Knowledge-Based Expert System in Traffic Signal Control Systems.

Kang-Won Lim*
Gyeong-Chul Kim**

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1. Introduction

Knowledge based expert systems(KBESs) have been developed in the field of artificial intelligence (AI). The aim of knowledge-based expert system is emulation and imitating social problems and then providing human-solving behaviour in complex real world tasks. The potentiality of such systems and their possibilities of application to transport problems have generated considerablely within the transport engineering field. [1]

Because of increasing transport demand which produces traffic congestion, safety problems and environmental degradation, the applications of knowledge-based expert system are likely to be the transport sector which are urban infrastructure design, transport planning, safety and maintenance, structures and equipment, vehicle scheduling, traffic monitoring and control especially in urban area and air traffic control.

In spite of effectiveness and usefulness of such systems, they still include some problems such as those of knowledge representation and elicitation.[2]

In this paper, the concept of knowledge-based expert system is presented and some differences between knowledge-based expert systems and conventional computer programs are

* Professor, Department of Environmental Planning, Graduate School of Environmental Studies, Seoul National University
** Ph.D. Student, Department of Environmental Planning, Graduate School of Environmental Studies, Seoul National University

discussed. Also, basic structure of knowledge-based expert system and building knowledge-based expert system are described. Finally some developments and applications of expert system in traffic signal control field are identified and discussed.

2. Basic Expert System Terminology

In order to understand knowledge-based expert system, it is necessary to define the basic terms.[3]

Artificial Intelligence: The part of computer science concerned with developing intelligent computer programs.

Expert System: A computer program using expert knowledge to attain high levels of performance.

Knowledge-Engineering: The process of building expert system.

Expert System Building Tool: The programming language and support package used to build the expert system.

Representation: The process of formulating or viewing a problem so it will be easy to solve.

Knowledge Based System: A program in which the domain knowledge is explicit and separate from the program's other knowledge.

Knowledge Base: The portion of a knowledge based system or expert system that contains the domain knowledge.

Rule: A formal way of specifying a recommendation, direction or strategy, expressed as IF premise THEN conclusion or IF condition THEN action.

Domain Knowledge: Knowledge about the problem domain; e.g., knowledge about geology in an expert system for finding mineral deposits.

Heuristic Rule: A rule of thumb of simplification that limits the search for solution in domains that are difficult and poorly understood.

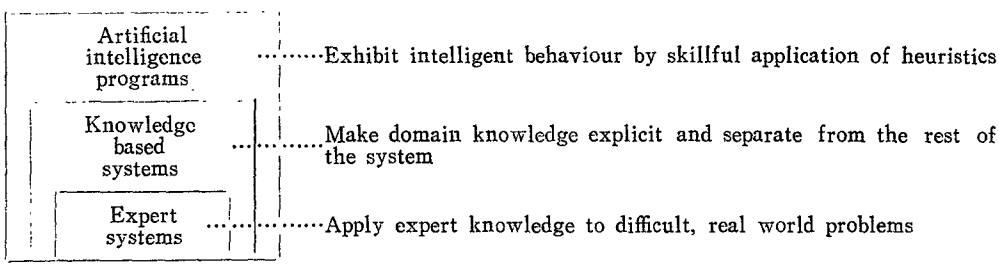


Fig. 1. AI., KBS., ES. Source: ref[2]

Inference Engine: That part of a knowledge system or expert system that contains the general problem-solving knowledge.

Meta-knowledge: Knowledge in an expert system about how the system operates or reasons. More generally knowledge about knowledge.

3. Knowledge-Based Expert Systems vs Conventional Programs

The knowledge-based expert systems are different from traditional computer programs. Most traditional computer programs involve the use of algorithmic procedures. Thsee algorithmic programs can only obey step-by-step commands or procedures in searching for a solution to a program. The operations never vary because the program solving sequence is predetermined by the programmer. If any element is missing, the program will not run.

However knowledge-based expert systems are program-solving programs modelled on the reasoning of human experts. These systems are designed to incorporate the expert's judgement, rules of thumb, heuristics and reasoning strategies, and moreover these are provided knowledge advice about the application task.

Knowledge-based expert systems are described the state by manipulating symbolic, non-

Table 1. Comparison of Conventional Programs and KBESs

*Convcntional programs	KBESs
1) Defined, complete sequence of operations	1) Collection of rules of thumb
2) Order of execution precisely stated.	2) Order of execution not specified prior to solving the problem
3) Amalgamation of information and control	3) Separation of knowledge and control
4) Correct data must be supplied in order to obtain correct results	4) Provision of data provide plausible solutions
5) All required data must be provided in input	5) Can operate with incomplete data
6) Provide only answers	6) May disclose their functioning and provide justification for there reasoning
7) User unfriendly	7) User friendly
8) May be difficult to use and understand.	8) Transparency of knowledge representation and dialogue
9) May be difficult to modify	9) Incremental growth capability
10) Often programmed in isolatation from domain experts and user	10) Development team includes domain experts by definition
11) May be extremely difficult to examine embedded knowledge.	11) Provides capability to easily examine knowledge base.

numeric information which is a logical representation of the problem domain, and these are based on a clear and explicit separation between the knowledge they store (called knowledge representation) and the mechanisms for manipulating such knowledge (called inference and reasoning strategies).

Furthermore, these knowledge-based expert systems are provided with some limited form of self-knowledge; that is, they are able to keep a representation of their internal structure and function. This characteristic allows them to control their reasoning and to reconstruct inference paths for the purpose of explaining and justifying solutions to the user. This point is a set of distinguishing features which characterizes their kind of system. A summery of the main difference between conventional algorithmic programs and knowledge-based expert systems are shown table 1. [3], [4]

4. Basic Structure of Knowledge-Based Expert System

A knowledge based expert system is divided into three basic modules; the knowledge base (state memory), inference engine (control strategies or inference mechanisms) and short term (dynamic) memory called context.

The other three additional components, which are important in developing usable and widely accepted systems, are the knowledge acquisition module, the explanation module and the user interface. These modules and their interrelationships are shown in Fig 2. [2], [3]

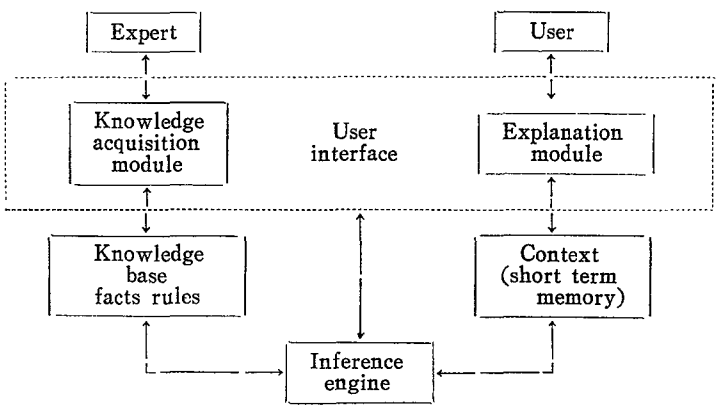


Fig. 2. Basic structure of knowledge-based expert system

4.1 Knowledge Base

The knowledge base serves as the storage place for the system's domain specific knowledge needed for understanding, formulating and solving the problem. If contains the facts (data

base) and rules or other knowledge representations (heuristics) that direct the use of knowledge to solve a given problem. So it represents the power of the expert system.

4.2 Inference Engine

The actual processing of the knowledge is performed by the inference engine. It comprises the control strategy or problem solving mechanism. It combines information supplied by the user with the rules or with the facts in the knowledge base to advise the user (through the user interface), which is how to solve a problem or to reach a goal, including, what conclusions can be reached or what additional information is required. This point is a major contrast between knowledge-based expert systems and conventional programs. So it is called by the brain of knowledge-based expert systems.

4.3 Context (short term memory)

The context contains the dynamic or problem specific knowledge, the user response to questions asked by the system, and other temporary information generated by the system. It is also known as the working memory, the work place or short term memory.

4.4 Knowledge Acquisition Module

The acquisition module is considered to be a subset of knowledge engineering. The main goals in knowledge acquisition module are to help the expert-educate system. That is, minimize or eliminate the role of the knowledge engineer as interpreter of the expert's knowledge. Furthermore it is to add in the development and maintenance of the knowledge base.

4.5 Explanation Module

The explanation module gives the system the ability to explain its reasoning process and to provide definitions and other information to the user. Also this module helps the domain expert check the system's reasoning in the system debugging.

4.6 User Interface

The user accesses the system through a user interface which should be friendly so that man and machine can communicate directly and efficiently.

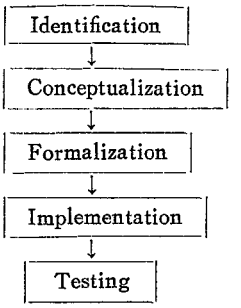
Currently actual language processors do not exist, so most user interfaces are implemented as a program-oriented subset of English.

5. Building Knowledge-Based Expert System

The major task of building an expert system is to transfer the expertise and knowledge

acquired from one or more expert to a computer program. This task of expert systems developers (knowledge engineers) is to carry out such a transformation and to system can reach the desired level. This step will vary depending on the characteristics of the program, the objectives selected.

However, the following stages are normally used in the development of an expert system. [7]



1) Identification

The first step in building an knowledge-based expert system is to identify the area, concepts, and characteristics of the problem and solution. In addition, the participants and resources (time, labour, and computing facilities) needed during development should be identified.

2) Conceptualization

The concepts needed to represent knowledge and the overall structure of knowledge-control strategies must be depermined before a preliminary system design can be completed.

3) Formalization

This stage involves design of the formal organization of the knowledge consistent with the development tools or language used. The detailed design of the system is formulated by the experts or knowledge engineers.

4) Implementation

In this stage the knowledge engineer turns the formalized knowledge into a working computer program.

5) Testing

The performance and behaviour of the prototype expert system are iteratively evaluated through comparison with the human expert's abilities. Revisions of the system are then made by a knowledge engineer using additional advice from the human experts.

In building expert systems, symbol-manipulation programming languages such as LISP

and PROLOG have been widely used. These languages have been specially designed for artificial intelligence applications. However, knowledge engineering tool-kit or shell have been also widely used, which comprises and includes an inference, empty knowledge base and context structure, and support facilities such as a knowledge base editor and user explanation facility.

6. Application of Knowledge-Based Expert Systems in Traffic Signal Control

Recent applications of expert system in transport engineering and planning are presented by Yeh and Michael. [1], [6]

1) Design
   a. Facility design, roadway design system
   b. Study design, data collection and sampling method
2) Planning
   a. Methodology development; planning scope, duration, data intensiveness, policy sensitivity and cost.
   b. Disaster response planning
   c. Bus transit network planning
3) Operations and control
   a. Traffic congestion diagnosis
   b. Roadway safety diagnosis
   c. Hazardous material transportation operations
   d. Air traffic control
   e. Road traffic signal timing control
   f. Dispatching and scheduling
4) Maintenance and rehabilitation
   a. Transit vehicle maintenance
   b. Pavement rehabilitation
   c. Bridge rehabilitation

In traffic signal control expert system, the timing optimization and co-ordinating of traffic signals provided with expert systems would be helpful for cities with similar characteristics. Such a system could provide a professional opinion to help local traffic engineers do their

jobs more effectively. And an expert system that performs like a human expert at an isolated signal controller can reduce manpower needs and provide continuous day and night services. Most of all, such an expert system would provide the best quality of service if the knowledge base were acquired from the best experts and modified to fit local conditions. [8]

Current and expected applications of knowledge-based expert systems are being studied in the traffic control problem areas, including rephasing signal at an intersection and updating a library with a new signal plans, and on-line surveillance and control operations.

The example of traffic signal control expert system is being studied in the European project. At this report, the advantages which the systems demonstrate at traffic signal control are that; [1], [9]

* the use of heuristics for the search of possible phase distributions helps in avoiding a complete enumeration of all possible sequences this also cut down the search space of solutions enormously, thus making it possible to deal with complex intersections.
* knowledge-based expert system techniques help in making the design decision process more transparent and, therefore, the final result more effective; that is, they may help in analyzing possible solutions when the selection of the best alternative involves multiple competing figures of merit(e.g., minimum delay vs acceptable delay and short average queues)
* the programs are quite easily extensible and adaptable to different users and situations because most of the signal knowledge is encoded in the knowledge base, that is they can be adapted with respect to the various national regulations of different countries.

7. Concluding Comments

The aims of this paper were to describe the characteristics of knowledge-based expert systems and some differences between knowledge-based expert systems and conventional computer programs. Also, basic structure of knowledge-based expert system and building knowledge-based expert system are discussed. Finally some developments and applications of the expert system in traffic signal control field are described.

In spite of effectiveness and usefulness of such systems, however, there are some problems concerning knowledge representation and elicitation. Many research project are under way so that the system may be utilized in the world, because so many of the problems at

traffic signal control system require specialized knowledge, skilled experience, and judgement for solving optimal strategies.

Considering the state-of-art in traffic signal control area in Korea, it seems to be quite fruitful to approach it from the viewpoint of the knowledge-based expert systems. This would help solving many pending problems and improving the quality of the traffic signal control systems.

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