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The second six months of this grant saw further development of GT-CATS--the Georgia Tech Crew Activity Tracking System and progress on research exploring tutoring concepts for tutors for mode management. The latter included data analysis and a preliminary paper summarizing the development and evaluation of the VNAV Tutor. A follow-on to the VNAV Tutor is planned. Research in this direction will examine the use of OFMspert and GT-CATS to create an 'intelligent' tutor for mode management, a more extensive domain of application than only vertical navigation, and alternative pedagogy, such as substituting focused 'cases' of reported mode management situations rather than lessons defined by full LOFT scenarios.

The following sections further describe each of these areas. They include copies of conference papers and presentations.

GT-CATS

Overview

The Georgia Tech Crew Activity Tracking System (GT-CATS) is a computer system
which embodies a methodology and architecture for understanding how operators select
and use modes of automation to control complex dynamic systems. GT-CATS has been
implemented specifically to track the activities of "glass cockpit" pilots as they use modes
of automation to fly a desired flight path. GT-CATS' activity tracking methodology
specifically involves: (1) hypothesizing the mode configuration the operator will select in
the current operational setting; (2) confirming that actual operator actions support the
hypothesized mode configuration; (3) determining whether a detected operator action in
fact supports a valid alternative mode configuration, or whether the action is in error; and
(4) identifying missed or late actions. The centerpiece of GT-CATS' methodology is the
capacity to revise an incorrect hypothesis about the expected mode configuration to arrive at
accurate explanations for operator actions that support an alternative valid mode
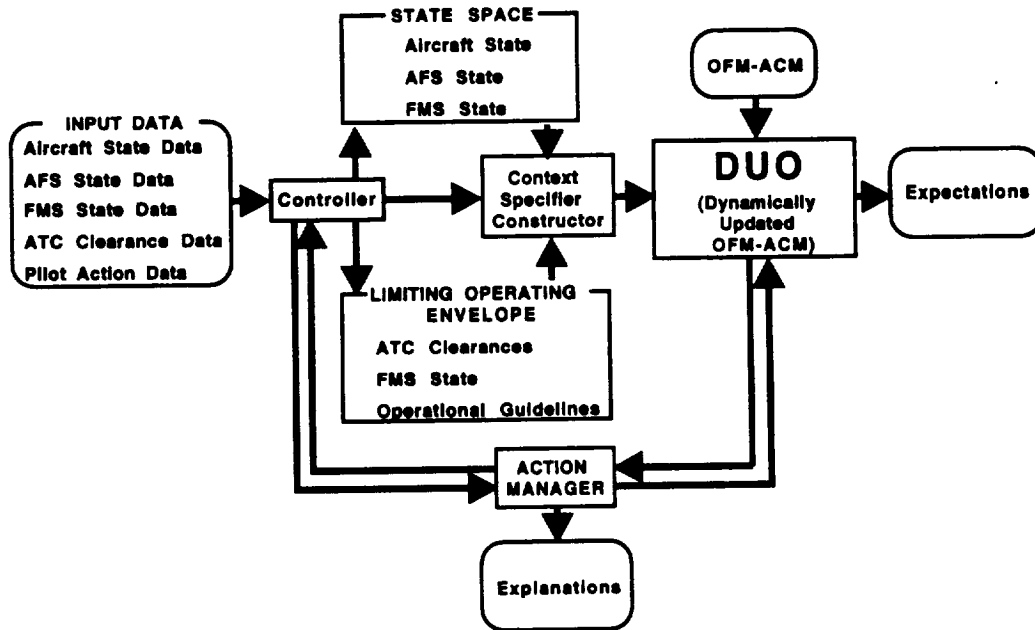configuration. A block diagram of GT-CATS is depicted in Figure 1.

Figure 1. GT-CATS Block Diagram

Current Work

Recent GT-CATS research has focused primarily on preparing for a formal evaluation
of GT-CATS' activity tracking capabilities. The planned evaluation seeks to demonstrate

GT-CATS' use and effectiveness for understanding how operators select and use modes of automation. The evaluation requires fifteen Boeing 757/767 type-rated pilots to verbalize the reasoning behind their autoflight system mode manipulations as they fly five flight scenarios on the Georgia Tech Electronic Flight Instrument Research Testbed (GT-EFIRT) simulator. The study will then compare the pilots' explanations to the expectations and explanations issued by GT-CATS. Output from GT-CATS should agree closely with the pilots' explanations, if GT-CATS' activity tracking method is to prove successful.

A considerable share of the evaluation preparations addressed the development of the experimental flight scenarios, to ensure adequate representativeness and realism. Flight scenarios from a major airline and a NASA Ames LOFT form the basis for the planned scenarios. The scenarios (Figures 2a and 2b) incorporate clearances designed to elicit a range of automation mode selections/transitions. Test runs have aimed toward ensuring that clearances are issued at appropriate times, and that selected automation modes perform in the required capacity (e.g., ensuring that the GT-EFIRT simulator observes a programmed crossing restriction in VNAV). As part of this process, consultations with actual Boeing 757/767 pilots helped to identify and correct problems with the GT-EFIRT simulator and scenarios.

Along with the development and testing of the experimental setup, GT-CATS research efforts also addressed the development of a preliminary plan for analyzing the data obtained in the planned evaluation. Recent refinements to the plan enable more effective examination of GT-CATS' activity tracking capabilities. The plan now allows for evaluation of the activity tracking methodology on an action-by-action basis, to assess in detail: (1) how well GT-CATS understands each type of pilot action, (2) which specific situations cause GT-CATS to revise explanations, and (3) which types of situations result in degraded understanding. Modifications to GT-CATS' output now make this additional information available. The output data will be formatted with the aid of a special analysis program. The program is designed to tabulate, by action type, how each action is interpreted, and generate summary information that describes GT-CATS' performance at a level adequate for assessing its strengths and weaknesses.

Presentations

Much of this work was formally presented at the 1994 IEEE Conference on Systems, Man, and Cybernetics in San Antonio, Texas. A companion paper entitled "A Methodology for Understanding How Operators Select and Use Automation to Control Complex Dynamic Systems" appeared in the conference proceedings. The paper and presentation are included as Appendix A1 and A2 of this report. A presentation on GT-

CATS was also given at the NASA Ames Training For Automation workshop (Appendix A3). Subsequent discussions explored possibilities for integrating GT-CATS into an intelligent tutoring system for advanced cockpit automation.
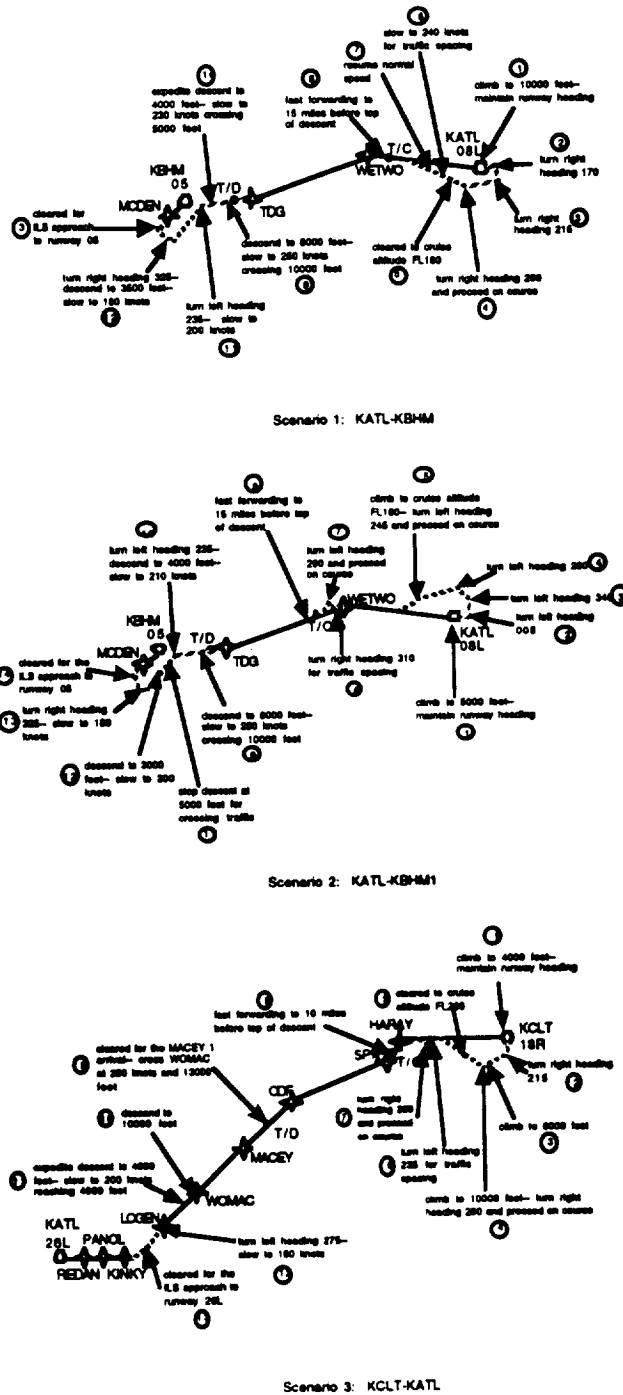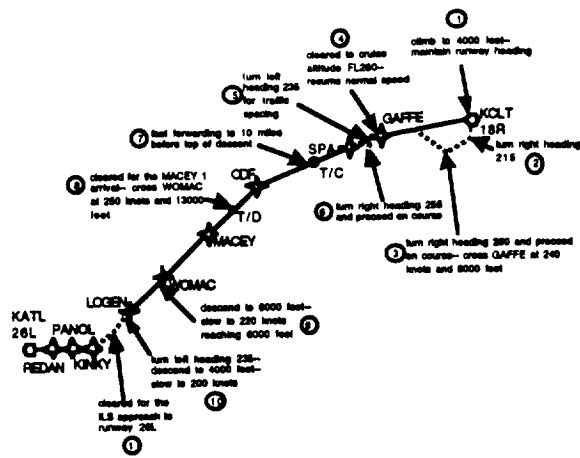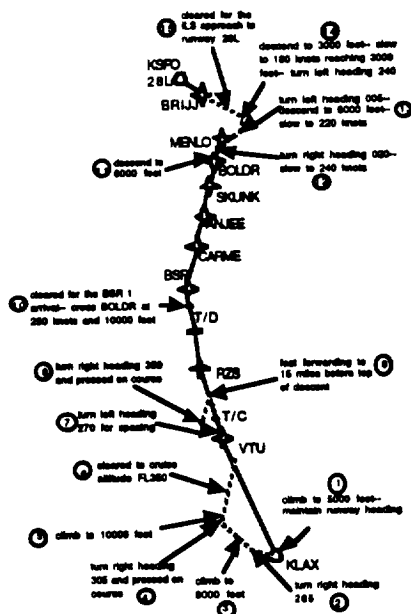
Scenario 1: KATL-KBHM

Scenario 2: KATL-KBHM1

Scenario 3: KCLT-KATL

Figure 2a. Scenarios 1-3.

Scenario 4: KCLT-KATL1

Scenario 5: KLAX-KSFO

Figure 2b. Scenarios 4-5.

APPENDIX A1

GT-CATS SMC Paper

Callantine, T. J., and Mitchell, C. M. (1994). A methodology for understanding how operators use modes of automation to control complex dynamic systems. *Proceedings of the 1994 International Conference on Systems, Man, and Cybernetics*, San Antonio, TX.

APPENDIX A2

GT-CATS SMC Presentation

Presentation Entitled "A Methodology for Understanding How Operators Use Modes of Automation to Control Complex Dynamic Systems" presented at the 1994 International Conference on Systems, Man, and Cybernetics, San Antonio, TX, October, 1994.

APPENDIX A3
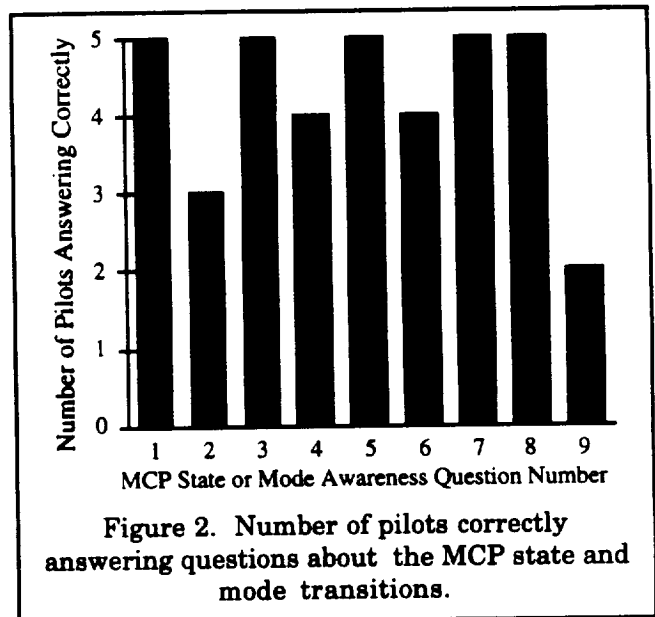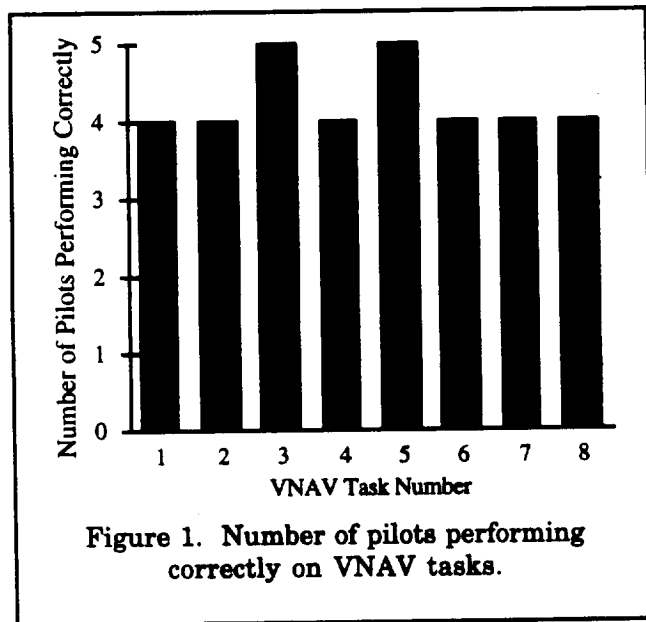
GT-CATS Training for Automation Workshop Presentation

Presentation Entitled "The Georgia Tech Crew Activity Tracking System" presented at the NASA Ames Training for Automation Workshop, Moffett Field, CA, August, 1994.

One of the primary research efforts for this grant is training systems for automation. In the past six months this effort included several complementary activities: evaluation and documentation of the VNAV Tutor, conceptual design of a case-based mode management tutor, and the establishment of a Silicon Graphics research environment, and participation in the Training for Automation Workshop. Progress on each of these activities is discussed below.

VNAV Tutor

A statistical analysis of the data from the initial evaluation of the VNAV Tutor was completed. This evaluation used five pilots transitioning from non-FMS aircraft to a glass cockpit aircraft. The major findings from this analysis show that students learn the actions associated with VNAV well (see Figure 1). In most cases they successfully learn the relationship between the MCP and the FMS as it relates to VNAV (see Figure 2). However, the students are less proficient at identifying data sources to confirm the accuracy of their actions or the accuracy of the VNAV control mode operation. The data supporting these findings and more detailed interpretation are presented in Appendix B1.

Figure 1. Number of pilots performing correctly on VNAV tasks.

Figure 2. Number of pilots correctly answering questions about the MCP state and mode transitions.

A paper titled "VNAV Tutor: System Knowledge Training for Improving Pilots' Mode Awareness" which documents the VNAV Tutor and the results of the evaluation was written. This paper was presented at the 1994 IEEE International Conference on Systems, Man, and Cybernetics and published in the conference proceedings. A copy of this paper and the presentation appear in this report as Appendices B1 and B2, respectively.

In addition, we started the formulation of a plan for the follow-on evaluation of the VNAV Tutor. The VNAV related functions, data sources, and operations taught by the VNAV Tutor were identified and enumerated. This list extracts and summarizes the salient points of each tutor message in the four training scenarios. Such a set of training objectives defines the starting point for a thorough evaluation of the effectiveness of the VNAV tutor. Preliminary versions of the revised pre- and post- tutor questionnaires have been completed. The in-flight evaluation focusing on VNAV use and mode awareness has also been developed. These evaluation tools provide insights into the capabilities and limitations of the VNAV Tutor. The information gained through this evaluation will guide future Georgia Tech research in training systems.

Case-Based Mode Management Tutor

In order to build on the lessons learned from the VNAV Tutor and other developments in training systems research we initiated the conceptual design for a new tutoring system, a case-based mode management tutor. This proposed system incorporates a case-base of flight scenarios (i.e., incidents and accidents drawn from the relevant literature, such as the ASRS data base). These scenarios are used to configure focused tutoring scenarios that highlight mode management, transition, and interaction. The tutoring system monitors pilot actions in order to control training both within and between scenarios. Within a scenario, the tutor uses a combination of expert and student models to guide the pilot's focus of attention and flight control actions. Expert and student models also guide the selection of new scenarios to systematically broaden the pilot's exposure to mode operation and potential mode management problems. Such an instructional system, combining case-based reasoning (CBR) and intelligent tutoring system (ITS) technologies, may provide an environment and instructional content capable of teaching pilots the wide range of complex and varied modes of control in modern glass cockpit aircraft.

Silicon Graphics Research Environment

A Silicon Graphics Inc. (SGI) Indigo 2 was purchased and configured. This dual head graphics engine duplicates the Mini-ACFS environment at Ames Research Center. A comparable configuration promotes better software transfer from Georgia Tech to Ames and other Ames grantees. Future Georgia Tech aviation research will develop and evaluate proposed systems on the SGI . Experiments will be conducted with the research software running on the SGI communicating via UNIX interprocess protocols with the GT-EFIRT simulator running on a Sun SPARCstation 10.

APPENDIX B1

VNAV Tutor SMC Paper

Crowther, E. G., Chappell, A. R., and Mitchell, C. M. (1994). VNAV Tutor: System knowledge training for improving pilots' mode awareness. *Proceedings of the 1994 International Conference on Systems, Man, and Cybernetics*, San Antonio, TX.

APPENDIX B2

VNAV Tutor SMC Presentation

Presentation Entitled "VNAV Tutor: System Knowledge Training for Improving Pilots' Mode Awareness" presented at the 1994 International Conference on Systems, Man, and Cybernetics, San Antonio, TX, October, 1994.