PERSPECTIVES ON KNOWLEDGE ENGINEERING

S. Imtiaz Ahmad
Information Systems Research Group
Department of Operations Research and
Information Systems
Eastern Michigan University, Ypsilanti, MI.

ABSTRACT

This paper introduces the concepts relevant to knowledge engineering. The use of the science of knowledge, and the scientific method for knowledge based systems is described and discussed. The role of knowledge engineer is defined. Relationship of knowledge engineering to the study of human mental faculties is described in terms of the theory and practice in areas such as artificial intelligence and psychology. Finally, a brief description of the historical developments and current trends is presented.

Key Words and Phrases:

Knowledge and knowledge engineering, information, problem solving, decision making, artificial intelligence.

1. INTORDUCTION

Knowledge comes from learning about things, and it requires mental apprehension or cognition. The process of learning consists of using existing knowledge, gaining new knowledge, organizing, and storing the new and old knowledge. Stored knowledge is recalled and used in responding to the events in the environment. Our present understanding of how the human mind organizes knowledge points to the following characteristics: what the mind stores is a refined form of received information and it also retains the context of this information.

Knowledge engineering deals with building systems based on the knowledge of someone who is well experienced in dealing with the events in some domain of application. Events generate stimuli and require responses. Stimuli consist of information and this information is received and processed in order to generate an appropriate response; this process is called problem solving. In solving a problem, one must have access to what may be previously known, retrieve relevant facts and rules, and apply this knowledge effectively. This may be described as a goal seeking process. Given some premise and some desired goal, one may use the knowledge to move forward from the premise toward the desired goal until that goal is reached. Alternatively, one may use the knowledge to move backward from the goal to the premise in order to establish that the goal can be reached from the premise. In either case, one goes through several intermediate steps, and collectively these steps constitute a chain of thought. Reasoning from the premise to the goal is called forward chaining, and reasoning from goal to the premise is called backward chaining; the choice generally depends on the situation.

Many people do not possess the knowledge that may be required to solve problems in a given area, or they are unable to use effectively the knowledge that they have. Those who do are known as experts. It takes a human being many years, possibly decades, to become an expert in some area. Direct use of an expert's knowledge is limited by the possibilities of personal contacts. However, if one can acquire successfully the knowledge of how an expert solves problems then it can be put to widespread use. Furthermore, if one can successfully transfer this knowledge to a machine, then the access and use of this knowledge can be increased manifold. Moreover, it then becomes possible to expolit the inherent capabilities of the machine to store vast amounts of information, recall it when needed, and put it to use at lightning speed.

2. KNOWLEDGE ENGINE

A mechanism for storing and organizing facts and rules from known situations, and for their use in resolving new situations is called a knowledge engine. Designed properly, a knowledge engine can unleash the problem solving power contained in knowledge. Traditionally, the human mind has served as the knowledge engine. It is fueled by the stimuli from the environment, uses existing knowledge to process information, solves problems, acquires new knowledge in the process, organizes and updates existing knowledge, and generates information leading to the creation of new knowledge.

Before the industrial revolution, tools for enhancing the mechanical abilities of humans were rather limited. With the industrial revolution came the steam, oil, electric, hydro, and nuclear powered engines which allowed the human race to alter the physical environment for its purpose. The changes affected the quality of life dramatically. With powered machines, it became unnecessary for human beings to exert their body to lift heavy loads, walk long distances, or endure harsh climates. Moreover, the power of one such engine could outperform a large number of human beings.

The powerful machines of the industrial revolution gave vast amounts of physical power to the human beings for their use. However, in order to keep up with these machines, the human beings were often required to perform repetitive tasks. Also, as the power and operational capabilities of the machines were increased, they replaced an increasing number of human beings in the work environment.

In a similar fashion, knowledge engines, also called information machines in a more general sense, are bringing another kind of revoultion. One may call it an information revolution. A mechanical machine can easily exceed the physical capacity of hundreds of human beings, particularly for tasks that do not require physical dexterity. An information machine, likewise, can exceed the mental capacity of hundreds of human beings for tasks that do not require mental adroitness. Furthermore, a human being can make the information machine to assist him in performing intellectual tasks thus allowing him to be more productive mentally, much the same way that he can use a mechanical machine for him to be more productive physically [1,15].

3. OF MIND AND MACHINES

A human being has physical faculties of force and motion, sensory faculties of seeing, hearing, touching and smelling, as well as the mental faculties. Examples of mental faculties are perceiving on seeing, discerning on hearing, and reasoning with facts and rules. Other sensory faculties such as the touch and smell also produce messages to be appropriately processed by the mental faculties. The information processing machine has the potential to enhance one's mental faculties. Those who use these machines effectively do enhance their mental faculties, produce more goods and are thus able to exert greater power and control in the society. The potential for others will continue to diminish unless the overall opportunities grow at a faster rate. Examples of these are given below in items a to d.

An information machine consists of a computer, a knowledge base of data and models, and a mechanism for controlling the operations. Control of operations includes the selection and application of data and models i.e. facts and rules relevant to a situation. There is indeed no doubt that the information machine, when used properly, serves to increase human productivity. The machine helps to organize and store the information needed to generate responses to events in the environment, select required information from thousands of stored pages, and scan for specific items from hundreds of pages in a matter of seconds.

Machines have a potential for benefit as well as detriment. Benefits come from one's ability to enchance the mental processes. Detriment lies in letting the machine take over one's normal mental processes. With proper use, an information machine may be visualized as a mind expander. Because of the unlimited potential that these machines offer, uses and abuses of information technology are likely to be far more profound than those brought about by the industrial revolution. Consider the following examples:

a. Planning, control, and review of complex business and government enterprises requires vast amounts of rapidly accessible information. Those who possess information technology can run the enterprise productively, increase their ability to produce more, enhance quality, and use less resources. They can, thus, dominate their competitors quantitatively as well as intellectually.

b. An architect, an engineer, or an accountant may be able to do high quality work better than ten architects, engineers, or accountants, respectively by using the information technology. The other nine architects, engineers, or accountants thus replaced must adapt or be eliminated.

c. The rapid changes occuring in information technology create rapid obsolescence, and new learning requirements. There may be many who are not educated enough to adapt to this rapid change.

d. Products of information technology which successfully model human mental faculties may gradually take over the work in many areas of human services, with possible intimidating situations.

Each example points to the benefits for those who can make timely and effective use of information technology. However, the same technology becomes detrimental to those who are unable or unwilling to deal with it effectively.

4. KNOWLEDGE ENGINEERING CONCEPTS

The basic material of knowledge engineering is information, in raw and refined form. This information consists of descriptions of object types, covering their explicit and implicit attributes and instances. Alternatively, we may say that an object type is described by some 'relevant' attribute names, whereas a specific instance of an object defines attribute values. Frequently, one may use the term object to refer to object name, attributes to refer to attribute names, and values to refer to instances.

As an example, consider a patient in a hospital. Here, one of the object types is patient, and the other is hospital. For the patient, the relevant attributes may be name, age symptoms, history, etc. A specific instance may be John Adams, 33, fever, none, etc. The choice of attributes for an object depends on what information needs to be represented. Furthermore, one must consider how this information should be structured to properly satisfy the requirements of the applications dealing with the objects. The extent to which an object is described depends both on our understanding about the object and the assumed context of the application.

The process of abstracting the attributes of an object may be difficult, particularly in the absence of any prior experience with it. Furthermore, the notions of how an object type should be described may change with time due to changes in our understanding about the object, or changes in the application context. One must also consider ways of collecting attribute values, and keeping them current, possibly maintaining a history of these values. For example, the current value of weight attribute may be relevant for a patient but so may be the previous history of the weight values i.e. how the weight has been changing between check-ups. It is not always possible to define precisely what attributes may describe an object adequately unless one is an expert on it. Previous knowledge about the object can be quite helpful in making the right choices.

Description of an object in not simply as to what it is, but also what capabilities it may have. The capabilities describe the operations the object permits, as well as those it can perform, resource requirements, and constraints. An object may be manipulated by some objects, and it may manipulate some of them
.The extent of an object description, and the ability to acquire instances of this description, determines the scope of the responses which may be generated when events related to the object occur in the apllication environment. All these considerations are relevant to engineering useful knowledge about an object.

The product of knowledge engineering is a system consisting of a knowledge base structure, an interface for knowledge acquisition and user queries, and a mechanism for activating the knowledge base in order to generate responses, all residing in a special or general purpose computer. Knowledge engineering deals with the concepts, tools, and techniques for describing the objects, structuring the description for acquiring and maintaining information, and developing mechanisms for sequencing of the operations [6, 7, 17, 20]. It also deals with the mechanisms for creating, mutating, and deleting the objects. The processor in the computer provides the raw power, fueled by the data and logic components of the knowledge base, to work as a knowledge engine. Speaking broadly, and sounding somewhat futuristic, one may define the goals of knowledge engineering as:

a. Creating intellect from knowledge i.e. creating a machine that could reason as a philosopher, offering new insights into historical and contemporary events, and

b. Creating mind inside matter i.e. creating a machine capable of independent thought. We will elaborate on these goals in the sections that follow.

5. ROLE OF KNOWLEDGE ENGINEER

A knowledge engineer is responsible for creating a mirror image of a particular reality i.e. creating an authentic model of what exists in the application domain. This work requires discovering what the reality is or how it is perceived, developing a representation consistent with the events and responses in the real world, and maintaining the integrity of the representation. In order to perform these tasks, the knowledge engineer must understand the science of knowledge, and the manner of its application.

Knowledge comes from observations, reasoning, and reflection. There are two categories of knowledge -- axiomatic and empirical. Axiomatic knowledge deals with the possibility of possible things, and the impossibility of impossible things based on well accepted assumptions and theories. Given an event, and axiomatic knowledge about it, one may describe a definite response. Empirical knowledge, on the other hand deals with observation and experimentation leading to strategies and rules that seem to work. Given an event, and only the empirical knowledge about it, one may choose a strategy and apply the rules based on past experience with such events.

In performing an analysis of the situation which is to be modeled, the knowledge engineer is required to use all sources of information, to discern specifics of the application domain, and to describe the knowledge thus gained. Generally, the knowledge engineer, or in this phase of the work one may call him the knowledge analyst, is not the creator or user of the knowledge in the application domain. He must refer to those who can validate his knowledge of the application domain. This requires tools and techniques of communication, and their use in a manner which encourages the vocalization of pertinent information. The purpose of the validation process is to remove ignorance about the application domain, and generate the knowledge for modeling and representation of the reality.

Systems built on ignorance about the domain of application either fail completely, or perform very poorly. However, at times it may be necessary to build a system based on incomplete knowledge. This deficiency may be over come by a mechanism which explains what knowledge was used, and how it was used in generating the response to some event. In this case, the user must have the knowledge to assess the validity of the response in a given siuation. The explanation facility also indicates the need for further knowledge acquisition whenever it becomes necessary. Most application domains are dynamic in nature i. e. data values are affected by aging, and the applicable policies are affected by changes in the environment. The knowledge engineer plays a key role in maintaining system integrity with time.

The internal design of a knowledge engine, or knowledge based system determines its space and time characteristics. One may assume that the purpose of the system is to augment human capabilities, and increase productivity of the operations. The knowledge engineer is, therefore, responsible for providing the facilities for the users to interact with the system. This interaction should allow the users to maintain their normal intellectual thought processes. The subservience, if there is to be one, should be of the system to the user, and not the other way around.

6. KNOWLEDGE BASED SYSTEMS AND ARTIFICIAL INTELLIGENCE

One may describe knowledge as a collection of facts and heuristics. Facts represent that part of knowledge which is widely shared, publicly available, and generally agreed upon by experts in a field. Heuristics, on the other hand, represent the part of knowledge which is mostly private, little discussed rules of plausible reasoning, good judgement, and good guessing.

Knowledge based systems store facts and heuristics for making inferences about situations. If the facts and heuristics normally used by an expert are acquired, and properly represented in a systems then such a system is called a knowledge based expert system [5, 7], or simply an expert system.

Artificial intelligence is the study of mental faculties through the use of computatuional models [2]. If what the brain does can be modeled as a computation then the work in artificial intelligence will successfully duplicate the human mental faculties. Through these models, one attempts to duplicate the mental faculties such as vision [9, 16], natural language [4], etc. [3, 10, 12, 13, 14]. All intelligent people have these faculties, and not just the experts. The tools and techniques of artificial intelligence are used in building intelligent systems.

The work in psychology, dealing with the study of human mind, has been influential in developing the direction of work in artificial intelligence. Looking at what the psychologists have to say, about the human mind, may help one better understand the current work and future trends in artificial intelligence. According to the theory of behaviorism in psychology, all human behavior can be described in terms of a cause and effect relationship between the stimuli from the external events and the responses. Once this relationship is understood and described in the form of a stimulus-response mechanism, it then becomes possible to predict and control human behavior. First definitve work on this subject was published by Watson who said [18]:

Psychology as the behaviorist sees it is a purely objective, experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his effort to get a unitary scheme of animal responses, recognizes no dividing line between man and brute.

However, behavioral psychology has not succeeded in producing a theory of behavior that is applicable in all situations [8]. Nonetheless, it continues to play a major role in situations requiring behavior modification.

Cognitive psychology introduces the notion of thinking i.e. people interpret the external stimuli by a thought process in order to produce a response. The passive cause and effect relationship advanced by the behaviorist is, therefore, not applicable to human behavior in all situations. The cognitive psychologist distinguishes the human from the other animals. It is, however, not clear whether the ability to interpret allows for the possiblity of directing one's actions, known as free will, without constraint by necessity or fate.

One may summarize the coginitive psychology model of the human mind in terms of the following:

a. The mind has operationally definable mediators (logical behabiorism),

b. The mind has a central mechanism for mediators (central cognitive processes and subprocesses), and

c. The central mechanism is not reducible to behavioral or peripheral terms (contemporary cognitive behaviorism, or information processing approach).

The fields of psychology and artificial intelligence will continue to cross-fertilize. Of course, a theory in psychology about the human mind does not mean that the mind actually works that way. It is important to make this distinction. The work in artificial intelligence does not claim that its goal is to produce methods which duplicate exactly those of the people [2]. Its goal is to build systems which exhibit intelligent behavior, solving problems in ways that resemble those of the humans. Again, it is important to make a distinctin between a machine which exhibits intelligent behavior and an intelligent human being. It is necessary to keep the humans ahead of the machines, retaining the challenge to improve the machines.

7. TRENDS IN KNOWLEDGE ENGINEERING

Earlier work in the use of computers for knowledge engineering was limited to areas of axiomatic knowledge, facts consisting of data and computations. In scientific and business applications, many situations allowed descriptions of planned responses to events in the environment. These early systems were called information processing systems, or simply information systems. Gradually, the developments in information technology and the understanding of its potential in human productivity, resulted in emphasis on building systems to support decision making [11]. Often, the decision making situations cannot be described fully in terms of cause and effect relationships. The system, therefore, consists of data, models, and interfaces to interact and produce ad hoc responses which the people could analyze and choose for making decisions. These systems are called decision support systems. In many situations decisions are based on plausible reasoning, more a matter of good judgement on the part of an expert. The expert's knowledge may be represented using the tools of artificial intelligence. Systems based on this knowledge, detailed and specific to a domain of application, are called expert systems. All of the above mentioned systems may be considered as instances of knowledge based systems, created to serve the potential users.

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