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TITLE DESIGN OF AN INTELLIGENT TUTORING SYSTEM FOR AIRCRAFT RECOGNITION

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DESIGN OF AN INTELLIGENT TUTORING SYSTEM (ITS) FOR AIRCRAFT RECOGNITION

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ABSTRACT

An intelligent tutoring system has been designed to teach aircraft recognition in support of air defense training. Design of the system incorporated requirements for dynamic assessment of student knowledge, individualized instruction, implementation on a microcomputer, and use of videodisc technology for visual presentations. System design methodology is discussed and compared to instructional system design for computer-based training. The components of the computer tutor are explained in the context of an overview of the tutoring system.

INTRODUCTION

At Los Alamos National Laboratory, an intelligent tutoring system has been designed to teach aircraft recognition in support of air defense training. This project was undertaken for several reasons: 1) to provide realistic training aids for air defense teams, 2) to exploit artificial intelligence (AI) technology for computer-assisted education, and 3) to incorporate auditory and visual media in computer-delivered instruction. An intelligent tutoring system for aircraft recognition would not only be useful for initial training for air defense crews, but also can serve in the field to maintain skills. This paper begins with a detailed definition of intelligent tutoring systems and then describes the background and approach used to design the Aircraft Recognition Intelligent Tutoring System (ARITS). It describes each major functional component of ARITS and concludes with a discussion of the status of this work.

DEFINITION OF INTELLIGENT TUTORING SYSTEM

An intelligent tutoring system is a computer-based system that emulates the learning environment between a student and a human tutor (Roberts and Park 1983). It employs AI techniques to represent domain knowledge, utilizes a specified instructional strategy, and uses inference techniques to assess the student's grasp of the material. An ITS provides intelligent feedback and appropriate educational material to instruct the student. Some ITS's can detect student misconceptions (Brown and Burton 1978, Goldstein 1982, Burton 1982) and attempt to correct them. They can operate on noisy or incomplete data (Sleeman and Hendley 1982) and decide when to intervene and what advice to give.

An ITS has four major components: 1) an expertise module, 2) a student knowledge model, 3) a tutorial advisor, and 4) a communication system. The expertise module contains the domain knowledge that is to be imparted to the student. The student knowledge model is an internal assessment of the knowledge of the student in the present domain. The student's knowledge may be modeled as a subset of an expert's knowledge (this is termed an "overlay representation") or alternatively as a set of rules consistently used by the student, whether or not they lead to correct results--the so-called "buggy" model (Brown and Burton 1978). The tutorial advisor is a model of the knowledge for selecting and presenting material to the student. It contains knowledge about teaching, about selecting material appropriate to the student's perceived learning level, and about when to intervene and what to tell the student in a tutorial session. The tutorial advisor implements the instructional strategy imposed by the ITS designer. The instructional strategy is the teaching approach adopted by an instructor, typically either coaching, games, simulation, Socratic dialog, a diagnostic approach, or some combination of these methods. The communication module is the set of functions that enable the expertise module, student knowledge model, tutorial advisor, and student to exchange information. It is often heavily integrated into the system and does not appear as a distinct program module; however, much attention must be given to its role in order to achieve a workable system (O'Shea, et al. 1984).

KNOWLEDGE DOMAIN

In air defense, ground station crews attempt to visually detect, identify, target, and possibly attack low flying jet aircraft. Because of the typical high speeds of attack aircraft, the opportunity for observation is limited to a few seconds. Although the cognitive skill level of recognition is low on Bloom Taxonomy (Bloom 1956), the skill of aircraft recognition resides at the higher level of "application" on the Taxonomy. This level requires the use of previously learned information in new situations. Accurate recognition is critical and priority is placed on attacking only enemy aircraft. Typically, the set of aircraft to be identified is relatively small, making the problem more tractable.

The features used in aircraft recognition are derived from a World War II canonical model of aircraft termed the Wings, Engine, Fuselage, and Tail (WEFT) model (USAADASCH FC 44-30, 1986). In this model any aircraft can be uniquely described in terms of the shape and placement of the wings, number and placement of the engines, shape characteristics of the fuselage, and shape and placement of the tail sections. Fig. 1 provides some examples of WEFT model features. It is often the case that only a few features are necessary to uniquely characterize a particular aircraft.

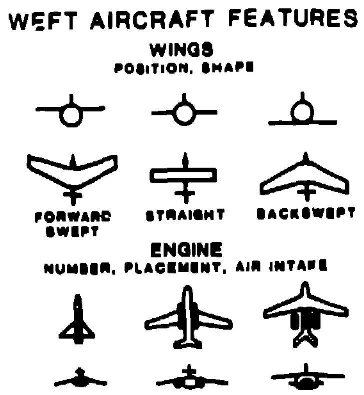

Fig.1

For example, a WEFT description of the F-14 Tomcat is:

- Wings. High-mounted, variable, swept-back, and tapered with curved tips. Retractable canards.
- Engine(s). Two turbofans in fuselage. Diagonally shaped, box-like air intakes alongside fuselage. Dual exhausts.
- Fuselage. Long, slender, box-like from air intakes to rear section. Pointed nose. Bubble canopy.
- Tail. Twin tail fins, swept-back, tapered, and slanted outward slightly. Tail flats mid-mounted on fuselage, swept-back with rounded tips.

The WEFT descriptions are intended to provide a mnemonic framework for the visual image of the aircraft. In most cases training for aircraft recognition uses the WEFT description in conjunction with still or moving pictures of the actual aircraft to reinforce the mental images of the aircraft. This enables the trainee to associate key features with a mental image and match perceived images with stored mental concepts and thus identify the aircraft.

REQUIREMENTS

The general criteria for ARITS include the capability to 1) present realistic images of aircraft, 2) dynamically assess the knowledge level of the student, 3) deliver individualized feedback based on the student's demonstrated expertise level, 4) provide limited student control of his path through the material, and 5) deliver the system on a microcomputer. An initial prototype will demonstrate the features of the system, will be tested with users, and subsequent evaluation will enable improvements to its components. The improvements are expected to be iterated over several evaluation cycles.

Imagery is to be delivered via a videodisc system controlled by the computer tutor. The dynamic assessment of student knowledge and the delivery of individualized feedback are to be accomplished by using an ITS structure. The delivery of ARITS on a microcomputer is a key criterion, as it is desirable for the system to run on Electronic Information Delivery System (EIDS) compatible systems. These are generally MS-DOS/IBM PC compatible machines. The ITS development will probably be on an AI workstation Lisp machine and the prototype code will be ported down to the microcomputer in a suitable language such as C, Ada, or Lisp.

DESIGN METHODOLOGY

The design of ARITS is modeled on the instructional design methodology used in developing computer-assisted instruction (CAI). Instructional design includes various phases of development: need analysis, design, development, formative evaluation, implementation, and summative evaluation. The development process used for ARITS is the same as for a CAI system, with the major exception of adding an analysis phase for describing the features of the tutoring system components. In the CAI production method, needs analysis consists of defining goals, establishing the instructional strategy, developing objectives, and defining performance measures for the system. The next phase is design, where each instructional frame is outlined and interactivity is specified using principles of screen design. For ARITS, this phase was preceded by an analysis of the characteristics of the computer tutor needed to meet the objectives and incorporate the specified instructional strategy. This involves specifying the user interface, knowledge representation for both subject matter and tutorial knowledge, student model, and a communication protocol. Storyboards and screen design are then done utilizing the input/output protocols of the user interface.

NEEDS ANALYSIS

In needs analysis, the instructional objectives are specified, as well as the goals, instructional strategy to be employed, and performance measures. In ARITS, the goal is to develop an effective initial training capability for visual aircraft recognition. The objective is to instruct students how to identify friendly versus unfriendly aircraft using realistic imagery on a well-defined, useful set of aircraft. In terms of performance, the system goal is to train students to achieve an accuracy in excess of 99% in correctly identifying friendly aircraft, and in excess of 95% in correctly identifying unfriendly aircraft. Since the student must perform his duties in the real world, friend/foe identification is required in three seconds or less, while the identification of the aircraft type (F-15, A-10, or Su-17, for example) may take longer. The instructional strategy selected for ARITS is a combination of drill and practice with tutorial intervention (coaching) as necessary. In this system, drill and practice takes the form of repeatedly showing the student video segments of selected aircraft and asking the student to identify the craft. Tutorial intervention is based on analysis of the student's input and consists of advice on how to improve identification performance. Student performance is measured by calculating the empirical probabilities of correct identification for friend and foe aircraft and the average time to identification for friend/foe and for aircraft type.

TUTORING SYSTEM COMPONENTS

The design phase begins with the definition of the tutoring system components. The communications module of ARITS is intended to facilitate interaction between the computer and the student. ARITS uses iconic menus for the identification of WEFT components. This graphic interface seems well suited for matching the real images of an aircraft to the corresponding iconic representations of its components, and thence to the mental images held by the student. Keyboard input is required for student identification, but usually input is via menu using either a touch sensitive screen or a mouse. Fig. 2 depicts a portion of an iconic menu for WEFT feature input. Uncertainty in student input is allowed by using question marks, "?", in a menu to indicate that a given feature was either not observed, not observable because of view aspect, or not recalled. Textual menus are used to input student path control data and aircraft type.

WEFT ICONIC MENUS

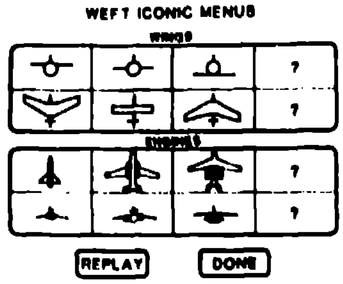

Fig.2

The expertise module of the tutor is composed of a knowledge base of WEFT features and a mapping of sets of WEFT features to individual aircraft types. A small expert system exists to infer aircraft type in the case of incomplete data provided by the student. To understand the structure and use of the ITS components, it is helpful to refer to the concept diagram in Fig. 3. The student logs onto the system and is prompted for path control, e.g., viewing aircraft by nationality, wing type, or some other feature. In the delivery of instruction, the student observes a videodisc image of an aircraft. The student is then required to identify the aircraft as friend or foe. Next the student selects the WEFT features he recalled observing by selecting the corresponding icons. He then identifies the aircraft type. At this point the student input is complete. Now the system must deal with three aircraft identities: A_t the true aircraft shown on videodisc, A_s the aircraft identified by the student via the text menu, and A_o the aircraft derived from the knowledge base using the student-observed WEFT features. These values are passed to the tutorial module which evaluates the input and updates the student knowledge model.

ARITS CONCEPT DIAGRAM

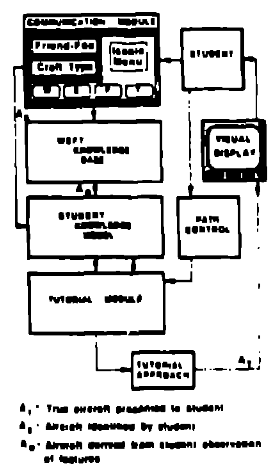

Fig.3

The tutorial module must attempt to infer what the student knows and doesn't know. Given the values of the tokens A_t, A_s, and A_o, the tutorial module identifies four cases:

1. $A_t = A_s = A_o$,
2. $A_t = A_s$ but $A_t \neq A_o$,
3. $A_t \neq A_s$ but $A_t = A_o$, and
4. $A_t \neq A_s$ and $A_t \neq A_o$.

In case 1, the student correctly identifies the plane and its component features. The tutorial module then updates the student knowledge model to indicate knowledge of this particular aircraft and the features. The student knowledge model is updated by incrementing appropriate counters in the model. In case 2, the student correctly identified the plane but supplied incorrect WEFT features. The tutorial module updates the student knowledge model to reflect knowledge of the aircraft type and to reflect lack of knowledge of the specific incorrect aircraft features. In case 3, the student incorrectly identifies the aircraft type but correctly inputs the WEFT features. Thus the student properly observes key features but does not accurately map the features to his mental model of the aircraft. In case 4, the student knows neither the aircraft type nor the corresponding WEFT features. The tutorial module updates the student knowledge model to reflect this.

The tutorial advisor, after analyzing input, responds to the student by relating the correct and incorrect aspects of his input. He is first told whether he correctly identified a) friend/foe, b) aircraft type, and c) WEFT features. The tutorial module then assesses the knowledge of the student on the topics just covered in order to determine whether to intervene with a tutorial or a needed topic. The decision on tutorial intervention is based on 1) overall student knowledge assessment, 2) student knowledge in the most recent topics presented, 3) knowledge thresholds in the student knowledge model, and 4) tutorial rules. The tutorial rules are represented as condition-action pairs and use the student knowledge model as a knowledge base from which to make inferences. Rules in the initial prototype are rather crude, but it is recognized that empirical data are needed to develop better tutorial hueristics. An example of tutorial rule is

> If aircraft identification is incorrect and aircraft identification was incorrect the last two times the aircraft was presented, then tutor on the distinguishing features of the aircraft, emphasizing those features least known by the student.

If no tutorial intervention is applied, ARITS selects another aircraft to present to the student according to the specified path criteria.

The student knowledge model is an overlay type; i.e., the student's knowledge is modeled as a subset of an expert's knowledge. The essential mechanism is to enumerate all units of knowledge pertaining to the material to be delivered. Associated with each unit of knowledge are three variables: a) a counter that is incremented whenever the student demonstrates knowledge of the unit, b) a counter that is incremented whenever the student demonstrates that he does not know the unit, and c) a value assessment of the level of knowledge, e.g., beginner, novice, journeyman, or expert, of the knowledge unit. An example of knowledge units and the associated variables is given in Table I.

TABLE I

Student Knowledge Model

Knowledge Unit	Counter Knows	Counter Does Not Know	Knowledge Level
EXAMPLE			
MiG 23 is foe	10	2	Very good
MiG 23 has variable geometry wings	8	4	Good
MiG has single engine in fuselage	8	4	Good
MiG has backswept tail mounted high on fuselage	4	8	Novice
MiG 23 has large vertical fin	2	10	Beginner
MiG has pointed nose	12	0	Expert
MiG 23 has box-like air intakes on each side of fuselage	10	2	Very good

The knowledge model looks like a collection of data records structured as arrays. There are structures for recording knowledge of WEFT components--Wings: delta, clipped delta, forward swept, back swept, or variable geometry; Engines: one in rear fuselage, two in rear fuselage, two on wings, three on fuselage, or four on wings; Fuselage: pointed nose or blunt nose; Tail: single stabilizer, double stabilizer, back swept, rectangular, or delta shape; Special Features: ventral fin, nose intake, round intake, oval intake, rectangular intake, canted intake, canopy type, etc. Variables to record measured performance and history of presentation of aircraft types are implicity included in the knowledge structures.

ARITS STRUCTURE

The block diagram of ARITS is shown in Fig. 3. Operation of ARITS is in two phases, the first phase is initialization where the student identifies himself and initiates a session with the system. This is concluded when the student specifies a preference structure for viewing aircraft. For example, one preference structure would be to view foe aircraft, then non-U.S. aircraft, then U.S. aircraft. The tutorial module uses this preference list when deciding which aircraft to present to the student. In Fig. 3 this is represented by the path control block. The next phase is the instructional phase in which aircraft are presented to the student on the visual display. The student relates his input on aircraft identity, type, and features to the communications module via iconic and textual menus. The student also has the option to replay the visual sequence, if he so desires, before providing identification input. The communication module passes the aircraft type to the student knowledge model, and the WEFT input to the WEFT knowledge base for determination of the aircraft type determined by student observations. A_t, A_s, and A_o are used by the tutorial module to update the student knowledge model and determine the next action. The next action will be either a tutorial intervention or the presentation of another aircraft. This is represented in the block for tutorial approach; it is either drill and practice, displaying more aircraft, or it is a coaching session. The system then begins another instruction cycle.

STATUS

ARITS was undertaken as an internal study project to investigate implementation of ITS's in microcomputer environments. To do this, a restricted knowledge domain, aircraft recognition, was selected. Previous work in the area (Aldridge 1984) had demonstrated that an expertise module could be built for this application. An ITS was designed to use the aircraft identification expert system as the basis for judging student responses. The ideas and concepts developed in this project supported other computer-based training projects at Los Alamos and established a model for the conceptual design of nontraditional computer-delivered instructional packages. These systems attempt to address the teaching of tasks that are higher on Bloom's taxonomy of cognitive skills such as analysis, synthesis, and evaluation. While the development of the ARITS design has been very helpful to other projects, certain aspects of further development, such as videodisc production, prohibit the continuation of ARITS as an internal effort. However, work will continue on the system as a secondary priority as needed elements become available.

SUMMARY

An intelligent tutoring system has been designed to teach aircraft recognition in support of air defense training. The criteria for ARITS include dynamic assessment of student knowledge, delivery of individualized instruction, implementation on a microcomputer, and utilization of videodisc technology for visual presentations. The system uses the WEFT model for identifying airplanes and has a small expert system to identify aircraft on the basis of student input of WEFT features. The student knowledge model is an overlay type, and tutorial knowledge is represented by condition-action pairs. Although the conceptual design is complete, implementation of ARITS is delayed because of resource constraints.

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