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Track 1

Human Performance

Quantitative prediction of automation effects on ATCo Human Performance

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Abstract— Human operation in highly automated environments has been extensively researched finding out that the human-automation interaction presents serious performance drawbacks due to the risk of the "out of the loop" effect especially in case of automation fail. This paper presents research on a psychological model for Air Traffic Controllers (ATCo) to be computerised to quantitatively predict the automation effects on ATCo performance. The research has been conducted within AUTOPACE project (Grant 699238) funded by the SESAR Joint Undertaking as part of SESAR 2020 Exploratory Research Programme. The psychological model is based on the cognitive system function of an ATCo and the required attentional resources for its functioning. The research includes a preliminary quantitative assessment of the cognitive demand expected for the ATCo in highly automated scenarios (2050 time frame horizon) in nominal and no nominal situations. This assessment has been achieved through (a) fast time simulations of future automation scenarios modelling 2050 concept of operation and; (b) psychological cognitive assessment of the ATCo tasks in such scenarios using an existing computational model, COMETA (COgnitive ModEl for aTco workload Assessment). COMETA results reveal how the functional structure and the functioning of the future ATCo cognitive system drastically change with automation. This paper provides strong justification to invest on further research to improve existing computerised models to predict ATCo performance that will support the design of mitigations.

Analyzing Pilot Decision-Making Using Predictive Modeling

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Abstract—Due to the increased availability of computational power and large amounts of data, predictive modeling and analytics are becoming increasingly popular in a wide variety of fields. Some predictive modeling techniques are fairly simple, such as linear and logistic regressions, whereas others are fairly complex, such as neural networks. Popular applications of predictive modeling include detecting fraud, diagnosing patients for certain diseases, and predicting traffic and travel times. This paper presents a novel application of predictive modeling in the field of commercial aviation safety. First, two different predictive modeling techniques are discussed: artificial neural networks and partition models. The application of the techniques is then demonstrated through a case study related to the determination of go-around criteria for commercial aircraft. Predictive modeling is used to analyze human-in-the-loop simulator data and questionnaire responses by a number of pilots to predict their go-around decision based on a given starting condition. Through these analyses, it was found that individual pilot personalities significantly affect go-around decision-making. In addition, comparisons are made between modeling methods, and the benefit of using such techniques in modeling human behavior to improve aviation safety is demonstrated.

A Machine Learning Approach on Past ADS-B Data to Predict Planning Controller's Actions

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Abstract—En-route airspace is one of the most congested airspace, as it is mainly used in the cruise phase of the flight. The en-route sector is usually managed by a team of two air traffic controllers: planning controller (D-side) and executive controller (R-side). D-side controller is responsible for processing flightplan information to plan and organize the flow of traffic entering the sector. R-side controller deals with ensuring safety of flights in their sector. A better understanding and predictability of Dside controller actions, for a given traffic scenario, may help in automating some of its tasks and hence reduce workload. In this paper, we propose a learning model to predict D-side controller actions. The learning problem is modeled as a supervised learning problem where the target variables are D-side controller actions and the explanatory variables are the aircraft 4D trajectory features. The model is trained on one month of ADS-B data over an en-route sector, and its generalization performance was assessed, using cross-fold validation, on the same sectors. Results indicate that the model for vertical maneuver actions provides highest prediction accuracy (99.7%). Besides, model for speed change and heading change action provides predictability accuracy of 88.7% and 72.4% respectively. The model to predict the set of all the actions (altitude, speed and heading change) for each flight achieves an accuracy of 0.68 implying for 68% of flights, D-Side Controllers can be predicted for all the actions from trajectory information at sector entry position.

Track 2

System Performance

Novel terminal arrival airspace robustness metrics via topological density clustering

A case study of the Chicago O'Hare International Airport

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Abstract— We leverage topological density clustering to analyze radar trajectory data, resulting in novel airspace robustness metrics with respect to convective weather in the terminal arrival airspace. Our method extracts trajectory clusters that occur during varying weather conditions and derives metrics based off of the quantity and quality of these clusters. We study these clusters for Chicago O'Hare International Airport (ORD), and obtain insights into the spatially-varying robustness of ORD arrival resources in convective weather conditions. We found that the southern arrival airspace resources at ORD fared worse in convective weather, indicated by a higher prevalence of and population within anomalous clusters. Our airspace robustness metrics via trajectory density clustering allow for cross-airport comparisons of resiliency, enhancing the ability of airport operators to learn and adapt traffic management strategies utilized at peer airports with similar airfield and airspace attributes.

Comparing Scheduled Block Time Setting in Europe and China Based on Multiple Linear Regression

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Abstract—Improving air transport system performance while not impeding and supporting traffic growth is a big challenge in civil aviation all over the world. Scheduled block time plays an important role in airline flight scheduling, which in return is a driver of capacity-demand-balance of air traffic management. In this context, a proper method of setting the scheduled block time is beneficial to air transport performance. In this study, the setting behavior was analyzed by comparing between China and Europe. A model based on multiple linear regression was developed and fitted separately with Chinese and European operational data. A hub airport analysis was carried out to support the fitting. The coefficients of the fitting results were compared and discussed according to the differences in ATM system characteristics between both regions. In general, the fitted model explains the schedule block time setting well with R^2 of above 0.8 for both regions, however significant differences exist for the different coefficients.

In Search of the Upper Limit to Air Traffic Control Communication

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Abstract— Communication between pilots and controllers plays an important role in the Air Traffic Control (ATC) process. There have been many studies on the ATC communication analysis but rarely on the suppression of voice activity. A censored regression model with a stochastic right-censored threshold is developed to estimate the relationship between ATC communication voice activities and the ATC operational environment through a wide and representative set of real operational ATC voice recordings. The model estimation result shows that flight operational volume, lead flight operations, time of day, meteorological conditions, visibilities, wind conditions, anomalous flight operations and runway configurations are good indicators of the ATC communication. Lastly, we use the estimated model to simulate the loss percentage of ATC communication. This study has profound implications on further understanding of ATC system capacity, aviation safety and human performance interfacing ATC.

CAMDA: Capacity Assessment Method for Decentralized Air Traffic Control

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Abstract—This paper presents a semi-empirical method to determine the maximum theoretical capacity of decentralized airspace concepts. The method considered here, named Capacity Assessment Method for Decentralized ATC (CAMDA), formalizes an earlier approach described in literature, extends it for three-dimensional airspace, and also improves the accuracy of the underlying models. CAMDA defines capacity as the traffic density at which conflict chain reactions propagate uncontrollably throughout the entire airspace. CAMDA identifies this critical density using a semi-empirical approach whereby models describing the actions of decentralized conflict detection and resolution algorithms are combined with empirically obtained conflict count data. The CAMDA method is demonstrated in this work for a decentralized direct routing en-route airspace concept that utilizes a state-based conflict detection algorithm, and a voltage potential based conflict resolution algorithm. Three fast-time simulation experiments were performed to study how the capacity of this particular airspace design is affected by: a) conflict detection parameters; b) conflict resolution dimension; and c) the speed distribution of aircraft. The results showed that CAMDA estimated the occurrence of conflict chain reactions with high accuracy for all cases, enabling capacity estimations using relatively non-intensive low density traffic simulations. Therefore, CAMDA can be used to speed up the airspace design process by reducing the number of time consuming high-density traffic simulations that are required when performing a trade-off between different airspace designs, or when fine-tuning the parameters of the selected airspace design.

A Probabilistic Model for Precedence Rules and Reactionary Delay in Air Traffic Management

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Abstract—Flight delays in air traffic management (ATM) cause significant costs for airlines. Understanding how they propagate and mitigating them is then a key challenge in ATM. Propagation of delays in the network of flights is generated and amplified for different reasons. Typically, a single aircraft operates several flights per day and its delay may be propagated downstream to successive flights. In addition, aircraft may need to wait for other aircraft to land before taking-off, if, e.g., the crew is on the in-bound flight. Such delays are often referred to as reactionary delays. This paper presents a stochastic model for reactionary delays and methods to evaluate their probabilistic distribution. The network of flights is represented as a graph whose nodes are all the scheduled flights and the edges are the interactions among the flights. We propose a framework based on the max-plus algebra and two computational algorithms to compute the reactionary delays, which are tested on a large sample of European traffic data. The effects of reactionary delays on sectors occupancies are then discussed.

Measuring the Benefits of NextGen Metroplex in Convective Weather: Case Study of North Texas Metroplex

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Abstract—A key component of the goals of the Next Generation Air Transportation System (NextGen) is to safely improve the efficiency of the National Airspace System (NAS) by enhancing inefficiency in metroplexes. Based on the use of precise satellitebased navigation, Time Based Flow Management (TBFM), and other advanced techniques and tools, the benefits of a metroplex have been identified through research, indicating that it is capable of making airspace more efficient with less queueing delay and more throughput. However, those studies focused only on operations in normal weather conditions; special weather conditions such as convection were not considered. This study investigated the quantitative impacts of a metroplex under representative operation conditions in convection. Investigations included identification of representative convective weather conditions, analysis of historical radar tracking data in a postmetroplex period, development of queuing system-based models of Terminal Radar Approach Control (TRACON) facility arrival operations with and without metroplex for the North Texas Metroplex, and simulations to evaluate airspace performance in terms of TRACON throughput and arrival delays. Simulation analyses showed an average 27% increase in TRACON throughput at a peak of 15 minutes, as well as 2.39 minutes saved per arrival flight at Dallas/Fort Worth International (DFW) and 1.65 minutes saved per arrival flight at and Dallas Love Field (DAL) when a metroplex is implemented in heavy demand. The increase in TRACON throughput and arrival time saved by a metroplex climbs as traffic grows; however, the increase reaches a limit when the amount of traffic reaches a certain point.

Track 3

Fuel and Emissions

Estimation of Aircraft Fuel Consumption Based on Air Traffic 4D Trajectory Data

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Abstract—Objective and numerical estimation of fuel burn is a critical technology to evaluate the efficiency of air traffic operations. In this paper, the models are constructed to calculate aircraft performance parameters based on 4D flight trajectories. We developed software within Visual Studio C# environment to compute fuel consumption data on the basis of recorded Radar track data. By comparing with QAR data, it is found that the error of the models constructed is no more than 5%. The models and software proposed in this paper are used to estimate and analyze the aircraft fuel consumption in different latitude and longitudinal grids, in different time periods and at different altitudes. They can also be applied to evaluate the efficiency of different air traffic control groups or the performance of individual controller. Based on the evaluation results, controllers can improve their control decision to ensure flight safety and improve airspace capability. The research results can be used to quantify and analyze the impact of new technologies and air traffic controllers' skill differences on Civil Aviation energy saving and emission reduction.

Estimating fuel consumption from radar tracks

A validation exercise using FDR data from descent trajectories

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Abstract—Fuel consumption is one of the major considerations for both the impact of aviation in the environment and the cost of operations. This paper assesses the accuracy of a method capable of producing aircraft fuel estimates based on their 4D trajectory and the weather forecast. Fuel consumption estimates generated for 2448 descents are compared with the flight data recorder (FDR) values provided by the airline. Fuel consumption is estimated by taking the 4D trajectory from two different sources: the FDR system itself and surveillance radar tracks. In both cases, the Base of Aircraft Data (BADA) and a model that fits manufacturers' performance data to polynomial functions are used to represent aircraft performance. Results obtained with the later show that fuel usage could be estimated with an accuracy of 16 kg (4.8%) by using the 4D trajectory as reported by the FDR system and 28 kg (7.8%) by using surveillance radar observations. It is also observed that the BADA 3.6 model underestimates the fuel consumption, illustrating the need for an improved performance model in the terminal manoeuvring area.

Quantification of WAFS weather forecast uncertainties and its effect on fuel burn using historical flight data

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Abstract—Weather conditions directly influence flight operations. Although daily weather forecast data has been employed when forming optimal flight trajectory and fuel requirements, no forecast is without error. In this regard, studies that sought to improve our understanding of weather uncertainties and their effect on trajectory and fuel burn prediction have shined a spotlight on future air traffic control, flight planning and fuel-saving strategies. Though such studies are not new, their findings are often difficult to apply to real-world airline operations. Most of these studies do not consider the fact that airlines, in practice, use lower resolution weather forecasts that are distributed from the World Area Forecast System (WAFS). In this paper, we introduce several data handling techniques to understand the cause of WAFS weather forecast error and quantify its effect on the predictions of cruise stage fuel burn. Using historical data, we merged the second-by-second recorded flight data with the corresponding WAFS weather forecast; we also calculated the deviation of different forecasted weather parameters to the realized weather conditions. Fuel flow deviations and overall cruise stage fuel burn deviations due to weather uncertainties were then modeled using the fuel consumption model. In summary, our analysis found that weather forecast errors increase with time elapsed from departure; we also found that weather forecast errors are route-specific. High variance in wind direction forecast error is found at low-latitude of the trans-Pacific routes and at high-latitude of the southern-hemispheric routes. Furthermore, an overestimation in forecast temperature is found in two southern-hemispheric routes. Based on the comparison between the performance under the forecasted weather and actual weather, the southern-hemispheric routes tend to overestimate fuel consumption with a median of up to 223 kg. An underestimation in temperature along with an underprediction in cruise stage fuel consumption with a median up to 202 kg is found for trans-Pacific and Asia-pacific routes.

Verification of the ozone algorithmic climate change functions for predicting the short-term NOx effects from aviation en-route

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Abstract—For the first time, the algorithmic Climate Change Functions (aCCFs) for ozone, methane, water vapor, and persistent contrails have been developed within the ATM4E project to provide information on the climate sensitive regions, which can be conveniently implemented for the climate based flight routing. These aCCFs need to be verified before they are implemented. In this paper, we focus on the verification of the ozone aCCFs to enable the prediction of the short-term NOx effects from aviation en-route. The verification is conducted from two aspects. Firstly, the climatology of the ozone aCCFs is calculated based on a one-year simulation and verified by the existing literature. Secondly, the effectiveness of the ozone aCCFs for optimizing aircraft trajectories concerning the climate impact is verified by the comprehensive climate-chemistry model calculation. The analysis proofs the concept of using the aCCFs as an advanced MET-service for the climate based flight routing.

Fuel and Emission Benefits for Continuous Descent Approaches at Schiphol

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Abstract—This paper presents an analysis of the potential fuel and emission benefits of implementing Continuous Descent Operations at Schiphol International Airport, from cruise altitude to the final approach fix, for a large scope of aircraft types. Using historical data from on-board sources and ADS-B, fuel-optimal continuous descents are simulated using the total-energy model. By comparing the fuel consumption between historical flights and the simulated continuous descent flights, fuel benefits are found. CO2 emissions are then calculated linearly from the fuel benefits. The results show average savings of 92kg up to 500 kg of fuel per flight. For Schiphol, this results in a total of 39 million kg of fuel savings per, year leading to more than 123 thousand tonnes of CO2 savings per year.

Research on Civil Aircraft Fuel Consumption in Cruise Phase Based on Least Square Support Vector Regression with Genetic Algorithm

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Abstract- Precise fuel consumption forecasting for civil aircraft is an important means to improve airline economic efficiency. The whole flight path includes several stages, and for each stage, the influential factors of fuel consumption are different. This paper focuses on the fuel consumption prediction in the cruise phase. Least square support vector regression (LSSVR) with parameters optimized by genetic algorithm (GA) is proposed to forecast fuel consumption. Aircraft initial performance and flight data are analyzed to determine the influence factors. The LSSVR model is then established to forecast fuel consumption with the identified factors as input and fuel flow as output and GA is used to optimize the LSSVR parameters. The model is trained and tested using 30 flight datasets for an airline's B737-800. Model performance is compared with standard SVR and three layer back propagation neural network models. Results show the proposed method has superior forecasting performance and greater impact on fuel consumption.

Track 4

Trajectory Optimization

Trajectory Optimization in Daily Operations

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Abstract— This study embeds multi-criteria optimized trajectories in today's procedures of flight planning, preparations and operations. Therefore, European air traffic procedures are substantiated by a review of today's regulative provisions and possibilities of intended deviations from filed flight plans initiated by both Air Traffic Control and flight crew. As a reference for future flight planning, we modeled and described multi-criteria optimized trajectories. Thereupon, we developed an efficient and reliable algorithm for the adaption of waypoint-less optimized trajectories within the current navaid infrastructure. This method aims at increasing airline efficiency in daily operations. For validation purposes an actual flight plan has been calculated by using the commercial flight planning tool JetPlan.com by Jeppesen. The commercial flight plan is compared to our adapted trajectories. The comparison allows for the quantification of the benefits of our adapted flight paths against the restrictions of today's flight planning. Here we used a performance metric, considering distance flown, time of flight and fuel burn.

Integrated Optimization of Arrival, Departure, and Surface Operations

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Abstract—Airports and surrounding airspaces are limited in terms of capacity and represent the major bottleneck in the air traffic management system. This paper proposes a twolevel model to tackle the integrated optimization problem of arrival, departure, and surface operations. The macroscopic level considers the terminal airspace management for arrivals and departures and airport capacity management, while the microscopic level optimizes surface operations and departure runway scheduling. An adapted simulated annealing heuristic combined with a time decomposition approach is proposed to solve the corresponding problem. Computational experiments performed on real-world case studies of Paris Charles De-Gaulle airport, show the benefits of this integrated approach.

A Fast and Flexible Aircraft Trajectory Predictor and Optimiser for ATM Research Applications

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Abstract—Trajectory prediction and optimisation algorithms will be the keystone for a successful trajectory based operations concept implementation, where accurate predictions and optimal trajectories will be needed for a wide variety of look-ahead times and operational contexts. The main goal of this paper is to present the architecture and capabilities of an aircraft trajectory prediction and optimisation framework suitable for various air traffic management research applications. The flexibility of this framework, called DYNAMO, allows for an easy implementation and assessment of actual and future concepts of operation, considering at the same time realistic weather data and aircraft performance models. In addition, its design enables the use for real-time applications and when a large set of trajectories needs to be rapidly generated for simulation and benchmarking purposes. The performance of the framework is demonstrated by means of different illustrative examples.

Dynamically Optimized Aircraft Trajectories Affecting the Air Traffic Management

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Abstract— The increasing demand for efficient and environmentally sustainable flight profiles and dynamically changing input parameters require innovative operational concepts, such as short-term trajectory adaptions. According to current air traffic regulations (e.g., ICAO Doc 4444 - PANSATM), flight trajectories are planned ground-based and submitted to Air Navigation Service Providers for an overall validation according to airspace and sector capacity limits. Today, the initial flight plan often relies on single atmospheric forecasts for the entire flight and is adapted only in cases of ATC advisories or severe weather phenomena. However, the most energy or costefficient flight profile relies on the quality of the forecast, which should reflect sudden changes of atmospheric parameters such as wind. This paper investigates the benefit of frequent updates of weather forecasts and the recalculation of optimized trajectories while the aircraft is en route. For varying shares of flights equipped with this novel capability, the potential of dynamic optimization during flight is assessed. The metrics used are fuel consumption, emissions and controller task load for safety reasons. For the European air traffic system, it was found that for only 75 % of the observed cases, this frequent trajectory optimization led to overall fuel savings with an increased task load of 5.4 %. Although the results do not confirm the concept without limitations, it should be emphasized that the savings depend on the quality of the weather data and the capability to consider trends over several hours. Therewith, the in-flight trajectory adaption would result in short-term fuel savings with manageable controller's effort.

Aggregate Multi-commodity Stochastic Models for Collaborative Trajectory Options Program (CTOP)

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Abstract—Collaborative Trajectory Options Programs (CTOP) is a Traffic Management Initiative (TMI) which controls the air traffic flow rates into Flow Constrained Areas (FCAs). CTOP can handle multiple FCAs within a single program, and allows flight operators to submit a set of desired reroute options (called a Trajectory Options Set or TOS) to express their conditional preference for different route choices for each flight. One of the core research questions in CTOP is FCA Planned Acceptance Rates (PARs) optimization under uncertainty. We will first discuss some characteristics of CTOP rate optimization, including the multi-commodity flow nature of the problem caused by multiple constrained resources, TOS-induced demand variability, and the concept of Rate Computation Loop (RCL). In this paper, we are focused on multi-resource rate planning given route assignment for each flight. Three novel aggregate multi-commodity stochastic programming models are proposed: a two-stage static model, in which the ground delays are assigned at the beginning of the planning horizon; a semi-dynamic model, in which the ground delays are assigned at flights' scheduled departure times to take advantage of the latest capacity and scenario tree structure information and a dynamic model, in which a flight can be ground-delayed multiple times by exploiting not only scenario tree structure but also flights' en route time information. The performance of these three models is tested on a realistic CTOP use case. The results are very promising in terms of system delay costs reduced and computational efficiency. These three models are not limited to be used in CTOP, but can be applied to solve the general multiple constrained airspace resource optimization problem as well.

Operational validation of the OPTAIN-SA Tool

Supporting optimized profile descent approach sequencing into Palma TMA

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Abstract— Air Navigation Service Providers (ANSPs) around the world as well as International Programmes are facing the conflict between increasing pressures from the general public to reduce the environmental impact while allowing for steady growth in traffic volume. In order to offer a solution to this dilemma a Spanish initiative started a study whose objectives were the development of a methodology, design and validation of optimised descent procedures(OPD) and Air Traffic Controller's (ATCo) supporting tool into Palma's Terminal Manoeuvring Area (TMA). This paper contains the main results of the operational validation performed on an the ATCo tool called OPTAIN-SA, which was developed ad-hoc during the initiative to support the efficient introduction of OPD procedures. Likewise, it covers the subjacent operational concept as well as live flight trial exercises. The tool supports ATCo on their daily tasks promulgating the use of CDOs (Continuous Descent Operations) in particular Optimised Descent Operations (OPD) as an environmental short term solution; while requiring no substantial upgrade to the ground systems and any to the on-board avionics. The ATCo tool showed good potentials for the introduction of OPDs in PMI. ATCo feedback and sequencing results underscored the benefits to the Controller while highlighting the operational lines of improvement. Two consecutive projects provide the core information to the paper and are evidence of the validation cycle performed: the OPTA (Optimised Profile Descent Approaches) project and the OPTA-IN (OPTA – Implementing Windows).

Predicting Aircraft Trajectory Choice – A Nominal Route Approach

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Abstract — In this work, we propose a novel approach to predict aircraft trajectory choice. A trajectory clustering technique is used to consolidate historical flight tracks into a small set, and the cluster assignment results are then used as the ground truth of the route choice. Three types of features are used to predict the trajectory choice: convective weather, wind, and Miles-In-Trail (MIT) restrictions. Dimension of the features is greatly reduced by matching them with the representative trajectories of different clusters, which we call Nominal Routes. Four popular machine learning models are explored and compared: logistic regression, support vector machine, random forest, and gradient boosting. We apply our methods to five airport pairs: IAH to BOS, BOS to IAH, FLL to JFK, JFK to FLL, and LAX to SEA. The random forest approach has the best performance for all pairs except IAH to BOS, where gradient boosting has slightly better performance. Based on the best models, we rank the importance of features for different airport pairs. Results vary, but in general, wind has the largest effect, followed by thunderstorm, rain, and MIT.

Track 5

Advanced Modeling

Object Tracking in Images of an Airborne Wide Angle FMCW Radar

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Abstract—Object tracking is performed when surveillance applications have multiple observations of an object over time. An example of such a surveillance application is mounting a wideangle Frequency Modulated Continuous Wave (FMCW) radar system on board of a General Aviation aircraft. This is done in order to observe its environment in detail, including noncooperative objects such as birds and windmills. Data generated by such a system follows different physical laws than the images of standard visual applications. In this paper, a novel tracking algorithm is introduced which is tailor-made for FMCW applications. The algorithm is tested in a simulated crowded general aviation airspace, and the resulting tracks are qualitatively and quantitatively analysed. The proposed algorithm performs better than a traditional algorithm on all aspects, but tracking errors can still be made in rare cases. The proposed algorithm can be used in conjunction with research focusing on observation quality or assignment problems.

Performance Analysis of a LiDAR System for Comprehensive Airport Ground Surveillance under Varying Weather and Lighting Conditions

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Abstract—Low visibility conditions and darkness regularly give rise to capacity backlogs, incidents and accidents linked to airport ground operations. Hence the availability of data capturing the local traffic situation and the operating conditions on the movement area is essential for today's airport surveillance system and for a more automated airport surveillance in the future. Technologically, LiDAR sensors and computer vision algorithms for object recognition have made considerable progress in recent years that when combined, offer a cost-effective, non-cooperative sensor solution to overcome the described deficiencies. LiDAR sensing benefits from typically high pulse repetition rates at high pulse intensities with pulse frequencies reaching into petahertz range and from the resulting extraordinary precision and accuracy in millimeter range. We could thus already demonstrate LiDAR's capability of detecting small, unknown static objects of a few cm^2 and simultaneously classifying known objects on the airport apron at distances of up to several hundred meters from the sensor.

This paper proposes and experimentally investigates a probabilistic sensor model for LiDAR based object height measurements particularly focusing on the airport movement area. The model is deemed crucial for future decision support functions that aim to improve the situational awareness of the controller under challenging weather and lighting conditions by means of probabilistic information, e.g., about the presence of potentially threatening objects or about conflicting traffic. First, the paper establishes the distributions of height over ground measurements derived from the laser return signal of a LiDAR sensor under varying weather and lighting conditions, i.e., day/night, rain/clear. The object height over ground distributions reveal the differences of the sensor behavior under these conditions. Second, the paper specifies the object height measurements as an inference problem in a graphical model, where the output yields the conditional distribution over true object heights given the measured height, thereby providing a fully probabilistic output. It is shown that the integration of weather/lighting as a probabilistic variable into the sensor model greatly improves its predictive performance and hence the reliability of a future controller assistance function derived from probabilistic height over ground measurements.

Assessment of Air Traffic Control for Urban Air Mobility and Unmanned Systems

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Abstract— This paper assesses how the introduction of urban air mobility services and unmanned aircraft systems may challenge Air Traffic Control (ATC) in the United States and what opportunities exist to support these forthcoming operations. Four attributes unique to these emerging operations were identified that may challenge effective ATC. Each attribute concerned the scalability of current ATC systems to support a large number of new airspace users at low altitudes. Six potential operational limitations were identified that ATC may impose upon airspace users in an effort to manage increased traffic demand. The fundamental mechanisms that set the aircraft capacity of an airspace, considered to be a surrogate for ATC scalability, were determined. The influence of ATC system architecture, technologies, and operational factors on these mechanisms was diagramed. Finally, the ability of various new ATC approaches to support high density, low altitude operations were reviewed with respect to these mechanisms.

A Multi-Layer Artificial Neural Network Approach for Runway Configuration Prediction

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Abstract—Runway configuration selection is a complex decision making process which involves the interaction of several factors, many of them stochastic in nature. Runway configuration identifies the set of runways that can be used, under certain operating conditions, for a given time constraint. The runway configuration has a major influence on the runway operating efficiency and the overall capacity of the runway system. This paper proposes an adapted Multi-layer Artificial Neural Network (MANN) model to predict the runway configuration and assignment of the appropriate runway to flights that lead to maximum runway capacity. The proposed model is trained and tested on Amsterdam Schiphol airport data with 1789 arrival and departures spread over two days. Several factors, including weather and wind, were identified and incorporated in the training of the MANN. In this research, different classes of ANN technique i.e., feed-forward back-propagation, cascaded feedforward, distributed time delay back-propagation and recurrent backpropagation has been applied and evaluated for predicting runway configuration. The validation and testing of the model are carried on with a subset of data using cross-validation and Mean Square Error to evaluate runway configuration prediction. The hourly throughput of each configuration is projected from the runway configuration capacity envelope of the Schiphol airport. Results demonstrate the viability and benefits of machine learning approach for predicting runway configuration in an operational environment.

Formal Modeling of Air Traffic as System-of-Systems

Air Traffic as Systems of Interdependent Operational Decision Making Processes

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Abstract—The aviation system is comprised of many heterogeneous systems like airports, aircraft, airlines and ANSPs each working towards the common goal of enabling flight operations. Cooperation between them is required to improve on operational efficiency. However, stakeholders have conflicting objectives so that a method of mediation is needed to find compromises which enable benefits for the overall aviation system. Modeling diverse entities with their relations and interdependencies to each other is difficult as specific domain knowledge is required and interaction mechanisms between them need to be unified. This paper introduces a modeling methodology in the context of the System-of-Systems (SoS) concept. We demonstrate how to create a formal model of interdependent systems around the core concept of solvers which generate workable solutions of operational decision making problems and centralize input-output relationships between systems. This enables analysis of interdependencies and introduction of new solvers which integrate local decision problems and enable cooperation of conflicting systems. Our contribution allows to model and implement future cooperative decision making systems in aviation viewed as a SoS.

Aircraft Mass and Thrust Estimation Using Recursive Bayesian Method

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Abstract—This paper focuses on estimating aircraft mass and thrust setting using a recursive Bayesian method called particle filtering. The method is based on a nonlinear state-space system derived from aircraft point-mass performance models. Using solely ADS-B and Mode-S data, flight states such as position, velocity, and wind speed are collected and used for the estimation. An important aspect of particle filtering is noise modeling. Four noise models are proposed in this paper based on the native ADS-B Navigation Accuracy Category (NAC) parameters. Simulations, experiments, and validation, based on a number of flights are carried out to test the theory. As a result, convergence of the estimation can usually be obtained within 30 seconds for any climbing flight. The method proposed in this paper not only provides final estimates, but also defines the limits of noise above which estimation of mass and thrust becomes impossible. When validated with a dataset consisting of the measured true mass and thrust of 50 Cessna Citation II flights, the stochastic recursive Bayesian approach proposed in this paper yields a mean absolute error of 4.6%.

Prediction of passenger boarding progress using neural network approach

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Abstract—Reliable and predictable ground operations are essential for 4D aircraft trajectories. Uncertainties in the airborne phase have significantly less impact on flight punctuality than deviations in aircraft ground operations. The ground trajectory of an aircraft primarily consists of the handling processes at the stand, defined as the aircraft turnaround, which are mainly controlled by operational experts. Only the aircraft boarding, which is on the critical path of the turnaround, is driven by the passengers' experience and willingness or ability to follow the proposed procedures. We developed a complexity metric for the real-time evaluation of the boarding progress and a machine learning approach to real-time predict the boarding time. The complexity metric is used as an input for a recurrent neural network approach, which aims on the prediction of discrete time series and inherently considers interdependencies between input values. In particular. we use a Long Short-Term Memory model to learn the dynamical behavior over time with regards to the given boarding indicators.

Track 6

Safety

Potential Safety Occurrences as Indicators of Air Traffic Management Safety Performances

A Network Based Simulation Model

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Abstract—This paper presents a Network Based Simulation Model developed with objective to assess new safety performance indicators of future air traffic management system within APACHE project (a SESAR Exploratory Research project). This model presents a part of APACHE System – a platform consisting of simulation, optimization and performance assessment tools. Developed model contains three modules: separation violation detection module, TCAS activation module and risk of conflict assessment module. Developed model was tested on 24 hour planned flights crossing the French airspace covering three test cases. It shows capabilities to calculate certain safety performance indicators and to provide valuable safety feedback to traffic and airspace planners.

Quantitative Assessments of Runway Excursion Precursors using Mode S data

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Abstract— A way to assess rare aircraft incidents (e.g., runway excursion) is to identify contributing factors (e.g., late braking, long landing, inappropriate flare, unstable approach) and to build a dependency tree (e.g., long landing may be the result of an unstable approach not followed by a go around) that describes the causality between these factors. Probabilities are then fed into such models in order to evaluate the assessed risk. When estimating such probabilities, many sources can be of interest. Airlines have access to the comprehensive flight data records of their fleet; manufacturers push to collect data for the aircraft they build; air traffic control log radar tracks. Albeit not as complete as other flight data records, Mode S data is very attractive, esp. for academics, as the data is open, may be published without obfuscation and offers reproducible results to the community. Mode S also provides an indiscriminate source of information (not limited to an airline or to an aircraft type) that is of great help for putting in context flights matching unusual patterns. We propose to discuss the advantages and limitations of an analysis based only on Mode S data with a case study around the runway excursion risk assessment.

Using Agent-Based Modeling to Determine Collision Risk in Complex TMA Environments

The Turn-Onto-ILS-Final Safety Case

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Abstract—In this paper we present an agent-based concept to assess aircraft collision risk (CR) for modern instrument flight procedures, focusing on the intermediate and final approach. The air-craft's, ATC and CNS systems' behavior are modelled as agents—acting stochastically by means of a Monte-Carlo simulation engine—to represent a statistically realistic environment. We first draw an overall picture of current CR estimation techniques focusing on blundering aircraft as a major hazard during approach. Then we present the ANP-based CR calculation and the agent-based simulation of nominal trajectories in detail, covering virtu-ally all other hazards. By applying the model to various approach traffic configurations, we could demonstrate the potential for de-tailed insight into CR drivers. Therefore, various acceleration techniques were evaluated (mathematical parameter reduction, parallelization, sampling heuristics). We could improve the implementation so as to apply the model to the 'classic' safety case of blundering during parallel ILS approaches as defined by ICAO SOIR and the 'novel' safety case of turning onto the final approach track from radar vectors at reasonable computing times. The results indicate that 'classic' CR values are reproducible from published assumptions and that only a few, well-justifiable and thus verifiable model extensions are required to successfully assess 'novel' safety cases. As such, the presented model may revive CR considerations for modern procedure design in complex TMA environments.

Probabilistic Aircraft Conflict Detection in the Terminal Maneuvering Area

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Abstract—Understanding and managing weather uncertainty is a necessity that the future Air Traffic Management system must address to increase its capacity, efficiency and safety levels. In this paper, a methodology to tackle the problem of aircraft conflict detection in the terminal maneuvering area of an airport considering wind uncertainty is presented. The wind components are modelled as random processes, characterized by a nominal and a stochastic term. The problem of two aircraft following three-dimensional multi-segment converging trajectories in the same airspace is considered. The conflict is characterized by two indicators: the distance of closest approach between the aircraft, and the conflict probability. The statistical characterization of these conflict indicators is obtained using the Probabilistic Transformation Method. Numerical results are presented for a particular conflict scenario and an uncertain vertical wind profile, obtained from a high resolution numerical weather prediction model. The results are compared with those obtained with the Monte Carlo method.

Sensitivity Analysis of Closest Point of Approach

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Abstract—The increase of air traffic demand leads to a higher risk of collision. In the process of ensuring the safety of air traffic, Closest Point of Approach (CPA) plays an important role in estimating potential dangers. Sensitivity analysis of CPA provides related information about the influences from different aircraft parameters to CPA. The parameters such as speed of aircraft, flight direction and relative position of aircraft are used as inputs, the closest distance between two aircraft and the time from the first observation to CPA are considered to be the outputs. The main idea presented in this paper includes the establishment of the model and the selection of sensitivity analysis method. The proposed model contains all possible encounter scenarios of two aircraft and can establish the relations between dependent and independent variables simply. The objective of sensitivity analysis is to detect the influential effects from the inputs to the outputs based on the model. Thus two methods are considered in this paper: Local approach uses the partial derivative corresponding to a specific point with respect to a certain input to determine the sensitivity. This method is limited by explaining one situation each time. Variance-based method which is under a probabilistic framework bases on random numerical sampling generates numerical results to determine the global influential effects with certain assumptions. The sensitivity analysis will benefit air traffic management controllers by offering auxiliary strategies while a dangerous situation occurs.

Efficient Conflict Detection for Conflict Resolution

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Abstract—Accurate tools to detect and solve conflicts are becoming necessary to assist air traffic controllers in their task. Air traffic controllers will eventually rely on tools to test and choose alternative trajectories. Enabling such tools demands a near real-time conflict detection algorithm.

A previous publication ([1]) proposed optimization methods to perform conflict resolution in real time on moderate size problems. However, this previous publication only considered the time to solve the associated combinatorial optimization problem. It did not take into account the time to compute the conflicts between the alternative trajectories. This time can be high in the scenarios envisioned in [1]. For each aircraft, 161 alternative trajectories were considered. Detecting all the conflicts required to compare 2,721,705 pairs of trajectories for a 15 aircraft scenario and 128,308,950 pairs for a 100 aircraft scenario.

The conflict detection procedure uses predicted trajectories which are inherently entangled with uncertainties. A seamlessly way to handle these uncertainties is to bound the future positions in a sequence of volume. This is how the uncertainties are modeled in the scenarios. However, this uncertainty model makes the conflict computation more time consuming.

In this paper we propose a Graphics Processing Unit (GPU) implementation of a conflict detection algorithm. Compared with a CPU implementation, the proposed algorithm reduces the computation time by two orders of magnitude. The 15 aircraft scenarios, as described in [1], are computed in 30 ms and the 100 aircraft scenarios are computed in 1 s.

An Introduction to Fast Time Simulations for RPAS Collision Avoidance System Evaluation

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Abstract—Collision avoidance systems are crucial for RPAS integration, yet comparing their performances remain difficult. We believe that using fast time simulations and standard evaluation metrics would facilitate their comparison while providing insight into their benefits. However, fast time simulations are often viewed as hard to set up and limited to large scale demonstrations. We believe even small experiments can take advantage of them with huge benefits. The aim of this work is to ease access to fast time simulations by providing explanations, examples and references to previous works and to free software. We also list commonly used evaluation metrics for collision avoidance system performance ranking. By easing the setup of fast time simulation experiments, we believe future works will be able to provide their results in a more detailed and comparable form.

Analyzing the Effect of Traffic Scenario Properties on Conflict Count Models

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Abstract—Decentralized en-route airspace concepts have been proposed by many studies to increase airspace safety and capacity. Most of these studies, including our own forays into this domain, have used fast-time simulation experiments to explore the benefits offered by decentralization. While simulations are indispensable during the initial design phase of any new airspace concept, the understanding gained using this approach can be difficult to generalize beyond the tested conditions. To address this issue, some researchers have presented analytical conflict count models to quantitatively analyze the effect of physical factors, such as traffic separation requirements, on the intrinsic safety of decentralized airspace concepts. However, the derivation of these models often make use of idealized assumptions regarding the behavior of traffic that do not always reflect realistic operations. To this end, this paper investigates the effect of these assumptions on the accuracy of the analytical conflict count models using targeted fast-time simulations of a direct-routing unstructured en-route airspace concept for a number of more realistic traffic patterns. The data collected from these simulations is also used to test so called 'model adjustments' that aim to relax the dependency of the models on the idealized traffic scenario assumptions. The results show that the assumptions do affect the accuracy of the analytical models, with some assumptions leading to a substantial under-estimation of conflicts. The results also show that the model adjustments increased accuracy for the more realistic scenarios to the levels previously found for the ideal traffic settings for all cases. Therefore, in addition to providing a physical understanding of the factors that affect airspace safety, the adjusted models can also be used as tools for practical airspace design applications.

Track 7

Complexity and Information

Predicting sector configuration transitions with auto-encoder-based anomaly detection

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Abstract—One of the key challenges of airspace configuration is to ensure “smooth” transitions between consecutive sector configurations, optimized at each time period. Optimization models therefore need to assess the appropriate transition cost from one configuration to another. The aim of the research presented in this paper is to develop a machine learning algorithm, trained with historical data of realized sector configuration transitions, to evaluate this cost. An anomaly detection model is used to quantify the abnormality of sector configuration transitions based on the reconstruction error of an autoencoder (or Replicator Neural Network). Results obtained on a French Area Control Center (Bordeaux) show that the model is able to predict promising transitions never realized in the past and poor transitions very unlikely to happen.

Geovectoring: Reducing Traffic Complexity to Increase the Capacity of UAV airspace

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Abstract—Both U-space in Europe, as well as UTM in the USA, develop concepts and tools for UAV airspace. Enabling high-density operations is one of the goals of these studies. Past and recent studies have analysed which factors affect the capacity of a UAV airspace. An improved understanding of this can lead to control methods for capacity management. Two general principles for capacity management can be distinguished: controlling the traffic density, and controlling the traffic complexity. The first approach can be achieved using geofencing or geocaging, which is foreseen for UAV airspace. The second approach is hardly addressed in the planned concepts. In this paper a new, general concept, called geovectoring, is proposed which could increase the capacity by reducing the traffic complexity for U-Space and UTM. This paper therefore proposes to add geovectoring as a third service to the already planned concepts of geofencing and geocaging.

Relative Trajectory Cost Estimation for CTOP Applications Using Multivariate Nonparametric Finite Mixture Logit

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Abstract—We study airline decision making in response to the Federal Aviation Administration's Airspace Flow Program (AFP) in order to empirically describe policy-relevant behavioral strategies and preference structure of air carriers. Using observed responses made by airlines we infer utility functions of different route options in AFP with respect to flight time and arrival delay using a finite mixture latent class choice model. We empirically describe the trade-off that airlines face between flight time and departure or arrival delay. We identify three distinct classes of flights that differ by their response to AFP. The results are applicable to future Traffic Flow Management programs, such as Collaborative Trajectory Options Program(CTOP).

Track 8

Unmanned Aerial Systems

Autonomous On-Demand Free Flight Operations in Urban Air Mobility using Monte Carlo Tree Search

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Abstract—Vertical takeoff and landing (VTOL) aircraft for personal air transportation or on-demand air taxi will bring fundamental changes to city infrastructures and daily commutes. NASA, Uber, and Airbus have been exploring the exciting concept of Urban Air Mobility (UAM). In order to enable safe and efficient autonomous on-demand free flight operations in this UAM concept, a computational guidance algorithm was designed and analyzed with collision avoidance capability. The approach is to formulate this problem as a Markov Decision Process and solve it using an online algorithm called Monte Carlo Tree Search. For the sake of illustration, a simplified numerical experiment was created to test the performance of this algorithm. Results show that this algorithm can help aircraft quickly reach the trip destination and avoid conflicts with other aircraft.

Autonomous Aircraft Sequencing and Separation with Hierarchical Deep Reinforcement Learning

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Abstract—With the increasing air traffic density and complexity in traditional controlled airspace, and the envisioned large volume vertical takeoff and landing (VTOL) operations in low altitude airspace for personal air mobility or on-demand air taxi, an autonomous air traffic control system (a fully automated airspace) is needed as the ultimate solution to handle dense, complex and dynamic air traffic in the future. In this work, we design and build an artificial intelligence (AI) agent to perform air traffic control sequencing and separation. The approach is to formulate this problem as a reinforcement learning model and solve it using the hierarchical deep reinforcement learning algorithms. For demonstration, the NASA Sector 33 app has been used as our simulator and learning environment for the agent. Results show that this AI agent can guide aircraft safely and efficiently through "Sector 33" and achieve required separation at the metering fix.

Dynamic Collision Avoidance using Local Cooperative Airplanes Decisions

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Abstract—Air Traffic Control (ATC) of the future will have to cope with a radical change in the structure of air transport [1]. Apart from the increase in the traffic that will push the system to its limits, the insertion of new aerial vehicles such as drones into the airspace with different flight performances will increase the heterogeneity level. Today's research works aim at increasing the level of automation and partial delegation of the control to onboard systems. In this work, we investigate the collision avoidance management problem using a decentralized distributed approach. We propose an autonomous and generic multi-agent system to address this complex problem. We validate our system using state of the art benchmarks. The obtained results underline the adequacy of our local and cooperative approach to efficiently solve the studied problem.

Centralized and Distributed UTM in Layered Airspace

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Abstract—We investigate strategies for management of conflicts among autonomous unmanned aerial vehicles (UAVs) in high density very low level (VLL) uncontrolled airspace. We consider deconfliction procedures which do not involve horizontal maneuvers, and study two types of airspace structure: single- and multilayered airspace. We compare different deconfliction paradigms by simulating a busy day of operations over a geographical area. Our main contributions are proposal of new de-confliction schemes for UAVs and assessment of the single- and multi-layered airspace designs. Our work aims to provide regulators and policy-makers with a framework for choosing between resolution strategies for the airspace management.

Detect and Avoid Algorithm for UAS with 3D-Maneuvers

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Abstract—In this article, we extend the 2D-framework introduced in 2016 to implement a horizontal detect and avoid algorithm for UASs flying in Terminal Control Areas. First, we introduce a model able to detect conflicting trajectories in 3D and select combined horizontal and vertical maneuvers, taking the urgency of the conflict into account.

We use a large data set of recorded real commercial traffic trajectories to evaluate the ability of our improved algorithm to avoid any loss of separation with commercial airliners. We test two different types of UASs, flying at 80 kt or 160 kt, with six different missions: constant heading or turning and leveled, climbing or descending. We consider both heading change and vertical maneuver so that UASs have more freedom to avoid conflicts, but keep the speed constant as they mostly have poor speed-up performance.

The article investigates the influence of the various parameters on the separation achieved and the amount of maneuvers required, especially the strategy used to select the best maneuver among the allowed headings. The analysis of our results shows that, amid two “basic” and “extreme” strategies that respectively favor minimal heading and vertical changes or the expectation to escape the conflict, the combination of both, switching from the first one to the second whenever the time before the conflict falls under a given threshold, gives the best results with very few remaining close encounters, while keeping low the amount and amplitude of maneuvers.

Track 9

Network Management

Selecting Parameters in Performance-Based Ground Delay Program Planning

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Abstract—In this paper, we consider the problem of selecting a set of parameters for a Ground Delay Program so that the program achieves a vector of performance objectives that is similar to a target vector. This could be used to support consensus-based ground delay program planning. We propose a method that selects several potential candidates of vectors, and we compare our method with a simple greedy algorithm. Our results indicate that our proposed method is able to provide multiple solutions that are closer to the efficient frontier than the greedy solution.

New insights on non-linear delay causation network for passengers and flights in Europe

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Abstract—The analysis of the dynamics of delay propagation is a topic of major importance in air transportation. Delays are emergent phenomenon yielding from the interaction of several dimensions of the system (e.g. flights, passengers, crew, etc.). While the attention of the community has started to focus on the dynamic nature of their propagation, little attention has been devoted to the possible non-linear nature of these propagations. Here we differentiate the detection of linear and non-linear channels of propagation from flight and passenger data using two causality metrics respectively effective at linear and nonlinear couplings detection. We identify how non-linearity is highly present within passenger data, but almost absent within flight data – therefore suggesting that each dimension of the system affects differently the information contained in each type of data. We are confident that such approach opens the door to a new understanding of delay propagation dynamics.

Local TBS delay reduction effect on global network operations

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Abstract – A flight may be late departing or arriving from an airport because of the delays that occurred earlier on that day. From a small amount of initial delay, it can propagate and compromise on-time performance of the overall operations of the same aircraft. It can propagate on the next legs and compromise other flights as well which causes disruption in the network. A lot of research has been done in the area of flight delay propagation and many models were created to help airlines and operators reduce that very same effect.

The Time Based Separation (TBS) project has brought new methods for separation of arrivals by time instead of distance. It's a promising method for reducing flight delays. In this paper, by collecting flight records data from the Central Office for Delay Analysis in EUROCONTROL, we've observed a significant decrease in delays in case of strong headwinds, which proves the very point of TBS's effectiveness in optimizing runway throughput and network operations. The dataset consisted of around 60'000 flights at London Heathrow airport. By using that data, a few analyses are executed which show us the overall effect on the network.

A Collaborative Demand and Capacity Balancing Model under Trajectory Based Operations

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Abstract— This paper introduces a collaborative demand and capacity balancing (CDCB) model in the scope of full trajectory based operations. Firstly, a trajectory negotiation process is presented, aiming at generating, for particular flights, the alternative trajectories that are able to accurately avoid, in either lateral or vertical directions, the hotspots areas based on short term predicted information issued by the Network Manager. These alternative trajectories, along with different types of delay measures, are accordingly integrated in an optimization model to together manage the traffic flow under a set of static scheme of airspace capacities. Hence, the combination of options and distribution of delays are optimized with the objective of minimizing the total deviation with regard to airspace users' preferences. Results suggest that delays can be reduced remarkably once with alternative trajectory options included. Nevertheless, in compensation with the delay reduction, large number of flights are diverted, which in turn proves the necessity of producing accurate alternative trajectories with minimal extra costs.

Analysing the Decision-Rules for a Ground Delay Program: Mexican Airport Network

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Abstract— Mexico City airport is located close to the center of the city and is Mexico's busiest airport which is considered congested. One of the consequences of airport congestion are flight delays which in turn decrease costumer's satisfaction. Air traffic control has been using a ground delay program as a tool for alleviating the congestion problems, particularly in the most congested slots of the airport. This paper uses a model-based approach for analyzing the effectiveness of the ground delay program and rules. The results show that however the rules applied seem efficient, there is still room for improvement in order to make the traffic management more efficient.

Track 10

Economics and Policy

Predicting a Dramatic Contraction in the 10-Year Passenger Demand

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Abstract— A cornerstone of any airport master plan is an aviation demand forecast, the forecast of future airport activity. A decision to plan and expand a runway, which typically spans a period of 10 years from the planning to completion, predicates on the accuracy of the projected future passenger demand. Yet aviation demand forecasts are known to be inaccurate at best and biased at worst. In this research, I develop a data-driven procedure to help airport planners evaluate the uncertainty of a dramatic contraction in passenger demand in the next 10 years using publicly available aviation and US census data. I show that socioeconomic trend metrics can be good indicators of a dramatic contraction in passenger demand in the next 10 years. This insight carries a significant relevance to airport planners especially in their airport master planning and aviation demand forecasting processes for runway expansions, as it could help them reconsider unwise investment decisions.

Analyzing Door to Door Travel Times Through Mobile Phone Data

A Case Study of Spanish Airports

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Abstract— A strategic objective of the European transport policy is the so-called 4-hour door-to-door target, according to which, by 2050, 90% of travelers within Europe should be able to complete their journey, door-to-door, within 4 hours. However, information on door-to-door travel times is scarce and difficult to obtain, which make it difficult to assess the level of accomplishment of this ambitious target. In this paper we extract door-to-door travel times based on the analysis of opportunistically collected data generated by mobile phones. Anonymized mobile phone records are combined with data from the Google Maps Directions API to reconstruct the different legs of the trip and estimate the travel times for the door-to-kerb, kerb-to-gate, gate-to-gate, gate-to-kerb and kerb-to-door segments. These travel times have been extracted for different scenarios, all of them focusing on the Adolfo Suárez Madrid-Barajas airport, with the aim of exploring their influence on total door-to-door. Results show that the methodology presented is able to measure door-to-door travel times, and that these travel times measured are far from the 4 hour door-to-door target. We finish by outlining future research directions.

Doctoral Symposium

Chair: Seth Young

Ontology-Based Approach for Human Competency Gap Analysis in Air Traffic Management

A Case Study of Georgia

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Abstract— The Global Air Navigation Plan is a flexible global engineering approach that allows all States to advance their Air Navigation capacities based on their specific operational requirements. Aviation professionals have an essential role in the transition to, and successful implementation of the GANP.

The research work is focused on the creation of methodology for the partial automation of the comparison competences of Air Traffic Management (ATM) personal and synthesis of training courses and modules, using a formal, ontology-based approach as a tool to solve these problems. One of the problems in the implementation of the GANP is that, on the one hand, there are currently no unified requirements for all categories of ATM personnel, and on the other hand, the development of ATM technologies is far ahead of the pace of training of personnel of appropriate qualifications. This problem becomes even more noticeable in countries that have just started an active modernization of ATC systems and do not have enough experience in this field.

The paper describes the general methodological approach based on the education ontology modelling for human competency gap analysis in ATM and for gap analysis between the university curricula outcomes and the ATM requirements. The ontology of key personnel competencies issues for the design and integration of large-scale future ATM programmes is proposed.

Egg-shaped conflict envelopes with fuzzy logic for airspace collision risk modelling

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Abstract—Safety has always been an important factor in air traffic management. Consequently, an indicator called the Target Level of Safety (TLS) is commonly used as the benchmark to evaluate the safety performance of airspaces and operating procedures. To evaluate the TLS, collision risk models (CRMs) were developed to model traffic condition and its interaction with the airspace. Traditionally, CRMs use standard geometries such as cuboids or cylinders to model aircraft conflicts in the airspace. These standard geometries proved easy to handle in analyses.

In this paper, a non-standard 2D conflict envelope based on the collision cone geometry is proposed. The proposed envelope, which takes on the shape of an egg, gives priority to the forward region of the aircraft, less priority to the aft, and varying priority on the lateral sides of the aircraft. In addition, tilting of the envelope is also proposed for aircraft about to enter a turn.

Subsequently, a multi-valued modification is done on the boundary of the conflict envelope. The original Boolean logic in classifying an aircraft conflict is therefore extended into a Fuzzy logic classification known as the degree of conflict.

Finally, some similarities and differences between fuzziness and randomness are briefly discussed in the ATM context. Several aspects of future work are also presented.

A Study on the Mechanism and Prediction of Flight Delay with ADS-B Surveillance Data

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Abstract—Enhancing flight punctuality is a major topic in air transportation and draws attention of scholars all over the world. Learning the mechanism of flight delay helps stakeholders improving punctuality. This study is aimed at revealing delay propagation mechanism and achieve accurate delay prediction. Towards this target, 4-dimensional trajectory data is used in microcosmic delay behavior analysis, and a data-driven method for delay mechanism modeling is introduced. In the first place, flight delay is evaluated with multiple nodes in order to capture the process of delay development. Secondly, variation of air navigation service (ANS) resource allocation through the process of delay is analyzed, and delay propagation is modeled from this point of view. At last, delay prediction is carried out with machine learning method where delay propagation is considered as a prior information.

Terminal Airspace Anomaly Detection Using Temporal Logic Learning

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Abstract— Given the evolution of the National Airspace System (NAS), it has become more critical to effectively identify safety threats or emerging risks. In this paper, we propose an unsupervised anomaly detection algorithm to generate a model which can be applied in real time to detect terminal airspace anomalies. The algorithm is based on temporal logic learning, which provides formulas that are easy to be interpreted and hence facilitate human feedback for identifying only operationally significant anomalies. The proposed algorithm is demonstrated with airport surface surveillance data.

Conceptual Design of a Speed Command Algorithm for Airborne Spacing Interval Management

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Abstract— Airborne Spacing Interval Management is a sophisticated Air Traffic Management solution, that allows to minimize excessive spacing between aircraft, increase air traffic efficiency and runway utilization. In recent years a Flight-deck based Interval Management solution using a dedicated speed control algorithm has been developed and tested with favorable results but operational concerns remaining. In this conceptual design study an alternative speed command algorithm is introduced, aiming to further promote the usability and efficiency of Interval Management systems under operational aspects.

Detection of individual anomalous arrival trajectories within the terminal airspace using persistent homology

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Abstract— In-air holding and missed approach/go-around procedures are highly undesirable within the terminal airspace. Such operations are fuel inefficient and add to controller workload, reducing airspace efficiency and predictability. However, the detection of isolated anomalous trajectories within a large aviation data set is difficult through classical methods. We propose using tools from topological data analysis to identify such anomalous trajectories. Our methodology – cyclic trajectory detection via persistent homology – identifies individual trajectories of aircraft that executed in-air holding and missed approach/go-arounds through the qualitative shape of the data. We preliminarily deployed this method on a data set of arrivals to the Chicago O'Hare International Airport and found that in-air holding incidences were relatively weather-invariant but missed approach/go-arounds were more common in inclement weather, particularly during runway configuration changes. We introduce topological detection of cyclic trajectories to address the difficulties in identifying, characterizing, and ultimately mitigating anomalous airspace events.

E-service quality performance measurement in airlines: An application on scheduled airlines in Turkey

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Abstract— Today, the developments in information technologies deeply affect many sectors and have brought concepts such as ecommerce and e-service into our lives. Undoubtedly, the air transport sector is one of the sectors most affected by developments in information technologies. It is known that the distribution activities of airline companies have shifted to a large scale internet sales channel instead of travel agencies. In this sense, the concept of quality, also emerges as an important competitive tool in e-services. On the other hand, the fact that eservice has effects on customer satisfaction, word of mouth and business profitability makes e-service quality a subject to be researched. In this context, this study will focus on the quality of e-services offered in the airline industry, one of the sectors where e-services are mostly used. In this study, which is planned to use the Analytic Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) methods, the importance levels of the factors affecting the quality of e-service will be determined in the first stage with the help of expert opinions. In the second and final stage of the study, airline companies offering scheduled services in Turkey will be ranked according to their e-service quality performances by interviewing passengers at various airports with the help of the questionnaire method.

Increasing the Resilience of ATC systems against False Data Injection Attacks using DSL-based Testing

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Abstract—Within aircraft communication, due to the un-authentication and un-encryption of the Automatic Dependent Surveillance-Broadcast (ADS-B) protocol, eavesdropping and broadcasting fake ADS-B messages is straightforward. As a consequence, attackers can perform False Data Injection Attacks (FDIA) on the ADS-B system, such as ghost aircraft injection or flooding, leading to unexpected but potentially devastating consequences. To increase the resilience of Air Traffic Control (ATC) systems against such attacks, this paper presents a framework under development that aims to generate FDIA-based test scenarios, which can be used as test cases to evaluate and improve the robustness of ATC systems. This test generation framework uses a Domain Specific Language (DSL) to specify FDIA-based test strategies in order to falsify legitimate ADS-B recordings. Such generated altered ADS-B recordings are finally executed on ATC systems to evaluate its resilience against FDIA. The paper details this process and introduces early results and future work.

The airline brand personality in the context of neuromarketing: FSC versus LCC

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Abstract—The marketing approach, showing a cyclical development until today, has evolved into a value-oriented (marketing 3.0) approach that tries to understand the human mentally and emotionally after a number of changes over time. Changes in marketing approaches over time have begun to take humans as the focal point. For this reason, it has become important to determine human needs and the effects of emotions on people's buying behaviors. In this respect, it is thought that the application of neuromarketing techniques will help to reveal the real feelings and thoughts of the consumers in the studies to be done in order to determine airline consumer behaviors more accurately and consistently. In the context of this study, it is thought that the brand personality traits of airlines are compared by using both the survey technique and the Electroencephalography (EEG) analysis method. In the first stage of the study, 42 traits of brand personality developed by Aaker will be shown as slides and the responses will be measured by the EEG analysis method. In the second stage of the study, the same voluntary participants will be required to mark the brand personality traits of the airline by converting Aaker's brand personality scale into a survey. As a result of the research, findings obtained from both methods will be compared.

Assessing the airspace availability for sUAV operations in urban environments: A topological approach using keep-in and keep-out geofence

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Abstract— The anticipated proliferation of small Unmanned Aerial Vehicles (sUAVs) in urban areas has garnered greater interest in capacity estimation of the low-altitude airspace. In the urban airspace, an airspace that is not only free but also usable needs to identified as a first step to estimate its capacity. In this paper, we propose an airspace availability assessment framework that incorporates the underlying geospatial complexity as well as operational requirements. Specifically, we utilize two types of geofence - keep-out and keep-in. The keep-out geofence creates a boundary around a static object to keep sUAV out. The keep-in geofence defines a boundary for a vehicle to keep in. Three scenarios, keep-out, keep-in, and dual geofencing, were applied to the real 3-D environment of Seoul, South Korea. The results showed the unique capability to identify corridor segments as well as tradeoffs between the two types of geofence in a built-up environment. Both geofencing methods need to be considered in parallel in urban area, and the decision on the geofence parameters should be based on the geospatial complexity and flight purposes, rather than relying on fixed values. The proposed framework is not only capable of evaluating airspace availability in an adaptive and intelligent manner, but also has the potential to be applied to the urban airspace and route design.

Flight Data Handling with Augmented Reality

From a display system to an interactive operating system for Aerodrome Control Towers

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Abstract—This paper presents the results of an exploratory concept study conducted with four aerodrome air traffic controllers (ATCOs) of the German air navigation service provider DFS. Different configurations of a context-adaptive assistance system combined with augmented reality were tested and evaluated against a conventional tower controller working position (CWP). During the simulation runs eye tracking data was recorded to analyze head up and head down times for the different CWPs. Post-run assessments of workload, situational awareness and system usability were conducted. The best rated CWP was coupled to an experimental tower flight data processing system (TFDPS) and a 3D controller, which allowed both indirect and direct interaction with flight data in the augmented outside view. This particular CWP also revealed 68% mean dwell times for head up in contrast to the conventional tower CWP with only 43% mean dwell times. The ATCOs also experienced the lowest workload levels and the highest situation awareness with this configuration. According to the ATCOs' feedback, the combined use of indirect and direct interaction with augmented flight data allows a flexible and intuitive use while working with such an assistance system. The results of the present study encourage a paradigm shift for flight data handling in combination with augmented reality: away from a solely display system to an interactive operating system.

Valuation of Public Guarantees with Real Option: New Istanbul Airport Example

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Abstract— Every area of life contains a certain amount of uncertainty and risk. Infrastructure investments are longtermed, large-scaled and high-demand risk contained. Infrastructure investments, which were traditionally carried out with public funding in the past, and are now executed through public-private partnerships (PPP). The most important success criteria in implementation of PPP is optimal risk sharing between the two parties. In this respect, the public sector has been offered some kinds of public guarantee mechanisms in order to reduce and share the risk and make project more attractive for private sector. Thus, private sector participation can be achieved in the projects by this way.

The real option (RO) method, which is considered as a new valuation method, helps decision makers to value investments within the context of flexibility. There are several studies suggesting that the RO analysis should be used as a complement to traditional methods under certain circumstances and conditions such as long lifecycle, uncertain demand etc. which perfectly addresses airport investment. In the literature, some researchers analyzed PPP investments with real option aspect. But most of them focused on highways and power plants. Government revenue guarantees in airport PPP projects have never been examined before. Motivated by this absence, this paper focuses on revenue guarantees in airport PPP projects. It is aimed to investigate how the RO method can be implemented in guarantee mechanism by taking New Istanbul Airport (NIA) as a case in which government offered revenue guarantee, which covers only international departing and transfer passengers' airport service fee, to the private party of the project.

Airport ground traffic optimisation

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Abstract— every movement of an aircraft causes the mobilization of a number of vehicles and equipment, providing handling on the ground, which covers simultaneous activities. Numerous technological innovations can improve the guide taxiing, in particular by making the operation of the airport less sensitive to declines in visibility and increasing overall security. The problem tackled here relates to the problem of moving objects tracking with wireless sensor networks. It is a specific problem in localization. Localization primarily refers to the detection of spatial coordinates of an object. Target tracking deals with finding spatial coordinates of a moving object and being able to track its movements. We propose a solution to this problem using a Bayesian filter to predict the targets position from the history measurements. When the target is in a position, the leader sensor calculates the target position according to the information collected by the nodes in its neighborhood. The simulation results show the potential benefit of this approach.

Merging Flows and Optimizing Aircraft Scheduling in Terminal Maneuvering Area Based on GA

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Abstract—Runway capacity problem have been emerging in current overloaded congestion airports. This paper focuses on improving the runway capacity and resolution of conflicts of aircraft in terminal maneuvering area and proposes its method which can find the feasible solution using detour structure. In detail, our proposed method use alternative routes or sub-route as detour to avoid conflict and to change the position of arrival sequence. Through the intensive simulation on Paris Charles De-Gaulle airport, we revealed that our proposed method can find the efficient arrival sequence without conflict and detours contribute to optimize the landing sequence.

Dynamic Prediction of Runway Configuration and Airport Acceptance Rate

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Abstract— Automated prediction of runway configuration and airport capacity is critical for the future generation of air traffic management. In the future aviation industry, where intensive information will be available for air traffic decision-making units, air traffic management personnel are in urgent need of an automated tool to assist them to make decisions. The goal of this study is to provide a decision support tool to predict runway configuration and Airport Acceptance Rate (AAR) simultaneously. First, we collected airport hourly data, flight data, weather observation and weather forecast data from different sources. Then, a program was developed to automatically process, decode and fuse data into the particular time frame. Then, we propose a time-dependent data-driven neural network modeling framework to predict runway configuration and AAR.

Inadequate Post Simulation Debriefings in Air Traffic Control and Pilot Training

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Abstract — In safety related domains such as ATC, advanced simulation offers realistic operations in a safe and controlled environment. These sessions are followed by a debriefing period where research has shown that these learning opportunities are greatly underutilized. Debriefings that are constructed with a lecture and learn format are not as effective in creating an environment where students can self-reflect on their performance and what they can take back to normal operations. Despite the willingness of instructors to manage the debriefing in a facilitated manner, there can still be impediments to student learning. These learning barriers, or knowledge shields, have to be overcome if effective facilitation and self-reflection are to be successful. Here we report on successful facilitation techniques and those signs that students arrive ready to learn in a constructive and self-reflected atmosphere.

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