ARTIFICIAL INTELLIGENCE TECHNIQUES IN HYDROLOGY

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ABSTRACT

Artificial Intelligence (AI) is an area which is getting popular now and finding great use in various disciplines of engineering. AI has achieved considerable success by the development of Expert Systems. The paper highlights AI techniques, Expert Systems and their importance in the field of hydrology.

1. INTRODUCTION

With the development of computers and numerous software for various applications, Artificial Intelligence is finding great use in a variety of subjects, like medicine, geology, engineering, flood forecasting and many others. It is a sub-field of computer science concerned with the use of computers in tasks that are normally considered to require knowledge, perception, reasoning, learning, understanding and similar cognitive abilities. Thus, the goal of Artifical Intelligence is the qualitative expansion of computer capabilities because people have traditionally, outperformed computers in activities that involve intelligence. People do much more than just process information. They understand it; they come up with new ideas; they use common sense. These abilities of intelligence come very naturally to people but they are very difficult to simulate on a computer. Thus, one simple view of Artificial Intelligence is the study of how to make computers do things which at the moment people are better at doing.

Artificial Intelligence is concerned with intelligent behaviour, primarily with non-numeric processes that involve complexity, uncertainty and ambiguity and for which known algorithmic solutions do not usually exist. It provides techniques for flexible, non-numeric problem-solving. These techniques include symbolic information processing, heuristic programming knowledge representation and automated reasoning. No other field or alternative technology exists with comparable capabilities and nearly all complicated problems require most of these techniques.

2. EXPERT SYSTEM

An Expert System is a computer programme designed to act as an expert in a particular domain (area of expertise) in order to act as an assistant to human experts and assist people who do not have access to an expert. An Expert System includes a sizable knowledge base, consisting of facts about the domain and heuristics (rules) for applying these facts (Fig 1).

An Expert System uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions. The knowledge necessary to perform at such a level, plus, the inference procedures used, can be thought of as a model of the expertise of the best practitioners in the field. The systems can be built by one or a team of experts. Its knowledge base can be altered by expansion or deletion of rules and rules themselves can be readily altered. Expert Systems operate particularly well where decisions are based on reasoning and not on calculating. The uses of Expert Systems are virtually limitless. They can be used in diagnosis, monitoring, analysis, interpretation, consultation, planning, design, instruction, explanation, learning and conceptualization.

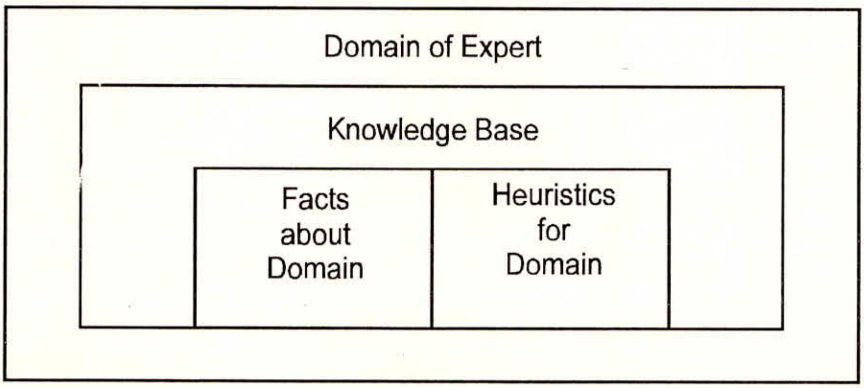

Fig 1 Expert System

2.1 Components of an Expert System

The principle components of an Expert System are knowledge base, inference engine and user interface. They are shown in Fig. 2.

2.1.1 Knowledge Base

If an expert system is to give intelligent advice about a particular domain it must have access to as much domain knowledge as possible. The component of an Expert System that contains the system's knowledge is called its knowledge base.

A knowledge base contains both declarative (facts, events and situations) and procedural knowledge (information about course of action). Depending on the form of knowledge representation chosen, the two types of knowledge may be separate or integrated. The most prevalent form of knowledge representation is the "rule based production system" approach.

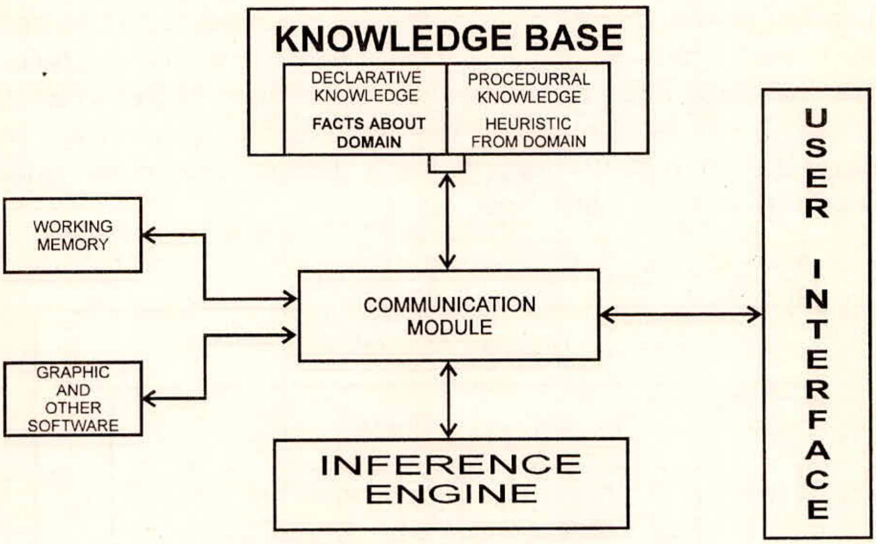

Fig 2 Architecture of ES building tools

In a rule base, the procedural knowledge, in the form of heuristic "if-then" production rules, is completely integrated with the declarative knowledge.

However, not all rules pertain to the system's domain. Some production rules, called "meta rules" pertain to other production rules. A meta rule (a rule about a rule) guides the execution of an expert system by determining under what conditions certain rules should be considered instead of other rules. Some meta rules contain knowledge that helps the system to determine the order in which the rule should be executed.

The knowledge bases are distinct from conventional data bases in four ways:

a) Knowledge bases contain explicitly represented rules as well as simple facts.

b) Knowledge base storage structures have low structural semantic content compared with data base structures.

c) Knowledge base systems include components for the automatic maintenance of semantic integrity in addition to components for syntactic checking as found in conventional data base systems.

d) Knowledge base systems include components which can make over the knowledge base, thereby providing a deductive retrieval facility.

2.1.2 Inference Engine

Just having a knowledge base does not make an expert intelligent. The system must have another component that directs the implementation of the knowledge. This element of the system is known as control structure, rule interpreter or the Inference Engine.

The inference engine decides which heuristic search technique may be used to determine how the rules in the knowledge bases are to be applied to the problem. Then it runs an Expert System by accessing the appropriate rules in the knowledge base executing the rules and determining when an acceptable solution has been found.

Since knowledge is not intertwined with the control structure, an inference engine that works well in one Expert System may work just as well with a different knowledge base thus reducing expert system development time.

2.1.3 User Interface

Although the designers of expert systems generally have a great deal of experience with computers, the intended users of expert systems are frequently computer novices. Even the most sophisticated expert system is worthless if the intended user cannot communicate with it. It is, therefore critically important to ensure that an expert system is specially easy to use. The component of an expert system that communicates with the user is known as the User Interface. Most user interfaces make heavy use of techniques developed in another artificial intelligence discipline: Natural Language Processing.

2.2 Development of Expert Systems

There are five sequential stages in the development of an Expert System, viz.

i	Identification	– determining characteristics of the problem;
ii	Conceptualisation	– finding concepts to represent the knowledge;
iii	Formalisation	– designing structures to organise knowledge;
iv	Implementation	– formulating rules embodying the knowledge, and
v	Testing	– validating the rules

3. LANGUAGES USED IN ARTIFICIAL INTELLIGENCE TECHNIQUES

Although it is formally possible to write any programme in any language, the process of building artificial intelligence systems can be facilitated considerably by the use of a programming language that provides support for a variety of common structures, both for data and for control.

In conventional procedural languages such as COBOL, FORTRAN, PASCAL etc., a programme consists of a series of procedures that instruct the computer how to perform a desired task and these instructions include the control of the sequence of procedural execution. But in artificial intelligence languages such as PROLOG and LISP a programme consists of a number of statements and functions which are either facts or rules. And instead of instructing a computer how-to-do a task they tell about what-to-do, i.e. the goal is mentioned not the procedure.

Further, though conventional languages are rich in syntax, they are weak in semantics, because they are intended to serve professional programmers handling different tasks in different situations, while semantics tend to be application specific. By contrast, Artificial Intelligence languages are rich in semantics.

The conventional programming languages are used most often for arithmetic, whereas LISP and PROLOG are intended mainly for non-numerical purposes.

3.1 Comparison of Artificial Intelligence Programming with Conventional Programming

Artificial Intelligence Programming	Conventional Computer Programming
– Primarily symbolic processes	Primarily numeric processes
– Heuristic search	Algorithmic search
– Solution steps implicit	Solution steps explicit
– Control structure usually separate from domain knowledge	Information and control integrated
– Usually easy to modify, update and enlarge	Difficult to modify
– Some incorrect answers often tolerable	Correct answers required
– Satisfactory answer usually acceptable	Best possible solution usually sought

4. NEED FOR ARTIFICIAL INTELLIGENCE TECHNIQUES IN HYDROLOGY

Hydrology is the science which deals with the waters of the earth, their occurrence, circulation and distribution on planet earth, their physical and chemical properties and their interaction with the physical and biological environment, including their response to human activity. It is the field which covers the entire history of the cycle of water, floods, droughts, drainage, erosion, pollution and their considerable ramifications etc. Hence, hydrologic studies, analysis and predictions require very large and exhaustive data bases. The type of technique to be used or procedure to be adopted depends not only on data but also on information utilisation. As such the decisions are complex and subjective in nature. Therefore, hydrologists have to deal with the design, development and management of complex systems and their planning in all subsequent phases, as per current knowledge. In each facet of his activity the hydrologist will be constantly making decisions on several aspects of the system, based on his knowledge about the behaviour of the system based on his knowledge about the current status of the system. Some areas in hydrology, often require decisions to be taken with little or incomplete data. In these areas the knowledge experience and judgment of an expert is required. Hence artificial intelligence may be used in these areas for speedy execution.

Most of the problems, mentioned above, can be handled by using a specialized hydrology knowledge base instead of a data base. This can be done by converting the data base into a knowledge base by adding to it desirable features like data independence and coexistence of external schemes along with the following:

a) Deductive retrieval, which involves inference of data which is not stored explicitly.

b) Semantic integrity checking, which involves preventing data, which represents a disallowed state of the universe, from being inserted into the database.

c) An intelligent natural language interface, which supports a variety of cooperative behaviour for successful man-machine interaction.

A knowledge base with natural language interface is not only attractive but also critical to be of effective use of any knowledge based computer system for a particular domain. It would not only be useful as an aid for analysis, planning and decision making to a nonexpert resource planner, in the effective utilization of a typical geographical area under study, but would also be used in a number of domain applications such as cartography, land use management, soil and landscape preservation and finding irrigation avenues, etc.

4.1 Application Areas

Artificial intelligence can be applied to various problems like interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instructions, control, text understanding, text generation, computer vision, robotics speech recognition, automatic programming etc.

In hydrology, it can be applied for elicitation, knowledge acquisition, data organisation, data management, organising design standards, selection of a model for analysis, selection of data for design, selection of components in design, policies in water resources management, selection of design norms, design flood estimation, frequency analysis, statistical analysis, time series analysis, flood forecasting, qualitative well log data interpretation, modelling of hydraulic systems for fitting watershed simulation models, fitting a water quality simulation model, modelling of urban storm drainage system, modelling of reservoir systems, well test analysis, drought management etc.

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