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CTAS: Computer Intelligence for Air Traffic Control in the Terminal Area

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Summary

A system for the automated management and control of arrival traffic, referred to as the Center-TRACON Automation System (CTAS), has been designed by the ATC Research Group at NASA Ames Research Center. In a cooperative program, NASA and FAA have efforts underway to install and evaluate the system at the Denver and Dallas/Ft. Worth airports. CTAS consists of three types of integrated tools that provide computer-generated intelligence for both Center and TRACON controllers to guide them in managing and controlling arrival traffic efficiently. One tool, the Traffic Management Advisor (TMA), establishes optimized landing sequences and landing times for aircraft arriving in the Center airspace several hundred miles from the airport. In the TRACON, TMA resequences missed approach aircraft and unanticipated arrivals. Another tool, the Descent Advisor (DA), generates clearances for the Center controllers handling arrival flows to feeder gates. The DA's clearances ensure fuel-efficient and conflict free descents to the metering gates at crossing times provided by TMA. In the TRACON, the Final Approach Spacing Tool (FAST) provides heading and speed clearances that produce an accurately spaced flow of aircraft on the final approach course. A data base consisting of aircraft performance models, airline preferred operational procedures and real time wind measurements contribute to the effective operation of CTAS. Extensive simulator evaluations of CTAS have demonstrated controller acceptance, delay reductions, and fuel savings.

Introduction

In response to the growth of air traffic and increased terminal area delays, the Federal Aviation Administration (FAA) has initiated a major effort to develop automated systems for assisting controllers in the management of terminal area traffic. FAA's objective is to achieve early operational benefits by pursuing accelerated development of such systems, leading to their deployment at critical airports within two to five years. In support of this objective, FAA, in a cooperative program with NASA, is planning to evaluate the Center-TRACON Automation System (CTAS) developed at NASA Ames Research Center.

CTAS has been implemented in the ATC Automation Laboratory at Ames on a network of Sun Microsystems, Inc., workstations equipped with high resolution color displays. CTAS provides computer intelligence for planning and control of arrival traffic. It is an integrated and human-centered set of automation tools for optimizing arrival traffic flow under diverse conditions. CTAS is integrated in several ways: First, it provides automation assistance to both Center and TRACON controllers and, second, it provides both coordinated Center and TRACON traffic plans and controller advisories to help achieve the plans. A major design guideline for CTAS was to provide human-centered automation, that is, provide tools which aid the controller in decision making tasks rather than provide a substitute for controller responsibilities (ref. 1). CTAS is comprised of three major sets of tools:

- Traffic Management Advisor (TMA): sequences and schedules arrival traffic to minimize delays.
- Descent Advisor (DA): provides cruise speed and descent clearances to help aircraft meet the TMA's schedules with minimum fuel consumption.
- Final Approach Spacing Tool (FAST): assists TRACON controllers in spacing aircraft accurately on final approach.

CTAS has been refined in the laboratory over several years of intense development, including thousands of hours of real time simulations with controllers and pilots. Controller subjects have included active controllers familiar with the geography of the evaluation site and pilot subjects have included airline flight crews.

Based on CTAS's potential for increased fuel efficiency, reduced delays, increased capacity and improved controller productivity, the FAA selected it to be implemented for field evaluation at two terminal areas: The Denver and Fort Worth Centers and their respective TRACON's.

Traffic Management Advisor (TMA)

The TMA continuously exchanges various types of information with the DA and FAST tools. The most important information obtained from DA and FAST is the estimated time of arrival (ETA's) for each arriving aircraft. The TMA's sequencing and scheduling algorithm uses the ETA's as an essential input in the process of generating efficient landing sequences, referred as the sequence of scheduled times of arrival (STA's) (ref. 2). The real time scheduling algorithm initially generates a feasible (though non-optimum) STA sequence based on ETA order. Then it attempts to minimize total aircraft delays by advancing the landing times of some aircraft ahead of their ETA's a permissible amount and by bunching together aircraft of the same weight class (heavy, large, or light) when that is appropriate (ref. 3). The latter technique is known as position shifting. After each cycle of STA computation, the TMA distributes them to all DA and FAST equipped controller workstations.

The TMA has been selected as the first element of CTAS to be evaluated at a field site, which FAA selected to be the Denver Center, located in Longmont, Colorado. Initially, the TMA will be operated in a standalone mode. In this mode the trajectory synthesis algorithm in the DA and FAST tools will supply the TMA with ETA's and other inputs, but no DA and FAST tools will actually be installed at the appropriate controller positions. Instead, a single combined DA and FAST workstation also will perform the trajectory calculations standalone. Without these tools, controllers cannot be expected to execute the TMA's traffic plans with a high degree of precision.

While this is a major limitation, experiments with simulated and live ATC data have nevertheless demonstrated that the standalone mode of operating the TMA can provide the Center traffic manager with useful information for the overall management of arrival traffic. Furthermore, CTAS designers can use the standalone TMA in off-line tests to tune the algorithm and evaluate the effectiveness of various CTAS capabilities.

The standalone TMA consists of two physical displays (19 in. color monitors), each with a keyboard, a mouse and associated processors that receive traffic data from the Center's host computer as well as weather data from the National Meteorological Center. Each of the monitors is reconfigurable to perform several display functions. One display function presents the traffic on time-lines in a mixed graphic and alphanumeric format. Alternately, the same monitor can display atmospheric data via a graphical user interface. The second monitor can be configured as a Horizontal Situation Display (HSD), which displays radar positions of aircraft in a plan view displays (PVD) format.

The standalone TMA can assist the traffic management coordinator in five ways:

• It generates a sequential order and landing time schedule for arrival aircraft.

• It displays the schedule and delay information in a graphical form for the traffic management coordinator's monitoring and approval.

• It allows the traffic management coordinator to override the automatic schedule such as manual insertions of additional aircraft, for example.

• It provides several traffic prediction displays and "what if" tools to aid in airport reconfiguration management.

• It provides historical 24 hour traffic analysis data on the screen and as hard copy, including various delay statistics.

The standalone TMA has recently been installed in the Denver Center. Operational evaluations are expected to begin in October 1992.

Descent Advisor (DA)

The DA is designed to assist Center controllers in accurately and efficiently delivering arrival traffic to the TRACON feeder gates in accordance with TMA's schedule. The heart of the DA is a 4-dimensional (4D) trajectory generation algorithm which is adaptable to different types of aircraft (ref. 4). It contains detailed models of aircraft performance and operational characteristics, and takes advantage of all real time inputs of atmospheric data available in its area of operation. The DA continuously resynthesizes 4D trajectory solutions for all arrivals based on controller inputs, aircraft state from radar tracking, and the TMA schedule. The DA translates these trajectory solutions into controller advisors that include speeds for cruise and descent, top of descent, and heading. The DA monitors the traffic, including overflights, and compares the trajectories it predicted for each aircraft. The controller is advised of any potential conflicts that are predicted up to 20 minutes or more in advance. The DA also provides continuous feedback on whether or not subsequent controller actions resolve the predicted conflicts. In effect, potential conflicts are resolved far in advance of the time a controller would have normally detected them without assistance from the DA (ref. 2).

The DA also includes navigation tools that give the controller capabilities similar to those of area navigation equipped aircraft. For example, the controller can plan the points of interception of an established jet route of an aircraft currently flying off-route. The controller can also obtain heading advisories that will cause an aircraft to capture a designed waypoint. In addition, a path stretching tool tells the controller when it is necessary to vector an aircraft off-route in order to absorb large delays. Once an aircraft is in path stretching maneuver, the tool tells the controller the precise point along the current aircraft course line where the required delay has been absorbed and the aircraft should be vectored back on-route.

All of the various horizontal, vertical, speed and conflict detection/resolution advisories of the DA are fully integrated with each other. Thus, controller-initiated changes in one function are automatically accounted for in all other related functions.

The DA's functions are interfaced with mouse-based, menu-driven controller display. The display features include those available on current Center PVD, as well as color graphics, timeline, and other advanced graphical features. A mouse pointer or trackball is used to select display objects including aircraft symbols, tags, and fixes; the controller invokes the DA's functions via on-screen "buttons" or keyboard inputs. In a series of simulator evaluations, controllers have found the DA tools to be very effective for strategic planning and tactical control (ref. 2).

Final Approach Spacing Tool (FAST)

FAST provides a set of keyboard functions and on-screen graphical advisories that help the TRACON controller to achieve an accurately and efficiently spaced flow of aircraft on final approach. FAST is based on the same set of 4D trajectory synthesis algorithms as the DA, but includes extensive adaptations appropriate for TRACON operation (refs. 5 and 6).

FAST analyzes each arrival aircraft's current state (position, velocity) by classifying its positional sequence in the traffic pattern relative to that of other aircraft in the pattern and computing an estimated time of arrival (ETA) at the runway threshold. The analysis makes use of the vertical wind profile to the degree known and aircraft performance characteristics. This information is sent to the Traffic Management Advisor (TMA) which computes the landing sequence and landing times for all aircraft and then sends that information back to FAST.

FAST then generates a series of indicated airspeed and heading advisories (magnetic headings, corrected for winds) which, if issued as clearances to the appropriate aircraft, will space aircraft accurately on final approach. The geographical points where speed and heading advisories should be issued are displayed as markers on the controller's monitor. They are always located a short distance ahead of the aircraft along its extended, current course line. The numerical value of the speed advisory is written on the third line of the data tag. In addition to the speed and heading advisories, a time line shows the landing sequence and time errors relative to the scheduled landing time. An aircraft's landing order is also indicated by an integer, called the sequence number, which is also displayed on the third line of the data tag.

One of the most important features of FAST is its resequencing capability. This feature is automatically invoked when FAST has detected a missed approach aircraft or an aircraft that has failed to execute a clearance. A typical event causing a resequence is the failure of an aircraft on downwind to execute a turn-to-base in a timely manner. Once resequencing has occurred, FAST immediately displays a new set of advisories that merges the affected aircraft back into the landing sequence.

Another feature of FAST is its ability to generate advisories for aircraft that require large delays in the TRACON airspace. Algorithms for path stretching incorporated in FAST include base extension (tromboning) for aircraft on downwind, extending the final approach course intercept point for aircraft on long base (fanning) and extended upwind and downwind turns for aircraft on initial approach segments.

All major software components of FAST have been designed and implemented. A real-time simulation evaluation has been ongoing since November 1990. In the simulation, operational controllers from the FAA have been exposed to a variety of traffic conditions including runway capacity-limited arrival rates for IFR conditions, over-capacity arrival rates, closely spaced parallel runway operations and multiple missed approaches. The evaluations have demonstrated a perceived decrease in workload in handling difficult traffic scenarios and a decrease in interarrival spacing at the runway for the automation assisted runs compared to manual or baseline runs without automation assistance. If the development of all hardware and software proceeds on schedule, live traffic evaluations could be conducted as early as 1994.

References

1. Erzberger, H.: CTAS: Integrated Automation Tools for the Center and TRACON. The Journal of Air Traffic Control, Oct.- Dec. 1990, vol. 32, no. 4, pp. 90-91.
2. Erzberger, Heinz; and Nedell, William: Design of an Automated System for Management of Arrival Traffic. NASA TM-102201, June 1989.
3. Neuman, F.; and Erzberger, H.: Analysis of Sequencing and Scheduling Methods for Arrival Traffic. NASA TM-102795, April 1990, Ames Research Center.
4. Erzberger, Heinz; and Tobias, Leonard: A Time-Based Concept for Terminal-Area Traffic Management. NASA TM-88243, April 1986.
5. Davis, Thomas J.; and Green, Steven M.: Piloted Simulation of a Ground-Based Time-Control Concept for Air Traffic Control. AIAA Paper 89-3625, August 1989.
6. Davis, Thomas J.; Erzberger, H.; Green, S. M.; and Nedell, W.: Design and Evaluation of an Air Traffic Control Final Approach Spacing Tool. AIAA Journal of Guidance, Control, and Dynamics, vol. 14, July-August 1991, pp. 848-854.

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