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AN INVESTIGATION OF AIR TRANSPORTATION TECHNOLOGY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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SUMMARY OF RESEARCH ACTIVITIES

1. INTRODUCTION

There are two completed projects and five new or continuing research activities under the sponsorship of the FAA/NASA Joint University Program as the 1991-92 period ends. There were a number of publications during the year which have been provided in this report. A brief summary of some of the continuing research projects is provided.

The completed projects were:

1. Hahn, E. and Hansman, R.J., "An Experimental Study of the Effect of Automation on Pilot Situational Awareness in the Datalink ATC Environment", MIT Aeronautical Systems Report, ASL-92-1, June 1992.

2. Midkiff, A., and Hansman, R.J., "Analysis of the Importance of Party Line Information in ATC Operations", MIT Aeronautical Systems Report, ASL-92-2, August 1992.

The active research projects are:

1. Extensions for the FASA (Final Approach Spacing Advisory) System (Chiang, M.C., Simpson, R.W.)

2. Radar Tracking around a Turn (Liu, Manly, and Simpson, R.W.)

3. Impact of Advanced Technologies on Single Pilot IFR Operations (Dershowitz, A., and Hansman, R. John)

4. System and Human Limitations in Millimeter Wave and Infrared Synthetic Vision Systems (Clarke, J.P., and Hansman, R. John)

5. Differences in Party Line Information Usage by Operational User Groups (Pritchett, Amy, and Hansman, R. John)

A publication from prior years, "Heat Transfer on Accreting Ice Surfaces" by K. Yamaguchi and R.J. Hansman, is included in this year's report. An annotated set of materials used to give a briefing at MIT Lincoln Laboratory on the continuing research on extending the FASA (Final Approach Spacing Advisory) system is also included.

The student thesis by Zhihang Chi (Reference 3.1) won the RTCA's William E. Jackson Award for 1991. Mr. Chi was a guest at the Annual RTCA Meeting on November 30, 1991 to receive the award and its $1500 prize.

2. REVIEW OF CONTINUING RESEARCH ACTIVITIES

2.1 Extending FASA (Final Approach Spacing Advisory) System

Prior research under JUP (Reference 3.1) created an initial version of an interactive decision support system to assist the controllers responsible for establishing the final approach spacings for aircraft at a busy airport. Current research is extending this work in a variety of ways in order to achieve capabilities described by a concept called ASLOTS (Adaptive Slots). The initial version only handled landing aircraft approaching a single runway. The current work is aimed at incorporating takeoff aircraft and multiple runways. It also will improve the dynamics of aircraft motion in the simulation and the representation of errors from radar surveillance and tracking. The original simulation was quickly constructed to provide a graphic means of demonstrating the real time operation of the logic and to investigate the problems of producing a robust code which implemented some of the desired capabilities of the ASLOTS concept. The logic and its code will be transferred to another, high fidelity airspace simulation called ATCSIM (which also simulates the motion of aircraft on the surface of the airport between runways and gates).

The FASA was implemented on an Apollo 3500 workstation in UNIX and the C language. It used X-Windows to provide a graphical display of aircraft and the landing slots. It is portable to other workstations and has been demonstrated by an IBM RS-6000. The logic will be incorporated into ATCSIM which runs on a network of SUN SPARCstations.

An annotated description of the ASLOTS concept is provided in this report.

2.2 Radar Tracking of Turning Aircraft

Under the assumption that a straight track at constant groundspeed is being flown, today's radar tracking processes provide a best estimate of current position, groundspeed, and track direction. These estimates are critical to the successful operation of various automated ATC processes such as Hazard Alert, Automated Final Approach Spacing, or Conformance Monitoring.

The best estimates are obtained from the recurrent position measurements on each scan of the radar which occur at 4.8 or 12 second intervals. There are three sources of noise in the measurements: 1)radar measurement errors in range and azimuth; 2) short term fluctuations in wind; and 3) aircraft maneuvering around the straight line path. The radar measurements are "filtered" or "time averaged" over the last several measurements to estimate speed and direction, and it requires several scans (30-60 seconds) to get an accurate and reliable estimate after tracking is initiated on a straight line path.

But if a simple turn is initiated at constant airspeed, current radar tracking processes will continue to assume a straight line path is being flown and severe transient errors can occur (e.g., $\pm$ 60° or 60 knots). It is possible to inhibit or modify the straight line tracking process, but it is difficult to create a successful method of turn detection using only successive, same direction, deviations from a straight line path. Some method of providing a turning signal to the tracker that the aircraft has changed to a turning mode of flight is needed. With the advent of Mode S radar, it is possible for the aircraft to send a "Turning Signal" indicating a left or right turn on any scan (e.g., if bank angle has exceeded 10° for 2.5 seconds, create a Turning Signal).

Given a Turning Signal, there are two options:

1. Turn off the Straight Line Tracker during the turn, and use the measured turn positions to estimate the initial values of groundspeed and track direction to re-initiate the tracker on the next straight line segment.

2. Switch to a Turning Tracker, using the measured turn positions to estimate values for groundspeed, track direction, and rate of change of track direction during the turn.

The first option is being studied in the current research. It does not provide estimates of groundspeed and direction during the turn, but the number of measurements and period of turning is small (there are less than six measurements for a 90° turn and most turns are smaller than 90°). It seems reasonable to try to use them to prevent transient errors and a good initial estimate along the new straight line segment.

The second option may be studied later. It is necessary to declare a model of the curved path, and it is known that it will not be circular nor at constant groundspeed when there are strong winds. It is possible to consider sending more information about the current aircraft state such as bank angle, rate of change of heading, or heading itself to augment an "aided" Turning Tracker; and for modern transport aircraft with a digital FMS, it is possible to send the onboard estimate of ground speed and track direction directly to the ground on each scan which obviates the need to implement any ground based Turning Tracker. It is not even clear that ground speed and direction during the turning maneuver is useful. Of much more value would be the intended final path direction for the turn since the future trajectory of interest probably exceeds its curving portion.

A simulation called TASIM for studying tracker performance has been created. Radar measurement errors are randomly drawn from a normal distribution of range and azimuth errors of known size. Aircraft are flown at differing airspeeds along paths which provide Radial and Tangential turns at varying distances from the radar site. The aircraft has an automatic guidance system which causes it to track these paths in the face of varying winds or navigation system errors. There is a guidance logic which initiates a turn at the appropriate point near the end of one straight segment of the path, and then transition to an acquisition of the next segment (which may have a dynamic overshoot due to winds and navigation errors). It is possible to vary the turn initiation time to occur at random times in the radar scan.

3. REFERENCES

3.1 Chi, Zhihang, A Graphic Simulation System for Adaptive, Automated Final Approach Spacing, Flight Transportation Laboratory Report 91-3, June 1991, Flight Transportation Laboratory, MIT, Cambridge, MA, 02139

3.2 Hahn, E., and Hansman, R.J., "An Experimental Study of the Effect of Automation on Pilot Situational Awareness in the Datalink ATC Environment", MIT Aeronautical Systems Report, ASL-92-1, June 1992.

3.3 Midkiff, A., and Hansman, R.J., "Analysis of the Importance of Party Line Information in ATC Operations", MIT Aeronautical Systems Report, ASL-92-2, August 1992.

3.4 Wanke, C., and Hansman, R. John, Hazard Evaluations and Operational Cockpit Display of Ground Measured Windshear Data, Journal of Aircraft, Vol. 29, No. 3 - May - June 1992

3.5 Hansman, R. John; Wanke, C.; Kuchar, James; Mykityshyn, Mark; Hahn, E.; Midkiff, A., Hazard Alerting and Situational Awareness in Advanced Transport Cockpits, Eighteenth ICAS Congress, Beijing, China, Sept. 1992