsequently translated to form the "rule of thumb". These rules were used to generate the expert system rules using the C Language Integrated Production System (CLIPS).

4.2 The Expert System Kernel

The central part of the expert system is the kernel, and it contains three main modules as shown in Fig. 2. The first module is the working memory and it is connected to an intelligent user interface unit. Through the interface unit, the end-user can communicate with the expert system by selecting any of the EIA prescribed activities. The selected activity will be recorded in the working memory and the inference engine mechanism and control procedures initiate the knowledge base and load all information for that category into the working memory. Inputs of the problem parameters will be acquired from the user and the reasoning mechanism activates rules to search the knowledge base and fires the activated one to form solution as an output.

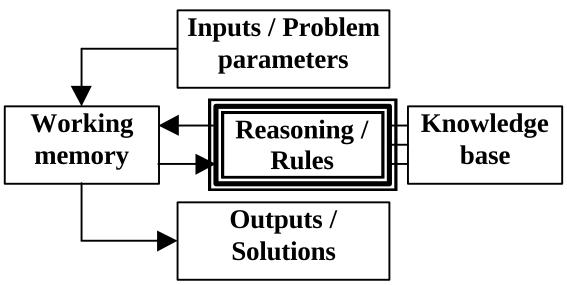


Fig. 2: Problem/Solution to Expert System Kernel

4.3 The EIA Selector

As mentioned in the previous sections, the EIA has nineteen prescribed activities. An EIA selector is implemented in the system as shown in Fig. 3. It speeds up the searching process by initialising the required modules concerning the set of rules for the selected category. The end user may use the system for certain projects that requires no EIA. An advantage of the EIA selector is that it determines expertly either to continue the process or to stop explaining to the user "WHY" it concludes not to have an EIA, by using the explanation facility provided in the system.

5.0 THE KNOWLEDGE BASE STRUCTURE AND INFERENCE STRATEGY

Owing to the categorisation of the EIA prescribed activities schedule [7], the design of the knowledge-based expert system structure comes in more attractive knowledge representation. By experience, an expert forms several sets of rules on a given problem. These sets of rules reflect the skill of the expert on the given problem. For this reason, a set of rules may be applied to the given task when needed, while on the other hand the same set of rules is inapplicable to other problems. Thus, in the case of separate categories of EIA, a modular structure is implemented in the system.

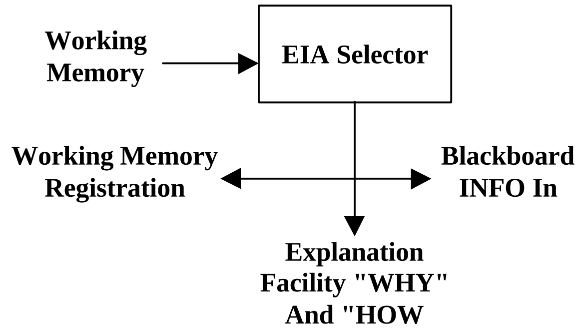


Fig. 3: Selecting EIA Category

5.1 System Strategy and Reasoning

Human solves problems by combining facts with knowledge. Experts first obtain facts about the problem and store them in the short-term memory. Experts then combine facts with the long-term memory knowledge and use specific rules of heuristic to derive logical conclusions.

A cooperative expert systems approach requires mechanisms of cooperative interactions that permit multiple experts to work together on the solution of a common problem. By understanding how human reasons from their wisdom and expectations, the system was developed in a manner to respond to the direction of the data captured during the acquisition stage in the working memory and report to the blackboard system to derive new information [17]. The system contains over 700 nested rules of type *IF Condition(s)-THEN Action(s)* rule structure. For example, the following rule reports to the blackboard both the Noise index and the Air pollutant index for projects under the industrial category.

IF (?Project_Type (Is_Industries))
AND (eq ?Project_Loc (Within_Industrial_Area))
THEN (Get_NoiseIndex)
(Get_AirPollutantIndex)
(Report_BB)

Normally in solving a problem, an expert will use knowledge that directs to the problem-solving. The system implements this type of knowledge base called *meta-knowledge*, or in other words, knowledge about the use and control of domain knowledge. This knowledge is used in searching the existing domain knowledge to determine the problem solution and infer new knowledge. An advantage of the modular structure is that it provides a natural ordering of the domain's rule sets by a top-down approach, where a specific module is used when appropriate. Through the end-user interface facility the knowledge base inference allows inspection of individual rules, and a recursive explanation function "WHY" traces the reasoning process of the system.

5.2 The Blackboard Approach

Researchers in the field of Artificial Intelligence conceived the blackboard architecture concept more than a decade ago [18]. The intent of this research was to address issues of information sharing among multiple heterogeneous agents in problem-solving [15, 19]. The name, blackboard architecture, was chosen to evoke a metaphor in which a group of experts gathers around a blackboard to collaboratively solve a complex problem [20].

The domain blackboard is a shared data structure through which the knowledge sources of the domain (reasoning knowledge sources) communicate with each other. Expert's knowledge is communicated through this system by posting information on a shared memory, the Blackboard, as shown in Fig. 4. The standard strategy for Blackboard problem-solving is often referred to as incremental hypotheses and tests or evidences aggregation [21]. The domain blackboard organizes the solution elements, also called hypotheses, at different levels of abstraction. These levels of abstraction represent the solution to the problem at different levels of detail.

The blackboard approach in the system is used as a central repository for all shared information obtained from EIA experts. The information on the blackboard represents facts, assumptions, and deductions made by the system during the course of solving a problem. Each expert brings a unique set of knowledge to bear, and each may employ a different problem-solving strategy. Each expert views the information on the blackboard, and tries to contribute to the solution, if possible. The blackboard controller function determines which information, at a given point of time, has the highest certainty factor to contribute to the problem's solution. The correspondent rule(s) will be activated and fired. This will be followed by a series of actions to allocate the necessary information to be channelled to the EIA report generator.

6.0 INFERRING EIA KNOWLEDGE THROUGH THE BLACKBOARD

If a group of experts are to work effectively in a cooperative manner, as in EIA task, it is necessary to overcome their reasoning limitations in terms of knowledge, processing and interaction. For better EIA decision-making, this tool should be based on a detailed description of the actual environmental situation as well as on a systematic analysis of every potential effect due to a proposed project or action.

EIA is important and can lead to better planning and effective prevention. One factor that is relevant in controlling the effectiveness of EIA is the accuracy of the baseline data. Expert knowledge and scientific disciplines on such areas of EIA should be involved in complex processes because of the various interference and interactions between the different environmental factors. This may require knowledge from several human experts thus making it a distributed problem-solving process. In such a case, different sets of rules in a modular structure should communicate information with one another forming the EIA knowledge subdomain. However, this can be implemented through the Blackboard System [22]. The Blackboard system speeds up the searching process for a solution by reducing the search space in the working memory and therefore increases the efficiency in problem solving.

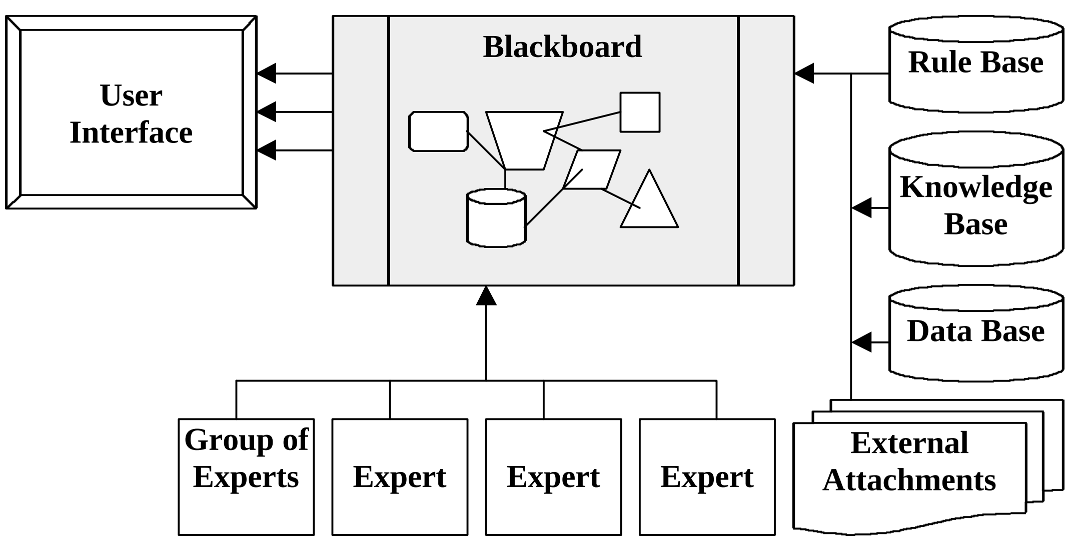


Fig. 4: The Blackboard Architecture

A problem-solving session begins with the facilitator writing the problem specification, along with all known relevant facts and assumptions on the blackboard, which is visible to all experts. As individual experts recognise opportunities to apply their own specialised knowledge to the present state of the problem solution, they request the attention of the facilitator. The facilitator selects from among those experts requesting attention, the most promising contribution, and writes that insight on the blackboard. This process continues until the problem has been solved. Fig. 5 shows the architecture of the EIA knowledge implementing the Blackboard structure. In the architecture, acquiring knowledge through the Blackboard is scheduled by the control procedures. A request made to the Blackboard from the end user is handled by the working memory. Information from various experts hereof will be written to the Blackboard requesting the desired modules to initiate the knowledge base section and the project database system. Using this method, the Blackboard acts as a short-term memory where new facts about the problem are inferred and the knowledge base is updated. In this way, the system learns from the past problems by updating its knowledge base dynamically. In more precise terms, the blackboard may be thought of as a database that represents the working memory of the problem-solving system. The experts are modular software subsystems called knowledge sources that represent different points of view, different strategies, and different kinds of knowledge, about how to solve a problem.

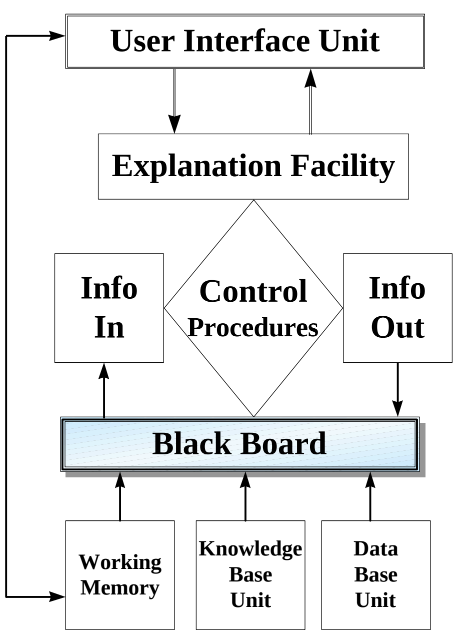


Fig. 5: EIA Knowledge Base System implementing the Blackboard Architecture.

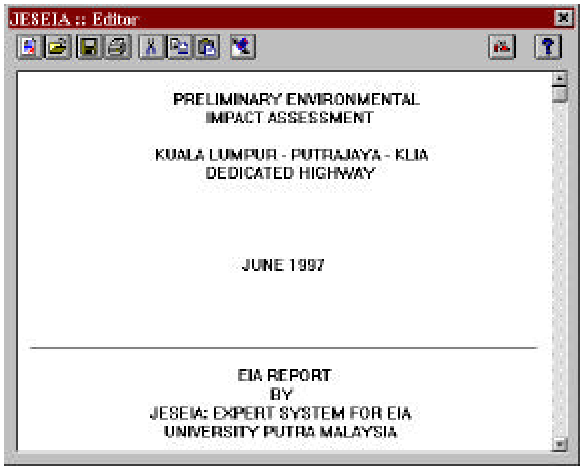
7.0 IMPLEMENTATION OF THE SYSTEM

The prototype knowledge base expert system proposed by Jazzar et al [23] has been implemented using CLIPS for PC platforms. CLIPS is a productive development and delivery expert system tool which provides a complete environment for the construction of rules and object-oriented expert systems. CLIPS was developed in 1984 at NASA's Johnson Space Centre [24]. The prototype uses CLIPS inference engine for its forward and backward chaining strategies. The system has a modular structure and uses the Blackboard approach and thus makes the system highly efficient and portable.

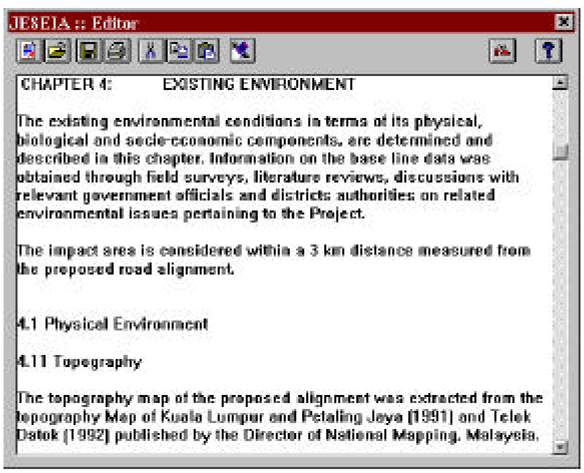
Fig. 6: Screen Shots of the System Interface

8.0 SYSTEM OUTPUTS

The final output of the system is to assist project proponents in the preparation of the EIA reports. A friendly and adequate user interface shown in Fig. 6 directs the user to select an EIA prescribed activity as a start. Upon the selection, the system initialises the necessary modules. The user will be asked to key in general information about the project that includes the type of project, the project location and other descriptions. This information will be reported to the blackboard system. As a result, the inference mechanism generates the initial parts of the EIA report such as the introduction chapter, the title of the project and project initiator as well as the existing environment chapters in the report. The system automatically saves information reported to the working memory and those inferred from the blackboard system into a temporary and a recovery file. A file management system was implemented into the report generator and the editor tool to handle the process. At any stage of generating new data and/or mitigating measures for potential significant impacts, the system asserts these outcomes into the corresponding chapters of the report. The final copy of the report as shown in Fig. 7a and 7b, will be saved and shown to the user. The user can edit and save the generated report and the system will automatically save a recovery copy to be used whenever the user leave the system to another application.



(a)



(b)

Fig. 7: Screen Shots of EIA Report Example.

9.0 CONCLUSION

The main objective of EIA is to ensure the potential problems are foreseen and addressed at an early stage in project planning and design. The task of EIA requires a qualified personal and expertise to prepare EIA reports and involves the collection, analysis, interpretation and review of an extensive amount of information. A knowledge-based expert system was developed to produce EIA reports in a significant time. The system has an advantage over traditional solution to EIA where these solutions are derived from the application of a substantial body of knowledge rather than applying an imperative algorithm. The system development used the blackboard approach as a central repository of shared expertise and knowledge on EIA derived from the multidisciplinary team of experts. The blackboard approach plays a major role in communicating expert's knowledge and strategies to infer intelligent advice and solutions. Expert's knowledge through this approach communicates by posting information on a shared memory, the Blackboard, and retrieving solutions and contribution from it. The system shows good results and could be used to prepare sufficient and adequate EIA reports in a short time.

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BIOGRAPHY

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