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ABSTRACT

This document contains a series of papers which attempt to de-mystify the subject of artificial intelligence and to show how some countries in the European Community (EC) are approaching the promotion of development and application of artificial intelligence systems that can be used as an aid in vocational training programs, as well as to stimulate discussion and an exchange of information throughout the EC. The six papers included in the report are "Artificial Intelligence and Training--An Initial Assessment" (I. Aleksander); "Artificial Intelligence and Education--Some Lines of Reflection" (M. Vivet); "Expert Systems in Training" (D. Kerr); "Artificial Intelligence Applications to Learning" (J. Gillingham); "Modeling an Automatic Tutor by Dynamic Planning--An Automatic Tutor Integrated in an Intelligent Computer-Aided Instruction System" (M. Fernandez de Castro, A. Sanchez, and M. Maillo); and "Tutorial Expert Systems Project" (P. Lees). (KC)

CEDEFOP Document

Artificial intelligence and its potential as an aid to vocational training and education

European Centre for the Development of Vocational Training

CEDEFOP Document

Artificial intelligence and its potential as an aid to vocational training and education

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INTRODUCTION

Developments in the field of artificial intelligence are attracting increasing attention with particular regard to their deployment in the work situation, and in activities designed to improve the efficiency and cost effectiveness of training and retraining.

In a recent paper on computer-integrated manufacturing in the factory of the future, produced by the Fraunhofer Institut für Arbeitswirtschaft und Organisation, Stuttgart, the section on the role of artificial intelligence states that artificial intelligence, as a part of information technology, has undergone a dramatic development in the past few years. The paper states that important areas for application of artificial intelligence include:

- diagnostics and quality assurance
- systems configurations
- planning and management functions

The report says that artificial intelligence will change the factory of the future and quotes an extract from the main article of Business Week on 9 July 1984.

"Expert systems may one day be more common than people on factory floors. They will be the brains that make robots intelligent and flexible. And they will assist engineers and managers in such diverse tasks as coordinating production, supervising orders and inventory. An expert system at Hewlett-Packard company advises how to manufacture integrated circuits, while at Digital Equipment Corporation, an expert system manages scheduling on the shop floor".

At the moment, artificial intelligence is regarded as a rather grand title which promises far more than can be achieved. However, the most important development in this field is the ever-increasing availability and application of so-called expert systems.

An expert system may be defined briefly as follows:

- a data bank system which enables experts to access programmed information of a highly specialized nature in a very complex subject area.

The term 'artificial intelligence' has probably done more harm to research and development work designed to improve on current computer performance, of which expert/knowledge-based systems appear to be the most promising developments at the moment, so far as vocational training and retraining is concerned.

One of the aims of this paper is to attempt to de-mystify the subject, and to show how some countries in the European Community are approaching the promotion of development and application of artificial intelligence systems which can be used as an aid in vocational training programmes.

Another aim of this paper is to stimulate discussion and an exchange of information and ideas across frontiers in the

Community, with a view to mutual benefit for those engaged in this exciting, but difficult work, which could transform the learning experience for many people, but, more significantly, cause education and training people to drastically rethink the way they structure their approach to the preparation of learning opportunities.

The development of expert systems software is a very expensive and time-consuming effort for companies and other organizations engaged in this work. This is an area which would benefit considerably from cooperation at national and Community level. The fact that the development of expert systems for a wide range of activities is still in its infancy, and that there had been many set-backs and disappointments, does not alter the fact that experts engaged in this work are convinced that there is an enormous potential benefit to be gained from pressing ahead with research and development work which would also have considerable implications for future developments in manufacturing automation and office work.

Learning with the aid of expert systems would also familiarize people with expert systems installations in their actual work situations and open up opportunities for open learning support to improve current performance, without the necessity of the people concerned having to travel to attend training sessions at some distance from their place of employment.

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ARTIFICIAL INTELLIGENCE

AND TRAINING

AN INITIAL ASSESSMENT

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EXECUTIVE SUMMARY

On a world scale, the field of Artificial Intelligence has received more directed funding in the last decade than any other sector of new technology. The products of this work are known as Knowledge Based Systems or, more specifically, Expert Systems. These are capable of packaging human expertise and delivering it through a computer system. These systems are available now, and have clear applications to Vocational Training. This report recommends to CEDEFOP to become the catalyst for the evaluation of these techniques in Europe.

The report explains the nature of these products and the path that they have taken to achieve maturity during the last thirty years or so.

It goes on to describe the way in which expert systems overcome many of the disadvantages of conventional computer-based training schemes. In essence, they are capable of more conversational and adapted means of interaction in near-natural language than was previously possible.

The report then illustrates the degree of penetration by presenting examples of current research work directed both at training and at application in business. Highly pertinent is a description of User Clubs that have been set up in the UK under the Alvey scheme.

It is argued that Vocational Training is ripe for the

development of user clubs on the Alvey pattern, but as yet, remains an unattended area. The major recommendation is that CEDEFOP should organize an early meeting between key people in the Member States.

1. INTRODUCTION

Almost for the first time in the history of technology, it appears as if the training problems created by the advance of technology may be solved by using technology itself. The advance here is that of the rapidly spreading phenomenon of "high" technology, and the techniques within that area that may help with training go under the heading of Artificial Intelligence (AI). The current trend is to avoid that particular phrase and to refer to Expert Systems (ES) or knowledge-Based Systems (KBS). The objectives of this report are:

a) To explain the nature of the AI, ES and KBS concepts;
b) To explain why they might help with vocational training;
c) To explore the extent to which the techniques are being developed in manufacture and services;
d) To assess the extent to which the training potential of the techniques has been explored;
e) To suggest future avenues for aiding the vocational training effort by the use of these techniques.

2. ARTIFICIAL INTELLIGENCE, AN EXPLANATION.

2.1 Early Motivation: Non-Numerical Computing.

The beginnings of AI may be traced to the suggestion in 1950, by Claude Shannon of the Bell Telephone Laboratories, that a computer might be used to play a game of chess against a human player. Indeed he wrote programs that took some short cuts in the process of assessing the ever increasing number of moves as the computer looks ahead in the game. These algorithms formed the backbone of many techniques for automatic reasoning that are still used today. The significant feature of this work that makes parts of AI relevant to training, is that it took computers into the domain of "reasoning" where previously they were simply seen as highly competent calculators.

Indeed, it is the computer's ability to calculate the consequences of actions and further consequences of actions taken on ramifications thus created, that is at the heart of most AI programming. It was realised in the mid sixties that this process is precisely what is involved if a computer is to be used to solve general rather than numerical problems. For example, if the machine were given the cost of various means of transport and the locations between which such means operate, it would be feasible to ask such a machine to discover the fastest or least costly way of getting, say, from the suburbs of Berlin to the United Nations building in New York. The computer would simply use its speed to search through all possible means at each stage of the process and choose the cheapest or fastest (depending on what was required) to get to the next stage.

Perhaps it is the word "intelligence" that has created a certain mystique around what is otherwise a straightforward way of solving problems on computers. Indeed it was John McCarthy of Stanford University who, in 1958, coined the phrase "Artificial Intelligence" for what in other parts of the world (Edinburgh University, for example) was called "experimental computing".

Undoubtedly this phrase has overtones of human-replacement which, in the context of introducing AI in the workplace, is less than helpful. The question that should remain uppermost in such negotiations is whether, whatever the technique is called, it is a constructive aid for the worker or not. Clearly the essence of this report is that only the helpful aspects of the technique should be developed in the context of vocational training. Indeed, it will be argued that the more fanciful overtones of human-replacement are bogus and do not constitute a threat.

2.2 The Lighthill Report.

During the first few years of the 1970s, AI became firmly entrenched in research laboratories and started making heavy demands on the provision of computer power for a study of matters that seemed unclear and appeared to lack application.

Worried by escalating costs, the UK Science Research Council asked an eminent mathematician, Sir James Lighthill, to carry out an investigation into the benefits that might be derived from this research. His report, published in 1973, was damning: He uncovered the "combinatorial explosion and argued that any attempt to make the problem-solving techniques useful led to an exponentially increasing demand for computer power. This is due to the fact that the number of possibilities that have to be searched in the process of solving realistic problems multiply alarmingly every step of the way.

Although the Lighthill report was entirely a British affair, it had a profound effect on all the researchers in this field, not only in the UK, but also in the USA where the majority of the work was being done. This led to a search for more efficient problem-solving techniques: techniques that avoid the "combinatorial explosion".

2.3 The Post-Lighthill Era.

The effect of the Lighthill report was to move AI techniques towards greater usefulness. This was achieved by a variety of means of which some need to be mentioned in the context of this report. First, it became clear that programs that are "intelligent" in some GENERAL way should be avoided, and the technology should move towards well-defined and restricted areas of knowledge. This proved to be a successful strategy and, as will be seen, made present-day expert systems not only workable, but also suited to training in specific topics.

Second, the shakeup led to an improvement in the way that communications may be established with these complex programs through the use of near-natural languages. That was made possible by the restricted area of discourse and was demostrated largely by Terry Winograd of MIT in the context of communicating with a robot capable of planning its actions based on its decoding of near-natural language instructions (1972). The point made by Winograd was that an instruction such as "pick pup the yellow box" may be decoded without a combinatorial explosion in a world where there are a limited number of coloured objects.

At the most general level this work showed the way in which knowledge may be stored and accessed in a computer. It also drew attention to the power of breaking down knowledge into facts and rules. For example the rules that go into responding to the request in the above illustration could be something like: "a box may be picked up if there is nothing on top of it and if the robot is not holding something else at the time". This goes together with simple logical facts such as "a box has a flat top", "a pyramid has a pointed top" and so on.

2.4 The Emergence of Expert Systems.

An expert system is a little like the above planning and reasoning system designed for robots, but without the robots. In fact, the origins of the notion go further back in the history than Terry Winograd's work and may be found in Ed Feigenbaum's work on DENDRAL in 1965 at Stanford University.

DENDRAL was a program designed to verify the structure of chemical compounds by analysing their mass spectra. The reason that this is hailed as the first expert system is that the rules for carrying out the identification were elicited from human experts and stored in a computer as an operational program. As with all good ideas, the potential of this technique became recognised soon after its invention. Considerable experience is needed by a chemist in order to identify mass spectra reliably. The packaging of such knowledge makes it available to those who are less experienced.

It is worth stopping and pondering on this point from a perspective of vocational training and employment. In general there is a shortage of people in industrialised society who have advanced knowledge of things, while there is an abundance of those who do not. Therefore the value of portable knowledge in the shape of an expert system is that of making skills available to a wider population. This is surely an up-skilling property and not one that robs humans of their toil.

But perhaps an even more pertinent property of a real expert system is its ability to search backward from the answer it has just given to a question, and explain how it got there in response to the question "why?". It is here that the training potential of expert systems comes to the fore: the ability to provide proper logical explanations of their own reasoning processes puts them head and shoulders above previous attempts at computer-based education. The latter are often no more than automated versions of tutor texts that simply reveal the right answer to the uncertain student leaving him no wiser as to how the answer was obtained (there are notable, but not widespread exceptions).

To make this point concretely, a system on car maintenance might say: "If an attempt to start the car causes the lights to dim, check the battery". The pupil may ask "why?", to which the expert system replies "as the battery may not be capable of supplying the current needed by the starter motor". Dissatisfied with this the pupil may ask "are there other possibilities?". A well designed ES would say "yes, there may be a short in the starter motor, but this is less likely, therefore I recommend that the battery be checked first". Few computer-based training programs of the past could sustain such a level of interactive discourse.

2.5 The Maturity of Expert Systems.

An expert system may now be defined as:
"A computer program that uses knowledge and inference procedures to solve problems that would otherwise require a human expert. The system must be so structured as to allow easy access to the stored knowledge, including explanation

facilities, to a user with no knowledge of computer programming and a minimum of keyboard skill".

As with many computing developments it has taken over 20 years since the potential of systems such as DENDRAL was noted, for this field to achieve a systematic treatment. In fact, because there are several ways of building expert systems and several approaches to the introduction of knowledge to them, the field has become known as the study of Knowledge-Based Systems (KBS). Suffice it to say here that the power of the technique has led to the "Fifth-Generation" computing programmes that have received so much directed Government attention in Japan, the USA and Europe.

3. VOCATIONAL TRAINING AND AI

3.1 The Role of the Computer.

The more progressive sectors of European industry have been quick at recognising the advantages offered by computers in the training arena. A good example is the "open learning" scheme at Austin Rover in the UK. The computer has infinite patience and allows its user to develop at his own pace. Besides this the often-quoted advantages are portability, access at times that are convenient, potential for high-motivation content in the material (e.g. use of reward techniques borrowed from computer games), realistic simulations (e.g. flight simulators) and adaptability in high-change situations. An example of the last of these is the rapid learning that is required when the sales material for new products needs to be learnt at regular intervals.

The main difficulties of the approach lie in the lack of flexibility of such systems. They generally provide over-simplified and awkward choices that adapt to individual users only in a minimal way. Their interfaces can have a de-motivating influence as they either operate on a menu basis or require stilted keyboard input. There is little in conventional systems that has the flexibility of a near-natural language interaction. Lack of user-modelling, lack of explanatory diagnostics and lack of standardization in the preparation techniques for materials detract from the initial advantages offered by computers in training.

The organizations that have appreciated the potential use of computers in training are in danger of being put off by the overwhelming disadvantages. It is against this background that an introduction of knowledge-based systems is seen as being capable of restoring the central advantages of using computers.

3.2 The Introduction of Stored Knowledge.

As part of research programmes in advanced Information Technology, some (but not much) attention is being given to directing knowledge bases towards training. The direction of Knowledge Based Training Systems research has been to reduce the gap between the inflexibility of the classical computer trainer and the tuition that could be obtained from a human instructor. It is important to stay aware of the fact that this is an area of on-going research. While it has not produced many usable systems its importance lies in defining future directions for knowledge-based training.

The main aims of such programmes are to produce systems that are adaptable to individual student styles, have a good educational grounding, allow the student a maximum of control over the interaction and stimulate a high level of motivation. These schemes rely heavily on KB technology and appear to require at least four distinct, interacting, expert systems.

First is the knowledge of the area that is being studied. This must be structured in such a way that the system can solve problems in parallel with the pupil and e'.plain its steps. Second, it must contain pedagogic knowledge, that is, rules about good teaching practice. Third, it must have an engine that keeps track of the student's state of knowledge, again as a set of facts and rules. It is through an interrogation of this knowledge base that the machine can take decisions about the presentation of material, again on the basis of given rules. Finally the communication with the student must be deployed at a reasonably sophisticated level. This implies the use of AI-like natural language understanding rules.

Much of this specialized research attention came from projects that have been in place since early 1970. They were mainly attempts at designing tutors that would teach mathematics to children and had to struggle with KB development from first principles. The first and often quoted system that benefited from available KB techniques is SOPHIE, developed in 1982 by Brown, Burton and de Kleer for the US Air Force to teach inexperienced personnel the techniques of electronic troubleshooting.

3.3 Direct Approaches with ES Shells.

Although the above four-element structure spells out an ideal training program, there are less ambitious ways of employing expert system technology, ways that could be tested using currently available software. To understand this, it is worth looking closer at byproducts of KBS design.

One of these is the ES "shell". This comes from the realization that an expert system breaks up into three major components: the database of facts and rules which form the "expert knowledge domain"; the "inference engine" that is a pre-defined program that searches for appropriate rules and matches appropriate facts; and finally, the user interface which allows the user to express his questions in a way that the system "understands" and frames the answers in a way that makes sense to the user.

The only thing that changes from one domain of expertise to another is the knowledge domain itself. An ES shell therefore consists of only the latter two sections: the inference engine and the user interface. The domain knowledge acts like a casette one deposits into a casette player the other two being the playing mechanism. The same shell may be used with different areas of knowledge chosen by the user.

Typical ES shells are "Expert-Ease", "Micro-Expert" and "ESP-Advisor". These are available in the UK as fully developed systems that cost about £600 for large PC (Personal Computer) systems or about £4000 for minis such as a VAX750. Clearly, the latter can accomodate larger knowledge bases than the former.

These systems can also be purchased as experimentation and training packs where a kit containing all three plus a MicroSYNICS dialogue generator costs about 600 and runs on PC systems.

As an example of penetration, the Microelectronics Educational Development Centre at the Paisley College has used ESP-Advisor to train lecturers in microcomputing techniques. This is a pointer to a way of overcoming the shortage of trainers in high technology areas.

3.4 Knowledge Elicitation.

In the context of using a shell, there is one difficulty that should not be underestimated: the problem of knowledge elicitation. This is the name given to the process of turning a human's expertise into that set of rules which can be slotted into the "domain knowledge" box of the expert system shell.

The process of haphazard elicitation is sometimes likened to the work of a substandard teacher or trainer. Industrial trainers who are not domain experts and who present their material badly, are in the position of an expert system with a badly elicited chunk of knowledge. Clearly this can be damaging.

AI has come up with frameworks for knowledge elicitation that are designed to remove the haphazardness from the process. This has given rise to a new kind of expert: the knowledge engineer. He uses this framework which includes observing experts at work, discussions about the way problems are solved and the use of expert-chosen examples followed by variations carefully selected by the knowledge engineer. The whole is then analysed, and sometimes played back before a "protocol analysis" is attempted to turn the result into a domain knowledge package.

But despite this seemingly scientific process, the number of areas that lend themselves to this procedure is still limited. There are many examples where the domain expert cannot make his own knowledge sufficiently explicit. These are areas that involve judgement, "feel" and experience. Areas where training is often done by example. For example it would be difficult to learn to ride a bicycle using an expert system. This is extreme, but in the same category one finds design processes, some quality control functions (dependent on perception and judgement) and use of metal-cutting tools that might involve judgement and feel for the finished product. On the other hand, tasks such as maintenance, troubleshooting and learning to use computer-based equipment, would lend themselves well to ES treatment. It is noted that these are precisely the tasks that are generated by high technology developments.

3.5 Logic Programming.

We have, as yet, said little about the way in which the programming that transfers knowledge into the computer is executed. Older, dedicated systems were usually written in a list processing language called LISP. Although this suits expert programmers, it is not an easy tool to use by someone who is not familiar either with the language itself or with database creation (i.e. the storing of knowledge) in general. Of course, commercial ES shells provide a relatively easy way of entering the data, but there is an alternative.

This is the language called PROLOG which was originally designed to express programs in terms of formal logic. This is a highly direct (or DECLARATIVE) language which has the laws of logic built into it. Hence the user merely makes logical statements, and the language automatically does the rest (this being the process of asking question about the statements that have been made). Thus the language can represent both facts and rules and may be illustrated by the following somewhat trivial example drawn from medicine.

A general rule in PROLOG may look like:

```
X may-have Y if
    X has Z and
    Z suggests Y
```

Facts can then be expressed in the form:

```
(stuffy-nose) suggests (cold)
(yellow-eyes) suggests (jaundice)
```

The use this elemental expert system the user may type in:

```
Fred has stuffy-nose
What Fred may-have?
```

To which the system replies

```
Fred may-have cold.
```

A curious user may here type

```
Why?
```

To which the system replies

```
I have used the rule
Fred may-have cold if
Fred has stuffy-nose and
stuffy-nose suggests cold.
```

The rapidly spreading use of PROLOG has implications on computer usage training. In the UK, schoolchildren have been found to take easily to PROLOG, which, if transferred to the training system designer in industry, may mean that the language can be used as a basic tool for the implementation of Expert Systems for training.

4. CURRENT DEVELOPMENTS: DEGREES OF PENETRATION

4.1 International Programmes.

Up to the beginning of this decade, AI was seen as the prerogative of computer science research laboratories: more of a 'tour-de-force' than an applicable technology. The announcement of the Japanese 5th generation programme changed all that. It was the fact that the Japanese specifically made knowledge bases the focus of this effort, that made the rest of the world sit up and take a serious look at these techniques.

The European response was based on the ESPRIT and ALVEY programmes in the EEC and the UK respectively. In the US there was no coordinated national programme, but DARPA (largely concerned with defence) redirected much of its effort towards research in knowledge-based systems and industry stepped up its own activity in this area. These programmes are not only directed towards KB but also towards support (e.g. Very Large Scale Integration) and application (e.g. Robotics in ESPRIT). It is the investment in Knowledge-Based systems that completely defines the progress of the development of KB products that are relevant to training. These investments run as follows:

KB investment in Alvey: £60 million (over 1/6th of total)
" " " ESPRIT: £80 million (under 1/10th of total).

From a point of view of this report, it is important to extract the work that is likely to lead to products usable in training and focus on work that is specifically directed towards training. There is a difficulty here with the ESPRIT programme in the sense that work to do with training was specifically excluded from the original remit. In Alvey on the other hand, the question of catering for training both using the technology and adapting to it has been considered in several ways. We shall review some of these below.

4.2 Direct Relevance Projects.

In this section we outline five research projects that are of direct relevance to training through the use of AI techniques. Although these are all in the research domain they are likely to be influential in the developments of the next phase that will involve users and field trials.

4.2.1 Guided Discovery Learning Systems

Cost: £200,000

Partners: Univ. of Lancaster
Univ. of Leeds

Start Date: Sept. 1985

Completion Date: Sept. 1988

Stated Objective:

To investigate whether AI machine-learning techniques support computer-aided instruction. It is proposed to develop a usable tutor which teaches decision-making, problem-solving skills and guided exploration of specific subject domains. Much attention is given to the development of student models and the knowledge base is used actively to this purpose. The scheme is being tested in a situation where the pupil is being taught to use a complex telephone switchboard console.

Comment:

This is an ambitious project in the sense that it USES a KB system to "understand" the pupil in a computer assisted learning situation.

4.2.2 Tactical Decision Aids

Cost: £2,170,000

Partners: Solartron, Rediffusion, Smiths Industries.
Start Date: April 1985
End Date: January 1989

Stated Objective:

To develop techniques that assist operators working or being trained to work under stressful conditions. Specifically these are in flight simulation, naval training, aircraft cockpit decisions. A wide variety of knowledge representation techniques are being used and tested.

Comment:

This is an expensive project directed at the defense industries. However, the findings of the project could be useful in industrial settings: crane control trainers, vehicle guidance, emergency control training and so on.

4.2.3 Knowledge-Based Engineering Training

Cost: £530,000

Partners: Logica, Engineering Industry Training Board, Imperial College, Kingston College of F.E., Exeter University.

Start Date: Feb. 1986

End Date: Sept. 1987

Stated Objectives:

The focus of this tutor is training to use maintain and program a Numerically Controlled Milling Machine. It makes imaginative use of video and graphics in an interactive mode.

Comment:

This is likely to be a most valuable excercise. It will eventually be mounted on a low-cost system and will have much potential for widespread use.

4.2.4 An Intelligent Arithmetic Tutor.

Cost: £500,000

Partners: The Open University Systems Ltd.
Start Date: Sept. 1985
End Date: Aug. 1988

Stated Objectives:

Both the design of a knowledge-based arithmetic tutor and a knowledge-based diagnostic package are being developed. These will be taken through to the product stage.

Comment:

This is taking a classical Computer-Aided educational area into the knowledge-based arena. Clearly the area of arithmetic would not be of much interest in vocational training. It is the techniques that result from the creation of robust products that may be of value.

4.2.5 Intelligent Training Manuals

Cost: £350,000

Partners: University of Lancaster, British Telecom Tech. College
Start Date: Imminent
End Date: 3 years from start

Stated Objectives:

Knowledge-based computer-resident training manuals are being investigated. At the same time test metrics are being developed to compare the efficiency of different designs.

Comments:

Although this project has as yet not started, it is of central interest to industrial training. It is likely to conclude with a completed prototype tutor.

4.3 Pointer Projects.

In this section we review three projects that, although not specifically directed at the use of KB systems in training, provide a flavour of alternative ways in which some KB work could have an impact in the training domain.

4.3.1 Natural Language Generation from Plans.
Principal contractor: U. of Sussex

This is an interface that generates, in a non-interactive way, a clear description of the actions required to support a complex plan that may have been generated by an AI programme. This technology is likely to improve the clarity with which eventual training systems communicate with their users.

4.3.2 Learning and Using Prolog
Main Contractor: U. of Sussex

This project seeks to optimise the teaching of Prolog. As this may be one of the tools that will be used by the industrial trainer, the results will not only anticipate the hurdles in the application of the language, but also suggest optimal ways of adapting to it.

4.3.3 Human Interface to Public Information Systems
Main Contractor: Loughborough U.

This project is targeted at an information and advice system for ex-trainees of the Youth Training Scheme operated by the Manpower Services Commission in the UK. The objective is to improve the way in which such a system delivers and individualizes the information it holds.

4.4 Users Club.

One of the most successful activities initiated by the Alvey KBS sector was the creation KB user clubs that could go beyond the £600 experimental pack and start developing their own expert system to meet some common need within the club. This is an important concept in the context of this report, as it is one of its recommendations to CEDEFOP that it should act as a catalyst in the creation of similar European clubs with a common interest in vocational training. Each of the projects below is funded largely by a small contribution of the participating members with an equal input from government. They range from £200,000 to £400,000 per project and are largely designed to give their users 'hands-on' experience.

4.4.1 RICS (Royal Inst. of Chartered Surveyors)

The Royal Institute together with the Portsmouth Polytechnic is heading up this project on behalf of its members. It is directed at the creation of an advice-giving system in quantity surveying.

4.4.2 PLANIT (Project Planning through IT)

This project contains an amorphous group of partners: a total of 27 including Jaguar Cars, British Gas, Rolls-Royce, Birds Eye, Wall's etc.. The link between them is the need for project planning. Three demonstrators have been built on three different planning topics. An expensive Kee/TI Explorer ES engine is being used and usable planning systems are to be delivered to the partners by the end of the project.

4.4.3 ALFEX (Financial Health Monitoring)

This is a grouping of 25 major financial houses (mainly banks, including the Banks of England and Scotland and investment firms such as Price Waterhouse and N. M. Rothchild). The project has already thrown out the possibility of using a shell and is now heading towards the completion of a full company health advisor that will run both on microVAX and IBM PC machines.

4.4.4 ARIES (Insurance Community)

Again this club contains the major Insurance Companies in the UK together with ES suppliers and academic consultants, numbering 25 in all. Two specific target areas have been chosen: clothing industry fire risk assessment and equity investment risk assessment.

4.4.5 TRACE (Transport Industries)

Typical of this group of nine are American Express, British Airways and the Thomas Cook group. The targets are the assistance and training of enquiry clerks in route selection and package selection. The system uses PROLOG and is intended to run on IBM AT type machines.

4.4.6 WIESC (Water Industries)

The target areas are water distribution network control and sewerage rehabilitation planning. High-quality SUN workstations are used, largely programmed in PROLOG. The two expert systems are due for completion in Oct. 1987.

4.4.7 DAPES (Data Processing Community)

Here the ES is turned towards the handling of data itself through the appropriate use of computers. Partners include: building societies. BP, the police and the Inland Revenue. The target areas are the maintenance of DP management over a large network, a help desk assistant (at W. H. Smiths, the stationers) and a communications troubleshooter for banks. These are due for completion in September 1987.

4.4.8 Comment on the clubs

The creation of the above clubs has not only proved to be useful to its members, but has caused the penetration of advanced techniques into the user community under the control and evaluation of the users themselves. This has been hailed internationally as a uniquely successful technique. It is proactive and will result in a proper pragmatic test of the methods. Those that have a clear payoff will be adopted and used within a short time scale.

5. SPECIFICALLY, VOCATIONAL TRAINING.

Having developed the theme that Knowledge-Based methods are well entrenched as ways of using computers, this section concentrates on issues that bear directly on vocational training, what needs to be done to harness KB techniques in solving some training problems.

5.1 Training for the Knowledge-Based Era.

Here one faces the well-known skills shortages in Information Technology. Although most organizations that use computers are familiar with data processing and office enhancement techniques, AI or KBS seems a threatening mystery. The Alvey programme was not slow to move in the direction of alleviating this need through the creation of the "Journeyman" scheme. This invites graduates (in most fields) to join research teams either at Imperial College or at the Turing Institute in Glasgow so as to work at the heart of KBS for a period of six months.

It is our belief that this is a good treatment for industries that will be involved in generating their own Expert Systems. In the rest of industry, perhaps the problem is not so acute. One of the advantages of Expert Systems is that once produced, they are easy to use, and only proven systems should be used in this context.

5.2 Knowledge Based Systems for Training.

The crux of this report is that development of Knowledge-Based Systems has advanced far enough to provide equipment for experimentation with the design of training systems in some key areas. In fact, the position is identical with that of other areas (insurance, surveying, finance etc.) which have been served by the Alvey clubs.

The large investment in research that has been discussed above, serves simply as a reassurance that the field is developing and will not pull the rug from under one's feet.

But there is no Alvey Club for training and yet, training must be the problem that unites a very wide industrial and commercial community. It is suggested that CEDEFOP may be in a good position to raise awareness of the possibility of the creation of European Clubs in several key areas of training and act as a catalyst in this process. It would be wrong to identify critical areas at this stage: this should be the topic of a meeting on the subject.

With this simple model in mind, it becomes possible to come to our concluding recommendations.

6. CONCLUDING RECOMMENDATIONS

These recommendations should be read bearing in mind that, outside of the MSC in the UK, very little is being done on the use of ES in industrial training. This is particularly true in the broader context of Europe. The MSC recommendations have now been accepted in the UK which adds a sense of urgency for the creation of a European activity, so that the rest of Europe should not fall behind.

6.1 CEDEFOP is well placed to act as a European focus for the creation of an Industrial Training activity to coordinate cooperation in the evaluation of Expert Svstems in key industrial areas.

6.2 The next step is for CEDEFOP to organize a meeting between those who are best placed to take initiative in their own environments.

6.3 The meeting should discuss the character of the work that needs to be done to create "club"-like activities that achieve a financing momentum of their own.

6.4 It is essential that the activity be based on EXISTING AVAILABLE EXPERT SYSTEMS. The meeting should therefore include an exposition of such systems.

6.5 CEDEFOP might investigate what financial input could be obtained from the governments of the participating states.

6.6 The agenda of the meeting should contain the selection of the key areas that could be attacked by ES techniques. Such areas could be chosen from:

Project planning;
Maintenance of complex equipment;
Safety Procedures;
The use of computers;
The use of computer-based machine tools;
Staff development matters;
Office Automation Training;
Union work development (negotiating techniques etc.);
Robot and FMS machinery operation;
Management techniques;
and so on.

6.7 Because there is considerable advantage to be gained in the up-skilling of workforces through expert systems, there should be good union presence at these discussions.

6.8 CEDEFOP could continue to act as a link between this activity and relevant clubs in say, the Alvey programme.

6.9 CEDEFOP could act as an information centre putting those who wish to use ES training techniques in touch with those who have experience of the techniques.

ARTIFICIAL INTELLIGENCE AND EDUCATION

SOME LINES OF REFLECTION

MARTIAL VIVET, UNIVERSITE DU MAINE
LE MANS

CEDEFOP
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ARTIFICIAL INTELLIGENCE AND EDUCATION

Some Lines of Reflection

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Summary: This paper begins with a report on the current situation in France with regard to artificial intelligence (AI) and education. The main part of the document discusses what possibilities AI has of contributing towards education. It explores both the interface area (man/machine communication) and also more fundamental aspects: role of expert systems, importance of exploring knowledge representation, investigation of "natural" reasoning, etc. The paper presents a description of potential AI applications in education: use in the classroom, use in distance learning, use in teacher training. It concludes with a number of still open questions.

Paper presented at the Anglo-French Workshop on "Information Technology and Education", Maison Française, Oxford, GB, 16 to 18 December 1985.

Introduction

This paper will attempt firstly to provide a rapid overview of the current situation in France with regard to the areas of interaction for AI and education. The second section charts out some lines of reflection on the subject of AI and education: a discussion of various aspects of the potential contributions which AI could make to education and a description of potential applications. It concludes by raising a number of questions. The reader should note that the paper does not investigate the problems linked with the teaching of AI and questions of the category "problem-solving with LOGO in particular".

I. AI and Education: State of the Art in France

AI is only just beginning to take on a structured form in France - mainly at the National Scientific Research Centre (CNRS) with the so-called PRC-IA project. This joint research project involves the most important research teams engaged in the field of AI in France and has strongly mobilized the available researcher potential. It addresses four major themes: modelling of reasoning and knowledge, analysis of inference and control, modelling of learning, application methodology. The personnel involved in the PRC project are essentially information scientists and their main concerns are far removed from those of the life sciences. Moreover, the project addresses no area which is of direct relevance to the theme of this paper. Indeed, the work being carried out on this particular theme is still very decentralized, involving individuals working in relative isolation. Nevertheless, there have been a number of activities of relevance to the theme:

- November 1983: launch of a series of monthly seminars "AI and Training", organized jointly by CESTA (Ministry of Industry and Research) and INRP. The seminars provide occasions for presenting and discussing findings relating to this theme. A list of the aspects addressed during the seminars is provided in the Annex.

- December 1984: publication of a special issue of the EPI bulletin by the Public Education and Information Science Association (EPI), an association which brings together teachers directly concerned by the introduction of information science in education. The special issue was devoted to the theme "Expert systems and education" and reviewed a number of ideas and achievements.

- Dissemination of an expert system drive (PENELOP) written in LE-LISP and of a special version of MICRO-PROLOG by the National Pedagogic Documentation Centre (CNDP). These two items of software can be run on the equipment installed in schools. We have only scant information on the use made of this software. MICRO-PROLOG is reported to have been used by a history teacher for inferring links between historical facts.

There are only a small number of university research teams known to be working on this theme. Their activities include the following:

- The work of M. C. Rousset and M. O. Cordier on AI applications in algebraic calculation at the Information Science Research Laboratory (LRI) of the University of Orsay

- The work of M. Quere and M. Grandbastien at the CRIN in Nancy

- The work being carried out at the IRISA, Rennes, on the teaching of geometry on the basis of interactive PROLOG programs

- The work of M. Baron and O. Palies at the University of Paris VI on the use of expert systems in teaching mathematics and electrical engineering (series and parallel circuits with resistors, coils and capacitors); M. Vivet (University of the Maine) and J. Mathieu (University of Rouen) are working in close cooperation with this team.

It should be noted that the Simon Report ("The Education and Information of Society", Documentation Française, 1981) provided an initial analysis of the links between AI and education.

II. Aspects Relating to AI's Potential Contribution to Education

If one goes along with the view of renowned expert R. Schank (Yale University, USA), AI will ultimately find major applications in the education field. In one of the most recent issues of Byte he states: "The most promising AI applications are perhaps those in education, helping people to learn to read, to recall and to think. This thanks to a better understanding of the fundamental mechanisms involved in these activities."

Such contributions present various aspects at various levels:

1. Interface aspects

These are the formal aspects, not necessarily directly affecting didactic considerations but playing a role at the man/machine communication level. Here, much can be expected from speech and image synthesis and recognition, and from the synthesis and comprehension of natural-language texts. The results achieved with AI do not yet appear to be sufficiently advanced to allow for the flexible communication required in a learning situation. It should be noted that these communication facilities are not only useful to the learner but can also be valuable aids for the teacher in preparing his instruction. Thought should be given to the question of collective applications for computer-aided instruction systems using speech as the means of communication (what, for example, becomes of exchanges between children if each child has his or her headphones and microphone or is enclosed in a glass booth as in a language laboratory?). On the other hand, the teacher may be very interested in the possibility of dictating his texts into a machine!

2. Hinge aspects between form and substance

The technology of the expert systems available today is already sufficiently advanced to be of great interest in developing education systems. Developing such systems is a relatively lengthy and costly process, and there are still no tools to facilitate the software-writing work. Expert systems are currently being developed in sectors which have much greater investment capacities than educational institutions. Two elements which are very important within a teaching-learning relationship form the basis of the interest here:

- An expert system is able, in principle, to solve the problem put to or which it puts to the pupil; moreover, it is able to solve it using the same methods as the pupil.

- An expert system can explain the possible line(s) of reasoning used to tackle the problem; it can explain how choices are made and also the steps in the reasoning involved in solving the problem.

With the knowledge of how to make an expert system reason, one can make such a system reason either correctly or incorrectly (false reasoning or reasoning based on inaccurate knowledge). Those involved in the study of pedagogy have discovered a large body of false reasoning; codification of this makes it possible to obtain precise diagnoses of wrong answers.

The use of expert systems in teaching should provide for:

- interface effects for the child: individual explanation is always more pleasant, leaving room for establishing confidence;

- profound effects: "the right explanation at the right time", which is so important in any learning situation.

An important fact should be recalled at this juncture: having a good system for solving problems in a given field is not the equivalent of having a good teacher in that field. This is true of human beings and is likewise true of expert systems. In particular, one should not be content with explanations of the "trace" type which are so often offered by inference generators. The problem of the explanations to be provided is a problem in its own right which should be tackled as such. Perhaps this complex could be entrusted to a secondary expert system working with a knowledge of the child concerned, a knowledge of psychology, "oratory", knowledge of the problem to be explained and an ability to infer the "right" explanation within the given context.

3. Fundamental aspects

- "Teaching" a machine to solve problems in a given field presupposes a profound knowledge of the reasoning processes and specific data applicable in that field. This is particularly true at the meta-knowledge level: knowledge of the use which can be made of a given body of knowledge and the strategies by which it is applied. This activity basically falls within the confines of education science, and having teachers work on such systems could be extremely valuable, even if they do not have such facilities within their clasrooms. Teaching teachers to become aware of the fact that one can equip the computer - undoubtedly the most stupid of all their pupils - with a certain number of abilities can be a valuable exercise from various viewpoints.

- The fundamental aspects warranting further consideration are as follows:

  - Analysis and representation of knowledge in a given field; of particular interest here is the manipulation of declarational knowledge, the discussion on the nature of knowledge and the interactions between declarational and procedural knowledge.

  - The general problem of learning: acquisition of knowledge (learning by heart), acquisition of meta-knowledge (learning of strategies to apply knowledge). Here, teachers could explore the various learning models. Mention can be made of the following: generalization on the basis of examples; inductive inference, representation changes, automatic rule generation, etc.

- The different forms of reasoning, in particular natural reasoning. This covers deductive forms of reasoning based on traditional syllogisms and links with logic but other forms too. Mention can be made of plausibility reasoning, reasoning using unverified, imprecise or incomplete knowledge (reasoning by default) and the links with "natural" logics (non-monotone, temporal, argumentative logics). The work begun by Polya on plausible reasoning and the teaching of mathematics warrants being extended to other fields. Apart from exploring the underlying fundamental aspects, it is also important to present the computer to the teacher and then to the pupils as a "deduction machine".

- The history of AI: a history abounding with achievements, kept and unkept promises, failures. Analysing the reasons for these failures and the development of the problem areas is an exercise which produces a wealth of insights.

III. Range of Educational Applications for AI-based Expert Systems

1. Using expert systems in the classroom context

What is concerned here is the use of software which has developed from computer-aided instruction software to become computer-and-AI-aided instruction software for transferring or verifying knowledge in the various fields of instruction. It could also mean using software based on simulation processes (of physical, chemical, biological, economic systems, etc.).

2. Use of remote-access expert systems via communications networks

This may be "home-based training" (for the disabled, for teachers); it may also be on-the-job vocational training. An example which could be envisaged here is that of training automobile mechanics in fault diagnosis and maintenance on a new type of vehicle. The client's vehicle serves as the basis for practical work guided by an expert system installed at the manufacturer's head office and accessed via a console located in the repair shop. It would thereby be possible to offer decentralized training for a large number of mechanics. For the company, training in handling a new model would imply introducing into the knowledge base the diagnosis and maintenance rules applicable to that new model.

3. Teacher training

"Intelligent" systems could find a direct application in the training of teachers. The BUGGY system, for example, which trains teachers to diagnose wrong behaviour patterns, represents one path which warrants further exploration. The quality of the instruction will continue for some time to depend on the quality of the teachers(!). Of uncontestable interest are systems which train teachers to listen, observe, analyse behaviour and diagnose invalid knowledge or reasoning.

IV. Some Questions

1. To turn to the problems of programming, what type of programming should today be favoured for teachers? And for pupils? Declarational programming, procedural programming? If it is to be procedural programming, should one start with the classical algorithmic languages (BASIC, PASCAL, etc.) or with functional languages (LISP, LOGO), or actor languages, object-oriented (SMALL TALK, etc.). What role should LOGO play? What role should PROLOG play? These problems are more fundamental than the merely surface aspects of the language dispute.

2. What adjustments should be made to hardware policies for teacher training centres and for schools to ensure that intelligent systems are really integrated into the various cogs of the educational machinery? Intelligent systems require fast processors, large and fast memories

and storage units. The hardware currently installed in educational establishments is too small. Should one move towards the remote accessing of large machines, microcomputers functioning in a console? Is it possible to define specifications for economically reasonable hardware systems for widespread dissemination which ca support all that AI has to offer in terms of applications for education?

Conclusion

This paper is merely an overview intended to stimulate discussion. The questions it raises are largely open questions. It seems that there is now an urgent need to realize some of the applications based on the ideas set out. This is a prerequisite for taking the discussion further.

Annex

List of the "AI and Training" seminars organized by CESTA/INRP

18.12.1983 M. VIVET - A. ROUCHIER
Expert systems in mathematics and the teaching of mathematics

13.01.1984: H. WERTZ - P. GREUSSAY
Intelligent environments for programming

16.02.1984: J. P. DESCLES
For a distinction between the representation of knowledge and quasi-natural languages in information science and its treatment of languages

G. SABAH
A classification of the knowledge types required for automated text interpretation and their relations with the various complementary comprehension methods

20.03.1984: M. BERGMANN
PROLOG

19.04.1984: A. BARR
Expert systems: recent developments and limitations

15.05.1984: H. DREYFUS
Round Table: Learning by analysis versus learning by intuition

2' .06.1984: J.C. SIMON
Open problems and conjectures in shape recognition and AI

16.10.1984: J. P. HATON
AI and oral dialogue. New means of man/machine communication

26.11.1984: M. S. LEGRANGE - M. RENAUD
Application of an expert system to study reasoning in the life sciences. Its pedagogic implications.

18.12.1984: Y. KODRATOFF
An approach towards symbolic learning

24.01.1985: E. MOUANGUE
Contribution of expert systems to computer-aided instruction

G. DAHAN - J. FERBER
A kit for AI training on a microcomputer

14.03.1985: A. N. PERRET-CLERMONT
Social interaction and the learning process

23.04.1985: D. CABROL - C. CACHET - R. CORNELIUS
Presentation of software to solve elementary problems in chemistry

EXPERT SYSTEMS IN TRAINING

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CEDEFOP
BERLIN
1987

Over the last few years AnCO has made a major effort to harness the use of computer technology in training. In 1981 AnCO first undertook research on the use of Computer-Based Training. This research concluded that CBT was a very useful training delivery method because it could cater for the trainee as an individual by providing self-paced feedback which is immediate and confidential. It would also allow the training organisation to maintain a consistency of input, a trainee record system and other aspects of computer-based management. Overall, therefore, CBT could allow AnCO to provide more efficient and effective training in certain areas.

AnCO now uses a variety of Computer-Based Training methods in its training courses. These range from standard information-question-prompt feedback programmes to highly sophisticated interactive video systems whereby the power and flexibility of the computer is linked to the impact and realism of video film to present a highly realistic demonstration and learning process. A list of programmes produced to date forms Appendix 1 of this report. AnCO has taken a corporate decision that by 1991 30% of all training programmes should be delivered using technology-based methods.

It is within this context that AnCO has been proceeding with the use of expert systems in training. It is recognised that even the sophisticated programmes developed to date can not provide a fully individualised training programme. In general they take only limited account of the trainee's current knowledge and learning styles and are usually based on a fairly simple behavioural model of learning. Equally, they are not usually very good at explaining their answers. Expert systems potentially can improve the effectiveness of computer-based training programmes by overcoming these deficiencies.

AnCO staff are being trained in expert systems and a number of expert system shells have been purchased and tried out. As well as being used for training purposes, AnCO has also been developing the use of expert systems in its administrative operations. An expert system has been set up in relation to sick-leave procedures within the Personnel Division. A fault diagnosis system has also been established for AnCO's computer network and work is now proceeding to develop an on-line expert system tuner for AnCO's computer system. In the area of training four projects are in progress. These are explained below.

LEARNING STYLES ADAPTATION

The aim of this project is to assess trainees' learning styles at the ginning of a programme and to design the programme to meet those styles. A standard learning styles questionnaire has been put onto a Computer-Based Training package and trainees are asked to complete the questionnaire. The results are then automatically scored and subsequently used (off-line) to design the training programme.

This project will, over the next couple of years, be further developed. It is intended firstly to adapt the standard learning styles questionnaire to make it more suitable for use with all trainees. (For example, the language used will be reviewed.) Then the revised assessment system will be turned into an expert system on-line front-end for training programmes.

TRAINING PROGRAMME SPECIFICATION GUIDE

This project has involved developing a relatively simple expert system to assist programme designers in writing training programme specifications. The system aims to increase the productivity of programme writers by ensuring that the essential elements of good programme design are achieved in their work. The system involves a series of prompts (questions) to which the programme designers must respond. The system will be made available to each AnCO Training Centre to assist individual instructors as well as to persons engaged in programme design centrally.

ENHANCING TRAINING PROGRAMMES THROUGH EXPERT SYSTEMS

In this project it is intended to improve an existing computer-based training programme by incorporating into it some elements of expert systems. The aim would not be to produce a full expert system but rather to improve the checking/testing aspects of the existing programme. In this way the programme would be better tailored to individual trainee's needs by having a greater range and sophistication of branching options. This project has not yet begun. It is likely that the CNC training programme will be chosen for this application.

REVIEW OF EXPERT SYSTEMS IN TRAINING AND DESIRABLE FUTURE APPROACHES FOR ANCO

This project is being conducted by Mr. John Dineen, a research scholar at the Human Factors Research Unit, University College, Galway. This scholar is being supported by AnCO under its Research Scholarship programme. The following pages present a summary of the findings of this project to date.

MAIN CONCLUSIONS TO-DATE

A. TO REVIEW THE USE OF EXPERT SYSTEMS IN TRAINING

The use of expert systems in training contexts has been less conspicuous than computer-based training (CBT) systems. However, to successfully develop an expert training system will require focusing on four major issues, namely,

- knowledge of the domain (concepts and processes);
- knowledge of teaching (teaching principles);
- knowledge of interaction (tutoring conventions); and
- knowledge of authoring (interface to input knowledge).

Knowledge of the domain

In order to build a tutor, the teacher needs to represent knowledge of concepts, rules, and learning in the subject domain. This knowledge can be classified as follows:

- DECLARATIVE KNOWLEDGE includes concepts in the domain and their relation to each other;
- PROCEDURAL KNOWLEDGE includes the reasoning used by the

system to solve problems in the domain; and

- HEURISTIC KNOWLEDGE describes actions taken by an expert to make measurements or to perform transformations in the domain. Heuristic knowledge defines the operations performed to solve problems in the field and the actions that are a part of an expert's experiential knowledge about how to realise situations in the subject area.

Knowledge of teaching

The second frontier to overcome is the representation of knowledge of teaching. By knowledge of teaching is meant the system must know how to ASK the right questions and how to FOCUS on the appropriate issue. The system should act as a partner, not as a disinterested, uncommitted, uncooperative colleague. Effective communication requires looking beyond the words used by the trainee and determining what the system and the trainee should be communicating about. The student model is an essential component of the knowledge of teaching. This model contains the system's knowledge of the trainee and it must be represented in very fine detail and updated dynamically during the course of the tutoring session.

The student model cannot be a simple subset of domain knowledge; it should contain common errors and misconceptions compiled by teachers.

Knowledge of interaction

The third barrier and one of the largest stumbling blocks in the design of an effective system is a lack of adequate representation of interaction conventions. One possible way is to propose a model of tutoring interaction that elucidates and refines certain maxims, for example,

- quality: be committed and interested in trainee's knowledge;
  be supportive and co-operative;
  do not take the role of 'antagonist';
- quantity: be specific;
  use a minimum of attributes to describe a concept;
- relation: be relevant;
  find a trainee's threshold of knowledge;
  teach at threshold level;
- manner: be in control;
  allow trainee to choose new topics;
  allow context to determine new topic.

Thus, qualitative inferences will be used to generate new problems and examples to be presented to the trainee. It will be used to evaluate and possibly redirect the progress of the interaction. The intent should be to use qualitative reasoning to improve the flexibility and reasonableness of the interaction.

Knowledge of authoring

The fourth barrier that must be addressed before building intelligent tutoring systems is knowledge of authoring, or, in other words knowledge of non-programming natural interfaces through which the teacher can modify the concept or rules of a system. To-date, progress toward the development of intelligent authoring systems has been slow.

B. TO EVALUATE THE POSSIBILITY OF DEVELOPING AN EXPERT SYSTEM TRAINING SHELL

A general-purpose Intelligent Tutoring System (ITS) is not practicable for the foreseeable future even though a specialised Training Shell could well be available in the next year or so. The major challenge is the development of a 'Student Model' - having a simulation of the ideal performance of a student - required for the "model tracing" methodology of tutoring (Reiser, Anderson and Farrell, 1985). The human learner's problem-solving behaviour is compared with the performance of the ideal model. This can be inferred by matching the learner's output to problem states generated by various ideal rules. Creating sets of production rules that simulate the problem-solving processes of an ideal student is a sizeable but largely achievable task. However, the number of man-hours alone required for achieving either an ITS or a Training Shell would need the services of a specialised Training Development Unit (TDU) with access to expertise in the areas of psychology, linguistics and computer science at the very least. As such this option is not a viable goal for AnCO to pursue.

C. TO ASSESS THE POTENTIAL ADVANTAGES OF COMBINING AN AUTHORING PACKAGE AND AN EXPERT SYSTEM SHELL FOR A TRAINING CONTEXT

The typical model of CBT has a number of important shortcomings as complete instructional systems, for example, the evaluation process of students' performance is solely dependent on the analysis of their responses to given questions. This response-specific evaluation is very useful for diagnosing the causes of students' problems and inferring their learning needs. However, it is not appropriate for measuring students' overall performance on a task because the response evaluation is limited to a specific (and frequently very small) aspect of the task. Also, it does not take into account the information available in students' long-term memory because the evaluation is based on the analysis of their immediate response to a given question. That is, existing CBT systems may have diagnostic mechanisms but not have appropriate measurement and evaluation components.

Perhaps what is required is to combine the advantages of both CBT and ES in an "Intelligent Authoring System". This route would allow AnCO to draw on its own considerable expertise in the area of CBT and to buy in the expertise available on AI as required. This particular alternative also allows AnCO to continue its thrust in the field of training without abandoning the possible gains from a major breakthrough in Intelligent Computer-Aided Instruction (ICAI).

An initial solution may be presented by combining an expert system shell and an authoring package - this part of the project will be addressed in the coming year!

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APPENDIX 1 ANCO INTERACTIVE VIDEO AND COMPUTER BASED TRAINING PROGRAMMES

Course Title

1. Finance for Non-Financial Managers
2. Costing
3. Robotics
4. Welding
5. Report Writing
6. Metric Micrometer
7. Developing Learning Skills
8. Troubleshooting Hydraulic Circuits
9. Resistors in Circuits
10. Fundamentals and Applications of AC Circuits
11. Money In - Money Out (Financial Literacy Series)
12. Problem Solving and Decision Making

ARTIFICIAL INTELLIGENCE
APPLICATIONS TO LEARNING

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CEDEFOP
BERLIN
1987

ARTIFICIAL INTELLIGENCE APPLICATIONS TO LEARNING

WHAT IS ARTIFICIAL INTELLIGENCE (AI)

1. There are as many definitions of Artificial Intelligence as there are AI researchers!

"Artificial intelligence is the science of making machines do things which would require intelligence if done by a human" according to Marvin Minsky(1).

2. This somewhat circular attempt gives an indication of the difficulty of arriving at a generally agreed definition. However, we are concerned with the application of AI, not AI research. So perhaps John Self of Lancaster University, gives us a better clue, when he says:

"Using AI products is not AI, it is software engineering: It is using known techniques to find cost-effective solutions to well-defined problems . . . . AI is the part of computer science concerned with tackling problems which are not well-defined".

BACKGROUND

3. In 1985 and 1986 those in the Manpower Services Commission concerned with New Training Technology, became aware that developments at the very leading edge of training technology must come to terms with the application of AI techniques as an extension of existing technologies.

4. A number o. projects were funded, largely based on the application of Expert-Systems to training and educational needs, such as:

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(1) Marvin Minsky, MIT

(2) John Self, University of Lancaster, 1986

a. An expert system in report writing.

b. An expert system in fault finding and a comparison with existing methods of training.

c. An expert system to train supervisors and managers in stock and inventory control.

d. An expert system on taxation for managers of small-businesses.

5. The MSC also funded a starter pack for Further Education in the use of expert systems across the FE curriculum. An FE college was also funded to conduct training in expert systems by the secondment of trainers from industry with an identified training need conducive to an expert system approach.

6. One very ambitious project was funded in an attempt to produce a generic training needs analysis system. Whilst a model for such a system was proposed the final product was a prototype course planning advisor.

7. Following on from these varied initiatives, in April 1986 the MSC agreed to fund a programme in "AI Applications to Learning" to run from April 1987 to March 1990 with a total budget of £3.2 million. The overall aims were:

a. To explore the use of AI techniques in developing more effective training methods.

b. To accelerate the appropriate applications of AI techniques in learning.

c. To encourage UK industry to become more competent and competitive by providing evidence and demonstrations of more cost-effective means of training.

PHASE 1 - ARTIFICIAL INTELLIGENCE - APPLICATIONS TO LEARNING PROGRAMME COMMENCING APRIL 1987

8. Based on advice from an External Working Group it was decided that the first phase of the programme would have 3 elements:

a. Evaluation 2 parallel projects running for the three years of the Programme 1987/88 to 1989/90, will provide external evaluation of the impact of the programme as a whole. The evaluations will be both formative and summative and will concentrate on the impact on the Further/Higher Education Sector and the Industrial/Commercial Sectors respectively.

b. Survey Projects MSC invited proposals for the following surveys-

(1) A mapping exercise of AI tools.

(2) A mapping exercise of intelligent courseware.

(3) A skills inventory/training needs analysis of the key people who could enable, influence or facilitate AI applications to learning.

The surveys reported at the end of August 1987 and have helped the MSC to decide the criteria for Phase 2 of the Programme. The findings and recommendations will be discussed later in this presentation.

c. Demonstrator Projects 3 projects were selected from over six million pound's worth of proposals received, they addressed learning needs in manufacturing industry, small businesses and the Further Education Sector. The general criteria for all the submissions were as follows:
They must:

(1) address an identified and specific training/learning need

(2) be a significant development of new technologies in training

(3) be shown to be a cost-effective method of meeting the need identified, or lead to proving that a particular technology is a cost-effective solution

(4) ensure that the outcomes have a generic application, whether as process or product, across other industries or sectors.

(5) be practicable and realisable within resource constraints and in particular have specific outcomes within 1 year of the commencement of the project.

The projects selected, which are due for completion in March 1988,were:

(1) An expert system on customer complaints procedure for use by catering students and local small businesses. (Granville College)

(2) CBT and simulation linked with an expert system which will train staff to operate and maintain a process plant. The package will enable staff to upgrade their skills to cope with the change from manual processes to automation within the working environment. (Redifussion and Tate and Lyle)

(3) An expert system training package to help business planning. The package will use the concept of a "position audit" of the business to help the owner-manager to identify critical success factors and the relationship between them. (NCC and Durham University Business School)

PHASE 2 OF THE PROGRAMME

9. Phase 2 is due to start in December 1987. The invitation for oposals will be made in September 1987 after criteria have been decided. Projects will then be selected and will start in January 1988.

10. Whilst the criteria for the selection of Phase 2 projects have not been decided at the time of the preparation of this paper, the findings and recommendations of the Study Projects have just been received. To give some indication of the direction the Programme is likely to go the most significant findings and recommendations are now outlined.

THE SURVEY PROJECTS

Some of the main findings and conclusions from the Surveys are as follows:

11. TOOLS

a. It is probably not appropriate for MSC to be involved in the direct funding of tool development. However, to date the MSC has promoted the use and awareness of expert systems. Future efforts should be made to encourage the wider application of AI techniques by considering 3 options:

(1) The AI Route Whilst a general purpose Intelligent Tutoring System (ITS) is not possible, probably for at least 10 years, it should be possible to map out milestones towards one and decide how best to get there. It may be possible to find practical projects to enable real life problems in organisations to be used as test-beds.
A reactive learning environment tool is also possible in the short term.

(2) The CBT Route An enhanced authoring language could be on the market within 1 year. Projects for funding could ensure that the product is prototyped on real-life problems.

(3) The Expert System Route A specialised training shell should be on the market in twelve months. The MSC should ensure that they integrate its launch with their campaign for increasing awareness

b. There is a need for continuing collaboration between users and researchers. It is vital for MSC to stress the desirability of collaboration projects. MSC could also co-ordinate a register of people looking for partners to develop projects.

12. COURSEWARE

a. The greatest need is practical examples of learning material using AI techniques. This is the fastest way of dispelling mystique and proving usefulness.

b. Projects should be problem driven.

c. They should cover a wide range of skills.

d. They should encompass a variety of different types of intelligent systems - with arguments as to the merits of each system over others.

e. Projects should be linked with other training technologies ie Interactive Video, Computer Based Training, Simulation etc.

f. Projects should be developed jointly with industrial and academic partners, to bridge the gap in perceptions and in research and implementation.

13. TRAINING/EDUCATIONAL/INFORMATIONAL REQUIREMENTS

MSC should:

a. Instigate a campaign to raise the general level of awareness of AI in learning. This would include an AI demystification process, demonstrations of how AI techniques can be used and an assessment of the benefits.

b. Commission the compilation of a starter pack addressed at 3 levels - decision makers, implementers and developers - possibly as an intelligent browser?

c. Commission a video or videodisc on AI in learning.

d. Finance a national resource centre for a limited period, in order to coordinate the awareness and training initiative and actively sell the concept of AI.

e. Map the skill requirements of trainees and commission re-training courses to provide trainers with the necessary skills to use AI techniques in their training.

CONCLUSION

14. This paper is designed to inform you of how the MSC beca. . involved in the application of artificial intelligence to learning, what lessons it has learned

to date and where it is hoping to go in the future.

15. The initiative is an exciting one, with, potentially, enormous advantages for learners across education and industry. However, the challenge facing our Programme is to proceed by relatively small practical steps, representing value for money for the UK, without losing sight of the distant vision when the products of AI research are freely available to all and can be applied across the whole breadth of human learning.

TRAINING TECHNOLOGY SECTION
MANPOWER SERVICES COMMISSION

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MODELLING AN AUTOMATIC TUTOR BY DYNAMIC PLANNING

AN AUTOMATIC TUTOR INTEGRATED IN AN INTELLIGENT COMPUTER-AIDED INSTRUCTION SYSTEM

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Modelling an automatic tutor by dynamic planning

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Keywords: Cognitive modelling, ICAI

Abstract

We describe an automatic TUTOR integrated in an ICAI system to teach programming at elementary level.
This TUTOR provides instruction tailored to the student combining explanations with skills verification. In particular exercises are proposed taking into account their difficulty degree and the student's previous performance. A dialogue interface facilitates communication in natural language.
Teaching is viewed as a process of transferring a mixture of schematic and heuristic knowledge following a socratic style.
Different aspects of the tutoring task are separated in specialized components. Behaviour is modelled as a cooperative process among diverse knowledge sources to acomplish an instructional goal. The representation scheme is the same for all of them. Components are formalized as a knowledge base of plans and rules. A plan is composed by a set of actions and goals.
Teaching strategies are independent of the subject area. Control structure is expressed in a declarative way by means of plans and conflict resolution rules.
A detailed description of the TUTOR is presented, and a technical example is developed.

1 . INTRODUCTION

1 . 1 Description of the system

Present work is a part of a more extensive project (CAPRA Project [Garijo et al. 84]) whose objective is to build an intelligent system to teach programming (at an introductory level) .

The system is composed by a tutor, an expert system to make programs, an interface for natural language di gue, and a student model.

The EXPERT module builds a program to solve a problem, following a programming methodology. It is able to explain the reasoning process step by step, showing the knowledge used in every decision point.

The TUTOR guides and controls the interactive process of learning by means of the DIALOGUE module.
Enohasis is made on methodological aspects. The teaching process is carried through different stages. First of all the student learns to make algorithms from the problem statements (using an abstract algorithmic notation), and then s/he learns to obtain a program from the algorithm.
First stage of learning is organized as a sequence of two steps (1) understanding a problem (specifying data and objectives) and (2) building an algorithm by stepwise refinement.
The idea of scheme or plan for reasoning about program construction has been appointed as a central issue by recent research both in programming methodology [Lucas et al. 83] and in Artificial Intelligence [Soloway 86] and [Waters et al. 82].
Our work [Garijo et al. 86] follows this approach. Teaching becames a process of transferring a mixture

of schematic and heuristic knowledge where expertise is acquired by increasing both plans and rules to choose and combine them.

Understanding the structure and function of a new piece of knowledge is a fundamental issue in order to relate it with previous one. Thus metaknowledge plays an important role in the learning process.

Our tutor follows a socratic style, combining explanations with skills verification. Instruction is tailored for each student. In particular exercises are proposed taking into account their difficulty degree and the student's previous performance.

1 . 2 Knowledge Base

Knowledge used by the different components of the system is contained in a structured base (figure 1) . The following are the most relevant parts:

- Pedagogic knowledge:
  - .. general: pedagogic plans to carry out teaching strategies.
  - .. over the domain: pedagogic structuration of the concepts to be tautgh
  - .. over the student: student model containing inferences about his/her learning history and communication style
- Domain knowledge:
  - .. description of the domain concepts
  - .. set of problems for every concept
  - .. design and programming rules
  - .. classification of misconceptions
- Natural language knowledge
  - .. syntactic/semantic rules
  - .. history of the dialogue
  - .. speaker models

Section 2 discusses some of the issues in the design of a Tutor and gives motivations for our approach. Components and the control structure are described in section 3. A technical example is developed in section 4. Finally a summary is presented.

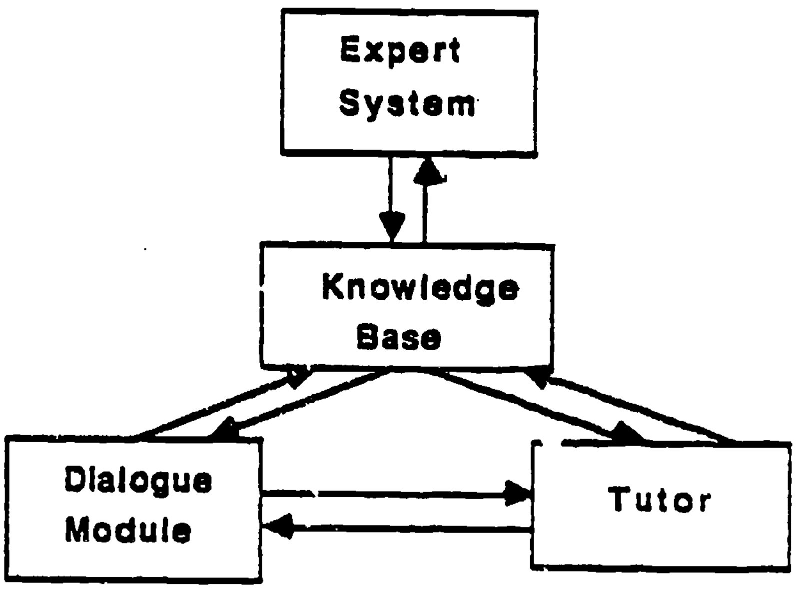

Figure 1

2. DESIGN OF AN INTELLIGENT TUTOR

2.1 Introduction.

Some important issues about designing intelligent tutors have been raised from recent research on the nature of explanation.

The idea of building a tutor on the top of an expert system was explored by GUIDON [Clancey 83], their authors analyse [Clancey 81b] the shortcomings of this approach. Compiled expertise (as in Mycin rules), is adequate to solve problems efficiently, but the lack of explicit structural and causal knowledge discards it for instructional purposes.
Genetic graphs [Goldstein 82] provide a set of evolutionary relationships to organise knowledge from a learning viewpoint. Generalization, analogy, refinement.. are some of the links to relate pieces of knowledge providing paths of progression to introduce new concepts.

Both experiences added a layer of metaknowledge to explain the reasoning of the system. We approach this problem in a similar way. A separate level is introduced to describe the subject area from a pedagogic point of view. In particular a hierarchy of requirements and difficulty degrees are associated to each piece of knowledge. The tutor selection of topics is made using this information.

Control modelling is another important factor to consider in designing an intelligent tutor. The question is how to generate observable behaviour in real human tutoring. Meno[Woolf 84] proposes a formalism combininig a transistion network (to structure sequences of tutoring states) and metarules to move the tutor off the default paths. States are classified in three levels according to their funcionality:pedagogical, strategical and tactical. Each level refines the previous one. Utterances are finally produced by the tactical level.
Metarules suggest a flexible control structure, however design modifications require reconfiguration of the network.

Our approach presents a framework based on dynamic planning. Different aspects of the tutoring task are separated in specialist components. Behaviour is modelled as a cooperative process among diverses knowledge sources to accomplish a goal. Like in Meno, teaching strategies are independent of domain knowledge, furthermore control structure is expressed in a declarative way by means of plans and conflict resolution rules.

2.2 Research methodology

Observations of human teaching are a fundamental activity to build an automatic tutor. In consequence, we planned and made several experiences involving different human tutors. The dialogues produced were recorded.

A first study of this material led us to the characterization of different teaching styles. At the same time the subject matter was systematized and exercises were collected and classified.
A second experience was carried out during years 84 and 85. An introductory course (14 hours) on programming was offered to novice students. Tutors and pupils communicated trough terminals. A total of 77 sessions (128 hours) have been studied.

From the analysis of these protocols we obtained:

1) A superficial characterization of errors
2) A first proposal for the student model
3) A formalization of the pedagogic description of the subject matter
4) A design for the tutor component

In this paper we will focus on the Tutor component, describing its knowledge structure and control organization.

2 . 3 Design justification

Modularity, flexibility and independence of the subject area have been considered as important criteria to guide the tutor modelling.
Work on protocol analysis suggested us a classification of instructional activities, leading to the definition of a number of components, each one encapsulating a type of task.

At the higest level of abstraction, we consider "Pedagogic Decision" where a general teaching approach is planned. In particular three kinds of actions are considered:

1) Indicating a pedagogic objective for a given situation.
2) Choosing a combination of strategies to attain the selected objective.
3) Developping the strategies established.

The refinement of a pedagogic objective in terms of the subject matter is carried out by the "Thematic Decision" component.
Explaining and controlling the acquisition are the main tasks performed by the "Teaching component". Communication is managed through the "Dialogue module".
The "Supervisor" focuses on conflict resolution among tutor and students's objectives, notifying to "Pedagogic Decison" if strategical changes are needed.

Control is shared by the different components, following a blackboard architecture. Each component encapsulates a source of knowledge to solve a type of goals. The representation scheme is the same for all of them. Components are modelled as a knowledge base of plans and rules. A plan is composed by a set of actions and goals.

A detailed description of the tutor follows. Characters in parenthesis appearing in examples are references to the protocol presented afterwards.

3 . DESCRIPTION OF THE TUTOR

3 . 1 Pedagogic Decision Module

Different strategies (obtained from the study of teaching experiences) have been classified into general and local ones. Among the first, we have : to introduce the student into the system, to remember briefly, to revise the conflictive points, to introduce new concepts, to finish a session, etc. Among the second we have : to check a concept, to resolve a doubt about a problem statement and to give an example.

A session can be seen as the result of the application of a set of strategies. A typical example would consist of "a general review, an introduction of new concepts, a review of conflicting points, and another introduction of new concepts", or " a brief review of the last session and an introduction of new concepts".
An objective (OB) has different plans associated with it. Depending on the strategy, one plan will be selected in order to achieve the objective. A plan is expressed as a composition of objectives and actions. Actions can be of two types: elementary actions (EA) and starting actions (SA). The first ones can be described in declarative form (by rules) or procedural form. The second ones establish objectives that will be resolved in other levels.

Therefore, the knowledge base of the Pedagogic Decision Module is composed by:(a)A structured description of the pedagogic objectives, the pedagogic strategies and the associated plans, (b) a set of rules for determining a pedagogic goal and for selecting strategies, (c) a set of rules to choose from to carry out a goal with a given strategy.

At the begining we have the objective (P-OB1): " decide a guideline of the session and apply it". This objective can be carried out with two plans. The first one (plan 1) follows :

Plan 1 : (P-OB3) decide the sequence of teaching strategies
(P-OB2) apply the teaching strategies
(P-OB1) decide a guideline of the session and apply it

A sequence of strategies is selected in terms of parameters. For example time between sessions and different information about the student. The objective (P-OB2) " apply the teaching strategies" is resolved by plans, whose execution leads, some time later, to the activation of the objective (P-OB5) " start the session". This can be resolved by different plans:

Plan 5: (P-SA1) select (initial concept C, explanation detail ED)
(P-SA2) introduce concept C with explanation detail ED

Plan 6: (P-SA1) select(revision concept C, explanation detail ED)
(P-SA3) remember concept C with explanation detail ED
(P-OB7) decide to check concept C

Plan 7: (P-SA1) select (list of concepts CL)
(P-SA3) remember the list of concepts CL
(P-OB7) decide to check the list of concepts CL

Rules for plans selection consider the current objective, the point of the session and the established strategy. Their general form is the following:

if *objective description* and
strategy description and
state of the session
Then apply plan *X*

One of the rules for the above example says:

If the objective is " start the session" and
the strategy is "general review"
Then apply Plan 7

Plan 7 is composed of the starting action (P-SA1) "select the concept list" (goal for the Thematic Decision Module) and (P-SA3) "remember the concept list (goal for Teaching Module) and finally the pedagogic objective (P-OB7), in order to decide if checking is necesary or not.

3 . 2 Thematic Decision Module

Once the Pedagogic Decision Module has established the associated plan to a strategy, it is necessary to refine it for the conceptual domain . Thematic Decision carries out this task for the subject matter teaching. It chooses the specific concepts that are going to be taught or reviewed, or the problems that must be proposed to the student so that s/he learns a particular concept.

As indicated in the introduction, there is an expert system whose knowledge base includes all the concepts of the syllabus and their features. Because this information is not sufficient for carrying out the teaching, it has been necessary to incorporate a pedagogic hierarchy organizing concepts in levels, in terms of their difficulty, pre-requisites, ect.

3 . 3 Teaching Module

The structure of the Teaching Module is similar to the Pedagogic Decision one, in the sense that there are teaching objectives which are solved trough plans composed of objectives and/or actions. In this module no strategy is determined since it is previously defined by the Pedagogic Decision module.

For instance, the objective (T-OB1) "The student has acquired concept X" has the following associated plans:

Plan 1 : (T-OB2) the student has acquired the X prerequisites
(T-OB1) the student has acquired concept X

Plan 2 : (T-OB3) teach the concept X
(T-OB4) the student know how to use concept X with a degree of certainty Y

Plan 3 : (T-OB5) the student has acquired the X subconcepts

Plan 4 : (T-OB3) teach concept X
(T-OB5) the student has acquired the X subconcepts

The association of plans to objectives are carried out by rules belonging to the general scheme

If *objective description* and
list of concepts conditions and
state of th ssion
Then apply Plan.

For the previous objective, one of the rules says:

If the objective is " the student has acquired concept X" and
((There is no prerequisites for X) or (the student knows the X prerequisites)) and
X is an active node and
X has no subconcepts
The apply Plan 2

As can be observed, these rules use knowledge belonging to the teaching level and also to the global knowledge base (hierarchy of concepts and student model).

Figure 2 shows the relationship between the Teaching module and the Pedagogic Decision module.

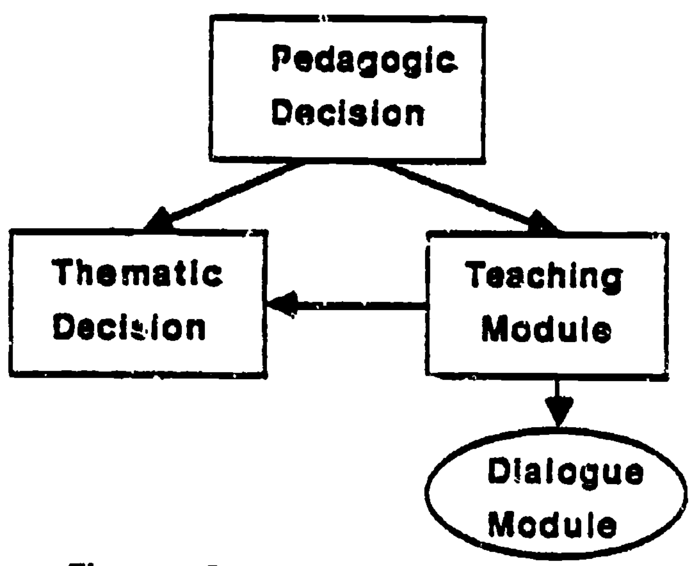

Figure 2

The execution of a Teaching module plan involves selecting texts for explanations and problems for verification. In addition student's interactions have to be handled.
The search of texts and problems is done by the Texts and Problem Search module.
The starting actions whose effect is to maintain the interaction with the student activates objectives of the Supervisor module. Actions of this type can be seen in the next example where plan 6 has been associated with the objective (T-OB4) " the student know how to use concept X with a degree of certainty Y"

Plan 6: (T-OB6) give a verification message(PROBLEM,CONCEPT)
(T-EA2) EXPECTED-ANSWER=
(Problem-solution, Doubt-problem statement, Doubt-solution)
(T-SA2) correct the student answer
(T-OB8) actualize the student model
(T-OB4) the student know how to use concept X with a degree of certainty Y

The objective (T-OB6) " give a verification message(PROBLEM,CONCEPT)" is solved by means of a plan which involves searching and sending the suitable problem to the student through the Dialogue Module. The starting action (T-SA2) " correct the student's answer" connects with the Supervisor Module and will be discussed shortly.

3 . 4 Dialogue Module

The human-computer interaction module carries out two types of tasks:

- sending messages from TUTOR to the student
- understanding student's answers which are expressed in natural language (spanish) and reporting them to TUTOR

Decisions relevant to discourse management such as "focus on topic" or "explanation detail" are made by the tutor before activation of the dialogue module.
Conversely the interpretation of student's answers is a task perfomed by the dialogue component. This includes recognizing student's intentions. A categorization of objectives have been established, some of them are : "question about proposed exercise", "more explanation about concept", "evaluable answer", "confirmation of proposed solution"...ect.

3 . 5 Supervisor

The Supervisor Module detects and solves conflicts arising between the strategy followed by the TUTOR and the student's objectives.

To accomplish it, Supervisor compares Tutor's objectives (current and waiting) with the student's objectives (established by the Dialogue Module). Conflicts are resolved by including local strategies or restating the general strategies. In any case the application of a strategy is a task belonging to the Pedagogic Decision module.

The structure of the Supervisor Module also fits the model of objectives, plans, actions, and rules of selection which has already been discussed. The rules for plans selection have the following general scheme:

If *objective description* and
description of student's objectives and
state of the sesion
Then apply plan X

Following our example , the starting action " correct the student's answer" establishs the Supervisor goal (S-OB1)" respond to the student's answer", that has the following associated plan:

Plan 1: (S-SA1) int. ret the student's answer
(S-EA1) establish priorities in the list of objectives
(S-OB2) respond to the list of objectives

The starting action (S-SA1)" interpret the student's answer" connects with the Dialogue Module, which analizes the answer and produces the list of the student's objectives.

The action (S-EA1) " establish priorities in the list of objectives" resolves possible conflicts and redundancies appearing in it. Finally, (S-OB2) " respond to the list of objectives" is solved by means of a plan whose development will activate the objective (S-OB3) " respond to the student's objective". In the case where the student's objective is "Evaluable-answer" the solving plan will generate the action (S-SA2) "problem correction ".
In this case, Supervisor has the following associated plans for (S-OB3):

Plan 3: (S-SA2) detect errors
(S-EA1) count the number of answers
(S-EA2) detect conflicts
(S-EA3) If CONFLICT
Then decide whether to follow the general strategy
or to insert a local strategy
Else decide a correction strategy
(S-SA3) apply a strategy

Plan 4: (S-SA2) detect errors
(S-EA3) If CONFLICT
Then decide whether to follow the general strategy
or to insert a local strategy
Else decide a correction strategy
(S-EA4) TYPE-MESSAGE(Problem) = "NOT ACTIVE"
(S-SA3) apply a strategy

For (S-OB3) the following rule determines which plan to apply

If the objective is "respond the student's objective" and
the student's objective is "evaluable-answer" and
the number of answers is less than LIMIT
Then apply plan 3

3 . 6 Pedagogic Correction Module

This module is invoked to correct the student's solution to a proposed problem, once the Error Detection Module has diagnosed the incorrect concepts from the error types produced.

As the other components, it consists of a set of error correction plans and a set of selection rules. Misconceptions of the studen's answer and the correction strategy selected by the Supervisor are included in the preconditions of the selection rules. In this way the most suitable correction form is selected, from the indication of the most important error to the exhaustive correction of every error.

Now we are carrying out, to the full extent, a study of protocols to build a complete knowledge base containing all corrections forms and selection rules.

3 . 7 Text and Problem Selection Module

The labor of this module consists of searching the suitable text and problems, for teaching the student a previously determined concept, with the suitable profoundness and/or difficulty level.

Figure 3 shows the complete organization of the described modules

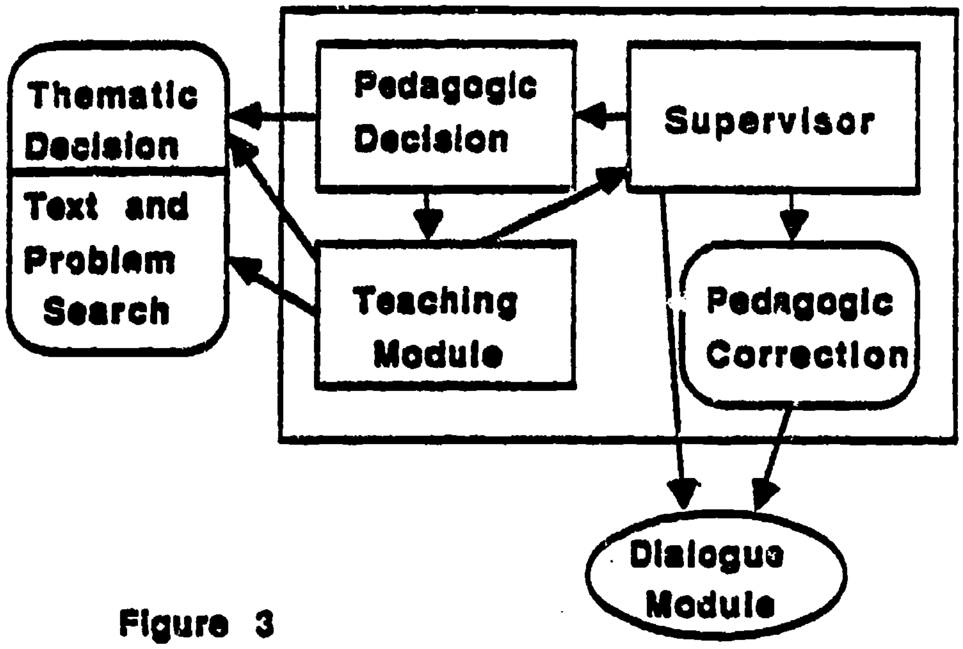

Figure 3

4 . The Control Scheme in a dialogue example

The following dialogue is part of one of the protocols . It corresponds to an intermediate session in the teaching process.

```
T 1.1   Last day you learned to specify  elements verifying a
        property (this property was expressed by a formula)
T 1.2   Dou you have any question about it?
A 1     No, go on, but could you give me an exercise?
T 2.1   I was going to do that
T 2.2   Specify  next problem:
        "Express in polar representation (module, argument) a
         given complex number (real part, imaginary part)"
A 2     I don't remember what is the polar representation.
        Could you tell me?
T 3     Given a complex number:
        X coordinate ---------- real part
        Y coordinate ---------- imaginary part

        to express it in  a (module, argument) form you must
        calculate module as:
        SQRT (X**2 + Y**2) ------ module

        and argument as:
        ARCTNG (Y / X) ---------- argument

A 3     Must I use the form of a pair?

T 4     Yes, you do
A 4     Can I use the concatenation instruction CONS?

. . . . .
```

When the first message (T 1.1) has been sent the Pedagogic Decision module has already determined the strategies that will be followed during that session : " brief review" and "introduction of new concepts". At the begining, the first strategy leads to determine (by Thematic Decision module) the concept to be remembered among the ones studied in the previous session: "Elements verifying a property".

The tree of objectives and actions, in figure 4, represents the development of the session until just the generation of (T 2).

As we have mentioned, at the begining (P-OB1) is activated and the selected plan to solve it determines the general strategies to develop the session. The application of the first strategy produces the objective (P-OB5): "start the session". Selection rules for this objective ,together with the strategy "Brief review", select the plan composed by (P-SA1), (P-EA3), (P-SA2). (P-SA3).

Thematic Decision selects the concept to be reviewed and the explanation detail, and action (P-SA2) activates (T-OB3) (goal for Teaching Module). The associated plan produces the Tutor's messages (T 1.1) and (T 1.2) (by means of the Dialogue Module).

Starting action (T-SA2) corrects and interprets student's answer (by means of Dialogue Module, too). Supervisor observes the coincidence between the student's answer and the outstanding action of Pedagogic Decision (P-SA3): "decide to check concept". Therefore, conflict resolution rules decide going on with the development of the session in (P-SA3).
At this point the tree generation is produced in the same way, i. e. objectives from different componentes are activated and plans to solve them are selected by rules.

Figure 5 represents the development of the strategy until a point corresponding to (T 3) in the text.

5 . SUMMARY

This paper has illustrated a new approach to tutor modelling based on dynamic planning to generate flexible behaviour.
The required instructional knowledge has been formalized by means of plans and rules, and organised in a modular way by types of tasks.

A prototype including the dialogue component is being implemented. Our current work is focused on two related questions : extending the bug catalogue and refining the student model to provide better strategies of correction.

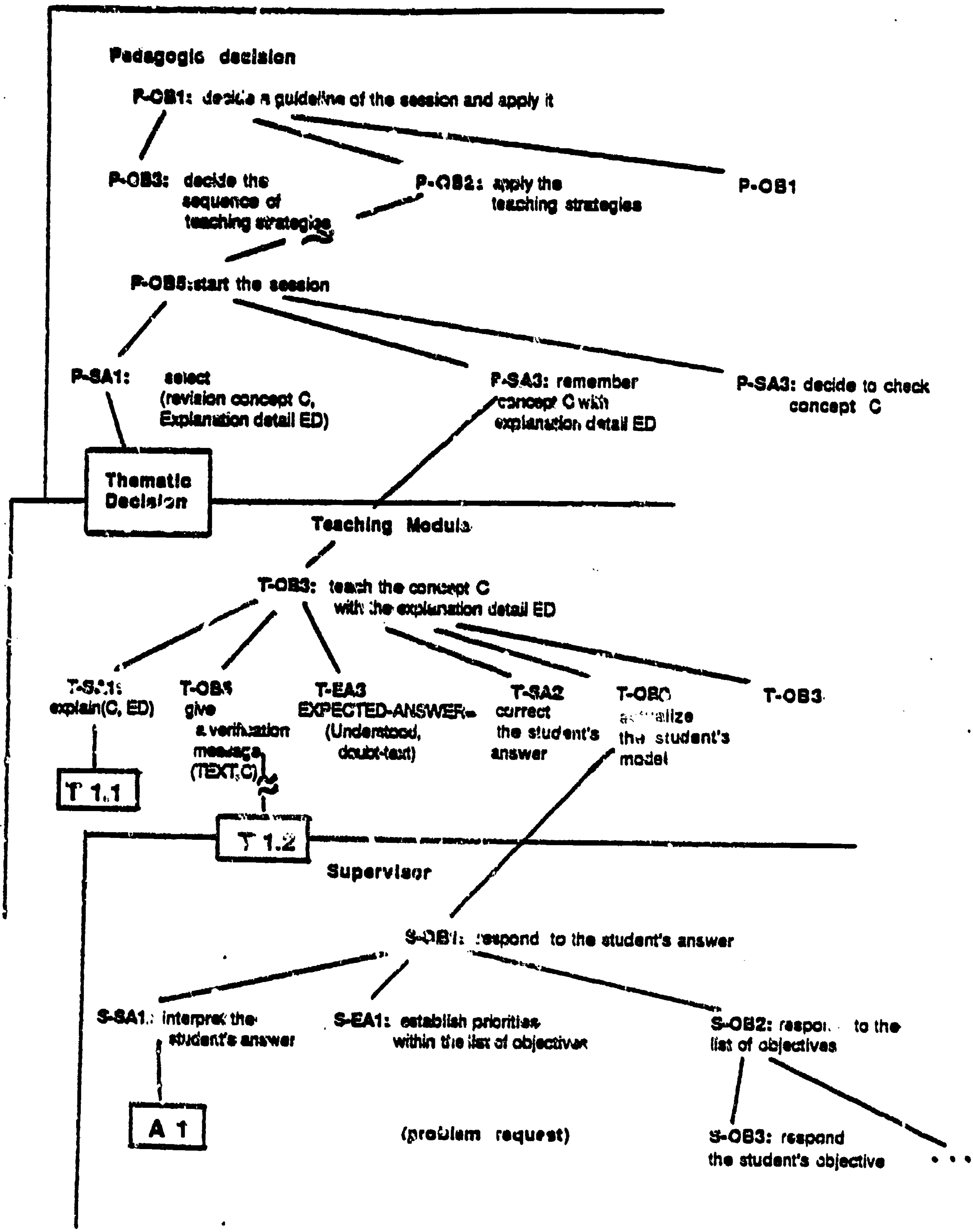
Pedagogic decision
P-OB1: decide a guideline of the session and apply it
P-OB3: decide the sequence of teaching strategies
P-OB2: apply the teaching strategies
P-OB1
P-OB5: start the session
P-SA1: select (revision concept C, Explanation detail ED)
P-SA3: remember concept C with explanation detail ED
P-SA3: decide to check concept C
Thematic Decision
Teaching Module
T-OB3: teach the concept C with the explanation detail ED
explain(C, ED)
T-OB4 give a verification message (TEXT,C)
T-EA3 EXPECTED-ANSWER= (Understood, doubt-text)
T-SA2 correct the student's answer
the student's model
T-OB3
T 1.1
T 1.2
Supervisor
S-OB1: respond to the student's answer
S-SA1: interpret the student's answer
S-EA1: establish priorities within the list of objectives
S-OB2: respond to the list of objectives
A 1
(problem request)
S-OB3: respond the student's objective
. . .

Figure 4

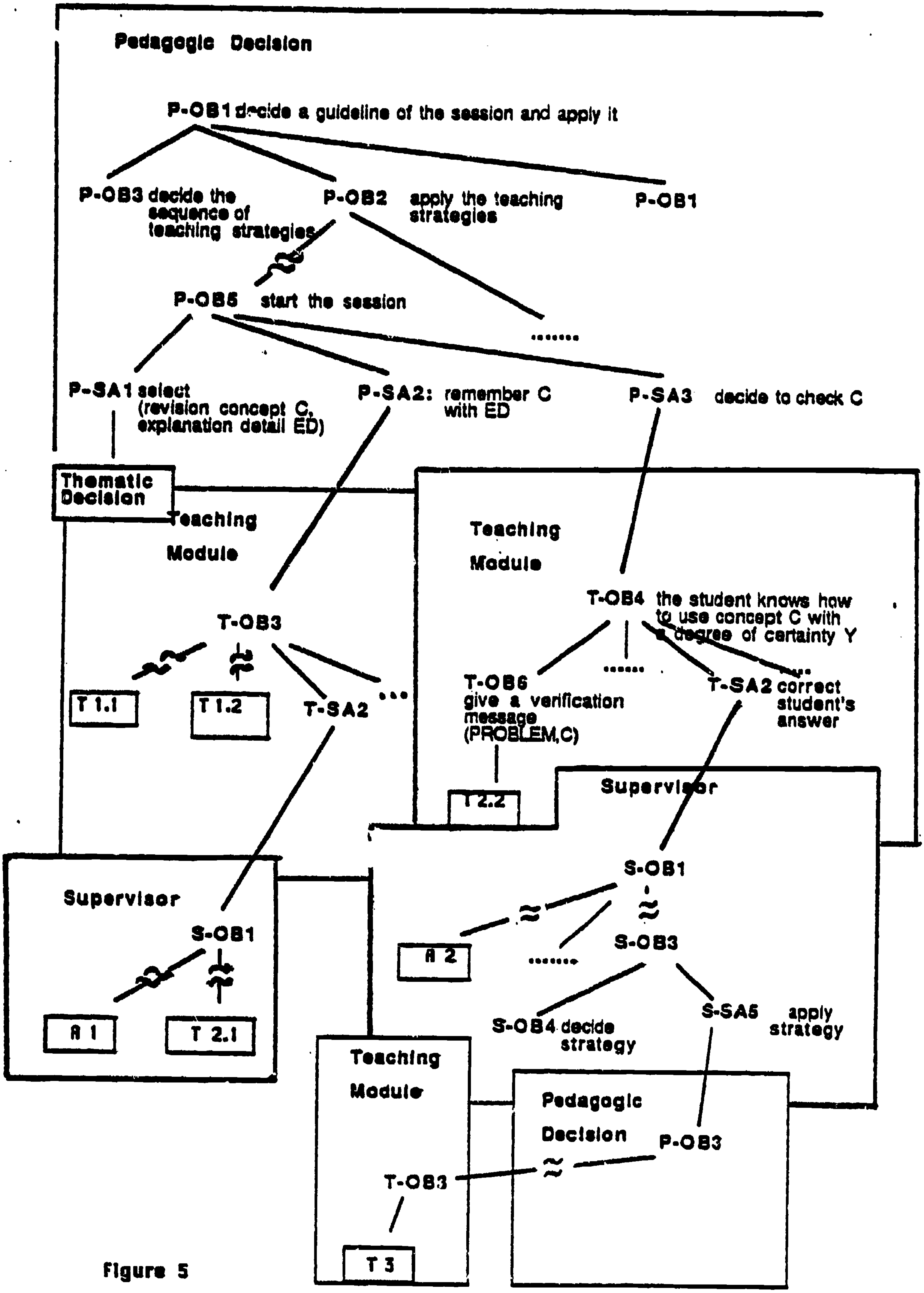
Pedagogic Decision
P-OB1 decide a guideline of the session and apply it
P-OB3 decide the sequence of teaching strategies
P-OB2 apply the teaching strategies
P-OB1
P-OB5 start the session
....
P-SA1 select (revision concept C, explanation detail ED)
P-SA2: remember C with ED
P-SA3 decide to check C
Thematic Decision
Teaching Module
T-OB3
T 1.1
T 1.2
T-SA2
...
Teaching Module
T-OB4 the student knows how to use concept C with a degree of certainty Y
T-OB6 give a verification message (PROBLEM,C)
......
T-SA2 correct student's answer
T 2.2
Supervisor
S-OB1
A 2
....
S-OB3
S-OB4 decide strategy
S-SA5 apply strategy
Supervisor
S-OB1
A 1
T 2.1
Teaching Module
T-OB3
T 3
Pedagogic Decision
P-OB3

Figure 5

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ARTIFICIAL INTELLIGENCE AND ITS APPLICATIONS TO VOCATIONAL TRAINING AND EDUCATION

TUTORIAL EXPERT SYSTEMS PROJECT

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INTERNATIONAL COMPUTERS LTD.,
UNITED KINGDOM

CEDEFOP
BERLIN
1987

TUTORIAL EXPERT SYSTEMS

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1. Introduction

ICL Interactive Learning Systems is currently undertaking a number of developments of the application of advanced technologies to interactive learning, especially in the areas of artificial intelligence and human-computer interaction. This paper will describe some developments in tutorial expert systems and their impact on training. Some developments lead to significant increases in efficiency of production and delivery of training materials; other developments lead to training being deliverable in a form not previously possible not only enabling further significant increases in productivity but also providing solutions to training problems that could not otherwise be addressed.

A project was recently completed which produced a Tutorial Expert System and carried out an extensive evaluation of the expert system approach in comparison with traditional methods. The project began in April 1986 and was one of a group of seven projects for the MSC which were designed to explore the application of artificial intelligence techniques to learning.

The expert systems based training program was not developed from the viewpoint of fundamental research. Instead, it was developed under the direction of industrial trainers whose main concerns are to be able to produce training packages for customers which will enable trainees to achieve a new skill quickly with the least possible disruption to normal working. In a commercial environment it is vital to be able to develop training programs quickly, efficiently and reliably. The Tutorial Expert System was developed as a feasibility study to show the teaching effectiveness of using basic artificial intelligence techniques for developing a computer based training program and to investigate the efficiency and effectiveness of courseware development using these techniques.

The subject matter selected for the training program was fault diagnosis in wave soldering, which is a method of mass producing soldered joints on printed circuit boards. The reason that this subject was chosen was because another unit in the STC Group had already done considerable work in this area on which the project could be based.

The acceptability, effectiveness and usefulness of the expert system was tested using a variety of target groups, including domain experts in wave soldering, and students in electronics and related areas from Colleges and MSC-sponsored schemes. The data that was collected was analysed for levels of student achievement and for user attitudes. It was also compared against other methods of training. The analysis included development effort and general efficiency measures.

2. Teaching Strategy

The aim of the Tutorial Expert System was to teach people to carry out a particular diagnostic strategy. The minimum goal for the student was that he or she should be able to go through a diagnosis procedure reliably, asking for whatever information was needed and making the correct decisions.

In addition it was hoped that the repetition of information and the frequent consideration of this information would result in incidental learning of the data required to make a diagnosis.

Initially the program forces a particular diagnostic strategy on the student in order to give the student experience of an efficient strategy. Later the student is given control and allowed to make non optimal (though not wrong) choices. We expected the student to learn from making a choice and getting feedback.

Figure 1 shows the possible routes through the diagnosis subtasks. Note that listing the possible faults and possible subprocesses are each regarded as a task.

3. Architecture

The Tutorial Expert System consists of three major components:

1. A knowledge base containing 'rules of thumb' from which a diagnosis may be made.
2. A teaching 'engine' which can generate problems, deduce symptoms and either teach or demonstrate how to perform a diagnosis. It was decided to restrict diagnoses to faults occurring singly and not to take account of probabilities.
3. A user interface which is menu driven. Contextual and model information is used to drive selection of suitable output text from a library.

Figure 2 illustrates the basic components of the software architecture.

4. Evaluation

4.1 Overview

Trials were arranged at test sites to answer the following questions:

1. Is the teaching program effective?
2. Is it efficient?
3. Is it acceptable to trainees?
4. Are there any user characteristics which predict whether the user will do well with the program?

Informed expert opinion was used to assess the following.

1. Is it possible to do things with an expert systems approach that is not possible using traditional authoring systems?

2. How do expert systems techniques and traditional computer based training techniques compare over the full life cycle of a project:

   analysis
   design
   implementation
   test and debug
   maintain

3. Is there anything which is easy to do using traditional computer based training techniques but difficult to do in Prolog (the language used to program the Tutorial Expert System)?

4.2 User Trials

Lecture based training courses are still widely relied on in industry. Therefore an expert within STC was asked to prepare a lecture suitable for HNC level students which would cover any material he felt would be useful in making a simple "first line" diagnosis of wave soldering problems caused during board manufacture. This lecture was used as the alternative training method with which the Tutorial Expert System was compared.

The trials showed that an expert systems approach to training does work and is potentially much more efficient than traditional methods. The trials also provided a great deal of information about appropriate training strategies and methods of introducing new users to expert systems based training programs.

Detailed results of the trials can be obtained from a report produced for the Manpower Services Commission (1). The following summary gives some idea of the way that group differences and conditions of training affected performance and attitude.

A group of HNC students for whom the subject matter was relevant were given easy access to the system. They achieved very low error scores when using the system and performed very well in a post test. The students were all highly favourable towards the program and the general approach to training. This is confirmed by their high work rate - one trainee worked through 66 examples.

A second, smaller group showing high levels of learning was a group of students who were given a lecture by an expert before they used the training program.

One group who did not do so well was a group of HND students who had a sophisticated knowledge of human computer interface design principles and who also had difficulty with availability of the computer used to run the training program. The demonstrator system was always intended to have a basic, but acceptable, human computer interface with development concentrated on the artificial intelligence techniques. The fact that the human computer interface fell short of the students' high expectations, together with difficulties of physical access, kept practice to a very low level where little training could be expected.

Analysis of results did not show any predictor of individual success or attitude towards the training program.

4.3 Comparison of development methods

A major interest in the project was to compare the use of expert systems techniques with the use of a good computer based training authoring language. Our conclusions are that expert systems techniques can potentially lead to enormous gains in productivity and programming quality.

One particularly important benefit is that a prototype can be built and evaluated (as has been reported here) and that modifications can be made to the program based on observations. In many instances extensive changes to the behaviour of the training program can be achieved by making only small changes to the code.

The program produced for this project was carefully designed to achieve good separation between the training behaviour, human computer interface and the teaching material. It has already been demonstrated, using a simple example, that the teaching material can be replaced with a different subject. This will allow us in the future to use the same training techniques for many different training programs giving us high productivity and confidence that we are using well tested methods and software.

5. Conclusion

An expert systems approach to computer-based training has been proved to produce courseware which is acceptable to students, which is effective in terms of training objectives and which has substantial cost-benefits on terms of courseware development costs and reliability. Further improvements in effectiveness and in efficiency of production and delivery of training materials are possible with wider application of the expert systems approach.

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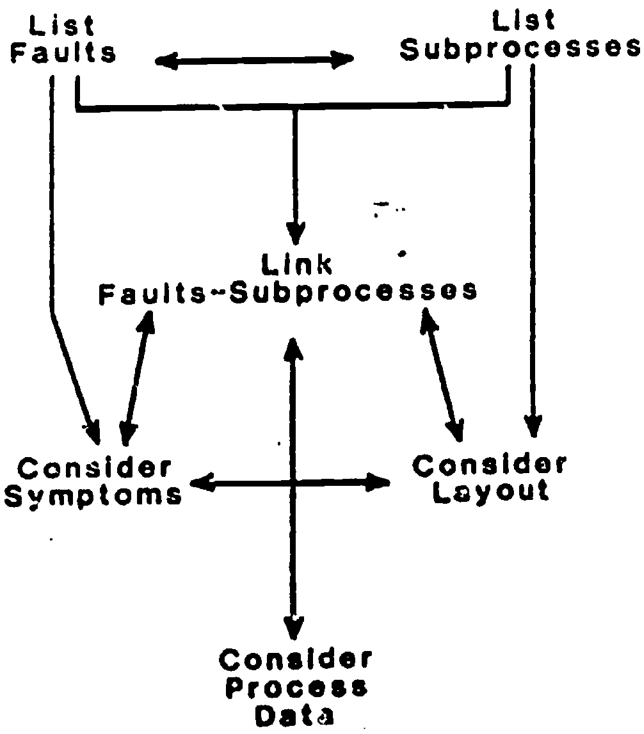

Figure 1 Possible routes through a diagnosis in the Tutorial Expert System

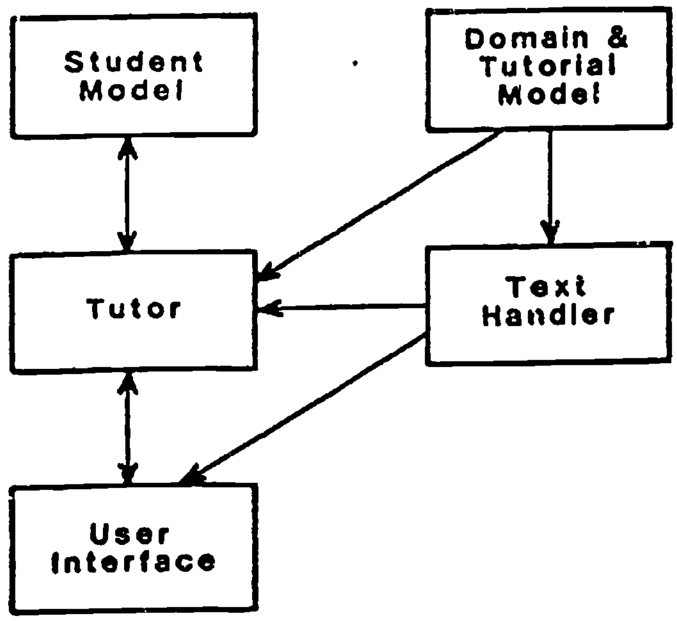

Figure 2 Components of the software architecture of the Tutorial Expert System

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Artificial intelligence and its potential as an aid to vocational training and education

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