
Contents

Introduction	ix
Chapter 1. The Context of Air Traffic Management	1
1.1. Introduction	1
1.2. Vocabulary and units	2
1.3. Missions and actors of the air traffic management system	3
1.4. Visual flight rules and instrumental flight rules	4
1.5. Airspace classes	4
1.6. Airspace organization and management	5
1.6.1. Flight information regions and functional airspace blocks	5
1.6.2. Lower and upper airspace	6
1.6.3. Controlled airspace: en route, approach or airport control	7
1.6.4. Air route network and airspace sectoring	7
1.7. Traffic separation	9
1.7.1. Separation standard, loss of separation	9
1.7.2. Conflict detection and resolution	11
1.7.3. The distribution of tasks among controllers	12
1.7.4. The controller tools	12
1.8. Traffic regulation	13
1.8.1. Capacity and demand	13
1.8.2. Workload and air traffic control complexity	15
1.9. Airspace management in en route air traffic control centers	16
1.9.1. Operating air traffic control sectors in real time	16
1.9.2. Anticipating sector openings (France and Europe)	17
1.10. Air traffic flow management	19
1.11. Research in air traffic management	20
1.11.1. The international context	20
1.11.2. Research topics	21

Chapter 2. Air Route Optimization	23
2.1. Introduction	23
2.2. 2D-route network	24
2.2.1. Optimal positioning of nodes and edges using geometric algorithms	24
2.2.2. Node positioning, with fixed topology, using a simulated annealing or a particle swarm optimization algorithm	28
2.2.3. Defining 2D-corridors with a clustering method and a genetic algorithm	29
2.3. A network of separate 3D-tubes for the main traffic flows	31
2.3.1. A simplified 3D-trajectory model	31
2.3.2. Problem formulations and possible strategies	34
2.3.3. An A* algorithm for the “1 <i>versus</i> n” problem	35
2.3.4. A hybrid evolutionary algorithm for the global problem	41
2.3.5. Results on a toy problem, with the simplified 3D-trajectory model	50
2.3.6. Application to real data, using a more realistic 3D-tube model	57
2.4. Conclusion on air route optimization	66
Chapter 3. Airspace Management	69
3.1. Airspace sector design	70
3.2. Functional airspace block definition	71
3.2.1. Simulated annealing algorithm	73
3.2.2. Ant colony algorithm	73
3.2.3. A fusion–fission method	73
3.2.4. Comparison of fusion–fission and classical graph partitioning methods	74
3.3. Prediction of air traffic control sector openings	74
3.3.1. Problem difficulty and possible approaches	78
3.3.2. Using a genetic algorithm	78
3.3.3. Tree-search methods, constraint programming	79
3.3.4. A neural network for workload prediction	80
3.3.5. Conclusion on the prediction of sector openings	83
Chapter 4. Departure Slot Allocation	85
4.1. Introduction	85
4.2. Context and related works	86
4.2.1. Ground holding	86
4.3. Conflict-free slot allocation	87
4.3.1. Conflict detection	88
4.3.2. Sliding forecast time window	90
4.3.3. Evolutionary algorithm	91

4.4. Results	95
4.4.1. Evolution of the problem size	95
4.4.2. Numerical results	96
4.5. Concluding remarks	98
Chapter 5. Airport Traffic Management	101
5.1. Introduction	101
5.1.1. Airports' main challenges	101
5.1.2. Known difficulties	102
5.1.3. Optimization problems in airport traffic management	103
5.2. Gate assignment	103
5.2.1. Problem description	103
5.2.2. Resolution methods	104
5.3. Runway scheduling	106
5.3.1. Problem description	106
5.3.2. An example of problem formulation	108
5.3.3. Resolution methods	109
5.4. Surface routing	111
5.4.1. Problem description	111
5.4.2. Related work	112
5.5. Global airport traffic optimization	115
5.5.1. Problem description	115
5.5.2. Coordination scheme between the different predictive systems	116
5.5.3. Simulation results	117
5.6. Conclusion	121
Chapter 6. Conflict Detection and Resolution	123
6.1. Introduction	123
6.2. Conflict resolution complexity	125
6.3. Free-flight approaches	128
6.3.1. Reactive techniques	129
6.3.2. Iterative approach	129
6.3.3. An example of reactive approach: neural network trained by evolutionary algorithms	130
6.3.4. A limit to autonomous approaches: the speed constraint	137
6.4. Iterative approaches	138
6.5. Global approaches	138
6.6. A global approach using evolutionary computation	140
6.6.1. Maneuver modeling	140
6.6.2. Uncertainty modeling	141
6.6.3. Real-time management	142
6.6.4. Evolutionary algorithm implementation	144
6.6.5. Alternative modeling	151

6.6.6. One-day traffic statistics	152
6.6.7. Introducing automation in the existing system	153
6.7. A global approach using ant colony optimization	155
6.7.1. Problem modeling	155
6.7.2. Algorithm description	156
6.7.3. Algorithm improvement: constraint relaxation	159
6.7.4. Results	160
6.7.5. Conclusion and further work	160
6.8. A new framework for comparing approaches	163
6.8.1. Introduction	163
6.8.2. Trajectory prediction model	163
6.8.3. Conflict detection	168
6.8.4. Benchmark generation	169
6.8.5. Conflict resolution	170
6.9. Conclusion	177
Conclusion	179
Bibliography	181
Index	193