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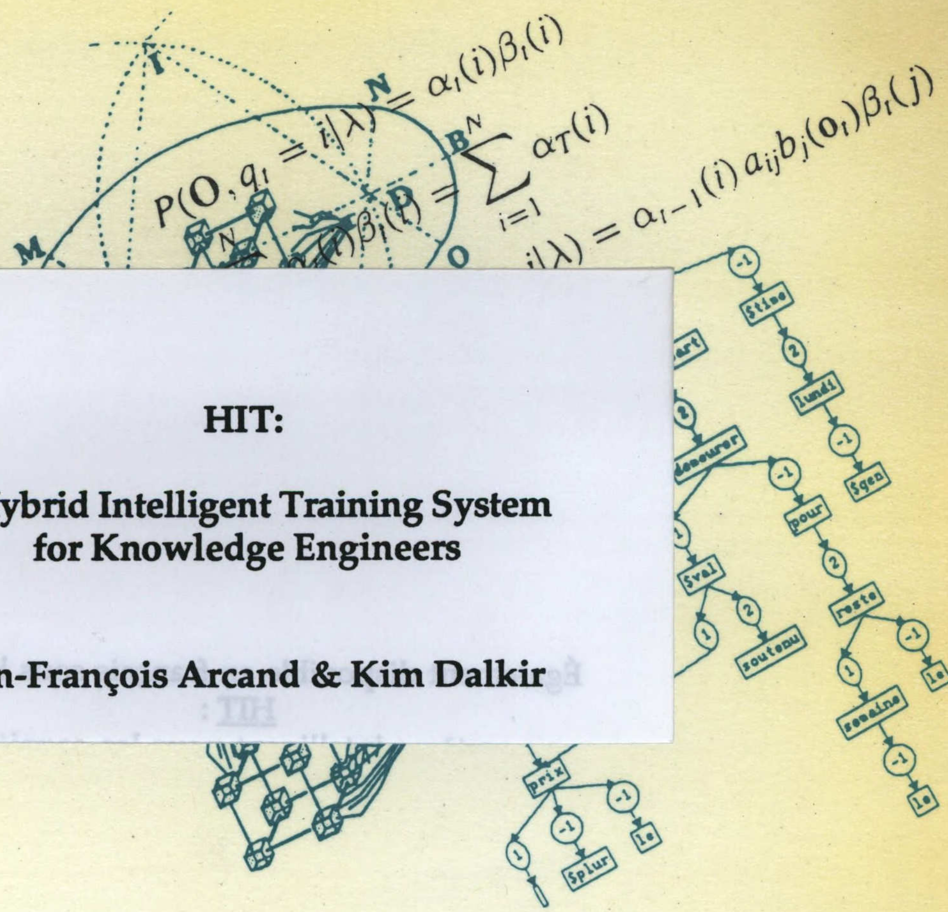

HIT:

A Hybrid Intelligent Training System for Knowledge Engineers

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Abstract

This article describes the design and development of a software tool that allows the psychological and mathematical analysis of knowledge engineering students' learning styles. The HIT system contains laboratory or project work elements that can be used in artificial intelligence courses, both in academic settings and in on-the-job or apprenticeship training contexts. The aim of this system is not to computerize textbooks on artificial intelligence, but to provide artificial intelligence-based software to supplement existing course materials.

The software provides a training environment that has a number of the characteristics commonly found in intelligent tutoring systems (or, as they are increasingly referred to, intelligent learning environments). HIT is intended to be a pedagogical complement, rather than a replacement, that enriches human teachers and tutors instead of automating the learning process. HIT is designed as a general environment, analogous to expert system shells, to teach and to precisely diagnose any cognitive difficulties individuals may have in learning course material. The software provides a course authoring tool, a motor for processing courses and students' progress through the courses, a neural network that maintains a permanent record of facts and actions (e.g. keystroke data) for each student, a neural network editor to modify or create new networks and a number of mathematical and statistical analysis tools for the subsequent analysis of these data. In short, HIT is a research laboratory, into cognitive aspects of learning, that helps in both data capture and data analysis.

The HIT system enables the efficient and continual training of one or more individuals in the area of knowledge engineering, more specifically in knowledge

acquisition tasks. Eventually, this can be further acted upon in order to adjust training (content, sequence, pace, etc.) to each learner based on aptitudes, preferences and learning goals. This article will focus primarily on the mathematical and psychological instruments used by HIT to analyze the learning styles of knowledge engineers in training. Potential applications of this tool will also be briefly addressed, as well as how they can be implemented in educational and training contexts.

Introduction

There is significant need for tools that aid in the selection and training of knowledge engineers. Existing courses offered in universities or by software vendors tend to concentrate on the use of specific tools and languages, and less on the actual craft of knowledge engineering. It is not enough to simply be proficient in an artificial intelligence tool: One needs a more comprehensive background in cognitive science in order to effectively function as a knowledge engineer. To this end, the skills needed for knowledge acquisition have been used as the preliminary content of the HIT system.

The primary goal of knowledge acquisition is learning. The knowledge engineer learns enough about the target domain, through various sources including human experts and documentation, to enable the encoding of the acquired knowledge in a computer implementable form. There are a number of methods and approaches possible, many borrowed from psychological testing tools. For example, the use of repertory grids, protocol analysis and on-site observation have long been standard practices in psychological and educational research. The HIT system focuses on three major knowledge acquisition strategies: human-based, or traditional, knowledge acquisition involving a knowledge engineer interviewing and observing the human expert(s), and two machine-learning based methods; induction, which involves generalization of rules from examples; and neural networks, which identify patterns in data to postulate relationships between inputs and outputs.

The HIT system is a computer-based training tool or laboratory that allows students to interact with these three knowledge acquisition modules. In addition, learners can also apply what they have learned immediately, via interaction with simulated experts, the design of inductive systems and the design of a neural network. In this way, both the knowledge and the know-how of knowledge engineering can best be imparted. Furthermore, the HIT system has a learning style diagnosis component which can assess how individual learners report they learn best, through completion of two standard learning style tests, and how they actually learn, through automated monitoring of how they interact with the system. This provides feedback to learners on their strengths and weaknesses. Each of these elements is described in further detail below.

Computer-based Training

In the past few years, knowledge-based technologies and artificial intelligence tools have joined forces to design and deliver new methods of teaching. These pedagogical vehicles favour self-study based on concrete needs expressed by each learner. The HIT software tool addresses the training of knowledge engineers. It is composed of knowledge-based technologies, learning style assessment instruments and neural networks. HIT can serve as a job aid, reference tool, decision aid or as an intelligent training/learning environment.

Intelligent tutoring systems are artificial intelligence tools that examine student answers, create a model of the learner, evaluate the degree to which a subject has been mastered and then provide the appropriate teaching intervention. Intelligent tutors also offer self-study modes which purport to fill the role of human tutors. Such machine-based tutors can cognitively diagnose student learning difficulties and motivate student learning by keeping track of strengths and weaknesses.

Machine Learning

Neural networks have been used in a number of domains, such as image recognition, credit analysis and robotics. They are characterized by a set of interactive cells, each of which executes a given mathematical function. The cells all operate in parallel fashion across the neural network. Unlike knowledge-based systems, neural networks generate their own decision rules. Knowledge acquisition is carried out by successive training and implementation of a learning rule in each cell of the network. A learning rule is a mathematical function concerned with the management of the network's memory--that is to say, these rules adjust the strength of each link as a function of knowledge is acquired. Links are strengthened or weakened by adjusting their weight based on whether the outcome was favourable or not.

An important characteristic of these systems is the manner in which they store information. Neuronal programming consists of distributed memory across each link between any given pair of cells. Network memory therefore exists in the form of links. Given the case where the input sample to a network is incomplete, the network can still proceed to generalize, with minimal error, due to the associative nature of memory. One of the major advantages of neural networks, then, is that if a cell or link disappears, the knowledge of the network is only partially affected. This is because the memory of the network is distributed in the set of links and not stored locally, as is the case with traditional computer systems.

A number of neural networks are capable of learning complex situations which require a vast sample size. They are also able to determine solutions to problems that humans have never been in a position to solve (e.g. the travelling salesman problem). Thus, neural networks are effective for those domains where human expertise does not exist or cannot easily be accessed. Neural networks therefore provide very useful cognitive models for human learning due both to their analogous way of learning rules and the fact that there is no consensus of expertise on how humans learn.

Learning Styles

There is much ongoing research on learning or cognitive styles. These are generally defined as patterns of learning; for example, whether one prefers to obtain an overall picture and then study the details (topdown) or vice-versa (bottom up), whether learners prefer concrete examples or abstract theories, and so on. One theory, postulated by David Kolb, is based on experiential learning. Kolb has devised a learning style test (*Kolb Learning Style Inventory*) which can be used to classify learners as one of four general types. Such inventories not only determine the learning style used by students but may also be used to prescribe the appropriate teaching style to be used in order to obtain the best results.

Another well known theory was proposed by Noël Entwhistle. *The Lancaster Inventory* determines learning style as well, but in a very different fashion than the Kolb instrument does. A learning style profile is generated for each student based on eight mathematical analyses. In fact, there are well over 30 learning theories with accompanying learning style inventories. They all purport to measure a set of learning constructs, which at times overlap. All have strengths and drawbacks. None is universally accepted as a valid measure of how individuals learn. As a result, we have decided to incorporate the Entwhistle and Kolb inventories in the HIT system. As most, if not all, learning style inventories are self-report questionnaires, the HIT system should serve to verify whether students are aware of how they learn best. The neural network pattern classifier will be used to validate both theories, as we will be able to check whether students placed in categories by learning inventories are indeed grouped together by the neural network, based on the actual performance.

The Hybrid Intelligent Trainer Project

The HIT software system consists of six modules developed using HyperCard 2.1 and various external C and Pascal programming resources. Data can be freely exchanged between these modules (i.e. can use output of one as input to another). There is extensive documentation for application development and maintenance, as well as a user manual for students. The HIT software may be run on both Macintosh and IBM-compatible microcomputer platforms. the system is fully bilingual, with French and English versions available. Each of the HIT system modules is described in further detail below.

The HIT Course Authoring Module

This module is much like a word processor that assists in the creation and/modification of a course to be learned using HIT. At present, three knowledge engineering subjects are available: traditional knowledge acquisition techniques, inductive techniques and neural network methodologies. Within each module, students are free to select topics and sequence them as they progress through the material. At all times, learners may request help, ask to see the glossary of terms, view an example, take a test or review the material. All these course elements are provided by course authors and entered using the various menu-driven commands in HIT.

The HIT Tutorial Module

The learning style inventories are administered within this module. Each learner is then tracked to see whether a classifiable pattern is followed, and if so, whether or not this pattern corresponds to either of the categories of the Kolb or Entwhistle tests. Each action taken by the student is recorded, for example: what sort of help was asked for; how much time was spent on a given screen or a given lesson; what sequence of lesson topics was chosen. This trace data can then be fed into a neural network for pattern analysis. Subsequent development work will be devoted to the implementation of appropriate teaching strategies based on the learner diagnosis data.

The HIT Trace Analyzer

The role of the neural network, and of the HIT system in general, is to evaluate learning styles and not to teach. A complete, dynamic and deep model of the individual learner is created and maintained in this manner. This module is used to classify individual learners or groups of learners as to their patterns of learning. This method of classifying learners differs from that of Kolb and Entwhistle in that individuals cannot misreport their capabilities nor their shortcomings. The results are therefore representative of the learning style adopted during attempted lessons. Learning style instruments are essentially self-reports of the "how do you learn best" type questions. They may or may not be valid because individuals may or may not be conscious of how they learn best.

The neural network trace analyzer offers a type of second opinion, based on actual observation of student learning performance. This is a statistical module that allows the calculation of a number of frequencies and the modelling of an individual as a function of the test results and keystroke data generated. It is possible to evaluate an individual's organization of time across the various options offered in the tutorial by looking at the trace left during an individual's progress through a lesson. The neural network in this module can also analyze the learning style through an analysis of mathematical frequencies, in order to identify a pattern of learning.

The HIT Principal Component Analysis Module

This module is responsible for the principal component analysis procedure performed on trace results left by individual learners as they progress through lessons. This additional statistical analysis tool enables the researcher to, again, categorize similarities and disparities between groups of learners and to compare these with the categorization generated by the Kolb and Entwhistle inventories as well as the categories generated by the neural network pattern classification scheme. Thus, researchers can use the same software package for both data capture and data analysis.

The HIT Skill Module

This module enables learners to apply knowledge gained during all three course modules. Students may practice knowledge engineering sessions using simulated experts for the traditional knowledge acquisition course module. Neural networks and inductive models can be developed using this component of HIT. A neural network editor provides two learning rules--backward propagation and competitive learning, for neural network construction. Students can choose the number of cells, layers or groups that will comprise the net and then train the network for a specific task. Similarly, students can develop an inductive model and generalize rules from a number of examples. This is a crucial component of HIT. Knowledge engineer training must necessarily involve not only comprehension of key artificial intelligence concepts but also successful application of this knowledge in order to create knowledge-based systems.

The Hit Job Aid Module

This module is a knowledge engineering job aid which provides information on the topic without going through any explicit training or teaching. This is a spinoff module that permits users to visualize the contents of HIT lessons in a browse mode. That is to say, users are not tested on their comprehension of the material nor asked to apply their knowledge, as is the case with the training mode. A dictionary of terms may also be accessed in this fashion. The flexible and rapid overview of knowledge engineering afforded by this module makes it a good job aid for knowledge engineers, artificial intelligence project managers and the general public seeking a good introduction to the subject, as well as those seeking responses to specific questions.

Discussion

The HIT system provides a number of potential uses. One is purely its content--a curriculum supplement of laboratory exercises or project work for knowledge engineer training. For example, the neural networks module has proven to be very popular in both academic and professional sectors. Neural network work is still considered to be in the research stage and there are not many courses in the area, especially not on the application of neural networks and on how to decide whether to use knowledge-based technologies or neural networks or both to solve a given problem.

Neural Network technology is the backbone of the HIT system. This learning capability is the key to adaptive training environments that are able to change the nature of pedagogical interventions as users evolve from novices to competent practitioners in the domain. At present, HIT only derives learner models. The next logical step is to intelligently decide what training action to undertake based on these models.

The HIT system can be thought of as an alternative means of delivering training in general, and to knowledge engineers in particular (as a supplement to books, academic and vendor courses in artificial intelligence, etc.). An intelligent learning environment has the advantages of computer-based training (such as self-paced study) without the drawbacks (need for priori programming of all possible branches, need to predict all possible student inputs, etc.). The HIT system is an example of how truly individualized (and therefore intelligent) instruction can be made available to each learner, based on background, prior knowledge, capabilities and preferences, as well as actual performance as progress is made through the materials. In the future, HIT will be extended to do more than diagnose a student's learning style. The detailed tutorial trace will be used to precisely adapt each teaching action to be undertaken with respect to an individual or to a group of learners.

Finally, HIT offers the possibility of assisting in both the selection and the training of knowledge engineers (and perhaps even in their certification as professionals). This can be achieved by providing a tool that can assess characteristics such as learning style. The HIT tool is thus intended to provide feedback to those considering knowledge engineering as a profession, or to those who are already working on a project and require more specific help. The HIT environment can provide a curricular supplement to knowledge engineers in training by assessing aptitudes and demonstrating the nature of the work involved in knowledge engineering, as well as by providing a practice laboratory for those already engaged in knowledge engineering work.

It must be noted here that the ultimate goal is not to simply label potential knowledge engineers as a certain type of learner, but rather to help them diagnose their learning strengths and weaknesses. The overriding premise behind this work is that good knowledge engineers must be excellent learners. Research on learning styles should contribute to helping train knowledge engineers in the fine art of learning.

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