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A Common Knowledge-based Expert System for Military Maintenance Support System

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1. Introduction

This paper presents a description of a novel approach to development of an expert system and a datailed view of the components of the VEMES model developed by empolying the new approach.

The approach and expert system model described in this paper are specifically designed to fit the Korean Army truck maintenance system. However, the model is intended to be adaptable to other expert system domains as well. In the following section, as a preliminary step, we will review and describe major features of existing expert systems which are relevant to the VEMS model.

2. Review of Relevant Expert Systems

Emerging as an application of artificial intelligence, expert systems have been developed for a number of problem domains. Examples of those having features relevant to the VEMES model development will be explained as follows;

MYCIN[SHO76] is a classical example of a production rule-based system. The task of MYCIN is diagnosis and therapy of certain classes of infections blood diseases. One of the key features of MYCIN is an explanation facility for end-users and knowledge engineers.

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ACE(VES83) identifies trouble spots in telephone networks and recommends appropriate repair and rehabilitative maintenance. It uses the productions rule-based knowledge representation scheme and control is accomplished by forward chaining. One interesting feature of ACE is that it has the capability of retrieving data from a data base.

DELTA(BON84) helps maintenance personnel to indentify and correct malfunctions in diesel electric locomotives by applying diagnostic strategies for locomotive maintenance. The system provides computer-aided drawings of parts and repair instructions from information stored on videodisc.

Other systems such as CASNET(WE178), COMPASS(GOY85), DART(BEN81b), IDT(SHU82), LES(PER84), NDS(WIL83), and ROTES(KAW84) are relevant expert systems which we reviewed.

All the existing expert systems reviewed are generally modeled on the basis of human experts, and the basic system framework consists of a knowledge base, an inference engine, and a working memory. In addition, most of the existing systems have a user interface to facilitate the use of the system. In some systems, an explantion facility (or report system) is also included, allowing the user, to challenge and examine the reasoning process underlying the system's answer. The framework reveals an interesting characteristic. Without exception, all the existing expert systems have been developed by employing a single knowledge-base for storing specific domain expertise, although the details of implementation, to meet the needs of the specific problem domain, have been somewhat different. For convenience, we term their framework as a 'single knowledg-base approach' as shown in Figure 1. This is to be compared with our new approach, a "common knowledge-base approach", described in section 4.

3. A Distinguishing Characteristic of the Military Equipment Domain

The underlying framework of the existing expert systems and their features as compared with the environments of the Korean Army truck maintenance system, direct application of their framework and features does not appear to be appropriate. This is due to a distinct

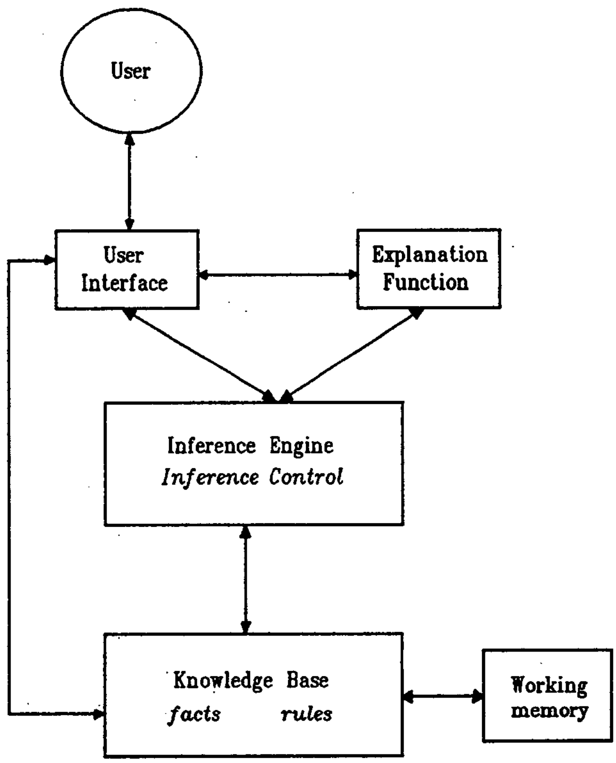


Figure 1. Single Knowledge-Base Framework.

characteristic of the Army equipment system.

In the military equipment environment, there are many situations wherein several different types of equipment share the same technology for their subsystems. For example, military trucks to be considered here (i. e., M900 series trucks and M700 series trucks) use the same technology in several subsystems such as the brake subsystem and the electrical subsystem. Accordingly, even though the usage and capability of the two types of truck are different, the maintenance knowledge of each subystem of the two types of truck must be the same from the maintenance soldiers point of view. In this case, if we employ the single knowledge-base approach for building expert systems, then there may be several possible disadvantages. We will employ three different types of truck to explain the disadvantages.

Supose there are three types of trucks, type 1, 2, and 3, and each of the trucks use the same technology in subsystem 1. Logicaily, the maintenance knowledge of subsystem 1 for the three types of trucks must be identical. For ease of exposition, let's suppose rule set 1, procedure set 1, and diagram 1 represent the maintenance knowledge of subsystem 1. Conceptually, three expert systems, which employ the single knowledge-base approach, can be diagrammed as shown in Figure 2.

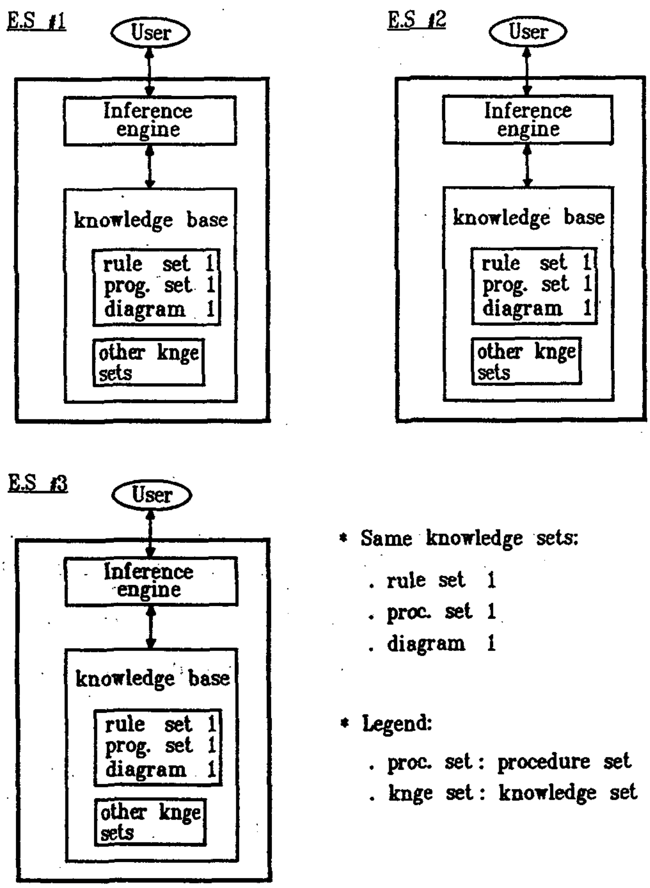


Figure 2. Single Knowledge-Base Approach for Multiple Expert Systems

As depicted there, all three expert systems redundantly contain the same knowledge sets. This phenomenon, knowledge redundancy, is due to the fact that the single knowledge-base approach focuses on the knowledge need of an expert system corresponding to each of the problem domains. That is, within the single knowledge-base approach, the knowledge engineer collects problem-solving knowledge sets for each of the three types of truck, possibly one at a time, and store the knowledge sets within the knowledge base of the corresponding expert systems. Accordingly, the single knowledge-base approach inevitably causes the three expert systems to contain identically the same knowledge sets.

From the conceptual diagram and our earlier discussion, we can logically conclude that this knowledge redundancy results in several possible disadvantages in the context of expert systems. These include low knowledge engineer and system programmer productivity, potential inconsistency of knowledge, excessive amount of effort required for the knowledge-base maintenance, and waste of storage (even though this may not be sigificant).

In order to alleviate the aforementioned drawbacks of the single knowledge-base approach, there is a need to develop an alternative approach. Here, we propose a "common knowledge-base approach." In the following section we will define this notion and present a generic framework.

4. Common Knowledge-Base Approach

To explain the cammon knowledge-base approach we need to formally introduce some concepts. After developing a generic framework for common knowledge-based expert systems, we describe anticipated benefits to be derived from this approach.

4.1. Concept and Definitions

In expert system terms, knowledge is information about facts, beliefs, and heuristic rules, which can be used for problem-solving in some domain of interest [HUN86] and can be represented in the form of production rules, textual procedures, diagrams, and so on [HOL87].

As discussed in the previous section, in cases like the the military equipment domains, several different expert systems may redundantly contain the same knowledge sets. For convenience, we term these knowledge sets "common knowledge" and define the term as follows.

Defintion of Common Knowledge :

In an expert systems context, we define common knowledge as the knowledge which belongs to several different expert systerms, but which is used for solving a common problem. It can be represented in various forms such as rules, text, and diagrams.

It is possible to collect the common knowledge in a common base and have several expert systems share the common knowledge. Accordingly, as a corollary of the term common knowledge, we intorduce the notion of a "common knowledge-base" and define it as follows.

Definition of Common Knowledge-Base :

In an expert systems context, we define a common knowledge-base as a collection of common knowledge that is shared by several expert systems for solving the same problems. The common knowledge-base concept enables us to develop a novel expert system framework similar to data base applications. This framework will be described in the following section.

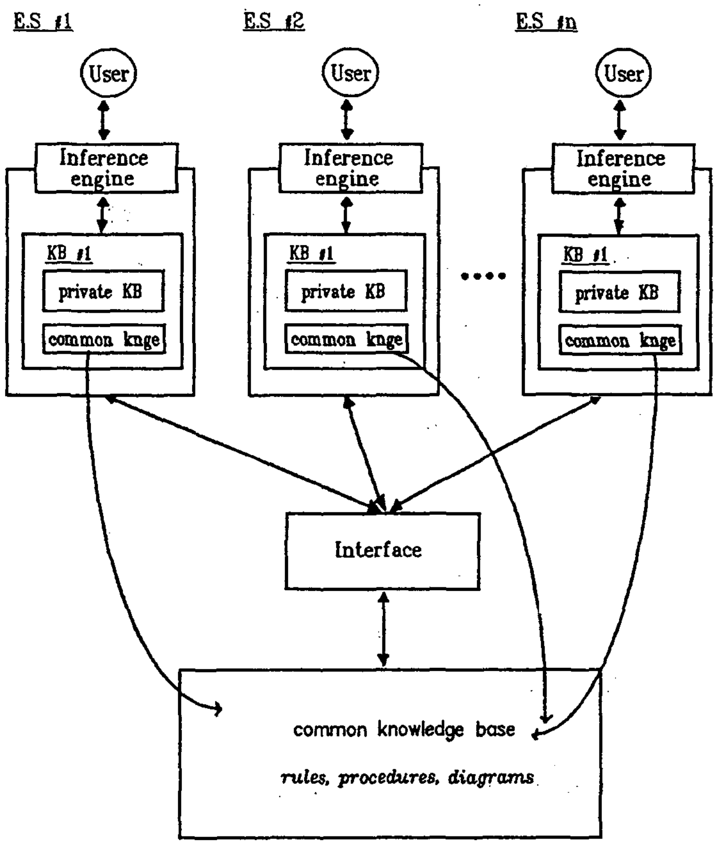
4.2 Generic Framework of the Common Knowledge-Base Approach

Figure 3 shows a generic framework of the common knowldege-base approach. As shown in Figure 3, each expert system has a private knowledge base for its own use. For instance, knowldege base 1(KB#1) is the private knowledge base for expert system 1, knowledge base 2(KB # 2) for expert system 2, and so on.

Here, rule set 1, diagram 1 and procedure set 1 represent the common knowledge. As discussed, in the single knowledge-base approach the knowledge sets are redundantly stored in the private knowledge-base of each expert system.

However, in the common knowledge-base approach, each expert system contains only its own distinct knowledge sets, and the common knowledge sets are stored in a separate common knowledge-base. The individual expert systems and the common knowledge-base are linked by an interface. Through the interface, the common knowledge stored in the common knowledge-base can be shared by several expert systems at any time.

In this apporach, the common knowledge is viewed as a shared resource that can be used by several expert systems. Therefore, the common knowledge-base concept is a new notion rooted in an attitude of sharing common resources. The notion represents a different



Legend : KB - knowledge base
knge - knowledge

Figure 3. Common Knowledge-Based Framework

concept in knowledge base management in the context of expert systems, providing several potential advantages such as reduction of inconsistency, and reduced knowledge-base maintenance effort. The advantages will be addressed in detail.

(1) Knowledge Consistency : By employing the common knowledge-base approach, knowledge redundancy can be effectively eliminated (or controlled) and thus the opportunities for inconsistency greatly reduced. In other words, with this approach, replication of storage of common knowledge can be minimized. Accordingly, when there are changes of the content of the common knowledge-base less effort will be required to update the changes, and thus the opportunities for disagreement on the content of the common knowledge base among expert systems will be reduced.

(2) Reduced effort of knowledge-base maintenance : Stored knowledge must be revised, modified, and added frequently for a variety of reasons. These changes require updating the expert systems that access the knowledge. A common knowledge-base approach can reduce the effort considerably by reducing unnecessary processes of collecting old versions scattered around many locations, making copies and redistributing new versions in turn.

(3) Knowledge Sharing : As discussed in earlier section, the common knowledge-base approach permits multiple expert systems to share the knowledge stored in the common knowledge-base. This means that multiple users can share the common knowledge even if the users do not have the knowledge sets within their own expert system. No knowledge sets in the common knowledge-base are owned by any one expert system.

Furthermore, the common knowledge-base approach implies not only that existing expert systems can share the knowledge in the common knowledge-base, but also that new expert systems can be developed to anticipate use of the existing common knowledge-base.

(4) Minimal Knowledge Redundancy : With the common knowledge-base approach, common knowledge sets which were previously stored in separate (and redundant) knowledge files are pooled into a single common knowledge base and used by many expert systems.

By using this approach, knowldege redundancy can be reduced. However, we do not mean to suggest that all redundacy should necessarily be eliminated. There can be sound reasons for maintaining mulitiple copies of the same knowledge. In a military truck environment, some remote units may keep only one or two types of trucks, and in this case we may want to keep individual expert systems for each type of truck. In the common knowledge-base approach, however, redundancy can be controlled

5. VEMES Model

Based on the generic framework of the common knowledge-base approach we developed an underlying model of VEMES. Before we describe the components of the model we will define the common knowldege in the intended context.

5.1 Common Knowledge of the VEMES Prototype

Here, we only deal with two subsystems, engine and brake subsystems, for the problem domain of the VEMES porototype. In the Korean Army equipment system, the two types of truck use exactly the same technology, an air-hydraulic brake system, for the brake subsystem. On the other hand they use different engine systems. M900 trucks have diesel engines, while M700 trucks have gasoline engines.

Although the size and power of the two types of truck are different, the basic technology, configuration, and locations of the brake subsystems of the two types of the truck are the same, and thus maintenance knowledge of the subsytem is equivalent from the maintenance soidier's view point, Accordingly in the VEMES prototype, the maintenance knowledge of the air-hydraulic brake subsystem will be common knowledge, and thus a collection of the maintenance knowledge sets(rules, procedures, diagrams) can be stored in a common knowledge-base.

On the other hand, since each type of truck uses different technology for the engine subsystem, the detailed maintenance knowledge must differ. Consequently, we will put the detailed maintenance knowledge of the two types of engine subsystem in separate private knowledge bases for each expert system.

5.2 System Requirements

Two major functions of the military maintenance support system are the maintenance support function, and the recording & reporting function. Accordingly, the underlying requirements for the VEMES model are :

(1) to provide maintenance knowledge to inexperienced maintenance soldiers on a real time basis :

(2) to provide automated recording and reporting capability for recording maintenance activities and producing reports to meet ad hoc requests.

These two requirements can be satisfied by merging two technologies, i. e., a common knowledge-based expert system and a data base system. In the following section, we will describe the VEMES model which results from merging these two technologies.

5.3 VEMES Prototype Model

Based on the common knowledge-base approach and relevant expert systems' features we develop a model for the VEMES prototype in order to meet the requirements discussed in the earlier section. Although the model is specifically designed to fit the Korean Army maintenance system, it may be adopted to other applications.

VEMES consists of two individual expert systems (the M900 expert system and the M700 expert system), a common knowledge-base, a data base, a common knowledge-base interface, a data base interface. The system model is shown in Fugure 4 and explained in the following paragraphs.

Individual Expert System :

Here, M900 E.S. (M700 E.S.) is the maintenance expert system for the M900 (M700) series truck. Essentially, the configuration of the individual expert system follows the traditional single knowledge-base approach which we described in Section 2. Hence the basic co mponents are a knowledge-base, an inference engine, a working memory, a user interface, and an explanation facility as shown in Figure 5.

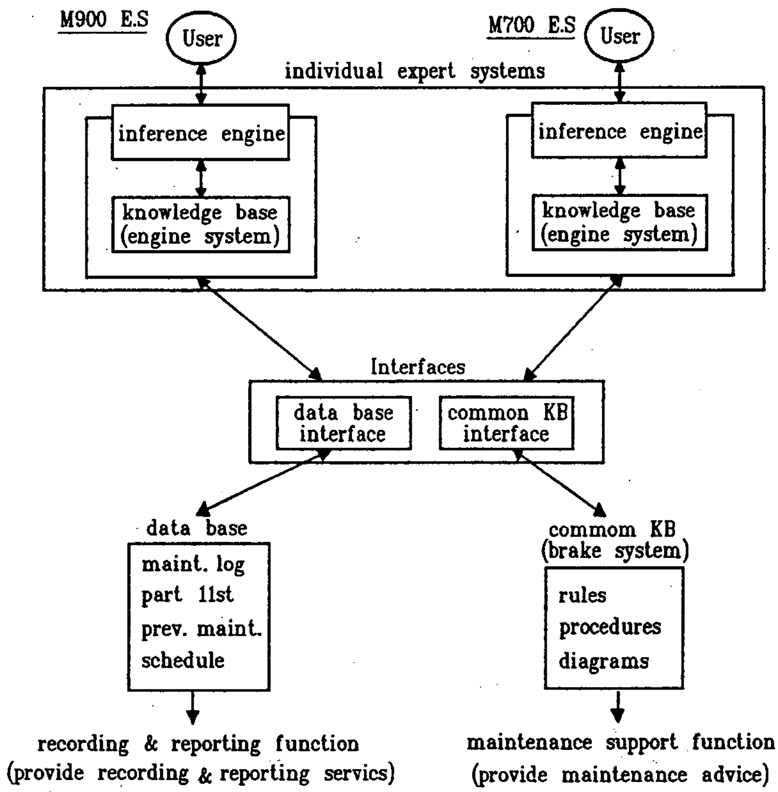


Figure 4. Underlying Model of the VEMES Prototype.

In addition to these components, we add one component, the problem library. The purpose of this component is to expedite searching for knowledge relevant to a specific consultation problems of interest. It works as an index of all problem-solving knwoledge which resides in the knowledge bases (including the knowledge in the common knowledge-base)

Common Knowledge-Base :

The common knowldege-base contains the maintenance knowledge of the air-hydraulic brake system. The knowldege is represented in the form of production rules, check and repair procedures, and diagrams. It is shared by the two expert systems through an common knowledge-base interface.

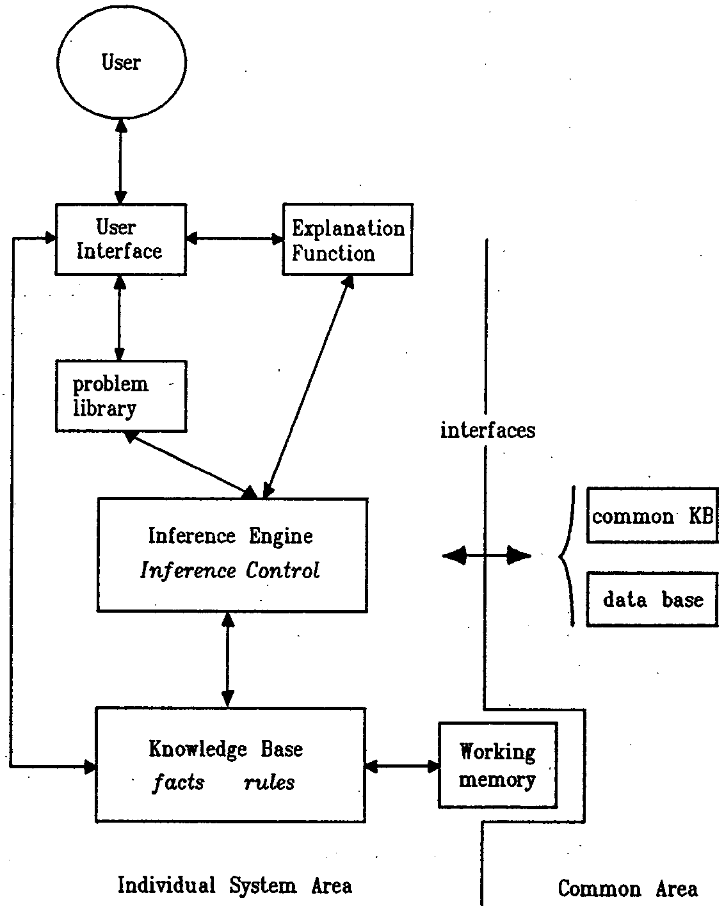


Figure 5. Individual Expert System

In many cases, inexperienced maintenance soldiers need the supplementary information for implementing "what to do" suggestions. This "how to implement" knowledge can be easily represented by textual procedures. Sometimes, they also also need to refer to diagrams of subsystem to make sure the exact check or repair point. For this purpose, diagrams of the subsystem are applicable.

Data Base :

The data base contains factual data about maintenance history, parts status, and preventive maintenance schedules. These data are shared by the expert systems through the data base interface. The user can directly record all the activities or change the content of the data base and use the data base for producing various maintenance management reports such as preventive maintenance schedules and the safety level of parts.

Common Knowledge-Base Interface :

In order to utilize the common knowledge stored in separate location the individual expert systems need a menans to invoke the common knowledge-base. The common knowledge-base interface is a means to provide this function. A user of an expert system can access the common knowledge-base through the interface and thus the user can have consultation with the common knowledge-base as if it were resident in the local expert system.

Data Base Interface :

The Data base interface provides correspondence between the expert systems and a data base. Kellog[KEL82] successfully attempted to merge English-like natural language and a data base, although not in the context of expert system. Based in Kellog's idea Vesonder[VES83] attempted to merge the two technologies in the context of expert system (an expert system, ACE) in a limited fashion and proved it to be useful for augmenting the consulting capability of the expert system.

Our approach is to use independent interface modules which can provide interfaces to several expert systems. By this approach several expert systems can refer to the content of a data base, record results of maintenance activities, and produce various maintenance reports.

6. Contributions

The efforts described in this paper offer several contributions to both the researchers and practitioners.

First, a notion of common knowledge-base has been developed. The notion reperesents a novel concept in knowledge base management in the context of expert systems. Common knowledge is viewed as a shared resource that can be used by many expert systems. In addition, in a practical sense, by adopting this notion practitioners can build expert systems with advantages.

Second, a suitable expert system model for the Korean Army maintenance system has been developed. The model deals with not only the traditional expert system's function (i. e., provision of expert's knowledge), but also with maintenance management function (i. e., the recording and reporting of maintenance activities). Based on this one underlying model, it is anticipated that many military expert systems can be developed.

7. Conclusion

In this paper, we proposed the notion of a common knowledge-base and designed an expert system framework based on the notion. The VEMES model described has been developed by merging this framework with a data base.

Although we developed a new approach, the common knowledge-base approach, with several possible advantages as discussed earlier, we do not suggest that it is beneficial in all situations. In many cases, even if several expert systems share some common knowldege sets, the portion of a common knowledge within the whole knowledge base may be very small and thus negligible. In this case, we may not need to establish the common knowledge-base. Therefore, knowledge engineers should carefully examine the benefits of the common knowledge-base when they consider this approach.

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