

ICRAT 2010

Fourth International Conference on Research in Air Transportation

June 2010
Budapest, Hungary



Fourth International Conference on Research in Air Transportation

Abstract Proceedings



**1st – 4th June 2010
Budapest, Hungary**

PREFACE

Welcome to the Fourth International Conference on Research in Air Transportation!

On the behalf of the ICRAT 2010 Steering Committee, we would like to express here our deep gratitude to the senior and young researchers in Air Transportation for having contributed to this young but challenging and exciting conference.

For this fourth edition of ICRAT, there were 94 qualified submissions by authors from 22 countries. The referee process resulted in 63 acceptances, for an acceptance rate of about 67%. All selected papers are of good quality, and we are very proud of the professionalism of all authors, reviewers, and of all Program Committee members. Thank you so much for your contributions and collaborations.

This is also the third time that Tutorials and a Doctoral Symposium have been included in the conference program. Three tutorials are scheduled for ICRAT 2010. There will be a full day tutorial on *Airborne Self Separation in Air Transportation*, with presentation by 10 of the leading researchers from Europe and the United States and half day tutorials on *Validation of ATM Operational Concepts* and on *Challenges Regarding the Integration of Unmanned Aircraft into Civil Airspace*. We are confident that they will increase the young scientists' understanding of "how things work" in air transportation. The Doctoral Symposium is expected to create a forum for young researchers to discuss their research approaches with senior researchers to obtain guidelines and support.

The opening session will have invited keynote speakers from the SESAR Joint Undertaking, from FAA, and from the Budapest University of Technology and Economics - all senior research scientists or strategists in Air Transportation. There will be two special keynote talks by senior air traffic controllers from Europe and the U.S. – both of whom have had extensive, close association with air transport research. We are very grateful for the presence, contributions, and support of these keynote speakers.

ICRAT 2010 and the proceedings you are handling are the result of much hard work from many people. We would like to thank:

- The authors and co-authors of the paper submissions. They are, of course, what makes the conference program great.
- The invisible tertiary reviewers, who often supply the most expert and informed comments on their review, and the ICRAT 2010 Program Committee. The 40 members on the committee spent most of their free time during the referee process to review the submitted papers and to return with careful comments. They are the guardians of the quality of the conference.
- The chairs of the committees: Dres Zellweger (General chair), Vu Duong and David Lovell (Program Chairs); John-Paul Clarke (Tutorial Chair); Mark Hansen (Doctoral Symposium Chair); and Sabrina Saunders-Hodge and Colin Meckiff (Grants & Awards Chairs).
- The logistics team led by Daniel Rohacs at Budapest University of Technology and Economics, and the conference secretariat team led by Yanjun Wang and Frizo Vormer of EUROCONTROL who worked hard to ensure the on-line processes with the authors, to collect, compile, and edit the final camera-ready proceedings.

- Telecom-ParisTech with the support to host the website, as well as for the time of Pr. Patrick Bellot and Loic Baud, who have worked pro-actively on the development and maintenance of the conference website.
- Daniel Rohacs and his local organizing committee members and volunteers, for all local arrangements, the printing of the proceedings on USB, and all the logistics at the conference place.
- The various institutions that provided the support for the paper process. The list includes the employers of all authors and co-authors and the employers of all reviewers and committee members.
- Eurocontrol, FAA, NASA, and JPDO for their financial support – which was instrumental in providing stipends for many of the ICRAT 2010 speakers.

Thank you all again, authors and reviewers, for your contribution to ICRAT 2010, that will surely be exciting. Thanks once more to the conference secretaries, Yanjun Wang and Frizo Vormer, and the principal local organizer Daniel Rohacs. The success of this conference will be yours!

Andres Zellweger and Jozsef Rohacs, *General Chairs*
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Track 1

Advanced Modeling

Data Driven Modeling for the Simulation of Converging Runway Operations

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Abstract—A novel methodology is presented for generating data driven models for the general application of modeling and simulation. This approach relies on the use of principal component analysis to decompose a given data set into a basis of linearly uncorrelated modes. Data-driven models are then constructed from radar track data in order to develop models for a Monte Carlo simulation to evaluate the collision risk of converging runway operations.

Keywords - data driven models, converging runway operations, principal component analysis, modeling and simulation

Tracking Failures in the Air Traffic System: An Ontology Based on Physical and Functional Decompositions

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Abstract—This paper presents an ontology for the air traffic system that aims at tracking failures and at measuring their impact on air traffic operations. This model is based on physical and functional decompositions of the air traffic system, which splits into facilities, aircraft, technologies, human operators, communication media, functions, tasks and operations. Possible failures are introduced at different levels of the decomposition and their consequences can be easily analyzed thanks to links between the blocks of the model. Two case studies illustrate how this model allows to anticipate the failures propagation and to find alternative solutions. A prototype implementation using MATLAB/Simulink is presented and illustrates the propagation of a secondary surveillance radar failure.

Game Equilibrium Analysis on an Auctioning Method for Single Airport Congesting Resource Allocation

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Abstract—Flight delays cause lots of additional operational costs of airlines. Because airspace capacity is a scarce resource and airlines are self-interested, how to optimize the capacity allocation and avoid “the tragedy of the commons” is a hard problem for the Air Traffic Management authority. Through defining the marginal cost function and the opportunity cost function about the airlines, we introduce the first-

price-sealed bid theory to realize the scarce capacity allocation of congesting airport to the airlines which want them. Under the ATM authority's resource allocation policy, the airline will develop a set of scenarios to minimize the potential disruption to its schedule and implement the one that is most cost-effective through a competitive bidding process with other airlines. Finally, the Air Traffic Management authority could get the optimized global allocation result of airspace resources under the equilibrium condition.

Keywords- air traffic management; ground delay program; first pricing sealed auction; traffic congestion

Fair Slot Allocation of Airspace Resources Based on Dual Values for Slots

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Abstract—Fair allocation of available resources among airlines is very challenging when there is a reduction in en-route resources. Each airline will typically place a different relative weight on delays, rerouting and cancellation. Whereas some airlines would like to preserve the on-time performance for certain flights and cancel or reroute many other flights, other airlines prefer to have less rerouting and cancellations while tolerating higher total delay. The value (or cost of delay) an airline associates with a particular flight may vary substantially from flight to flight. Airlines who wish to receive priority for certain flights usually are willing to pay more for specific time slots. To accommodate richer carrier preferences so that airlines can express the relative importance of delays, rerouting and cancellations, new concepts of slot values and dual pricing are introduced in this research. Unlike Ration By Schedule (RBS), the current algorithm in use for rationing airspace resources, that gives priority based on scheduled flight arrival times, our new allocation method provides flexibility to carriers to achieve their goals. Specifically, it also allows carriers to receive “premium” slots for an extra “charge”. In this paper, we describe a new rationing and randomized allocation method. We analyze the performance of the new method and compare it with RBS based on data derived from a real application. Our method has potential usefulness both in Airspace Flow Program (AFP) planning and in the emerging System Enhancements for Versatile Electronic Negotiation (SEVEN).

Keywords-resource rationing; flow management; fairness; equitable allocation; AFP; Dual Price

Modeling and Predicting Taxi out Times

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Abstract — This paper proposes a set of regression equations to model the taxi-out and taxi-in times at airports. The estimated results can be used to calculate the nominal taxi times, which are essential

measures for evaluating the taxiing delays at airports. Given the outcomes of the regression model, an iterative algorithm is developed to predict taxi times with inputs such as gate out times, landing times, and runway capacities. A case study at LGA shows that the proposed algorithm demonstrates a higher accuracy in comparison to other algorithms in existing literature.

Keywords-taxi time delay; nominal taxi times; predicting taxiout time; iterative algorithm.

A TMA 4DT CD/CR Causal Model Based in Path Shortening/Path Stretching Techniques

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Abstract— In the present paper a discrete event model for Conflict Detection and Conflict Resolution algorithm in a TMA 4D trajectory scenario is presented which focuses mainly on the arrival phase. This arises from the overcrowding of airspace near large airports and the need to more efficiently land and take off larger numbers of aircraft. Some attempts to alleviate airspace congestion such as the reduced vertical separation minima, negotiation of voluntary reductions in scheduled service, and the construction of additional runways at major airports, have been done, however, there is still a pending matter to be solved regarding how to improve available airspace capacity avoiding non efficient procedures such as the use of holding trajectories. A deep knowledge about all the events that take place in the management of 4DT and their interactions in a TMA is essential to remove non-effective operations, to avoid delay propagation between arrivals and optimize the occupancy of the runway. The causal model developed considers different alternative predefined turning points for each flight evaluating path shortening/path stretching of all trajectories upwards the merging point in a TMA.

Keywords-component; ATM, trajectories, DSS, CPNs, Conflict Detection, Conflict Resolution.

Impact of Lightning Strikes on National Airspace System (NAS) Outages - A Statistical Approach

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Abstract— Although it is reasonably well accepted that lightning strikes are a significant cause of outages on the National Airspace System (NAS), there remains a serious lack of comprehensive analyses providing sound estimates of outages caused by convective weather. Current estimates and methods generally cover specific outages and try to determine their causes by comprehensively analyzing the lightning strikes that occurred in the vicinity of the system. Such methods are inadequate when trying to evaluate the global impact of convective weather on very large systems such as the NAS, which is

composed of more than 70,000 systems. In this paper, a statistical method is developed to estimate the number of outages caused by lightning strikes, which take into account both the time detection of the outage and the localization of the strikes. In addition, we present results of its application on the NAS outages between 1999 and 2005.

Index Terms - component; lightning strikes; outages; NAS; NLDN; logit model

Ontology and Rules for International Airspace Security

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Abstract- The air transportation system will modernize over the next 15 years. As part of that modernization, tasks that are done manually today will be performed by automated computer functions. In the airspace security domain, automated functions need to be dynamic and able to adapt to the latest intelligence reports. These automated functions can be expressed as “if-then rules.” In order to gain a better understanding of the level of effort involved in creating rules for airspace security, we chose four specific restricted airspaces we felt represented the cadre used to manage security issues and developed the set of terms and relationships needed to define them. This paper outlines the process we took to develop these terms and lists some examples. This paper also presents some sample rules and potential challenges faced in using rules in airspace security. Finally, this paper recommends that in order to obtain a near-term benefit from rules, the airspace security community should consider generalized definitions and broad scopes when developing rules. The potential application and definition of rules is being developed and will be further validated through experimentation in a simulated environment over the next several months.

Keywords: airspace, aviation, security, ontology

Queueing Models for Operations in NextGen

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Abstract—This paper develops a queueing model for trajectorybased aircraft operations, a cornerstone of the Next Generation Air Transportation System. Aircraft are assigned scheduled times of arrival at a server, which they meet with some normally distributed stochastic error. A recursive queueing model with deterministic service times is formulated, and Clark's approximation method is employed to estimate each flight's expected queueing delay. The model is further developed to account for aircraft's runway occupancy time, and to track aircraft's delay through a series of servers.

Keywords-queue; aircraft; NextGen; 4D operations

Applying Economy-wide Modeling to NextGen Benefits Analysis

Katherine Harback, Leonard Wojcik, Jr, Michael B. Callaham,
Shane Martin, Simon Tsao, and Jon Drexler

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Abstract—This paper applies an economy-wide modeling framework, computable general equilibrium, to trace how the Next Generation Air Transportation System (NextGen) could impact non-aviation industries. The specific model used is an adaptation of Monash University’s U.S. Applied General Equilibrium model known as USAGE-Air. Modeling results presented here are based on a simple notional representation of NextGen costs and benefits.

Keywords- economics, investment, NextGen, computable general equilibrium, CGE

Optimal Route Generation with Geometric Recourse Model under Weather Uncertainty

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Abstract— There has been growing interest in air transportation community to develop a routing decision model based on probabilistic severe weather. In the probabilistic air traffic management (PATM), decisions are made based on the stochastic weather information in the expected total cost sense. In this paper, we propose a geometric model to generate optimal route choice to hedge against weather risk. The geometric recourse model (GRM) is a strategic PATM model that incorporates route hedging and en-route recourse to respond to weather change. Hedged routes are routes other than nominal or detour route, and aircraft is re-routed to fly direct to the destination, or recourse, when the weather restricted airspace become flyable. Aircraft takes either the first recourse or the second recourse. The first recourse occurs when weather clears before aircraft reaches it when flying on the initial route. The second recourse occurs when the aircraft is at the weather region. There are two variations of GRM: Single Recourse Model (SRM) with first recourse only and Dual Recourse Model (DRM) with both the first and second recourse. When the weather clearance time follows a uniform distribution, SRM becomes convex with optimal solution is either at the upper bound or interior. Convexity gives optimality conditions in a closed form and analytic interior solution is approximated with marginal error. We prove that DRM has an important property such that when the maximum storm duration time is less than the flight time to the tip of the storm on detour route, it is always optimal to take the nominal route. Numerical study shows a substantial cost saving from using geometric recourse model, especially with DRM. It also indicates the need to consider ground holding in combination of route hedging.

Keywords-ATM; PATM; stochastic optimization; geometric model; risk hedging; severe weather event

A Diffusion Approximation to a Single Airport Queue

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Abstract—This paper illustrates a continuum approximation to queuing problems at a single airport adapted from the wellknown diffusion approximation, as encapsulated in the Kolmogorov forward equation of stochastic processes or the Fokker-Planck equation of physics. The continuum model is derived using special artifacts of the airport problem context. The appropriate initial and boundary conditions are defined and a numerical solution scheme based on the finite element method is presented.

Keywords-*queuing theory; diffusion; delay; aviation system performance; Kolmogorov forward equation, Fokker-Planck equation; finite element method*

Track 2

Airline Operations and Marketing

The Responses of Traditional Airlines to Low Cost Airlines

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Abstract — The significant growth in low-cost carriers has generated a lot of competition in the airline industry. Traditional airlines have come under pressure with a collapse in profitability while many low-cost carriers have enjoyed profits. The low cost airline business model can cut costs to 40-50% of traditional airline costs while the traditional airline business model has been challenged to cover costs. Major airlines have attempted to reshape their business model to boost revenue, cut costs and react to competitive threats from low-cost carrier. These strategies include establishing their own low cost airlines, increasing labour efficiency, intimate low cost airline operation, and introducing charges for catering and luggage. This paper aims to investigate the responses of traditional airlines to low-cost carriers. Secondary sources of information for this paper will include a review of current academic literature and published industry sources.

Keywords- low-cost carriers; airline; competition

Estimating Domestic U.S. Airline Cost of Delay based on European Model

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Abstract— Researchers are applying more holistic approaches to the feedback control of the air transportation system [12- 13]. Many of these approaches rely on economic feedback, including the cost of delays to the airlines. Therefore, finding the true cost of a delay is essential for air transportation management. A 2004 EuroControl study [2] describes a methodology and presents results detailing the cost to airlines of delays during various segments of a trip. The costs are divided into short delays (less than 15 minute) and long delays (greater than 65). The data used in the study consisted of data collected from European airlines, air traffic management as well as interviews and surveys conducted by the research team. However, their model is not explicitly defined and therefore no sensitivity analysis is possible in case the involved cost factors change significantly (e.g. fuel). Furthermore, the model is generated based on data from EU airlines for only 12 aircraft, so applying these delay costs to other aircraft or US airlines is not possible. This paper details a method for applying these delay costs to other aircraft and other airlines. The individual cost factor delays are applied to US data. The approach allows one to update the cost whenever any of the factors (crew, fuel, maintenance, and ground costs) change. It considers the size of the aircraft when making such calculations, both from the perspective of fuel burn and passenger costs. Data for Philadelphia airport (PHL) is displayed as a case study to show current delay costs.

Keywords-component; airline delay costs; airline delays; economic modeling of airlines;

Track 3

Airport Design and Operations

Airport Ground Access and Egress Passenger Flow Model (AGAP)

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Abstract— The problems of airport landside capacity assessment are of industry-wide interest. Evaluation of landside capacity enables airport operators and airport designers to identify passenger and baggage flow bottlenecks, identify the primary cause of bottlenecks formation and take measures mitigating the impact of bottlenecks on the airport terminal operation. Many studies dealing with the problems of airport landside capacity are focused mainly on the processing part of the airport terminal and consider the airport terminal to be an isolated system. Even the most of models of airport landside operations developed using either generic or dedicated simulation software packages (e.g. PaxSim, SLAM, WITNESS, ARENA or EXTEND) are designed for simulating the passenger and baggage flows only between curb-side and apron. Although this approach provides valuable data concerning capacity, delays or processing bottlenecks, in some cases identified capacity constraints are only the symptoms of the actual problem. In order to discover the cause of the problem, it is necessary to consider the airport terminal as an integral part of much more complex regional, national or international transportation system. This article reflects the above mentioned requirements and introduces an innovative approach to passenger and baggage flow simulation based on the fact that airport terminal is considered as an integral part of air passenger door-to-door transportation process.

Keywords-airport ground access; fast-time simulations; airport capacity enhancement; door-to-door transportation process.

Operational Evaluation of an Airport Centered Flow Management

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Abstract — As hub airports become larger and larger, it is vital that available runway capacity is used optimally to prevent them turning into air traffic bottlenecks. This paper presents the Cooperative Local Resource Planner (CLOU), which has been developed as a prototype to assist in “airport-centered flow management”. An overview of the first steps to be taken to guarantee a smooth operational implementation is also given. Different runway-use strategies will be discussed, using the German Frankfurt Airport as an example. Furthermore, the display of the planning results of CLOU and the integration into the air traffic controller work area are addressed. Finally, embedding of CLOU into existing system environment is presented.

Keywords: Air Traffic Flow Management, Network and Strategic Traffic Flow Optimization, CLOU

Door-to-Gate Air Passenger Flow Model

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Abstract—Ever growing traffic in air transport with associated capacity constraints brings problems to air passenger flows at airports. In efforts for improvement new original future airport concepts are thought out. For the purpose of evaluation of future airport concepts the passenger flow model is developed. The model consists of two sub-models: Airport Ground Access Passenger Flow Model (AGAP) and Airport Terminal Passenger Flow Model (PaxMod). AGAP is based on random generation of passenger flows from the catchment area to Airport Bratislava using statistical data. PaxMod is based on linked cumulative diagrams representing airport queuing systems and simulates passenger flows through the airport terminal facilities. Both models are interconnected and are used to evaluate Airside- Landside Separation concept (ASLS) by simulating two scenarios. First scenario is baseline scenario where classic air passenger transport is simulated. Second scenario simulates passenger flows in Airside-Landside Separated airports and the result of simulation is compared to the baseline scenario. Simulations showed that for most passengers the door-to-gate transit time in ASLS scenario is higher than in classic scenario.

Keywords—Passenger Flow Model, Airport Terminal, Airport Access, Queuing, Cumulative Diagrams, Travel Time, Airport Catchment Area, Air Passenger

The Airport Ground Movement Problem: Past and Current Research and Future Directions

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Abstract—Determining efficient airport operations is an important and critical problem for airports, airlines, passengers and other stakeholders. Moreover, it is likely to become even more so given the traffic increases which are expected over the next few years. The ground movement problem forms the link between other airside problems, such as arrival sequencing, departure sequencing and gate/stand allocation. This paper provides an overview, categorisation and critical examination of the previous research for ground movement and highlights various important open areas of research. Of particular importance is the question of the integration of various airport operations and their relationships which are considered in this paper.

Index Terms—Airside airport operations, ground movement, taxiing, survey, future work, integration of airport operations.

Modeling of Aircraft Surface Traffic Flow at Congested Airport Using Cellular Automata

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Abstract— To manage the recent growth of air transportation, effective air traffic control and a 4-dimensional trajectory control concept have been already developed. However, most studies consider the flight phase only, which makes the airport surface congestion a bottleneck. The control of the airplane during the ground phase is almost entirely in the hands of the pilot and its uncertainty makes the simulation of airport traffic difficult. In addition, a congestion is a complicated phenomenon, not investigated in detail yet. This paper proposes a new airport surface simulation method considering a congestion phenomenon based on cellular automata. The floor field model is applied, and an aircraft speed decision process involving long-range interaction is developed. The effectiveness of this method is verified by comparing the results obtained with actual airport surface traffic data.

Keywords-component; airport surface; cellular automata; airport simulation; NS model

Iterative Planning of Airport Ground Movements

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Abstract—Optimization of ground traffic is a major issue of air traffic management: optimal ground circulation could decrease flight delays and consequently decrease costs and increase passenger wellness. This paper proposes a planning algorithm for ground traffic based on contract reservation. This algorithm is iterative: it plans aircraft itinerary one after the other. A first version is described using the classical A* algorithm. Then the model is extended to deal with time and speed uncertainty to ensure the feasibility of the planned trajectories while avoiding conflicts between aircrafts. Its efficiency is evaluated on Toulouse-Blagnac airport, regarding quality of the solution and computation times.

Potential of Dynamic Aircraft to Runway Allocation for Parallel Runways

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Abstract – A flexible and demand-driven utilisation of available runway infrastructure plays an important role to meet aviation's future targets regarding capacity, efficiency and environmental sustainability. This paper presents and validates a heuristic algorithm to dynamically allocate arrival aircraft to one of two parallel runways. It considers both ATC regulations and modelled preferences of the airspace user and airport operator. It is designed to balance runway loads to reduce arrival and departure delays, taxi times, resulting fuel consumption and aircraft emissions. Particular focus is also

set on ATC controller workload to avoid negative effects on safety. The implemented algorithm was applied in a set of fast-time simulations for the new Berlin Brandenburg International Airport (BBI). It promises significant operational potential, especially but not exclusively for airports with independent parallel runways.

Keywords: Runway Allocation, Arrival Management, Airport Capacity, Efficiency, Environmental Sustainability.

Track 4
CNS/ATM

An Analysis of Delays in Air Transport in Japan

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Abstract—To cope with the increase in air traffic demand, improving ATM (air traffic management) performance is important. This paper describes an analysis of delays in air transport in Japan as part of ATM performance evaluations. The study examined arrival punctuality and departure punctuality at major Japanese airports. Punctuality is measured according to scheduled times. Characteristics of punctuality in Japan are compared to those in the United States and in Europe. Delay is studied in terms of conformity with flight-plans. It is assumed that high conformity is represented by a small average and distribution of delay. To study the conformity in each operational phase, an aircraft operation is divided into four distinct phases: predeparture, taxi-out, airborne and taxi-in. Delays are calculated for standard times and the averages and the standard deviation is studied for each phase. The division into operational phases revealed that pre-departure delay is the main driver of fluctuation in delay. We also examined ATFM (air traffic flow management) impact on pre-departure delay.

Index Terms—ATM Performance, delay, punctuality, air traffic flow management

Analysis of “Tarmac Delays” at Philadelphia Airport

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Abstract— Several incidents about passengers sitting on the runways have focused attention on Tarmac Delays. Several attempts have been done since 1990 to protect the rights of passengers. It was until December 2009 when, the Department of Transportation (DOT) approved the bill with regards to Tarmac Delays. The new regulation gives responsibilities to the airlines when passengers stay in the airplane for more than two hours. When this happens, airlines must provide food, water and lavatory service to passengers. After three hours, passengers should be allowed to return to the gate and de-plane. The right to deplane shall be waived if the pilot of such aircraft reasonably determines that the aircraft will depart or be unloaded at the terminal not later than 30 minutes after the 3 hour delay; or the pilot of such aircraft reasonably determines that permitting a passenger to deplane would jeopardize passenger safety or security. In order to investigate the occurrences of tarmac delays and effect in passengers, this paper describes the results of an analysis of “tarmac delays” at Philadelphia airport from 2005 to 2009: (a) the probability of a flight experiencing a tarmac delay of greater than 2 hours is 0.44%, (b) the average tarmac delay was 157 minutes per flight, (c) the number of tarmac delays has remained the same over the 5 year period, (d) June and July are the worst month for tarmac delays, (e) flights bound for Chicago O’Hare are the most likely to experience “tarmac delays,” (f) an estimate of the annual cost to the airlines as a result of tarmac delay regulations at PHL is \$17,000 per year or \$37 per flight.

Keywords: Tarmac delays, apron delays, lengthy aboard aircraft waiting times, ground delay, departure delays, on-board flight delays.

Trajectory Prediction by Functional Regression in Sobolev Space

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Abstract—In this paper we consider the problem of short to mid-term aircraft trajectory prediction. That problem aims to predict collisions between aircraft in airspace. Our approach is based on local functional regression which consists in the three following stages : data pre-processing, localizing and regression. This algorithm has been successfully applied on aircraft trajectories between Toulouse and Paris.

Index Terms—Trajectory prediction, wavelet, functional regression.

A New Method for Generating Optimal Conflict Free 4D Trajectory

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Abstract—The need for increasing air traffic capacity motivates 4D trajectory planning concept. In order to generate conflict free 4D trajectories, we introduce a new concept based on light propagation modeling algorithm. This algorithm is a wave front propagation method that yields a natural solution for the path planning problem specifically in the case of air traffic congestion. We conclude this paper with numerical experimentation of our approach on a simplified (2D + time) test problem.

Resource Allocation in Flow-Constrained Areas with Stochastic Termination Times and Deterministic Movement

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Abstract— In this paper we address a stochastic air traffic flow management problem. Our problem arises when airspace congestion is predicted, usually because of a weather disturbance, so that the number of flights passing through a volume of airspace (flow constrained area – FCA) must be reduced. We formulate an optimization model for the assignment of dispositions to flights whose preferred flight plans pass through an FCA. For each flight, the disposition can be either to depart as scheduled but via a secondary route, or to use the originally intended route but to depart with a controlled (adjusted) departure time and accompanying ground delay. We model the possibility that the capacity of the FCA increases at some future time once the weather activity clears. The model is a two-stage stochastic program that represents the time of this capacity windfall as a random variable, and determines expected costs given a second-stage decision, conditioning on that time. This paper extends our earlier work on this problem by allowing the FCA to move in a 2-D spatial plane with a constant speed rather than being stationary. The FCA can have any given constant speed and any given direction. We conduct experiments considering a range of such speeds and directions and draw conclusions regarding appropriate strategies.

Keywords: ATM; Air Traffic Managemnt; FCA; Flow Constraint Area; Rerouting; Stochastic Programming; Ground Delay; Airborne Delay.

The Air Traffic Flow Management Problem with Time Windows

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Abstract—This paper defines a set of temporal intervals, called time windows, which are defined prior to flight departure and constitute milestones to be met during the flight execution. The size of the time windows is variable as it reflects all known constraints, such as punctuality at destination, runway capacities or congested en-route areas that the flight will cross. Once a time window is defined, all the air traffic actors are committed to guarantee that flight operations, e.g. enter an airspace sector, depart from or arrive at an airport, are executed within the time window. We propose a two-step approach based on a mixed integer programming formulation. The first step determines a set of time windows such that the overall cost of delay is minimized. Then in the second step we choose the set of optimal time windows which also maximizes the overall time window size. In such a way, we provide to all air traffic stakeholders the largest degree of flexibility to perform their operations under the constraint that the minimum achievable delay is kept constant. We also gain information on the critical flights of the system:

if the optimal width of a time window is equal to its minimum available value, any disruption that may cause the flight not to meet it may produce undesired downstream effects. Our preliminary computational experience based on small-scale random instances confirms that the flexibility granted to flights increases with the capacity while the system delay simultaneously decreases. We also show that when there is no congestion a non negligible share of small size time windows may exist, thus indicating the existence of bottlenecks and critical flights.

Keywords - Air Traffic Flow and Capacity Management, Time Windows, Delay, ATFM, ATFCM

Flight Profile Variations due to the Spreading Practice of Cost Index Based Flight Planning

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Abstract—The current paper stresses the increasing relevance of the cost index (CI) based flight planning process of the Airspace Users for the Air Traffic Management (ATM) system. Based on data analysis performed together with Lufthansa Systems this paper quantifies the speed and vertical profiles in dependence on the chosen CI. Realistic CI scenarios are developed to gain a better knowledge of the ranges of flight profiles that have to be expected by the air traffic controllers. The paper shows that in cruise a range of up to Mach 0.09 for one aircraft type due to CI variations is realistic. This corresponds to about 10% speed variations. During climb and descent the range of speed can even be higher and reach values of 96 knots, corresponding to 30% speed variations. Also the vertical speed during climb and descent is influenced by the CI. Exemplary investigations of the descent profile indicate that the optimum position of the top of descent can differ up to almost 20NM in dependence on the CI. The paper gives a detailed overview about the achieved results and briefly discusses the implications to the ATM system.

Index Terms—Cost Index, Time Costs, Fuel Management, Business Trajectory, Delay Management, Air Traffic Management, ECON Speed.

Stochastic Integer Programming Models for Ground Delay Programs with Weather Uncertainty

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Abstract— Convective weather is a major contributor to air traffic delays. There is much uncertainty associated with weather predictions so stochastic models are necessary to effectively assign ground delay and route adjustments to flights. We describe a two-stage stochastic integer program for this problem. We then compare the results of this formulation to algorithms already in the literature.

Keywords: air traffic flow management, integer programming, stochastic programming

Enhanced Wind Magnitude and Bearing Prediction

Onboard algorithm

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Abstract—The article deals with the aircraft onboard wind prediction if there is no up-to-date accurate weather forecast available. The simple method for extrapolation of measured wind dynamics is presented. Also the algorithm for blending average wind trends with measured data is presented.

Keywords - wind prediction, RUC (Rapid Update Cycle) analysis, wind trends

Radar Cross Section Generation of the Possible Non-cooperative Targets

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Abstract—This paper defines non-cooperative targets and presents a calculation method of their radar cross section also in bistatic cases. First a three-dimensional model is given which is built up by triangular facets. From the available flight path the azimuth and elevation angles are determined to position the target model. Then simple shadowing algorithm is used in order to have short computational time and acceptable accurate. The calculation of radar cross section uses physical optics theory. The surface integral is numerically evaluated over the illuminated surface only. Radar cross section is calculated by summarizing the results of each triangle. This work is part of the EU FP6 SINBAD (Safety and security Improved by New functionality for Better Awareness on airport approach and departure Domain) project leading by THALES.

Keywords: Non-cooperative Target (NCT), TNB Frame, Triangular Facet, Shadowing, Physical Optics (PO), Radar Cross Section (RCS)

Study on Conflict Detection Method with Downlink Aircraft Parameters

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Abstract—In order to maintain the safety of air traffic, ENRI (Electronic Navigation Research Institute) tries to improve CA (Conflict Alert) functionality using airborne information via Mode S data-link. CA supports air traffic controller in their maintaining of safe separation between aircraft by predicting

aircraft positions and detecting potential conflicts. The aim of this study is to develop a new DAPs-CDM (Conflict Detection Method using Downlink Aircraft Parameters) and evaluate the impact of its introduction by computer simulation. Firstly, in order to understand the characteristics of the conventional CDM, we calculated horizontal and vertical prediction errors in aircraft position. The conventional CDM uses linear prediction with only radar information on the ground. We also analyzed CA occurrences on conventional CDM. We found that both horizontal and vertical prediction errors were reduced by using airborne information in addition to radar information. We also found that it was better to smooth vertical speed for prediction and to utilize selected altitude in DAPs-CDM. Finally, the characteristics of DAPs-CDM were studied and the advantages were demonstrated. The new function of DAPs-CDM is to predict aircraft positions using aircraft velocity on the airborne side and to determine aircraft flight phases using roll angle and selected altitude. For the purpose of comparing DAPs-CDM with the conventional CDM, ENRI developed CDES (Conflict Detection Evaluation System). It can simulate both DAPs-CDM and the conventional CDM under air traffic situations and system parameters almost the same as operational situations and system parameters. As a result of computer simulation with CDES, the determination of vertical flight phases by selected altitude was most effective in reducing the number of unnecessary CAs.

Keywords-component; Conflict Alert; Conflict Detection Method; Downlink Aircraft Parameters

En Route Air Traffic Control Input Devices for the Next Generation

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Abstract—The purpose of this study was to investigate the usefulness of different input device configurations when trial planning new routes for aircraft in an advanced simulation of the en route workstation. The task of trial planning is one of the futuristic tools that is performed by the graphical manipulation of an aircraft's trajectory to reroute the aircraft without voice communication. In this study with two input devices, the FAA's current trackball and a basic optical computer mouse were evaluated with the "pick" button in a click-and-hold state and a click-and-release state while the participant dragged the trial plan line. The trial plan was used for three different conflict types: Aircraft Conflicts, Weather Conflicts, and Aircraft + Weather Conflicts. Speed and accuracy were the primary dependent variables. Results indicate that the mouse conditions were significantly faster than the trackball conditions overall with no significant loss of accuracy. Several performance ratings and preference ratings were analyzed from post-run and postsimulation questionnaires. The release conditions were significantly more useful and likable than the hold conditions. The results suggest that the mouse in the release button state was the fastest and most well liked device configuration for trial planning in the en route workstation.

Keywords-input devices, en route, controller, workstation, mouse, trackball, NextGen

Track 5

Decision Support Tools

An Advanced Particle Filtering Algorithm for Improving Conflict Detection in Air Traffic Control

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Abstract—Enhanced accuracy in aircraft conflict detection allows for more efficient use of the airspace and increased safety levels. Trajectory prediction lies at the heart of most conflict detection algorithms. By comparing the predicted trajectories of different aircraft against each other, we can detect real threats while avoiding false alarms. We show how trajectory prediction tools that account for weather forecast errors can improve the performance of a conflict detection scheme. Using information from multiple aircraft at different locations and time instants, wind forecast uncertainties are reduced increasing trajectory prediction accuracy. We present a particle filtering algorithm that can efficiently cope with the high dimensionality and the non-linearity of the problem and show how using this algorithm can improve considerably conflict detection rates in mid and short term horizon encounters.

A Stochastic Model for Air Traffic Control Radio Channel Utilization

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Abstract—This paper offers a stochastic model for radio channel utilization in air traffic control. A log-normal probability distribution for the interaction frequency (‘interarrival’ times between successive radio interactions), as well as a multivariate joint probability distribution for speech/silence timed sequences have been constructed empirically from over 1,300 hours of recorded radio communication. While the density of communication is nonlinearly reflective of the density and type of traffic, its sequencing and other emerging patterns are also consequences of the controller cognitive and task processes. Such a model for radio channel utilization is a step toward adjusting automated conflict avoidance and decision support tools to effectively match controller attention patterns and task loading. By tuning the output of automated aids to more closely coincide with flight instructions in a manner easily comprehended and perceived by human controllers, this will help reduce workload, improve situation awareness, and address safety concerns by insuring effective human monitoring and trust of future automated maneuvers. Applications may be found in the use of automated advisory assistants suggesting flight instructions in humanly acceptable, albeit mathematically suboptimal, temporal patterns.

Keywords: *air traffic radio communication; frequency utilization stochastic model automated conflict resolution advisor decision support tool*

Impact of US Airline Network Topology on Air Transportation System Performance

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Abstract— Much of the current research aimed at reducing the air transportation system’s impact on the environment revolves around increasing the aircraft fuel efficiency or improving air traffic management practices. There are, however, many other factors that play a role in determining the system-wide performance of air transportation, such as the airline service route network topology characteristics, aircraft fleet mix and resource allocation. This paper investigates the impact of different service route network topology types on transportation efficiency and robustness metrics developed by the authors.

Keywords-network; efficiency; airlines; environment; systemwide Performance

Estimation and Comparison of the Impact of Single Airport Delay to the National Airspace System using Multivariate Simultaneous Models

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Abstract— The U.S. air transport as we all know is under significant stress with frequent delays and congestion. Airports are considered as bottlenecks of the National Airspace System (NAS). The major causal factors of flight delay at one airport are over-scheduling, en-route convective weather, reduced ceiling and visibility around airports, and upstream delay propagation. Meanwhile, the delay occurred at this airport will be passed on to other airports in the NAS. Hence, to optimally allocating resource for airport capacity expansion, it needs to quantify the impact of single airport delay to the NAS and vice versa. This research explores the methodology to analyze not only airport delay impact to the NAS, also explore if the delay spillover is widely dispersed across 34 OEP airports or more concentrated using multivariate simultaneous regression models. Three stage least square (3SLS) is used to regress the models and obtain coefficients for the multivariate equations.

Keywords-Airport delay; NAS delay; delay propagation; 3SLS

Track 6

Environmental and Weather

Throughput/Complexity Tradeoffs for Routing Traffic in the Presence of Dynamic Weather

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Abstract—We present efficient algorithms for computing trajectories for routing multiple aircraft avoiding a set of static or dynamic obstacles (e.g., hazardous weather cells). We present results of an implementation of our algorithms, comparing the throughput and traffic complexity across three routing paradigms:

Static Airlines: A set of lanes for air traffic is established. The aircraft move in trail along each lane, forming a highly structured traffic pattern. The drawback is that the lanes, being static, may not stay clear of hazardous weather as the weather cells move and potentially block lanes.

FreeFlight: Each aircraft determines its own trajectory in space-time, avoiding moving weather cells and other aircraft. This strategy can result in highly complex traffic patterns that are not amenable to human controller oversight.

Flexible Flow Corridors: This model combines advantages of the static airlines and the FreeFlight solution. The aircraft are routed along a set of lanes that slowly change as the weather cells move. This results in a structured traffic flow amidst moving weather.

Our routing algorithms employ searching in discretized spacetime, using a hexagonal packing of disks in free space and a uniform discretization of time. The algorithms allow us to take into account additional routing constraints relevant for Air Traffic Management (ATM).

Contribution of European Aviation on the Air Quality of the Mediterranean Region: A Modeling Study

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Abstract—Aviation is one of the anthropogenic activities with significant past and forecasted growth rate. The emissions from aviation alter the atmospheric composition and have many non neglectable impacts on regional air quality and climate. The study of such processes can be conducted with mathematical models which use an online approach of the meteorological and chemical processes that affect and/or are affected by aviation. The Integrated Community Limited Area Modeling System (ICLAMS) is a fully integrated atmospheric model developed at the Atmospheric Modeling and Weather Forecasting group of the University of Athens. It deals with atmospheric meteorology and chemistry and their interactions in an online coupled way and on the same spatial, temporal and projection platform. The model was tested for the month of July 2005 for Europe and the Mediterranean Region. Two simulations have been performed, one with emissions from all anthropogenic activities and the second excluding the emissions from aviation. The comparison of the model results, with and without the aviation emissions, gave the opportunity to assess the impact of airport operations on the air pollution levels of the region and downwind areas, under characteristic summer meteorological conditions. The area that is influenced by the emissions from European aviation operations is very large, and the most affected region is the Western and Eastern Mediterranean and several areas in North Africa. The prevailing west – northwest circulation over West and Central Europe favors the transport of pollutants towards East, South East

Europe and North Africa leading to perturbations in the atmospheric composition especially up to 4 – 5 km above surface. The ozone field is altered by the aviation emissions with perturbations in its daytime values that reach 5 - 8 ppb. The atmospheric concentrations of other gas and aerosol pollutants are also affected.

Keywords-air quality, pollution models, Athens Airport, emission inventories, aviation emissions

Generating Day-of-Operation Probabilistic Capacity Profiles from Weather Forecasts

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Abstract—It is common understanding that weather plays an important role in determining the capacity of an airport. Severe weather causes capacity reductions, creating a capacity demand imbalance, leading to delays. The role of air traffic flow management (ATFM) measures is to reduce these delay costs by aligning the demand with the capacity. Ground delay program (GDP) is one such measure. Though the GDP is initiated in poor weather conditions, and weather forecasts are subject to errors, present GDP planning procedures are essentially deterministic in nature. Forecast weather is translated into deterministic capacity predictions on which GDP planning is based. Models which employ probabilistic capacity profiles for planning GDPs have been developed, but their application has been limited by the inability to create such profiles from weather forecasts. This paper focuses on San Francisco International Airport (SFO) and provides a methodology to generate probabilistic capacity profiles from the two terminal weather forecasts: Terminal Aerodrome Forecast and San Francisco Marine Initiative (STRATUS). The profiles are inputs to a static stochastic GDP model to simulate ATFM strategies. The solution from the model is evaluated against realized capacities to determine the benefit of the forecast. The benefit of inclusion of the weather forecast is assessed by comparing costs of delays from ATFM strategies simulated from probabilistic profiles developed without the weather forecasts. It is also shown that inclusion of weather forecasts reduces the cost of delays. The paper also compares the cost of delays from strategies simulated using the profiles generated from TAF and STRATUS. It is shown that on average TAF offers similar benefit in controlling cost of delay when compared to STRATUS, indicating that other airports would also benefit from using TAF in planning of operations.

Keywords- Air traffic flow management; Ground delay program; Probabilistic Capacity Profiles; K-means Clustering; Terminal Aerodrome Forecast; STRATUS

Track 7

Future Concepts and Innovative Ideas

Dynamic Allocation and Benefit Assessment of NextGen Flow Corridors

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Abstract—A flow-based modeling approach is proposed to identify candidate airspace for high-density flow corridors. The input to the model is a set of projected user-preferred, wind optimal, and unconstrained 4D trajectories (4DT). We compute Velocity Vector Fields (VVF) in the 4D space-time and cluster the velocity vectors both in time and space to define flow of aircraft when they fly their preferred trajectories under high capacity conditions. A sliding time window is implemented to dynamically create and optimize corridors' coordinates based on the changes in preferred trajectories. From this process we compute a NAS-wide corridor network that mimics the dynamics of user preferred trajectories. In operational setting, flights will have the option of joining a corridor that is closest to their optimal trajectory. Using NAS-wide simulation, we assess the benefit of corridor network by comparing efficiency gained by joining the corridor network against extra distance traveled to join the network. We show that much of the overall corridors benefit may be gained by creating very few corridors.

Coordinating Multiple Traffic Management Initiatives with Integer Optimization

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Abstract—In this paper, the problem of coordinated resource rationing is considered in the face of current operational practice. In the United States, access to congested aviation resources is typically controlled by a system of capacity rationing wherein flights are assigned to slots at specific times. This is a well-accepted and efficient system, but it is not well equipped to handle the problem faced when a single flight is controlled by more than one rationing initiative. The question of which, if any, initiative takes precedence over the others is not easily answered. An integer optimization model is introduced in this paper to find the delay-minimizing combination of multiple slot assignments for a set of flights and rationing initiatives. Rather than approach the problem comprehensively, this model treats each rationing initiative as somewhat independent, including only a constraint to guarantee that whatever slot pairs are assigned are mutually compatible. Computational results, including a case study, are reported along with directions for continuing research.

Keywords— *ground delay program, airspace flow program, resource rationing, integer programming*

Collaborative Rerouting in the Airspace Flow Program

A Framework for User-cost Based Performance Assessment

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Abstract— The Airspace Flow Program (AFP) ground delays flights in order to control their flow through capacity constrained airspace regions. It has been successful in controlling traffic with reasonable delays, but the procedures must be improved upon to handle future projected demands. This paper explores a future AFP where centrally-managed rerouting and user input are incorporated into the initial resource allocations. A modeling framework was developed to evaluate and compare allocation strategies, under differing assumptions about traffic managers' knowledge about airline flight costs. It is used to quantify tradeoffs regarding the quality and timing of airlines' input information. Three allocation strategies were developed; they differ with respect to the input requested of airlines, and the resource allocation philosophy. They are assessed based on the total cost impact of the AFP initiative on flight operators. To this end, a flight cost function was developed to represent the cost of delay specific to each flight; it consists of deterministic components to represent what traffic managers know about the airlines, and a stochastic component to represent that which they do not. A numerical example demonstrates the situations under which better information quality could be more desirable than timeliness, and vice versa. Identifying these types of tradeoff points is a key contribution of this research effort.

Keywords- delay; air traffic flow management (ATFM); Airspace Flow Program (AFP); Collaborative Decision Making (CDM); user cost; strategic planning.

An Optimisation Framework for Aircraft Operators Dealing With Capacity-Demand Imbalances in SESAR

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Abstract—This paper presents a framework for the negotiation phase that is foreseen in the new operational concept proposed in the Single European Sky Research (SESAR) program. In particular, this paper describes a possible strategy for the airspace users in order to deal with the Collaborative Decision Making (CDM) process that is expected in this future scenario. In the SESAR scenario, airspace users will become owners of their trajectories and they will be responsible to solve possible mismatches between capacity and demand in a particular airspace sector. The aim of this strategy is to improve the efficiency in the CDM process by computing the different operational costs associated to different solutions that may solve a particular demand-capacity imbalance in the airspace. This will allow them to optimise their operating costs while reducing fuel consumption and therefore being more environmentally friendly. Some suggestions have already been done for the CDM mechanism, for instance the use of auctions. However, the different options that aircraft operators might use have not yet been sufficiently investigated. In this paper, the authors propose an optimisation framework for aircraft operators aimed at computing 4D trajectories with time constraints to deal, in this way, with possible airspace regulations. Once a nominal flight plan and a potential regulation is known, it is suggested to compute several possible alternative flight plans (including rerouting, but also altitude and speed profiles) that may solve the capacity-demand problem. If more than one regulation is applied to the flight, a tree of options is subsequently computed. The cost of each optimised option is also calculated in order to allow the airspace users to initiate the negotiation process with other airlines. Finally, a preliminary example is given at the end of this paper in order to better illustrate the proposed methodology.

High-fidelity Human-in-the-Loop Simulations as one Step towards Remote Control of Regional Airports

A Preliminary Study

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Abstract—The paper reports on an experimental work environment for simulating remote control of regional airports and initial results obtained by high fidelity human-in-the-loop simulations. At the Institute of Flight Guidance of the German Aerospace Centre a concept for remote control of regional airports was developed since 2002 and a corresponding experimental testbed realized, consisting of facilities for field testing at the Braunschweig research airport and a tower simulator extension for operational remote tower (RTO) simulations with controllers. Human-in-the-loop simulations were conducted, simulating Braunschweig airport to show the operational feasibility of the new working environment. Therefore two tower controllers handled traffic scenarios using a common 200-degree tower simulator, but also using the new work environment, the RTO (Remote Tower Operation)-Console. This setting allows a direct comparison of an evaluation of the RTO-Console and the tower simulator as work environment. Augmented vision aspects were implemented in the simulation runs at the RTO-Console. Moreover, a zoom camera with an automatic tracking function integrated in the work environment for remote control was evaluated. Subjective data from questionnaires and free interviews were gathered for each simulation run. Objective eye data were recorded for the simulation runs using the RTO-Console. The main result from the questionnaires depicts the work environment of the RTO-Console to be comparable with working in a tower simulator. The eye data show that most of the time (53%) the tower controller is looking at the area of interest in the simulated far view, which is in line with former work analyses. The results of the human-in-the-loop simulation suggest the feasibility of tower operation using the RTO-Console. For the operational deployment of remote control of small airports a stepwise validation using human-in-the-loop simulations is indispensable.

Keywords - Remote Tower, Controller working position, simulation, validation, eye-tracking

Investigating String Stability of a Time-History Control Law for Interval Management

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Abstract—Interval Management is a concept being developed as a part of the Next Generation Air Transportation System (NextGen) and Single European Sky ATM Research (SESAR). Within the FAA, standards and concept development are being sponsored by the Surveillance and Broadcast Services (SBS) office. The objective of Interval Management is to achieve a more precise spacing interval between a spacing aircraft and an assigned target aircraft. Speed commands, calculated by ADSB-based avionics equipment, are implemented by the spacing aircraft in order to achieve a desired spacing interval relative to its target aircraft. In some Interval Management operations, it is expected that a string of aircraft will be formed, where each aircraft is spacing relative to its target, or preceding, aircraft. In the design of a speed control law to perform Interval Management operations, one must not only examine the performance and stability of one aircraft relative to another, but also the performance and stability of the entire string. String behavior fundamentally affects the potential operational practicality of successfully implementing Interval Management in certain operational environments. This paper

presents a simplified, closed-form string stability analysis for a time-history speed control law, which has been proposed for Interval Management. Simulation results are shown to validate the closed-form analysis and are used to evaluate string behavior and system performance for an approach-spacing operation.

Towards Universal Beacon Code Assignment Spatial and Temporal Analysis of En-route Traffic in NAS

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Abstract— Beacon codes are a set of very limited National Airspace System (NAS) resource. Currently, the beacon code allocation process is based upon the concept of discreet beacon code assignment to each ARTCC. Due to the mismatch between the limited number of beacon code subsets available and the volume of traffic, duplicate beacon code assignment is unavoidable under the current scheme. In this paper, the spatial and temporal structure of en-route NAS traffic is analyzed. This analysis provides the foundation of exploiting the inherent structure of NAS traffic to enable a more efficient beacon code assignment, i.e. with fewer beacon code changes per flight.

Keywords-component; Beacon Code, Squawk Code, ATRBS, En-route traffic, NAS, Air Traffic Controller workload.

Track 8

Human Factors

The Structure and Color Optimization Process to Generate Metro-like Maps of Flight Routes

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Abstract— Aircraft must follow strict Air Traffic Control (ATC) rules. One of these rules is that aircraft have to fly over predefined Flight Routes (FR). Current ATC visualizations do not display FRs because they are numerous and run into each other, and thus spoil the visualization. The schematic views for metro maps are used to maximize the transmission of relevant information (lines, metro stops) of network visualization. In this paper, we will focus on two different issues. First, we show how we transposed mathematical constraints used to produce metro maps into the specific field of ATC. The view produced is a context compatible, 2D picture of a metro-like view for Air Traffic Control. Second, we propose to investigate the generation and placement of colors to be assigned to lines of the network. The first step is to find as many colors as lines of the network. These colors must be perceptually as distinct as possible, and available in the vocabulary of colors. The second step is to solve the NP-complete problem of the optimal assignment of these colors so that close lines have the most perceptively distant color. Finally, we assess the map produced through experimentation to validate its quality.

Keywords-component; Visualization, metro map, colors assignment, Air Traffic Controller.

A Participatory Design for the Visualization of Airspace Configuration Forecasts

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Abstract— Currently, airspace-related activities in Air Traffic Control Centers (ATCC) are dispatched between the Flow Management Position (FMP) operators and the control room manager, and take place in two different time frames. The first activity (FMP) is the planning, 2 days ahead, of airspace usage and anticipated overloads, using coarse-grain and relatively inaccurate workload prediction metrics. The second activity (control room manager) is the day-to-day operation, where workload is re-assessed in real-time and where airspace may be re-configured according to the actual traffic of the day. In previous works, a workload model relying on relevant air traffic complexity metrics was proposed, using a neural network trained on past sector operations. This workload prediction model was combined with tree search algorithms, in order to compute optimal partitions of the airspace in Air Traffic Control (ATC) sectors. This method provides more accurate airspace configuration forecasts than today, thus improving the overall predictability of the Air Traffic Management (ATM)/ATC system. When relying on accurate 4D-trajectory predictions, as expected in the SESAR program, it could contribute towards bridging the current gap between the pre-tactical airspace/flow management and real-time operations. In this paper, we detail the participatory design approach that we used to develop a research prototype displaying the algorithm's results. As there is no such forecasting tool today, the main issue was to create a user interface in the absence of an existing user.

Keywords: User-Centered Design, Human Computer Interaction, Airspace Configuration Forecasts

Flight experience and executive functions predict flight simulator performance in general aviation pilots

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Abstract— Unlike professional pilots who are limited by the FAA's age rule, no age limit is defined in general aviation (GA). Some studies revealed significant aging issues on accident rates but these results are criticized. Our overall goal is to study how the effect of age on executive functions (EFs), high level cognitive abilities, impacts on the flying performance in GA pilots. This study relies on three components: EFs assessment, pilot characteristics (age, flight experience), and the navigation performance on a flight simulator. The results showed that contrary to age, reasoning, working memory (WM) and total flight experience were predictive of the flight performance. These results suggest that “cognitive age”, derived in this study by the cognitive evaluation, is a better mean than “chronological age” consideration to predict the ability to pilot, in particular because of the inter-individual variability of aging impact and the beneficial effect of the flight experience.

Keywords: *piloting performance, executive functions, flight experience, decision making, normal aging.*

Economic Issues Provokes Hazardous Landing "Emotional" Neural Pathways

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Abstract— The analysis of aeronautical accidents highlights the fact that some airline pilots demonstrate a trend to land whereas the approach is not well stabilized. This behavior seems to be the consequence of various factors, including financial issues. Our hypothesis is that financial constraints modulate the brain circuitry of emotion and reward, in particular via the interactions between two prefrontal structures: the dorsolateral prefrontal cortex (DLPFC), main center of the executive functions (EFs), high level cognitive abilities, and the ventromedial prefrontal cortex (VMPFC), structure linked with the limbic system, major substratum of emotional processes. In our experiment, participants performed a simplified task of landing in which the level of uncertainty and the financial incentive were manipulated. A preliminary behavioral experiment (n = 12) was conducted. A similar second experiment using functional magnetic resonance imaging (fMRI) is in progress and a case study only is reported here. The behavioral data showed that the participants made more risky decision to land in the financial incentive condition in comparison to the neutral condition, where no financial incentive was delivered. This was particularly

true when the uncertainty was high. The functional neuroimaging results showed that the reasoning performed in neutral condition resulted in enhanced activity in DLPFC. On the contrary, under the influence of the financial incentive, VMPFC activity was increased. These results showed the effectiveness of the financial incentive to bias decision-making toward a more risky and less rational behavior from a safety point of view. Functional neuroimaging data showed a shift from cold to hot reasoning in presence of the financial incentive, suggesting that pilot erroneous trend to land could be explained by a temporary perturbation of the decision-making process due to the negative emotional consequences associated with the go-around.

Keywords: decision making; emotion; reward; piloting performance.

Empirical Analysis of Air Traffic Controller Dynamics

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Abstract—This paper addresses an empirical analysis of Air Traffic Controller activities using a human dynamics and complex systems approach. Workload metrics have been long well investigated from a cognitive engineering, human factors approach, and have been widely used as an indicator of controller's activity levels. However, the dynamical property of workload is still unknown, which make it difficult to predict workload ahead of time. Recent investigations on human dynamics show several empirical evidences that, different from common belief respecting random-based Poisson distributions, patterns of human activities fit into power law distribution with heavy tail patterns. Our hypothesis lies upon the question whether or not controller's dynamics obeys the same power law pattern. Our first attempt consists in analyzing the temporal characteristics of controller activities, in term of communication activities. The analysis on ATCOSIM Air Traffic Control Simulation Speech corpus shows that intercommunication times do follow a heavy tail pattern. Over certain thresholds, the distribution of inter-communication times approximates power-law decaying, and the correlations between communication events and traffic activities are influenced by the time-scale selected. However, the meanings of the thresholds are not interpretable due to the lack of available information.

Keywords- air traffic control; human dynamics; complex systems;

Predicting Controller Communication Time for Capacity Estimation

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Abstract—We consider the complexity and controller task load problem common to air traffic management. Expanding upon previous works that correlate controller communications to workload and complexity, a stochastic model is developed to determine the distribution of the minimum time required by an air traffic controller to manage a sector. The resulting model serves as a predictive tool for rapidly determining future workload/complexity of air traffic by considering communication time or task load time as a metric.

Track 9

Prospective Studies and Economics

What Kind of Aviation Infrastructure Privatization is needed in China?

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Abstract—Aviation infrastructures used to be considered critical to national security and the public interest. They were also considered natural monopolies. Consequently, it was believed that government or public entities should be responsible for the ownership and management of aviation infrastructures. However, since the late 1970s, commercialization and privatization began to become increasingly widespread in airports. This paper will investigate underlying rationales for the introduction of private sector participation in aviation infrastructures, be it in terms of privatization or in terms of delegated management, and all this both in the cases of China's and developed economies' airports and air traffic management. It is argued that partial privatization may be much more appropriate in the case of China's aviation infrastructure sector.

Keywords- aviation infrastructure; privatization; China

Capturing the Impact of Fuel Price on Jet Aircraft Operating Costs with Engineering and Econometric Models

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Abstract— Challenges in forecasting fleet development and deployment are in part due to fuel price uncertainty. To address this issue, a recent study developed an aircraft-specific Leontief technology operating cost model (LM) to compare aircraft costs under fuel price uncertainty. This model considers individual aircraft types to be Leontief technologies, such that the key drivers of cost must be used in fixed quantities. While asserted in the literature that models in this form can more accurately predict operating costs, the Leontief specification precludes a precise examination of how aircraft size will change due to economic forces. To this end, an econometric operating cost model (EM) is developed. The translog functional form is used to capture the effect of the key drivers of cost on jet operating costs and also allow for substitution between inputs. A comparison of the LM and EM shows that the Leontief technology assumption limits the LM to capturing operating costs in only a snapshot in time, while the EM captures the input substitution that occurs with factor price changes. The conclusion that the EM has strong predictive potential encourages a strengthening of the model towards capturing costs related to passenger preferences. This study takes a total logistics cost approach (TLC) and considers passenger value of frequency along with operating cost to be the total cost per operation. The cost-minimizing seat size is smaller and more reflective of existing conditions under TLC compared with operating cost alone, yet the difference diminishes as fuel price increases. This study highlights the predictive potential of econometric cost models and also the importance of considering passenger preferences in predicting future aircraft economics.

Keywords—Jet Aircraft; Operating Cost; Aircraft Size; Logistics Cost; Fuel Price; Leontief Technology; Econometric Model

En route charges for ANSP revenue maximization

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Abstract—In Europe, all Air Navigation Service Providers (ANSPs) finance their activities by charging airlines using their airspace. These ‘en route charges’ usually account for a significant part of the cost of a flight, and they can therefore influence the route choice: airlines may decide to fly longer routes to avoid countries with higher charges. If ANSPs want to maximize their revenues, they must choose the optimal charge to impose on their airspace. We show that this optimal charge can be identified through a Network Pricing Problem (NPP) formulation in the form of Bilevel Programming where the leader (i.e. the ANSP) owns a set of arcs (the airways in its national airspace) and charges the commodities (i.e. the flights) passing through them. As the en route charges are proportional to a Unit Rate value fixed by the ANSP, we are able to apply a similar methodology as in the case of a single toll arc for the NPP. By exploiting the structure of the problem, we propose an exact algorithm to compute the optimal Unit Rate and apply it to a case study relying on real air traffic data and realistic flight cost figures.

Keywords - *Network Pricing Problem, En route charges, Air Navigation Service Providers, Air Traffic Management*

Track 10

Safety and Security

Bayesian Analysis of Accident Rate, Trend and Uncertainty in Commercial Aviation

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Abstract— An established approach in the evaluation of aviation accident statistics is to determine point estimates of the accident rate by dividing number of accidents by number of flights and to determine an uncertainty interval through evaluation of the underlying binomial distribution. The trend, however, is not estimated. Another established approach is to perform a regression analysis to estimate rate and trend, but then uncertainty is not estimated. In this paper we overcome these limitations of established approaches by studying the problem as one of Bayesian estimation of the joint conditional density function of accident rate and trend given accident and flight statistical data. Subsequently, a particle filter is used in order to perform numerical evaluations. The novel approach is shown to work well on commercial aviation accident data.

Keywords-Bayesian estimation; accident statistics; particle filtering; uncertainty estimation

Stochastically and Dynamically Coloured Petri Net Model of ACAS Operations

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Abstract - Current international regulations and policies do not consider the effect of an airborne safety net for the analysis of safety risks. This widely accepted practice tends to create significant tension between the realization of the ambitious safety improvement targets of SESAR and NEXTGEN, and the standing regulations. In order to close this gap between SESAR and NEXTGEN requirements, and standing regulation, there is need for a systematic development of safety risk analyses of airborne safety nets within the specific ATM context, which may range from current practices to advanced ATM concepts. The aim of the research described in this paper is to make a contribution through the systematic development of an unambiguous model of TCAS II version 7, together with its interactions with pilots and ATC. The specific modelling formalism used for this is Stochastically and Dynamically Coloured Petri Nets (SDCPN). The developed SDCPN model contains the technical, human and procedural elements of ACAS operations. The SDCPN model is demonstrated to work well for a historical en-route mid-air collision event.

Keywords - ACAS, Petri Nets, Safety Risk Assessment, Safety Critical Systems

A Quantitative Safety Assessment Tool Based on Aircraft Actual Navigation Performance

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Abstract: With this paper, ATM safety research at TU Dresden presents its ongoing effort to establish a safety metric for normative air traffic operations as the first step in a DFG-funded research project aimed at leveraging operational safety methodology for TMA sectors, the terminal area around major airports. After a brief introduction to the field of research and agreed-upon target levels of safety (TLS), available methodology is analyzed with the conclusion that operational safety is most appropriately assessed by probabilistically evaluating quantitative flight performance data. To gain an overall objective view on the ATM's total system safety, collision probability, a measure for the safety criticality of aircraft interactions, was selected. Though thankfully mostly marginal, collision probability is always nonzero as it arises from omnipresent navigational, flight technical, human and weather-induced positional inaccuracies. Being such an important parameter, the inaccuracies have been quantified by means of radar data analysis – leading to precise mathematical dependencies for selected critical flight phases (see Thiel & Fricke in this volume). These actual navigation performance values (ANP) are used for adaptive parameterization. As a proof of concept, segregated operations on parallel runways (SOIR) and the related planning rule (1/5 runway staggering) are subjected to safety assessment at various levels of elaboration (from a simple critical distance analysis to simulative applications of the safety assessment tool presented here). The results suggest that a collision probability approach could once have led to the planning rule, but also point out the benefits of ANP-based considerations. The paper closes with an outlook: in conjunction with an agent based simulation the tool shall help to gain insight into the safety impact of present and changed ATM procedures and variations and limitations of human performance.

Keywords: *operational air traffic safety; quantitative safety assessment; safety methodology; collision risk; human performance*

Study of SESAR Implied Safety Validation Needs

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Abstract—Safety validation of changes to an individual organization's local ATM system has become common practice in Europe. However, the SESAR program is planning changes in air traffic operations in Europe that go much further than changes to a local ATM system. This paper identifies the issues on which safety validation approaches need extensions, in order to move from safety validation of changes to a local ATM system to safety validation in SESAR. Subsequently, it identifies approaches that address the identified extension needs. This way an integrated view is developed from the fragmented research results in this area.

Keywords-*Safety validation, ATM, SESAR.*

Collision Risk on Final Approach – A Radar Data Based Evaluation Method to Assess Safety

ANP Based Obstacle Assessment Surfaces

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Abstract— Many major airports around the world are facing the problem of highly congested airspace and are therefore seeking ways to enhance capacity. Innovative RNP/ RNAV procedures in terminal areas, in particular RNP/ RNAV procedures for the final approach segment may be a possible solution due to increased flexibility when using the available airspace. However, these procedures must be designed according to their navigational performance requirements to ensure safe operations. Measuring safety of upcoming RNAV approach procedures in terms of navigational accuracy is crucial for their implementation at airports, as there is a need to develop specific obstacle assessment surfaces (OAS) and collision risk models (CRM). Designing specific OAS is essential for future airport development if benefits of improved navigational performance shall be fully exploited. This paper presents a method to determine actual navigational performance (ANP) during the final approach phase and a strategy for calculating ANP- based OAS executed here for an ILS final approach by means of radar data evaluation. Radar data will be used for statistical analysis of approach path deviations during the final approach phase and for modeling specific OAS based on the derived deviations.

Keywords: *Safety; Collision probability; Actual navigation performance (ANP); Obstacle Assessment Surfaces; Radar data analysis*

Comparison of Arrival Tracks at Different Airports

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Abstract—This paper analyzes arrival flight track data at Chicago (ORD) and Atlanta (ATL) airports. We investigate distributions of vertical and lateral position at different distances from the runway threshold in instrument meteorological conditions (IMC) and visual meteorological conditions (VMC). In IMC, the observed standard deviations at different distances are similar between the two airports. The results reported in this paper are also similar to those reported at St. Louis (STL) in [1]. Visual comparison of the observed distributions also shows a close similarity. This provides some indication that distributions observed at one airport in IMC may generalize to other airports. In VMC, there are some differences between the distributions. We also fit probability density functions (PDFs) to lateral and vertical positions. In general, the normal distribution provides the best fit among the normal, lognormal, gamma, and Weibull families. The quality of the fit is better in IMC closer to the runway threshold.

Keywords- *flight tracks; probability density functions*

Stochastic Validation of ATM Procedures by Abstraction Algorithms

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Abstract—In this paper we propose a methodology for formal reasoning based on stochastic hybrid systems theory and abstraction algorithms for stochastic dynamical systems, which provides a powerful framework to analyze stochastic models of ATM procedures. We propose the use of automatic tools for verifying probabilistic properties of ATM scenarios. In particular, we propose to use PCTL logic to define probabilistic properties of interest. We address a simple single-agent procedure of the A3(Autonomous Aircraft Advanced) ConOps (Concept of Operations), describe a dynamical model for the aircraft deterministic dynamics and for the wind stochastic dynamics, and used MATLAB and PRISM tools in order to perform stochastic analysis of properties of interest of the addressed scenario.

Index Terms—Air traffic management, Stochastic hybrid systems, Abstraction algorithms, Probabilistic model checking.

Doctoral Symposium

Establishing an Upper-Bound for the Benefits of NextGen Trajectory-Based Operations

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Abstract—NextGen enabling technologies and operational initiatives seek to increase the effective-capacity of the National Airspace System. Concepts-of-operations, such as Trajectory- Based Operations, will allow flights increased flexibility in their 4-D trajectories as they traverse Center airspace. Shifting trajectories in this way can minimize the airlines operating costs (i.e., distance flown), shift the geography of Air Traffic Control (ATC) workload (i.e., sectors used), shift the time-intensity of ATC workload (i.e., flights counts per sector).

This paper describes the results of an analysis of one day of operations in the NAS using traditional navigation aid-based airway routes compared to direct, i.e., Great Circle Distance, routes. The results yield: (i) a total of 599 thousand nm (average 30 nm per flight) savings generated by flying direct routes, (ii) a redistribution of flights across sectors resulting in a reduction of 3% in the total time the flights in a sector are in excess of the Monitor Alert Parameters for that sector, (iii) a reduction in ATC workload reflected by a 47% drop in the number of flights requiring conflict resolution. These results indicate upper bound of benefit opportunities for both ATC and the airlines based on the introduction of flexible routing structures in NextGen.

Index Terms—NextGen, evaluation, conflicts, FACET, distance flown, delays.

The Research of Multi-Airport Ground Holding Problem Based on the Schedule Optimization

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Abstract—In this article, a Multi-objective and Multi-airport Optimizing Model (MMOM) is firstly built based on flights schedule, integrating airspace capacities and aircrafts turnover. Then the non-dominated sorting genetic algorithm II (NSGA-II) Algorithm is introduced to propose near-optimal solutions which achieve different goals with different estimated departure times. Finally, an instance concerned the recently schedule of three main airports in China is analyzed in detail, and the simulation results show that the model's correct and efficient.

Keywords-Air traffic flow management; multi-objective; multi-airports; NSGA-II Algorithm

Using Online Data to Investigate Airline Passengers' Multi-Airport Choices

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Abstract— This paper provides my proposed research plan for my doctoral dissertation. In short, I am aiming to leverage unique internet data sources to build and validate discrete choice models in multi-airport cities. The project is divided into four steps: (1) data collection, (2) catchment area analysis, (3) discrete choice models development, and finally (4) validation of the discrete choice models, using data sources readily available to academics. From past experiences I have gained a lot of knowledge by sharing my research ideas with academics and industry professionals, and anticipate by sharing these ideas at the doctoral symposium at the ICRAT conference I will receive more valuable feedback.

Keywords- aviation; discrete choice models, air travel demand

A Study of Characteristics of Solutions Obtained by Heuristics for Regional Air Traffic Flow Management

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Abstract—In order to accommodate the growing demands for regional air traffic flow management decision support, this paper firstly presents an integer programming model of the problem. For the purpose of solving the problem in real time, heuristics is used to reduce the computational complexity. This heuristic method divides the capacity restriction problem of multiple-unit into a sequence of capacity restriction problems of single-unit. The algorithm will converge. It is found that the locality where the flight delay happens will have an impact on the result of the algorithms, which is measured as the total delay for all the flights. Two different delay strategies are compared in different sector capacity conditions. It is found that either single delay strategy is always more efficient than the other under any airspace conditions. Therefore, it is necessary to add heuristic information concerning delay distribution to improve the heuristics applied in this paper.

Keywords-regional air traffic flow management; heuristics; integer programming

A Mixed Integer Linear Model for Potential Conflict Minimization by Speed Modulations

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Abstract—As air traffic volume is growing around 5% each year in Europe it has become a priority to improve air traffic control in order to deal with tomorrow's air traffic configuration. In 2007 the SESAR (Single European Sky ATM Research) project was created under European Community law as an initiative to design the future of air traffic management over Europe. One of the objective of SESAR is to increase air traffic density and optimize flight route plans. This can be achieved through en-route deconfliction. Reducing the global number of conflicts through speed regulation has been tested in the ERASMUS project (En-Route Air traffic Soft Management Ultimate System) and efficiency of the concept has been analysed through tests and simulations [2]. It provided many insights related to en-route control using speed variations hence becoming a solid reference. In this paper we develop a mixed integer linear model for a speed regulation problem that suits SESAR requirements. We focus on flights crossing times at intersection points rather than distance to ensure separation along our resolution. Speed regulation is thus converted into travel time control. Finally we propose an integer linear program aiming at minimizing the global potential conflict quantity by speed modulations.

Index Terms—ATM, Conflits, Mixed Integer Programming, Speed Control.

Using On-Line Data to Explore Competitive Airline Pricing Policies

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Abstract— Since the mid 2000's, the airline industry has seen volatile fuel prices, a record number of carriers ending service, and a merger between two major airlines. In a time of such turmoil in the industry it is increasingly important to understand the relationship between airline consolidation and competitive pricing policies, as this relationship will directly impact the formation of future airline policies associated with competition policy (anti-trust), deregulation, and mergers. However, there is a lack of consensus about market concentration and its influence on airfares, mainly due to data limitations of past research. Given the emergence of on-line booking engines, there is a new opportunity to collect detailed fare data. This project uses disaggregate, on-line airfare data to study the relationship between market concentration and pricing policies. The dataset includes 62 markets that cover a broad range of market structures. A case study approach is used to analyze the data. Using disaggregate fare data, this study finds low price dispersion can be associated with both low and high levels of market concentration. As the day of departure approaches, price dispersion is seen to either increase or decrease, depending on the specific market. Additionally, peak and off-peak periods demonstrate differing pricing strategies. Also, markets with codeshares are shown to sometimes exhibit unusually high price dispersion.

Keywords-price disperion, competitive pricing, market structure

Evaluating Light Detection and Ranging (LIDAR) Technology in the Terminal Aerodrome Environment for Potential Enhancements and Air Traffic Management

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Abstract—It is believed that implementing a LIDAR ground based system into a terminal aerodrome will enhance air traffic management and airport operations. Implementing a technology of this magnitude to become a fully marketable system will require additional research and time to better understand the operations of LIDAR and its capabilities in the terminal aerodrome environment.

Keywords- Lidar; Radar; airport; aerodrome; Nexgen

The Aircraft Sequencing Problem

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Abstract— This paper describes a research on the aircraft sequencing problem intended for a Master thesis. The aircraft sequencing problem is a problem of determining the landing times for a sequence of aircrafts on available runways in a way that they land during the predetermined time windows for landing while respecting separation criteria for safety. The goal of this research is to model and analyze the problem from several viewpoints to determine the criteria for optimization. This will involve formulation of appropriate objective functions and comparison of computational results after solving the problem using methods such as mixed integer programming and network flow programming.

Keywords-aircraft sequencing; scheduling; air traffic control

Models for Aircraft Landing Optimization

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Abstract—Due to an anticipated increase in air traffic during the next decade, air traffic control in busy airports is one of the main challenges confronting controllers in the near future. Since the runway is often a bottleneck in an airport system, there is great interest in optimizing usage of the runway. Our study first presents a brief review of the aircraft landing problem. A model for the problem is then introduced, and possible solution approaches are discussed.