LIFTES - AN EXPERT SYSTEM FOR LIFT SYSTEM DESIGN

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ABSTRACT

This paper describes an expert system, called LIFTES, which was developed to provide advice for effective lift system design in multistorey buildings. The system's knowledge base is structured as a set of production rules concernig physical laws and heuristics derived from documented experience on lift systems design. The inference mechanism uses forward and backward chaining tecniques which are selected by the user according to the problem at hand. The system is also enriched with a library that includes common analytical models from the literature on lift system design. LIFTES is expected to be a relatively inexpensive and easy to use tool for lift system design.

1. INTRODUCTION

A good design of a lift system is by no means an easy task due to the multiplicity of both quantitative and qualitative factors involved. The lift design problem has been investigated by many researchers in the past. Some (Alexandris et al, 1979, 1985, 1986) use mathematical or stochastic models, while others (Barney and Dos Santos, 1985) employ simulation models. Recently, more computationally advanced techniques involving computer aided design methods have been developed (Barney and Dos Santos, 1985). However, most of the researchers focus on the quantitative factors of the problem only. As a result, the above approaches provide the designer with partial solutions due to the assumptions made for problem refinement.

In this paper the lift design problem is approached by means of expert system techniques. The objective is to aid the designer gain insight about the advantages and disadvantages of a range of possible scenarios by taking both quantitative and qualitative factors into account.

The project was untertaken at the Piraeus Graduate School of Industrial Studies (PGSIS) and resulted in the development of an experimental expert system for lift design called LIFTES. At present, LIFTES contains a built-in mathematical model library that is invoked by the user in order to resolve the prescriptive aspects of a problem. In future developments, a simulation model library is to be included in an attempt to introduce the time factor within the traditionally time-neutral expert system environment. This paper describes the up-to-date version of the expert system LIFTES.

2. ASPECTS OF LIFT SYSTEM DESIGN

Designing the lift system of a new building involves good knowledge of the relevant building dimensions. Unfortunately, it is often the case that the architect responsible for the building design will have fixed the building core limiting the space available for the lift system or even will have defined the number of shafts, their dimensions and travel (Tregenza, 1976). This removes one very important degree of freedom for the lift traffic designer. Building circulation, both horizontal and vertical play an important role to the functionality of any building. Hence if a successful building is to be designed it is essential that the architect take expert advice at the initial stages of building design. This does not imply that the lift designer will take over the core design of the building, but simply that by means of a team approach various aesthetic and conceptual ideas can be considered and better solutions offered. The expert system described in this paper provides much of the guidance needed by the architect with regard to lift system design .

According to the purpose they serve modern buildings can be classified into one of the following categories: commercial (e.g. offices, stores), institutional (e.g. hospitals, universities) and resintential (e.g. hotels, flats).

The traffic patterns vary with the building and are divided into five main categories : up-peak, down-peak, two-way, four-way and interfloor. For each type of building the floor population is either equal or unequal (included zero population in some floors).

In general, the arrival pattern varies with the type and other characteristics of the building. However in most cases the assumption is made, supported by observation, that arrival pattern conforms one of the well known statistical distributions such as Uniform, Poisson or Erlangian (Strakosh, 1967, Barney and Dos Santos, 1985).

In addition to these factors, passenger behaviour due to psychologigal and physiological factors should be taken into account in the design of an effective lift system.

Consideration of these factors leads to estimate in advance several parameters such as the expected number of stops, the mean highest reversal floor, the round trip time, the expected number of passengers in the queue, the mean waiting time, the mean number of busy lifts, the probability that a passenger arriving at each floor has to wait more than a certain amount of time. These parameters are blended to form a measure of performance of the lift system (Warning, 1986).

Owing to the multitute of factors that are involved in lift design, an expert system seems a reasonable alternative to tratitional methods used; it provides the designer with a relatively simple and inexpensive tool.

3. THE EXPERT SYSTEM APPROACH

Expert systems are a class of computer programs that attempt to solve problems in specific domains (using deductive reasoning) that normally require the expertise of a human specialist. Most expert systems are designed in such a way that, according to some logical rules and facts, can analyse, categorize and eventually arrive at an answer or consultation or diagnosis (Townsend and Dennis, 1986).

To do this, these programs simulate the reasoning of a human expert in a certain domain by means of a knowledge base containing facts and heuristics and of an inference mechanism for utilizing the store knowledge. As expert systems are computer-based and they function using the natural symbols of the computer, some type of interface must be added which can help the user communicate with the system. The user interface with an expert system usually consists of two functions: advice and explanation giving to the user and knowledge acquisition managing.The knowledge of human expert is mapped into a knowledge base. Then a dialogue begins between the user and the system while the inference mecanism analyses situations, establishes goals and draws conclusions (Wells and kulikowski, 1984; Henry, 1986; O'Keefe, 1985).

In most expert systems the interface needs a special process of determining how the parts of a sentence fit together. This process enable the user to use complete sentences in the dialogue with the computer by determining the subject ,verb, object and other parts of the sentences. Moreover, because most experts and users they do not trust a conclusion reached by any type of knowledge-based system unless they could query the system on how the decision was made, an explanatory interface is the component of the expert system that explains how the conclusion was reached.

The inference mechanism examines the existing facts in the working memory (or data base), which is a part of the expert system containing a set of facts that describe the current situation, adding new facts in the working memory, when possible and determines in which order the rules are scanned and fired. Thus, the inference mechanism could be considered as consisting of two parts: the inference and control. The inference part handles the task of examining rules and adding new and the control part determines the order of the inferencing.

Although an expert system approach has been shown to be quite effective and efficent in situations where most knowledge is normative, it is doubtful whether equally good results could be produced in the presence of prescriptive knowledge. One way of overcoming this problem is to enhance the expert system with a library of analytical or simulation models whose application to the problem domain would enrich the amount of knowledge available. The expert system LIFTES presented in this paper could be considered as a contribution towards the direction of blending prescriptive theories and traditional expert systems techniques.

The problem of lift system design provides a challenging area for applying the hybrid expert system approach due to the wide application of simulation and analytical techniques and due to the fact that lift systems design is an area of direct applicability and much interest to the industry.

4. DESIGN OF THE EXPERT SYSTEM LIFTES

The configuration of the expert system LIFTES consists of the following modules (Figure 1).

- a knowledge base which is divided into a rule-base stuctured as a set of IF-THEN rules that represent the knowledge required to solve a problem and a working memory where all facts concerning lift dynamics and building characteristics are stored. This includes facts derived from physical laws, human physiological and psychological characteristics and heuristics based on designer judgements.
- an inference mechanism whose purpose is to chain a set of rules in order to form a line of reasoning and to manage the whole system through a control component.

- a model library which contains analytical models.
- the model usage module which provides assistance to the user for selecting one or more models for the problem at hand.
- a user interface which establishes communication between the user and the expert system in a menu-driven form.

A special editor is used for addition of rules in the knowledge base and for modifications of these rules in the light of new findings. Another editor helps the user enter analytical models into the model library.

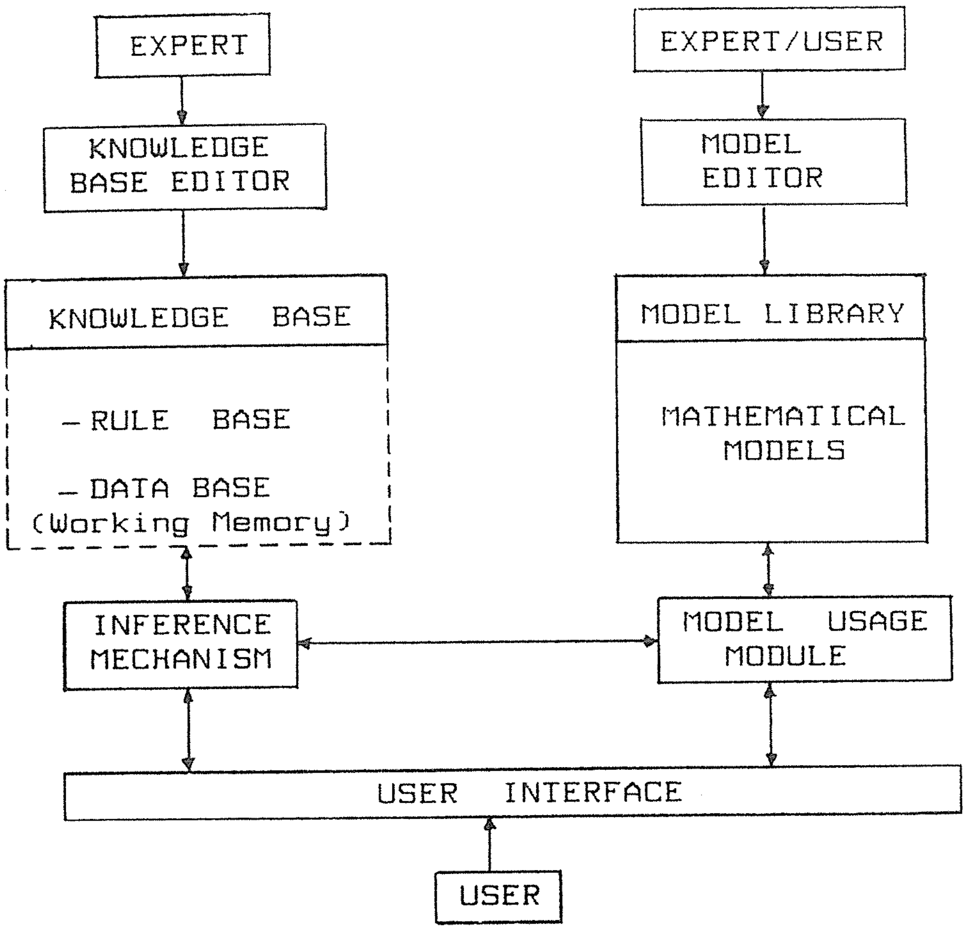

FIGURE 1. The configuration of the expert system LIFTES.

The expert system LIFTES has been specifically developed to run on the MS-DOS operating system which is well known to be an almost stardard operating system for microcomputers. This is compatible whith the objective set for the project to provide a tool for lift system design that would require minimal investment from the user. The main memory requirements of the system is about 250Kb.

The various modules of the expert system have been written in FORTRAN . The decicion to use FORTRAN and not one of the typical AI languages, such as LISP or PROLOG, was the result of several factors including compatibility with application software already developed by the authors, compatibility with generally available subroutines for lift system models and portability. The implementation language is irrelevant to the user, since the software is fully transparent to the user.

5. RUNNING A CONSULTATION SESSION.

The following example concerns the problem of determining the number of cars required to serve passengers within a specific time interval in multistorey building. Lift dynamics, number of floors and floor population of the building are given. The potential of dividing the building into zones to achieve better performance is also examined.

```
      .
      .
0161  IF
0162  PWAIT > 50  AND
0163  BUILDINGTYPE = "INSTITUTIONAL"
0164  THEN
0165  REJECT SOLUTION
      .
      .
0223  IF
0224  LOAD = "HIGH"      AND
0225  PWAIT = "NORMAL"   AND
0226  COST = "REASONABLE"
0227  THEN
0228  ACCEPT SOLUTION
      .
      .
```

FIGURE 2. Example of the knowledge base.

Figure 2 shows a relevant to the problem portion of the knowledge base. For instance, lines 0161 through 0165 constitute a rule, indicading that if passenger waiting time is greater than 50 secs and building type is hospital then the solution should be rejected. The fact that a "hospital" belongs to the broader category "institutional buildings" has been declared in an another part of the knowledge base.
Lines 0223 through 0228 show another rule stating that the

solution is accepted when the lift load is high, the passenger average waiting time is less than the upper limit specified and the situation is achived at a cost within the budget available. Other criteria for arriving at an acceptable solution such as lift safety and acceleration, are considered elsewhere in the knowledge base.

```
0010        PASSNO=LAMDA*INTAR
0011        DO 12 K=1,N-1
0012   12   MHRV=MHRV+(K*1./N)**PASSNO
0013        MHRV=N-MHRV
0014        ENS=N*(1.-((N-1.)/N)**PASSNO)
0015        RTT=2*MHRV*TV+(ENS+1)*TS+2*PASSNO*TP
```

FIGURE 3. Example of the mathematical model library.

Since several calculations are required to arrive at a decision, an appropriate model is neccessary to provide the working memory part of the knowledge base with additional data. The mathematical model invoked in this example is shown in Figure 3.

Line 0010 calculates the number of passengers carried in each trip, lines 0011 through 0013 calculate the average highest floor reached, line 0014 calculates the number of stops made above the main terminal floor and line 0015 calculates the round trip time.

```
C>LIFTES
@ ENTER PASSWORD :######

@******** WELCOME TO LIFTES **********

@      LIFTES - Command Sample
|-------------------------|----------|
| Create Knowledge Base   |  CKB     |
| Load   Knowledge Base   |  LKB     |
| Update Knowledge Base   |  UKB     |
| Load Library            |  LLB     |
| Run Consultation        |  RCL     |
| Print Results           |  PRS     |
| Enter Goals             |  EGL     |
|-------------------------|----------|

@ PLEASE ENTER A COMMAND :
@ NAME OF KNOWLEDGE BASE :
@ NAME THE MODEL :
@ NAME GOAL :
```

FIGURE 4. Sample of consultation session.

Figure 4 shows a transcript of the consultation session. After performing the necessary calculations and storing the results in the system's knowledge base (working memory part), a forward chaining search was conducted in order to evaluate alternative solutions. When the cost was specified to a certain low limit and the passenger waiting time was set to less than 50 secs the system responded that no solution could be suggested. Then a backward chaining search was conducted with the goal "Accept solution". The system suggested trying to divide the building into zones that would be served by a number of cars. However, additional information was required in order to suggest an optimal zone division. This information was provided by means of an empirical method developed by the authors but the system responded negatively again. The cost was then increased and a solution was arrived at suggesting that no zone division of the building was necessary.

6. CONCLUDING REMARKS

The integration of expert systems and traditional models provide the lift system designer with new powerful tools. The designer may be given some information at the speculative stage of a project or perhaps only when a sketch plan of the building is available. The expert system LIFTES advises the user about lift provision for several parameter values that depend on a number of eventualities or reasons and explains many peculiarities or anomalies that can arise. Further development of LIFTES with the inclusion of a simulation model library is currently under investigation.

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