THE USE OF ARTIFICIAL INTELLIGENCE TECHNIQUES IN THE FEDERAL AVIATION ADMINISTRATION SYSTEMS

David A. Spencer, Massachusetts Institute of Technology, Lincoln Laboratory

Software techniques and development methodologies from artificial intelligence have a role to play in the National Airspace System as this system becomes more automated. However, the applications must be carefully chosen. Artificial intelligence (AI) techniques must always be compared with more conventional "algorithmic" methods for achieving the required behavior. Where an algorithmic approach is known, it is generally preferable to an AI approach. At the opposite end of the spectrum of complexity, there are behaviors which may be desirable but which cannot be achieved with any current technology. Both the "algorithmic" boundary and the "impossible" boundary are fuzzy and change over time. Research is often needed to determine where a specific task lies. AI techniques appear to have advantages in areas where the necessary flow of control is very complex, or not well understood, or where the system is likely to be extensively modified during its lifetime in unforeseen ways, or where it is desirable that the reasons behind the system's behavior be understandable to users. The latter might include giving the system the ability to answer questions about why it took a certain action.

Software Development Environments and Methodologies

The software development environments and methodologies used by AI researchers are important in their own right, whether or not the system being developed uses AI techniques. These include powerful personal work stations, such as LISP machines and the highly integrated environments created by the LISP machine software systems. Awareness of and experience with these capabilities should be encouraged within the Federal Aviation Administration (FAA). Although the FAA normally does not develop its own software, it would benefit from use of similar techniques by its contractors.

One interesting software development methodology is that used in creating expert systems. This involves quickly creating a prototype design, using some representation such as production rules that is modified. This prototype is then tried out on test problems and the results criticized by an expert. If errors are found it is relatively easy (compared with conventional implementation in a procedural language) to find the offending rule or fact and modify it to get the desired behavior. This approach has two advantages. First, it exposes the design to criticism by the eventual users or other knowledgeable persons early in the design phase. Second, this criticism is based on actual performance of the prototype on test problems, rather than on a system description in a specification or design review document. Over time, these test problems are made harder and more realistic, ultimately becoming the actual production environment.

Functional Specifications

While such a prototype may not satisfy all the system requirements in terms of real time performance, capacity, or resource usage, it does provide the basis for a functional specification of the system that is known to work as desired. This functional behavior can then be reimplemented, if necessary, to achieve performance goals. This approach explicitly recognizes that a certain amount of debugging of the requirements, the specification and the design always occurs, and that it is better to do this in a low overhead situation rather than at the point where dozens of contract personnel are trying to implement the operational version of the system.

This approach can be contrasted with two alternatives. In the first the requirements are very broadly stated, the contractor is given considerable latitude in how to meet those requirements, and it is not always clear whether or not a particular approach will ultimately satisfy the requirements. A rapid prototype effort would resolve the requirements in more detail and settle critical aspects of the technical approach before the detailed design is begun.

The second alternative is that a large, detailed specification is written by one contractor and another is hired to implement it. The specification may not be validated against realistic scenarios until the production system enters acceptance testing.

Rapid prototyping such as is proposed here is particularly efficient when done in an environment such as a LISP machine work station, and is facilitated by techniques developed by AI researchers for representing data and procedures in an easily modified manner. This combination of capabilities provides a software environment where rapid implementation and modification of a prototype are feasible, and provides a flexible inteactive graphics interface which can be programmed to simulate functionally any necessary displays and controls. The gain in flexibility is paid for by greater resource usage, by lower system capacity or slower response time, and by lack of mechanical (as opposed to functional) realism in the man-machine interface.

In summary, there are beneficial side effects from AI research in the area of software engineering. These are independent of whether or not AI techniques are used in implementing the operational software.

ARTIFICIAL INTELLIGENCE AND AIRSPACE MANAGEMENT

Paul C. Leonard, Air Transport Association of America

Artificial intelligence (AI) introduction into airspace management must not attempt to automate the controller. Just as the flight crew's functions have changed with the introduction of more sophisticated flight management systems in current and future aircraft, airspace managers will most certainly function differently than controllers do today. The flight management systems on aircraft will need to interface with the ground airspace management system with pilots and airspace managers making virtually none of the routine decisions.

Given that airport capacity problems will be addressed by more efficient use of reliever airports, improvements in the utilization of existing airports, and development of some new airports, unconstrained operation should be the rule rather than the exception. Current Federal Aviation Administration (FAA) planning documents such as the National Airspace System Plan and the Research, Engineering and Development Plan do not presently reflect this notion. Rather, they reflect a design philosophy of continued constraint to the airspace users. This notion is particularly reflected in the Research, Engineering and Development Plan which is driving toward an ultimate system called "Flow Management". The message which must be stated emphatically is the need to influence the direction which system planners within and outside the FAA must take to incorporate AI efficiently into airspace management. Again, a goal of unconstrained operation to airspace users must be the rule.

ARTIFICIAL INTELLIGENCE AND OTHER ASPECTS OF AIR TRAFFIC CONTROL

Robert W. Crosby, Federal Aviation Administration

Much of the attention of the artificial intelligence (AI) workshop was focused on direct air traffic control (ATC) issues: conflict resolution, flow control, and weather prediction. This was entirely proper, and the Federal Aviation Administration (FAA) advanced automation program fully concurs with this emphasis. However, rather than reiterate the contributions of others, it would be preferable to use this opportunity as a means of establishing the potential benefit of AI in some of the less direct, but equally important, aspects of ATC. Specifically, the following three topics are suggested: software (SW) design, system repair and maintenance, and training.

Software Design

The reliability of the advanced automated system (and its successors) will be critically dependent on the SW design. Because of the extremely high reliability desired, on the one hand, and the complexity of the SW on the other, it is essential that techniques be used that: 1) minimize the number of hidden faults inadvertently designed into the system; and 2) provide fault tolerance for those that remain. Existing design methods may be enhanced substantially by incorporating AI techniques. Two such techniques come to mind immediately: the use of intelligent search techniques to explore a branching SW tree; and knowledge based systems that make use of expert techniques to solve complex SW design problems.

System Repair and Maintenance

The availability of the ATC system depends critically on rapid failure detection, isolation, and repair. As experience is accumulated on failures, it is likely that this knowledge can be incorporated into an expert system that will reduce system repair time significantly. A second area relates to the detection of incipient expert failures. Again, based upon accumulated knowledge, it should be possible to anticipate many hardware (HW) failures with aid of an expert system. As an aid to maintenance personnel, AI techniques can improve both system performance and personnel productivity.

Training

For the foreseeable future the ATC system will be operated primarily by controllers, with automation being used to aid them, particularly in performing routine tasks. The training of controllers, as well as the operating and maintenance personnel who support them, is thus a key link in the performance of the system. Computer based instruction (CBI) has been used by the FAA for over a decade in the training of these personnel. However, existing CBI, through rote learning techniques, seeks primarily to reduce the number of instructors required for training. Although rote learning may be suitable for routine tasks, the successful operation of the ATC system also requires, from time to time, innovative solutions to new or unpredictable events. As the degree of automation of the ATC system increases this need can be expected to increase. CBI based upon rote learning tends to reject those people who are good at innovation, but bored by routine. Obviously, the ATC system needs both types of people. New and more powerful CBI techniques are now being explored that make use of AI techniques to provide a more versatile learning environment. The development of such a training system for the FAA should be given high priority.

AIRPAC: ADVISOR FOR INTELLIGENT RESOLUTION OF PREDICTED AIRCRAFT CONFLICTS

Curtis A. Shively, Mitre Corporation

SUMMARY

AIRPAC is an expert system being developed to assist air traffic controllers with the planning of resolutions for predicted violations of safe separation or "conflicts" between aircraft. AIRPAC uses knowledge-based system (KBS) techniques to suggest aircraft maneuvers that will prevent a conflict. AIRPAC's choice of a resolution is based on decision rules gathered via consultations with air traffic controllers. By applying these rules to a description of the conflict, AIRPAC produces a single "best" resolution that includes detailed parameters of the recommended aircraft maneuvers. To plan resolutions, AIRPAC uses a hierarchical approach similar to the nested levels of abstraction in a human reasoning process. AIRPAC explains its operation by providing an audit trail of rules used in the search for a resolution. This explanation capability and the representation of resolution rationale in symbolic terms natural to humans are significant benefits provided by the KBS approach.

Introduction

The Federal Aviation Administration (FAA) is undertaking the development of the automated en route air traffic control (AERA) system (1). AERA is intended to automate many of the routine tasks performed by today's air traffic controllers. AERA will also provide computer-based tools for assisting controllers with the more complex planning and control functions requiring human intervention. An important purpose of the U.S. air traffic control (ATC) system is to assure that aircraft are safely separated from one another. An objective of AERA is to predict potential violations of safe separation or "conflicts" between aircraft ten to twenty minutes in advance. These predictions will be based on aircraft flight plans, wind observations, anticipated pilot or controller actions, and other information. If a conflict is predicted with sufficient lead time, AERA can suggest aircraft maneuvers to resolve it in a way that reflects desirable considerations beyond avoidance of imminent collision. The capability to predict aircraft conflicts and plan their resolutions in advance is expected to increase controller productivity and permit more airspace users to fly the routes they prefer.