

MODELING OF AIRPORT OPERATIONS USING AN OBJECT-ORIENTED
APPROACH

by
Caoyuan Zhong

A dissertation submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

IN

CIVIL ENGINEERING

APPROVED:

Dr. Antonio A. Trani, Chairman

Dr. Donald R. Drew

Dr. Richard D. Walker

Dr. R. Sivanandan

Dr. Keying Ye

February 4, 1997
Blacksburg, Virginia

Keywords: Airport, Simulation, Object-Oriented Modeling, Java

MODELING OF AIRPORT OPERATIONS USING AN OBJECT-ORIENTED APPROACH

by

Caoyuan Zhong

Dissertation Director

Dr. Antonio A. Trani

(ABSTRACT)

This research develops an object-oriented approach to model airport ground network traffic operations. A generic modeling library is developed as a tool kit to model the basic traffic operations in the airfield using an object-oriented approach. The proposed generic modeling library for airfield operations is a collection of predefined abstract components implemented in the Java object-oriented programming language. Classes are defined and used as the basic components in a variety of airfield operation modeling, simulations, and optimizations.

The generic airport modeling framework consists of a set the components that are necessary for modeling the basic activities of airfield traffic operations. By using the multi-threading techniques, components are integrated into the proposed modeling framework. Unlike traditional sequential simulation model, this framework organizes simulation activities into four major groups which are: flight schedule, aircraft movement, time, and animation. Instead of using built-in control logic, the framework adapts an open system policy which gives the flexibility to the end users to incorporate the user-preferred control logic into the end models. Another purpose in this research is to provide a future mechanism to study airfield ground traffic automated control systems with Just-In-Time forecasting and model system performance in a real-time ATC environment. The proposed generic library could be implemented into a Internet/intranet ready application which can query real time information and

provide real time advice to pilots and air traffic controllers. This study is one of a few current research projects that are of using multiple threading technique to study traffic operation problems.

The proposed generic library is originally implemented with C++ and, in the final stage, with Java, a truly cross-platform object-oriented language. Application written in Java can run on most of the mainstream computer operating systems without modifications. Although the proposed library is for airfield traffic control system, it could also be extended into air traffic control system as well as advanced transportation system.

ACKNOWLEDGMENTS

I would like to express my sincerest thanks to Dr. Antonio A. Trani, who serves as the chairman of my dissertation committee, for his guidance and continuing support of my graduate study. Without his thoughtful advice and encouragement, this experimental research would have not been finished.

My thanks go to Dr. Donald R. Drew for his invaluable supporting me to start my graduate study at Virginia Tech. I benefit greatly from his philosophy of system dynamics.

I would like to thank Dr. Richard D. Walker for serving as my dissertation committee member and his technical advice. I enjoyed working as a teaching assistant for him.

I would like to thank Dr. R. Sivanandan for serving as my dissertation committee member and his technical advice. I enjoyed working as a teaching assistant for him.

I would like to thank Dr. Keying Ye for serving as my dissertation committee member and his advice in this research.

I gratefully acknowledge the support of a previous research by FAA through a research fund. This research is based on the valuable results of the previous research.

I am deeply indebted to my parents, to my whole family, and specially, to my wife, Yin Fu, for their encouragement and dedicated support.

Table of Contents

Preface	ii
Acknowledgments	iv
Chapter 1 Introduction	
1.1 Background of the Problem	1
1.2 Objective and Scope of This Study	4
Chapter 2 Evaluation of System Modeling Technologies	
2.1 System Modeling Technologies	6
2.2 New Requirements of System Integration	7
2.3 Object Oriented Programming(OOP) and Modeling (OOM)	7
2.4 Characteristics of Object Oriented Programming	27
2.5 Comparison of Traditional Modeling Paradigm and Object-Oriented Paradigm	30
2.6 Current Applications of Object-Oriented Method in System Modeling	30
2.7 Current Airport Systems Simulation Tools	33
2.8 A General Framework for Airport Operation Modeling	34
Chapter 3 Designing A Task Engine to Simulate Airfield Operations	
3.1 Description of Airport Operation System Dynamics	35
3.2 Task Driven Simulation Engine	37
3.3 Queuing with Priority	38
3.4 Interleaved Interpretation of Concurrency	38
3.5 Basic Structure of the Task Class	41
3.5.1 Identifier data	41
3.5.2 Supplemental Data	44

3.6 Structure of Simulation Clock Class	45
3.7 Communications between the Task Queue and Global Clock	46
3.8 General Task Handling Mechanism	48
3.9 Task Analysis of Airfield Traffic Operations	49
3.9.1 Basic Airplane Related Tasks	50
3.9.2 Basic Traffic Network Related Tasks	51
3.9.3 Traffic Control Related Tasks	52
 Chapter 4 Basic Airfield Traffic System Components	
4.1 Airplane List Class	54
4.2 Airplane Class	58
4.2.1 Description of Airplane States during the Simulation	58
4.2.2 Airplane States	61
4.2.3 Structure of Airplane Class	62
4.3 Airport Ground Network Class	65
4.4 Shortest Path Class	69
4.5 Connecting Task Engine with Other Basic Components	72
 Chapter 5 Simple Applications of Airfield Traffic System Simulation Framework	
5.1 Overview of the Simulation Framework	77
5.2 Initialization of the Airfield Ground Network	80
5.3 Initialization of Flight Schedule	81
5.4 Running the Multi-Threaded Simulation	84
5.5 Implementation of the Airport Ground Network Control Logic	85
5.6 Analyzing the Air Field Traffic Flows of the Given Configuration with Different Control Strategies	86

Chapter 6	Conclusions and Recommendations	96
	References	98
	Appendix A	104
	Vita	146

List of Figures

Figure 2.1 Coad/Yourdon object-oriented analysis (reproduced from Carmichael,1995).	11
Figure 2.2 Booch class diagram (reproduced from Carmichael,1995).	12
Figure 2.3 Three data views (a)Martin/Odell; (b)Rumbaugh; (c)Shlare/Mellon (reproduced from Camichael,1995).	13
Figure 2.4 Jacobon's data view (reproduced from Carmichael, 1995).	14
Figure 2.5 Shlare-Mellor State Transition Diagram (reproduced from Carmichael,1995).	16
Figure 2.6 Martin/Odell's object flow diagram (reproduced from Carmichael, 1995).	18
Figure 2.7 Wirfs-Brock collaboration graph (reporduced from Carmichael, 1995).	20
Figure 2.8 Hierarchical Modeling Concepts Presented by Luna (1990), reporduced from AbouRizk(1194)	31
Figure 3.1 Multitask event (tasks) handling channel.	39
Figure 3.2 Illustration of interleaved concurrent process.	40
Figure 3.3 The message flow of the global simulation clock.	42
Figure 4.1 Message flow of airplane list class.	55
Figure 4.2 A linked list structure of the airplane list.	56
Figure 4.3 State model for a landing airplane	59
Figure 4.4 Message flow of airplane class.	63
Figure 4.5 Data structure of airplane class.	64
Figure 4.6 Message flow of airfield network class.	67
Figure 4.7 Message flow of shortest path processor.	70
Figure 4.8 Message Flow of Airfield Simulation Framework	76
Figure 5.1 Interface of airport ground monitor	78
Figure 5.2 Airport ground network scenario.	83
Figure 5.3 Average travel time for arriving aircraft.	90
Figure 5.4 Average travel time for departing aircraft.	91

Figure 5.5 Average travel time in the network.	92
Figure 5.6 Average arrival delay.	93
Figure 5.7 Average departure delay.	94

List of Tables

Table 2.1 Contrasting Traditional and Object-Oriented Paradigms for Simulation Modeling, (reproduced from [Mize, 1992]).	32
Table 5.1 Exits for Runway 16 R	88
Table 5.2 Traffic Paths in the Airfield Network	89