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AIR-CONDITIONING EXPERT SYSTEM FOR BUILDINGS IN THAILAND

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บทคัดย่อ

ปัญญาประดิษฐ์เป็นศาสตร์ที่เติบโตอย่างรวดเร็วและอาจจะเป็นสาขาที่กำลังเป็นที่สนใจที่สุดในวิทยาการคอมพิวเตอร์ในขณะนี้ การประยุกต์ที่ประสพกับความสำเร็จมากที่สุดของปัญญาประดิษฐ์ก็คือระบบผู้เชี่ยวชาญ บทความนี้อธิบายถึงหลักการและการพัฒนาระบบผู้เชี่ยวชาญ การปรับอากาศสำหรับเครื่องไมโครคอมพิวเตอร์ 16 บิท ฐานความรู้ประกอบด้วยข้อมูลสำหรับการวิเคราะห์ภาระความเย็นสูงสุด และการเลือกชนิดของระบบปรับอากาศที่เหมาะสมสำหรับอาคารที่ตั้งอยู่ในภูมิอากาศที่ร้อนและชื้นเช่นประเทศไทย ลำดับขั้นตอนสำหรับการคำนวณภาระความเย็นเป็นไปตามคำแนะนำของ ASHRAE และสามารถทำการคำนวณได้ 12 เดือน พร้อมกับการหันของอาคารไปในทิศต่าง ๆ ได้ 8 ทิศ ผู้ใช้โปรแกรมสามารถเลือกค่าตัวประกอบต่าง ๆ เช่น ค่า U อัตราการระบายอากาศ ค่าความร้อนจากคน และอื่น ๆ ได้จากเมนูบนจอภาพ หรืออาจจะระบุค่าอื่นตามที่ผู้ใช้ต้องการได้

ฐานความรู้สำหรับการเลือกชนิดของระบบปรับอากาศประกอบด้วยเครื่องปรับอากาศ 10 ชนิด ในการเลือกจะคำนึงถึงตัวประกอบต่าง ๆ เช่น ขนาดของอาคาร น้ำสำหรับการระบายความร้อน วิศวกรประจำอาคาร ตัวประกอบทางด้านเศรษฐศาสตร์ เป็นต้น ระบบผู้เชี่ยวชาญเป็นระบบที่ใช้กฎหรือระบบโพรดักชันพร้อมกลไกวินิจฉัยแบบย้อนกลับ ระบบจะสามารถระบุระดับความมั่นใจสำหรับระบบปรับอากาศที่เลือกมาด้วย

ภาษาที่ใช้ในการสร้างระบบผู้เชี่ยวชาญคือ ภาษาโปรล็อก สถาปัตยกรรมของระบบผู้เชี่ยวชาญประกอบด้วย ฐานความรู้ กลไกวินิจฉัย และการปฏิภาคด้วยภาษาธรรมชาติที่ดีจนกระทั่งไม่ต้องใช้คำสั่งพิเศษใด ๆ ดังนั้นระบบผู้เชี่ยวชาญจึงเหมาะสำหรับวิศวกรระบบปรับอากาศในการนำไปใช้วิเคราะห์ภาระความเย็นสูงสุด และเลือกระบบปรับอากาศสำหรับอาคารในประเทศไทย

ABSTRACT

Artificial Intelligence is a fast growing area and probaby the hottest things to ever happen to computer science. The most successful application of AI is in the area of expert systems since they can mimic the behavior of human experts in certain well defined knowledge. In the present paper, the principle and development of an air conditioning expert system for 16 bits microcomputers have been described. The knowledge base contains database for peak cooling load analysis and air conditioning system selection for buildings in hot and humid climates such as Thailand. The procedure for cooling load calculation closely follows the ASHRAE recommendation and capable of doing twelve-month calculation with eight directions of building orientation with respect to solar load. Factors such as U values, ventilation rate; occupant heat gain, etc., can either be selected from the driven menu or specified by the users. Hence, practically almost no air conditioning manual is required.

The domain knowledge of system selection part consists of ten air conditioning unit types to be inferred to suit the characteristics and usage of the buildings by considering various factors such as size of building, availability of cooling water and maintenance engineer, economic factors, etc. The expert system is a rule-based or production system with backward-chaining inference engine capable of concluding system selection at different certainty levels depending on whether all or some of production rules have been satisfied.

The language used in building the present expert system is Prolog with the concept of modular programming. The architecture of the expert system comprises knowledge base, inference engine, any natural language interface. The user interface is excellent and does not require and special commands. Thus, this expert system is a very convenient tool for air conditioning engineers to consult on cooling load analysis and system selection for buildings in hot and humid climates.

INTRODUCTION

Artificial intelligence (AI) is a fast-growing area in computer science. Not until the 1980s has AI gone from minimal academic interest to probably one of the major areas of computer science. This rapid change is probably due to several factors, such as the advancement and availability of AI language, including Prolog, Lisp, and so forth; the success of expert systems; more successful application examples of AI; and the Japanese commitment of Prolog as the fifth-generation AI language.

The most successful application of AI is in the area of expert systems (ES). Expert systems can be loosely defined as computer programs that mimic or immitate the behavior of human experts, especially in making decisions and recommendations. These systems use information supplied by the user during a consultation session to render an opinion on a certain subject. In other words, an ES asks the user to answer questions or directs the user to supply information until it can conclude a goal that presumably matches the required answers. The first successful ES was probably the medical diagnosis program called MYCIN (Shortlife 1981), developed in the mid-1970s.

The need for building ES for various applications is obvious since, unlike human beings, ES can be duplicated and can work constantly throughout the day, especially when the human experts are not always readily available. Hence, creating an ES for air-conditioning consultation will help young engineers work efficiently with less help from experts. Any successful installation of an air-conditioning system requires several steps which comprise some or all of the following:

- feasibility study and planning the project
- conceptual design
- analysis of cooling load
- system selection
- detailed design
- deliver design and specifications for bidding
- supervision and installation
- system monitoring and maintenance

In this paper, an air-conditioning expert system for 16-bit microcomputers has been developed. The knowledge base contains domain knowledge for peak cooling load analysis and air-conditioning system selection for buildings in hot and humid climates, such as in Thailand. The procedure for cooling load calculation closely follows the ASHRAE (1981) recommendation and is capable of doing 12-month analyses for eight building orientations.

The domain knowledge of the system selection consists of ten air-conditioning unit types commonly used in Thailand. The selection criteria are based on the characteristics, use, and constraints of the building, considering various factors such as the size of the building, availability of cooling water, economic factors, qualifications of the building engineers, and so forth.

The ES is a rule-based or production system with a backward-chaining inference engine. The AI language used for this development is Prolog.

Architecture of an Expert System

The concept of modular programming has been employed in building this ES by dividing the ES into modules which in turn can be further divided into submodules. After each module has been tested and proved correct, all the modules are linked to form a complete project. The architecture of the ES is shown in Figure 1, and each part is described below.

Knowledge Base. This part is a database that holds specific information and rules about a specific knowledge. In Prolog, this information includes facts and rules about that knowledge. The knowledge base consists of two parts : static and dynamic databases. The static database is the collection of facts and rules created within the knowledge base by the knowledge engineer during ES building. This part of knowledge will always remain unchanged during the consultation process. For the cooling load calculation part, the examples of static database are

- cooling load temperature difference (CLTD) for roofs at different solar time
- CLTD for walls at different solar time and building orientation
- solar heat gain factor (SHGF) and cooling load factor (CLF) for different types of glass
- rules for various heat gain calculations
- rules for psychrometric calculations
- sensible and latent heat gains from occupants

For system selection, the static database consists of the description, characteristics, and constraints for each system in relation to the buildings and applications, mostly represented in rules of the IF-THEN type.

The dynamic database is the collection of facts and information obtained during the consultation process by asking the user to answer questions or directing the user to supply information until a goal or conclusion is reached. In other words, besides the existing knowledge, the static database, the ES can learn more and more by itself through the consultation process.

For the cooling load analysis example, ES will ask or direct the user to supply the information for walls, floors, roofs, the month required in the calculation, building characteristics, and so forth. The dynamic database resulting from this information is the heat gain for each item. The process continues until the goal, or the total cooling load, is obtained.

For the system selection, the users have to supply the following information :

- the range of estimated cooling load
- the size of the building
- the availability and qualifications of building engineers
- the available space for machine room, cooling tower, etc.
- the constraint of initial investment

In general, the ES domain knowledge can be classified into three categories, namely :

- General knowledge : Knowledge about general characteristics of air-conditioning plant, cooling load factors, heat gain factors, etc.

- Constraint knowledge : Constraints imposed by the refrigeration plant, air-conditioning unit, availability of space, etc.
- Procedural knowledge : Knowledge of how to do psychrometric calculation, rules for cooling load calculation, etc.

Inference Engine. The Inference engine or decision-making part of an ES uses facts and rules within the knowledge base, including those obtained during the consultation process, to find an object that matches the desired goal. This is the most important part of ES. Besides its decision-making function, the inference engine controls the efficiency of ES. Popular types of the inference engine are the backward-chaining, forward-chaining, and hybrid-chaining methods. Due to convenience and the inherent character of Prolog, the backward-chaining method has been chosen for this ES development.

Natural Language User Interface. Interfacing the user to a microcomputer is an excellent means of facilitating the use of ES. In this ES, questions and answers on the screen have been made simple, and no special command is required. Hence, any air-conditioning engineer can master this expert system within an hour.

Explanatory Interface. In ES terminology, the explanatory interface is usually the capability of an ES to explain why that it is asking a certain question or how it comes to a conclusion. This is usually done by bringing up a reasoning chain on the screen. The only part that might require this capability is the system selection. However, considering the relatively simple knowledge base, there is no need to include such a capability.

Knowledge Aquisition System. Knowledge aquisition is the process of building up the knowledge base with specific knowledge. Ideally, the domain expert should be able to access the ES shell without a priori programming knowledge. Also the ES should be able to update its own knowledge by learning from experience from previous cases. However, this type of system is still being researched and an effective system is yet to be invented. Hence, the knowledge engineer acts as the missing part in the knowledge aquisition system by looking up facts in documents or handbooks, or interviewing people well-versed in the subject.

Domain Knowledge

The proper partition of the domain knowledge into subdomains facilitates the development of ES. The entire domain can then be understood in terms of its subdomains and their interrelationships. Figure 2 shows the hierachical decomposition of the domain knowledge. The breakdown of the system selection into subdomains is based on the type of air-conditioning units in use in countries with hot and humid climates, notably in Thailand.

Knowledge Representation

As previously mentioned, domain knowledge can be classified as general knowledge, constraint knowledge, and procedural knowledge, represented as facts and rules in Prolog. The recommendation for system selection includes a certainty factor, which depends on how many conditions fit the description of the particular type of air-conditioning unit. This certainty factor is assigned on a heuristic basis, which relies on the collective experience of the domain experts. An example of a simple rule relevant to the system selection is as follows:

IF:

the total cooling load is between 100 to 450 TR and
the space requires central distribution and
there is space for ducting and
there is space for water piping and
there is outdoor space for a cooling tower and
there is space for a central machine room and
there is a good and reliable water supply and
the expected life of the system is about 15 to 20 years

THEN

the system may be a water-cooled, reciprocating water chiller with Certainty Factor F

AND CONFIRM IF:

there is large variation in cooling load and
there is an engineer for operation and service and
constraint on initial investment is moderate and
low noise is necessary for the air-conditioning space and
the interior appearance of the building is important and
the operating hours per day is between 10 to 16 hours

Conclusion

An expert system for air-conditioning consultation has been developed in Prolog. The expert system is a production system with a backward-chaining inference engine. The expert domain consists of two main parts: the peak cooling load analysis and the system selection. The procedure for cooling load calculation closely follows the ASHRAE recommendation. However, only CLTD data for certain construction materials used in most buildings in Thailand have been included in the knowledge base. Eight directions of building orientations can be selected for the calclulation for each month. The domain knowledge of the system selection part consists of ten types of air-conditioning units presently in use in Thailand. The expert system is suitable for IBM compatible microcomputers and has been used by many air-conditioning engineers in Thailand.

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