A Modularized Approach to Comprehensive System-Wide Computer Simulation of Air Traffic Systems

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Abstract

The dramatic increase of air traffic over the last decade has caused the air traffic system to come to its full capacity. The projected growth indicates that the system will head into a gridlock in the near future. In order to reduce delays and other problems, several changes to the Air Traffic Management (ATM) system have been proposed. These changes range from short-term solutions such as controller decision support tools to long-term solutions where the decision-making responsibilities are distributed among participating parties to strip the system of its heavily centralized hierarchy.

Any changes to the ATM system and its procedures have to be evaluated and verified before they can be deployed. As a result, developments of verification environments become critically important to further advances in ATM. Due to the complexity of the ATM system as well as the costs and risks associated with flight tests, system-wide computer simulations have become almost the only feasible approach for evaluating automation tools and new concepts.

This thesis will present a new modeling approach to system-wide computer simulation of ATM systems. The main part of the research that will be presented emphasizes the modeling and computer implementation of all relevant ATM components and their dynamic interactions. By introducing an object-oriented modeling approach for each object, it was possible to simulate it "as-it-is" in real life. In the course of deriving the models, it was necessary to develop methods for the application of techniques such as feedback linearization and extrapolation schemes.

The developed simulation model was evaluated by obtaining results from performing a simulation for several simulation scenarios. These results will show that the modularized modeling approach is capable of emulating a realistic behavior of the simulated system. Compared with existing ATM computer simulation programs, the presented simulation model is highly flexible so it can be used to study both the current and future ATM systems. It provides a realistic and consistently accurate simulation environment and is simple to use.

Contents

List of Acronyms and Symbols

Greek Symbols

α	Angle of Attack
χ	Velocity Heading
ϕ	Latitude
γ	Flight Path Angle • Isotropic Exponent for Gas
η	Flap/Spoiler Deflection Angle
κ	Engine Throttle Setting
λ	Longitude
μ	Bank Angle • Mean Value
θ	Temperature
ρ	Density
σ	Standard Deviation
ω	Frequency
ζ	Damping
Λ	Wing Aspect Ratio
Φ	Probability Distribution Function

English Symbols

a	Speed of Sound • Semi-Major Axis of the Earth Ellipsoid
b	Semi-Minor Axis of the Earth Ellipsoid
c	Constant
d	Distance
e	Oswald Span Efficiency Factor
f	Flattening
g	Gravitational Constant
h	Altitude
k	Gain
m	Mass
p	Probability Density
q	Dynamic Pressure
r	Radius
t	Time
x	x-Position
y	y-Position
w	Wind
D	Drag
D	Variance
E	Expectation
F	Force

G Gear
L Lift
M Mach Number
P Probability
R Specific Ideal Gas Constant
Re Reynolds Number
S Gross Wing Area • Spoiler
T Thrust
V Velocity
W Wind

Sub-Scripts

a Aerodynamic
b Break
c Coefficient
d Desired
f Fuel • Flap
m Multiplier
p Pressure
s Spoiler
t True

CAS Calibrated Airspeed
CF Centrifugal
D Drag
I Inertial
L Lift
MAX Maximum
MIN Minimum
R Radar
SA Standard Atmosphere
SL Sea-Level
T Thrust

Mathematical Notations

$|x|$ Absolute Value of x
$\approx$ Approximately Equal to
Δ Difference
! Factorial
$\int$ Integral
$\wedge$ Logical AND
$\vee$ Logical OR
$\prod$ Product
∂ Partial Derivative

$\sum$	Summation
$\dot{x}$	Time Derivative of x
÷	to
$\bar{x}$	Vector of x
$x\|_i$	x at Point i

Basic Units

[h]	Hour
[min]	Minute
[s]	Second
[ft]	Feet
[in]	Inch
[m]	Meter
[nm]	Nautical Mile
[kn]	Knot $\hat{=}$ [nm/h]
[°]	Degree
[rad]	Radian
[kg]	Kilogram
[lb]	Pound
[K]	Kelvin
[J]	Joule
[ppm]	Part per Million
[-]	No Unit

List of Figures

Chapter 1 Introduction

Chapter 2 Air Traffic Management System – Present and Future

Chapter 3 Analysis of Related Work

Chapter 4 Air Traffic Management Components Modeling

Chapter 5 Design of a Simulation Architecture

Chapter 6 Computer Implementation Tools

Chapter 7 Numerical Solution Methodologies

Chapter 8 Simulation Model Output and Error Analysis

-

Chapter 9 Numerical Results

Chapter 10 Conclusions

-

Appendix A Earth Modeling and Navigational Equations

Appendix B Aircraft Performance Data

Appendix C

-

Appendix D Additional Data

List of Tables

Chapter 1 Introduction

-

Chapter 2 Air Traffic Management System – Present and Future

Chapter 3 Analysis of Related Work

Chapter 4 Air Traffic Management Components Modeling

Chapter 5 Design of a Simulation Architecture

-

Chapter 6 Computer Implementation Tools

-

Chapter 7 Numerical Solution Methodologies

-

Chapter 8 Simulation Model Output and Error Analysis

-

Chapter 9 Numerical Results

Chapter 10 Conclusions

-

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-

Appendix B Aircraft Performance Data

Appendix C Feedback Linearization

-

Appendix D Additional Data