AUTOMATION CAPABILITIES ANALYSIS METHODOLOGIES FOR NON-CONTROLLED AIRPORTS

AIAA-2003-5601

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AIAA Modeling and Simulation Technologies Conference
Austin, TX
12 August 2003
Overview

- Motivations and background for this research

- Research objectives
  - Motivations
  - Automation System Modeling
  - Simulation methodologies

- Flight simulation laboratory research capabilities
  - Current capabilities
  - Enhancements for this research

- Summary and future work
Motivation

The Picture Says It All: Congestion is a Problem!
Small Aircraft Transportation System (SATS)

Expanded Accessibility to several times more destinations

Airports today with “near all weather” availability

Of 5,400 public-use airports, only 715 (13%) have precision instrument approaches (ILS),

Near all-weather accessibility to 5,400 public-use airports?

- 22% within 30 minutes of major/hub airport
- 41% within 30 minutes of any commercial airport
- 93% of population within 30 minutes of SATS-type airport

Ref. SATS program briefing charts

Veritas Fugae

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What SATS Does

The SATS concept seeks to achieve:

- **Higher Volume Operations at Non-Controlled Airports**
- Lower Landing Minimums at Minimally Equipped Landing Facilities
- Increased Single-Pilot Crew Safety & Mission Reliability
- En Route Procedures & Systems for Integrated Fleet Operations
What is a Non-Controlled Airport?

Generally, a non-controlled airport is an airport without operation tower and terminal radar facilities. It is surrounded by class G airspace.
Research Overview

Objective

• Develop automation capabilities analysis for non-controlled airports

Approach

• A new functional description of the airport terminal area infrastructure: Multi-Layer Air Traffic Space (MATS)
• Use intelligent agent system architecture
• Define operations concept and procedures
• Create priority sequencing/scheduling algorithms
• Enhance existing simulation methodologies

Assumptions

1. Arrival IFR traffic uses CTAF to guarantee separation from VFR traffic
2. Aircraft are ADS-B equipped, and data report provides sufficient surveillance data
3. ATC provides the separation service for the en route phase of flight
Airspace Infrastructure
Multi-Layer Air Traffic Space (MATS)

- **En route Layer**: all airspace outside the Negotiation Layer

- **Negotiation Layer**: airspace 50NM from airport, from ground to 10,000 ft AGL, not including Terminal Layer.

- **Airport Terminal Layer**: airspace 10 NM from airport, from ground to 2,500 ft AGL.

*All radii and altitudes proposed here are provisional. Future efforts will seek to optimize the shape and size of MATS*
Intelligent Agent System (1)

En Route Layer

Negotiation Layer

Airport Terminal Layer

Traffic Management Agent

Aircraft Agent

Smart Airport” Airport Agent
Intelligent Agent System (2)

**Aircraft Agent:** It conducts real-time flight operations. With information on the nearby traffic and weather situation, it plans its maneuvers for an optimized and safe trajectory.

**Traffic Management Agent:** It monitors all of the aircraft inside the negotiation layer with a well-maintained active table. When some aircraft agents are unable to negotiate a profitable conflict-avoidance maneuver in the negotiation layer, it acts as an arbitrator.

**Airport Agent:** It accepts the requests from traffic management agent for sequencing and use of ground facilities, including runways, taxiways, and gates. In order to provide safe and efficient landing and departure operations, the aircraft agent implements algorithms to schedule, sequence and take complete control of the aircraft inside the terminal layer.
Airport Terminal Layer Operations

- Safety is the paramount concern and rigid constraints must be imposed.
- Procedural separation is applied (one-in-one-out paradigm).
- Aircraft should obey the instrument arrival/departure procedures that the “smart airport” assigns.
- *In general, the landing procedure has a higher priority than departure procedure.*

**d0y6025:**

- There is no central controller in this layer, the distributed aircraft uses its ADS-B equipment to accumulate information and then engages its Conflict Detection & Resolution (negotiation algorithm) module to plan maneuvers for an optimized and conflict-free trajectory.
- *Only one aircraft is allowed to take the operation in this layer at one time, either approach or departure. Additional requests for operations are postponed until the current procedure is completed.*
All of the aircraft agents inside this layer use negotiation algorithm as their first choice to find their profitable conflict-free trajectories and determine sequence priority.

If the aircraft can not negotiate a conflict-avoidance maneuver, an arbitration request will be sent to the traffic management agent, it will act as the arbitrator.

When an aircraft plans for either landing or departure, a clearance request must be sent to the traffic management agent first, then the traffic management agent transmits the request to the airport agent. If the terminal layer is clear and the request waiting queue is empty when the request is submitted, then aircraft gets the permission to fly into the terminal layer and complete the operation, otherwise, the request is postponed and a request waiting queue is maintained by the traffic management agent, the airport agent will implement its sequencing/scheduling algorithm and determine who is the next one to be granted the permission when the terminal layer is clear.
Something I’m pretty sure…

- Reordering the priority list should be limited to inserting small numbers of departure between previously ranked arrival requests and deferring departure requests.
- As part of the algorithm, delay estimates should be generated well in advance and be disseminated for pilot advisories.

Something still needs lots of thoughts…

- How to weigh those factors involved in the priority ranking?
- How to define a set of performance metrics to compare the performance of the priority scheduling algorithm and the baseline algorithm, say FCFS? Minimizing the operation time to complete all the requested procedures? The ability to match the preferred arrival order?

Something I don’t even think about…
Traffic Scenario Generator

Flight
- Flight states: LAL, LON, ALT, HED, SPD of the flights
- Aircraft model
- CD & R model

Airspace domain
- ARTCC: En route airspace with determined center (location and size).
- TRACON: Airport model with terminal airspace around the airport.

Mode selection
- Interactive mode: Command input window is engaged during the simulation
- Batch mode: Simulation is started with a batch configuration file, no interaction during the simulation process.

Data source
- Recorded real traffic data: Parsing algorithm must be implemented to read the traffic data files. Some perturbation should be added to introduce randomness.
- Complete random or based on known distribution: an algorithm to create random flight plan that create comparable realistic traffic must be implemented. It is not the case for TRACON domain since flight plan is not necessary.

Airport model

Final approach procedures
- Gates fix
- Standard Instrument Departure (SID)
- Standard Terminal Approach Route (STAR)
- General flight profile: nominal flight profile, fast flight profile, etc.

Autonomous ATC (the “smart airport”)
Weather model

Data source
- Data points in database: National Weather Service or Aviation Digital Data Service
- Mathematical expression

Data Domain
- En route airspace weather
- Terminal area airspace weather

Data components
- Atmospheric data: density, temperature, pressure.
- Wind condition: speed, directions.

Interpolation & extrapolation methodologies
- Linear interpolation
- Polynomial interpolation
- Rule-based model identification

GUI/display design

IO---traffic scenario generator window
IO---run-time command input window (optional)
Aircraft---FMS interface
Aircraft---navigation view
Airport---physical view
Airport---traffic information view
Airspace---moving map including weather view

GUI can make AIMS a friendly software, and graphic display makes more sense during the simulation process, especially for the students. However, we should be aware of the potential...
Simulation System Software Components (2)

Three-tier communication model

Data Service
- System Database

Operation Service
- Message Interpreter
- Information Broadcasting
- Scheduling & Sequencing
- CD & R Arbitration
- Dynamical Information Processing
- Other Services: timer, etc.

Clients
- Simulated aircraft 1
- Engineering Flight Simulator
- Simulated aircraft n
TAMU Flight Simulation Lab

• Nonlinear, 6-DOF Commander 700; AV-8A Harrier, F-5A Freedom Fighter
  • SGI Onyx Reality II sim engine
  • Networked bank of PC’s
  • Center stick; sidestick
• 155° projected field of view
  • 30 Hz refresh rate
• Programmable Head Up Display
**TAMU Flight Simulation Lab (2)**

- **Head Down Displays (HDD)**
  - Reconfigurable
  - CRT; touchscreen LCD

- **Autopilot**
  - Glide slope capture
  - Heading
  - Altitude
  - Pitch attitude

- **Flight Management System (FMS)**
  - Jeppesen data base
  - Pre-flight planning and enroute updating
  - Moving map display
Capabilities and Enhancements (1)

Research work completed in FSL

- Engineering Flight Simulator
- Real-time simulation with pilot-in-the-loop for *single GA aircraft*

*Batch simulation of multiple GA aircraft* within Multi-layer Air Traffic Space

- Necessary operations concepts and procedures
Capabilities and Enhancements (2)

Research work completed in FSL

- Hierarchy agent system for pilot decision-making
- Conflict detection and resolution algorithm

Upgrade

Executive Agent

Weather Radar

Ground Weather

Other Weather

Flight Plan

ADS-B

Other Traffic Info

Traffic Agent

Weather Agent

Aircraft Agent

Traffic Management Agent

En Route Layer

Negotiation Layer

Airport Terminal Layer

“Smart Airport” Airport Agent

- Intelligent agent system architecture for automation capabilities analysis of non-controlled airports
- Arrival/departure sequencing algorithm
Capabilities and Enhancements (3)

Research work completed in FSL

- General aviation pilot advisor and training system
- Soft pilot/FMS interface
- Moving map display

Upgrade

- Aircraft approach and landing assistant
- Multi-functional head down display
- Highway In The Sky Display
Summary and Future Work

Characteristics

• New functional description of the airport terminal area infrastructure named Multi-layer Air Traffic Space
• Automated terminal operations and procedures
• Several types of intelligent agents with negotiation functions
• Simulation methodologies
• Concepts represent a provisional design only

Future Work

• Develop detailed requirements for implementation of concepts
• Experiment design and simulation
• Modify MATS model to be compatible with current ATC structure
• Integrate new operational concepts and procedures into current NAS

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Questions?