CHAPTER 5: KNOWLEDGE ACQUISITION AND REPRESENTATION ISSUES

This chapter discusses different knowledge acquisition and representation techniques used in the design and development of expert system. The issues related to the knowledge acquisition and representations of ESQs are discussed.
5.1 Introduction

There are several problems to be challenged when implementing an expert emulation approach in the design of an expert system. The first one is choosing a suitable expert in the specific domain. The second one is finding suitable knowledge acquisition techniques to aid the elicitation process and the third and the last one is that there is a need for knowledge representation of the area of syllabus to be tested.

This chapter first lays the foundation for knowledge acquisition by describing the context in which the research is conducted. In a face-to-face classroom teaching, an expert/teacher always performs adaptive testing when assessing a student’s knowledge in a subject domain on a one-on-one interaction. Different Knowledge acquisition techniques are discussed in this chapter.

In the expert system development process, Knowledge Representation (KR) is an important issue mainly because of two reasons: (a) It affects the development, efficiency, speed and maintenance of the system, (b) Expert system shells/tools are designed for a specific type of knowledge representation such as rules or logic.

This chapter discusses some Knowledge Representation (KR) techniques. Section 5.2 describes knowledge acquisition and section 5.3 explains different knowledge acquisition techniques. In section 5.4, I have discussed the knowledge acquisition issues related to the design of ESOA. Section 5.5 describes the context in which expert emulation is carried out and section 5.6 describes different knowledge representation techniques. A comparison of Knowledge Representation techniques that are being used in expert system design are presented in Section 5.7.
The knowledge representation issues in ESOA are discussed in section 5.8.

5.2 Knowledge Acquisition

There are several steps in knowledge engineering process. All the steps need to be completed for an effective expert system design. Domain identification is the first step. It is an important step as better domain knowledge may yield a better expert system design. In this process, Knowledge Acquisition process is the next important step. This step is not only time consuming but also known as the greatest bottleneck in the expert system development process. This step requires knowledge engineers to extract data, information and knowledge from experts of the identified domain, or from other resources like books and journals. After obtaining data, information and knowledge, knowledge engineering present them in a machine-usable form. All these steps, starting from domain identification to presentation is referred to as knowledge acquisition and presentation process. How to acquire knowledge efficiently from a domain and represent it in an appropriate computer format is an extremely difficult and challenging task. As a result, huge efforts can be seen in this research, and over the years many knowledge acquisition methods have been discovered. Although, studies suggest that there is no perfect method but there are suitable methods for almost every domain. However, a technique that is suitable for one domain may not necessarily work for other domains. As a knowledge engineer one must discover a suitable method for his application domain.

Moreover, we must understand that knowledge elicitation has certain issues we must be aware of (Epistemics, 2003). Such as that even if we
extract knowledge from books, journals, and other written resources, it is not enough, our knowledge base will still be lacking the knowledge that remains locked up inside the experts’ heads’. We must also keep in mind that experts time is valuable thus it is hard to keep him away from his work for long periods of time to extract the knowledge he has.

Another couple of issues we must understand are that even though experts have immense knowledge, yet they do not have all the knowledge of that domain, and that knowledge when extracted has a “shelf-life”. As if to say, the knowledge has an expiration date in certain domains, where the information must be updated or it is of no use to the system.

Another important issue in this process is the unclear or tacit knowledge that we must extract from the experts, who cannot explain to us this type of knowledge, it is a hard process and in some cases impossible.

With these issues in mind, engineers must learn to adapt or work around them. For example, since experts are too busy, why not take them out of their current jobs for a period of time, also, do not depend on a single expert, interview more than one expert, and try and extract as much knowledge as possible, also make sure the knowledge is well maintained and validated on regular basis.

5.3 Knowledge Acquisition Techniques

According to Epistemics (2003), some of the knowledge acquisition techniques are:
1. Protocol-generation techniques which include a variety of types that range from interviews (unstructured, semi-structured and structured), to reporting techniques and observational techniques.

2. Protocol analysis techniques are used with transcripts of interviews or other text-based information to discover the different types of knowledge, such as goals, decisions, relationships and attributes.

3. Hierarchy-generation techniques, such as laddering, are used to build taxonomies and other hierarchical structures such as goal trees and decision networks. Laddering means the creation, reviewing, and modification of hierarchal knowledge.

4. Matrix-based techniques are about constructing grids in which they indicate things such as problems encountered against possible solutions or hypotheses against diagnostic techniques. Frames are considered an important type used with these types of techniques because we can represent properties of concepts. Matrices are mostly used to validate knowledge rather than elicit it.

5. Sorting techniques are used for capturing how people compare and order concepts, and can lead to the revelation of knowledge about classes, properties and priorities.

6. Limited-information and constrained-processing tasks are techniques that either limits the time and/or information available to the expert when performing tasks.

7. Diagram-based techniques include the generation and use of concept maps, state transition networks, event diagrams and process maps. The use of these is particularly important in capturing the "what, how, when, who and why" of tasks and events.
5.4 Knowledge Acquisition Issues in ESOA

The knowledge used in expert systems may be two types: (1) Factual knowledge and (2) Heuristics knowledge. Factual knowledge can be referred as the knowledge of the problem domain which is found in textbooks or journals and these types of knowledge are represented usually in most of the expert systems developed for diagnosis purposes. Heuristic knowledge is domain specific and learned from experiences or from a mentor. ESOA is designed with modular structure. Three modules are used in the system: (a) knowledge acquisition module (b) student/learner module (c) expert assessment module

In our expert system, the knowledge acquisition module consists of three elements: domain expert, teaching expert and student model. There is however a significant difference in the timing of that acquisition. For the domain expert and the teaching expert, the knowledge is acquired before (or while) the system is built. There is a growing literature on the subject of knowledge acquisition for expert systems in general (McGraw & Harbison-Briggs, 1989). In the case of the student model however, some of the knowledge are acquired during the tutorial intervention. This implies a two-stage approach to knowledge acquisition. First the student modeller must obtain information (off-line from expert teachers) about the kinds of information it should try to obtain. Then it must obtain that information on-line from the student.

The student/learner module is used to identify a student’s current state of understanding of the subject domain (described in chapter 2). The knowledge that describes the student’s current state of knowledge is stored in the student model. The student module should permit the
system to store relevant knowledge about the student and to use this stored knowledge to adapt the instructional content of the system to the student’s needs.

The Expert assessment module is responsible to provide questions to each of the students by analysing the student model and providing some intelligent feedback after each assessment process.

5.5 Context

This section describes the context in which expert emulation is carried out. It describes the choice of experts, the type of students under study, the choice of domain, and the role of the expert in his interaction with his students.

5.5.1 Choosing an Expert

The task of finding a suitable expert is not an easy one. Firstly, the expert must be willing to participate in the elicitation process (Lightfoot, 1999). Secondly, there is the task of distinguishing a skilled tutor from a novice, in terms of experience in teaching and tutoring. For example, studies have shown that strategies of an expert differ from a novice in tasks such as problem categorization and tutoring. For example, in a study conducted by Glass, Kim, Evens, Michael and Rovick on the CIRCSIM Tutor, it was found that expert tutors are more likely than novice tutors to query students for information as opposed to informing them directly.

The validity of expert systems depends on the quality of the emulated experts. For the experimental work described in this thesis, a large number of experienced teachers were selected as experts. They have
been in the teaching profession for over ten years and have taught Computer Science subjects at various universities/colleges. They are familiar to interacting with students in a classroom setting as well as on a one-to-one basis. They have taught students from widely differing backgrounds and capabilities.

5.5.2 Types of Students

The type of student population under study is a non-typical one. This is a population of ODL (Open and distance Learning) learners, who do not share many of the characteristics of conventional classroom students. The key characteristics of this type of population are:

- the transient nature
- diverse educational and cultural backgrounds
- varying levels of prior knowledge in subject domain
- generally low academic achievements
- low motivation and confidence levels

5.6 Approaches to Knowledge Representation

According to Dictionary of Psychology (2001, p.405), Knowledge Representation (KR) is defined as “The encoding and storage of knowledge in computational models of cognition.” Knowledge is of primary importance in expert systems. In fact, an analogy to Wirth’s classic expression:

Algorithms + Data Structures = Programs

For expert system is

Knowledge + Inference = Expert Systems
Representation of Knowledge in computational models is a complex problem. Its complexity makes it difficult to devise good KR techniques. However, there are criteria for judging their goodness. The knowledge representation technique should not only be functional but also should able to explain the functionality and have provisions to store the pertinent data that may be needed to justify decisions at a given point of time. Among many, semantic networks, production rules and frames are the three main structures that more or less meet these criteria. Their properties and usage have been thoroughly investigated for encoding and storage of knowledge which is referred to Knowledge Representation techniques in computational models of cognition.

A good system for the representation of knowledge in a particular domain should possess the following four properties:

(a) **Representation Adequacy**: the ability to represent all kinds of knowledge that are needed in the domain.

(b) **Inferential Adequacy**: the ability to manipulate the representational structures in such a way as to derive new structures corresponding to new knowledge inferred from old.

(c) **Inferential efficiency**: the ability to incorporate additional information into the knowledge structure that can be used to focus the attention of the inference mechanisms in the most promising directions.

(d) **Acquisitional Efficiency**: the ability to acquire new information easily. The simplest case involves direct insertion, by a person, of new knowledge into the database. Ideally, the program itself would be able to control knowledge acquisition.
Unfortunately, no single system that optimizes all of the capabilities for all kinds of knowledge has yet been found. As a result, multiple techniques for knowledge acquisition exist.

The prevalent KR techniques are briefly reviewed next. Section 5.6.1 discusses the semantic networks, Section 5.6.2 discusses frames and in Section 5.6.3 production rules are discussed.

5.6.1. Semantic Networks

It has been used mainly to transform the natural language into a graph structure where nodes and edges correspond to concepts and relationships respectively. In this representation, nodes represent entities and classes of entities as well.

It is easy to use semantic representation if we’re implementing simple relationships between objects and classes.

5.6.1.1. Literature in Semantic Networks Representation

In the late 1980s, Ram and Wang (1988) researched an expert system, PMES (Protocol Machine Expert System), for communication protocol which later was implemented and tested on the Department of Defence's communication protocol TCP (Transmission Control Protocol). The network was used to represent the states of the finite state machine in each node. And with each communication protocol, the semantically built knowledge base is used to encode it. As a result, it has increased the standardization and efficiency of TCP.

In the area of information quality Zumegen (1990) presented a QIS, Quality Information System, which utilizes semantic networks supported by probabilistic inference.
A Fuzzy Expert System on Personnel Development, FESPD, developed by Ishikawa and Mieno (1992) can be considered a pioneer in its field because it assists decision makers when negotiating their employees’ future status such as demotion, promotion, and retirement, based on personal achievements, personality and other important factors that affect their decision. They exploited the benefits of semantic representation to analyse and create the possible future scenarios for the employees.

In the design of an expert system for assisting in hardware specification Chaouat et al., (1996) have used semantic network to represents all possible configurations for modelling the designs to serve their purpose by inferring the modelling rules and aiding the decision making.

Recently, one of the disadvantages of the semantic network which is the vagueness of the relationships between the nodes has been criticized (Bahrami, 2008). Bahrami combined the semantic network with XML to eradicate the disadvantage of semantics network. Their approach supports the definition of complex objects and relations.

5.6.2 Frames

Frames are useful for simulating common sense knowledge, which is a very difficult area for computers to masters. Semantic nets are basically two-dimensional representations of knowledge; frames add a third dimension by allowing nodes to have structures. These structures can be simple values or other frames. While semantic nets lack description of objects, frame representation fills that void. While Frames represent objects, the slots represent the description. Frames are known for their perfect reflection of domain knowledge, efficiency, default reasoning, and support for procedural knowledge.
Section 5.6.2.1 introduces some literature on frame-based expert systems.

**5.6.2.1 Literature in Frame Representation**

Smith and Clayton (1980) presented a paper which acts as a standard architecture for production expert systems and they introduced an experimental system called WHEEZE. It covers the same area as PUFF except it is frames-based representation and not rule-based. The test cases were successful and the system performed as successful as PUFF. They have offered flexibility and extensibility with their frame-based architecture.

Another successful study by Elio and de Haan (1985) present an expert system for a storm forecasting system. They incorporate rule and frame based representation in an expert system called METEOR. It predicts severe storms intensity and direction and factors which supports these predictions.

Kojima et al., (1989) put forward a paper for the development of power systems restoration methods. They favoured the use of object-oriented programming and frame representation due to the complexity of the domain and equipment. The prototype has proved that frames performed efficiently, and the expert system was flexible and stable.

Sasaki et al., (1989) also proposed a system in the same area of power systems, however it focuses on security of the power controls. It judges the power supply line operating conditions, and then displays the control options for the operators. The system proposed was built using frame representation to categorize the production rules into six categories. This made the access to modify the knowledge base easy.
The system is yet to be put to practical use, and still needs more tests, and the human input in decision is essential as well.

5.6.3 Production Rules

The simplest form of representation made of simple IF-THEN rules. They are condition-action, if a condition is met, corresponding rule is fired and action is taken. If more than one condition is met, corresponding rules are fired, and due to this conflict, no action is taken until a conflict resolution method results in selecting one rule, and then it performs the action of that rule. Their modularity, simplicity, and good performance are what make them most often used in simple domains. Moreover, when dealing with domains that contain complex relationships, rule base are not the best representation type since it is hard to deal with uncertainty as well.

The next Section 5.6.3.1 includes related literature to production rules.

5.6.3.1 Literature in Production Rules Representation

Buchanan and Duda (1982) present a research in the principles of rule-based expert systems. They state that simplicity, extendibility, and explicitness are the basic characteristics of knowledge representation techniques. And they include both MYCIN and EMYCIN as successful systems that integrate rule-based systems efficiently.

Clancey and Letsinger (1982) present a Rule-Based Expert System for Application to Teaching. NEOMYCIN is a medical consultation system in which MYCIN’s knowledge base is reorganized and extended for use in GUIDON, a teaching program. The new system constitutes a psychological model for doing diagnosis, designed to provide a basis for interpreting student behaviour and teaching diagnostic strategy.
Soe and Zaw (2008) present an expert system for network fault management. They have used production rules as their representation method. They proposed a design and implementation of the system, and state that rule-based representation was the best technique for describing real world domains as it was proved to be successful when tested.

5.7 Comparison of Knowledge Representation Techniques

This section compares all three techniques against the following criteria: expressiveness, efficiency, effectiveness and explicitness (Finlay and Dix, 1996).

- **Expressiveness**: Indicates how well a representation handles complex relations and structures, and maintains clarity to knowledge engineers and domain experts.

- **Effectiveness**: It portrays how well one can infer new knowledge from old, and how well the representation supports inferring tools.

- **Efficiency**: Knowledge should be gathered efficiently and represented efficiently.

- **Explicitness**: The ability to provide good reasoning and explanations.

Table 5.1 shows all three representation schemes against the four criteria elements.
<table>
<thead>
<tr>
<th>Techniques/ Criteria</th>
<th>Rules Representation</th>
<th>Semantic Networks</th>
<th>Frames</th>
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<tbody>
<tr>
<td>Expressiveness</td>
<td>Rules are very good at representing knowledge. The rules also support clarity.</td>
<td>Semantics allows the representation of relationships between nodes and it’s understandable</td>
<td>Frames include a more complex structure and inheritance is strengthened which increases clarity.</td>
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<tr>
<td>Effectiveness</td>
<td>Easily infers new knowledge using inference techniques.</td>
<td>The inference is through property inheritance which can be easily done through the different AI languages.</td>
<td>Knowledge is inferred through slots and facets.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Its efficiency and flexibility lies in easy domain</td>
<td>Semantics reduce the representation</td>
<td>The structure allows knowledge to</td>
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Table 5.1 Representation Techniques Comparison
<table>
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<tr>
<th>Explicitness</th>
<th>Rule back tracking allows for explanation in rules representation.</th>
<th>Reasoning is through the links provided through the representation.</th>
<th>With this additional structure, reasoning process becomes more precise.</th>
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5.8 Knowledge Representation Technique Used in ESOA

From the above study, I have identified that the production rule based KR technique is suitable in the design and development of proposed expert system, ESOA.