Chairs & Committees

General chairs:

Marc Bourgois	Eurocontrol	BE
Eric Niederman	FAA	US

Program chairs:

David Lovell	Univ of Maryland	US
Hartmut Fricke	TU Dresden	DE

Tutorial chair

Michael Schultz	UniBw M.	ES

Doctoral Symposium chair

Seth Young	Ohio State	US

Local Arrangement chair

Yu Zhang	U. South Florida	US

Program Committee

Sameer Alam	NTU Singapore	SG
Kenneth Allendoerfer	FAA	US
Hamsa Balakrishnan	MIT	US
Lorenzo Castelli	Univ of Trieste	IT
Andrew Churchill	Mosaic ATM	US
Daniel Delahaye	ENAC	FR
Luis Delgado	Univ Westminster	UK
Nicolas Durand	DSNA	FR
Joost Ellerbroek	TU Delft	NL
Alex Estes	UMN	US
Bert Hackney	Metron Aviation	US
Carla Hackworth	FAA	US
Mark Hansen	UC Berkeley	US
Peter Hecker	TU Braunschweig	DE
Robert Hoffmann	Metron Aviation	US
Gokhan Inalhan	ITU	TR
Kurtulus Izzetoglu	Drexel Univ.	US
James Jones	MIT Lincoln Labs	US
Radoslav Jovanovic	Univ. of Belgrade	RS
Yoon Jung	NASA	US
Amy Kim	Univ. Alberta	CA
Xavier Lopez	Boeing	ES
Sandra Lozito	NASA	US
Guglielmo Lulli	Univ. de Milano	IT
Jonas Lundberg	Linköping Univ.	SE
Amber McNair	Ohio State	US
Lothar Meyer	LFV	SE
Max Mulder	TU Delft	NL
José Luis Muñoz	aslogic	ES
Joe Post	FAA	US
Xavier Prats	UPC Barcelona	ES
Jose Ramasco	IFISC	ES
Damian Rivas	Univ. Sevilla	ES
Megan Ryerson	U. Penn	US
Dirk Schaefer	Eurocontrol	FR
Michael Schultz	UniBw M	DE
Sherri Shearon	FAA	US
Lance Sherry	GMU	US
John Shortle	GMU	US
Manuel F. Soler	Univ. Carlos III	ES
Banavar Sridhar	NASA	US
Sybert Stroeve	NLR	NL
Dengfeng Sun	Purdue Univ.	US
Xiaoqian Sun	Beihang Univ.	CN
Pernilla Ulfvengren	KTH	SE
Adan Vela	UCF	US
Thomas Vossen	Univ. Colorado	US
Sebastian Wandelt	Humboldt U.	DE
Yanjung Wang	Nanjing Univ.	CN
Peng Wei	GWU	US
Seth Young	Ohio State	US
Yu Zhang	U. South Florida	US

Table of Contents

Track 1

Human Performance

The Impact of Mental Model Switching on Air Traffic Controller's Workload in Multi Remote Tower Operations

Lu Zhenna, Sameer Alam, & Nimrod Lilith
Saab-NTU Joint Lab,
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
{zhenna.lu | sameeralam |
nimrod.lilith}@ntu.edu.sg

Billy Josefsson
LFV
Norrköping, Sweden
billy.josefsson@lfv.se

Abstract— Multi Remote Tower (MRT) infrastructure is increasingly being deployed to provide Air Traffic Control (ATC) services for low traffic and regional airports. Although the safety of Multi Remote Tower Operations (MRTO) has been successfully validated, some open questions remain, such as what factors might affect perceived workload and situational awareness of Air Traffic Control Officers (ATCOs) when monitoring more than one airport. Particularly, it has been raised that mental switching between airports is one of the challenges. The present study investigates if the frequency of mental model switching between airports under control could increase perceived workload in a high-fidelity MRTO human-in-the-loop simulation environment. In this study ATCOs are required to land 12 aircraft arriving at either of two airports, while wearing an eye tracker headset. This is the first study independently manipulating the frequency of mental model switching in a realistic MRTO working environment, without varying task load. Mental model, broadly speaking, is a mental representation of all stimuli, beyond just the visual domain, that affects decision making. Specifically, in the present study, mental model switching is operationalized as visual attention shifts across airports, which are recorded by the eye tracker. To improve the validity of perceived workload, eye metrics (blinks, fixation and gaze distance) associated with workload levels are tested alongside subjective self-ratings. The results do not show any significant differences in perceived workload and attention shifts, between different levels of mental model switching in a MRTO environment.

Rostering practices and ATCO productivity in Area Control Centres

How much spare capacity is there and how to make best use of it?

Goran Pavlović
EUROCONTROL
Brussels, Belgium
goran.pavlovic@eurocontrol.int

Radosav Jovanović
University of Belgrade,
Faculty of Transport and Traffic Engineering
Belgrade, Serbia
r.jovanovic@sf.bg.ac.rs

Milan Stanojević
University of Belgrade,
Faculty of Organizational Sciences
Belgrade, Serbia
milan.stanojevic@fon.bg.ac.rs

Abstract— The process of staff planning and rostering in ANSPs has a considerable effect on ATCO productivity and, consequently, on capacity and cost-efficiency delivered to airspace users. The aim of this paper is twofold. Firstly, to establish a relationship between ACC taskload (represented by daily capacity profiles), rostering flexibility in place and the number of ATCOs needed. And secondly - to explore how varying rostering practices applied in ACCs affect spare capacity in the system. To that end, an initial mathematical model for optimizing ATCO staffing requirements has been proposed and tested on a case study involving three ACCs, reflecting different hourly variability in demand. The results suggest that - for different combinations of shift patterns and capacity profiles - substantial variation exists in both the minimum number of ATCOs (needed) and the associated spare ACC capacity. It has also been shown that a certain amount of spare capacity is inevitably present in the system due to inability to perfectly match ATCO hours with demand. Different options and enablers for exploiting such capacity are also discussed in the paper.

The Influence of Rostering Factors on Fatigue in an Irregular Shift System in Air Traffic Control

Maximilian Peukert and Lothar Meyer
Air Navigation Services of Sweden (LFV)
Research & Innovation
Norrkoping, Sweden
firstname.lastname@lfv.se

Abstract— The aim of this field study was to investigate the effects of rostering factors on subjective and objective fatigue in an irregular and preference-based shift system in Air Traffic Control. Subjective and objective fatigue as well as sleep duration were measured over a three-week period in N = 21 operational active individuals. The Stanford Sleepiness Scale and a three-minute Psychomotor Vigilance Task were administered three times during each shift in the study period. Differences in objective and subjective fatigue were found within and between shifts. Fatigue increased over time for three of four shift types. Fatigue was highest on night shifts and lowest on late shifts. A shorter time interval between shifts and a counterclockwise rotation pattern increased initial fatigue on the subsequent shift. Overall, a discrepancy was found between objective and subjective fatigue, indicating lower accuracy in self-evaluation of fatigue.

Investigating Ocular and Head-Yaw Measures as Indicators for Workload and Fatigue under Varying Taskload Conditions

Lothar Meyer, Maximilian Peukert
Air Navigation Services of Sweden (LFV)
Research & Innovation
Norrköping, Sweden
firstname.lastname@lfv.se

Tatiana Polishchuk, Christiane Schmidt
Communications and Transport Systems, Linköping University
Norrköping, Sweden
firstname.lastname@liu.se

Abstract— Both workload and fatigue are decisive for human performance in current air traffic control (ATC), and, thus, should closely be monitored to ensure safety. Well-validated self-assessment and secondary-task performance measures are available but are impractical for operational monitoring because of intrusiveness and low efficiency. To overcome this gap, we investigate ocular measures and head-yaw based on eye tracking as potential non-intrusive indicators of workload and fatigue in ATC. For validation, we conduct human-in-the-loop simulations with licensed tower controllers in both single and multi remote tower working conditions. Qualitative and quantitative comparisons with conventional reference measures of workload and fatigue reveal that, among others, the eye (blink) opening speed and head yaw speed is a potential indicator of workload. Moreover, we confirm blink closing & opening amplitude as well as blink closing speed with reservations. Blink duration and blink opening amplitude may qualify as a fatigue indicator.

Study of Different Task Loading and Cognitive Workload Changes Using Functional Near Infrared Spectroscopy

Justin T. Serwinski, Jaime Kerr, Pratusha Reddy, Kurtulus Izzetoglu
School of Biomedical Engineering, Science & Health Systems
Drexel University
Philadelphia, Pennsylvania, United States of America
{jts356, jkk57, ylr26, ki25}@drexel.edu

Patricia A. Shewokis
College of Nursing and Health Professions & School of Biomedical Engineering, Science & Health Systems
Drexel University
Philadelphia, Pennsylvania, United States of America
pas38@drexel.edu

Abstract— Neuroimaging enables the examination of brain activation during rest and cognitively demanding tasks. Functional near infrared spectroscopy (fNIRS) is a portable neuroimaging technique that measures cerebral hemodynamic response in laboratory and field settings. However, research utilizing fNIRS to quantify changes in human performance has been limited in its ecological validity since realistic scenarios are often difficult to reproduce in lab settings. This study explored cognitive workload, as measured by hemodynamic response and behavioral performance measurements, of novice unmanned aircraft systems (UAS) sensor operators in a realistic setting. Operators engaged in a simulated search-and-surveillance task that varied in difficulty (task load) as determined by visibility. While previous studies observed workload effects during nonsequential task loading, this study compares cognitive workload changes of sequential task loading. Descriptive statistics are presented to summarize performance data, while results of a Friedman two-way ANOVA by Ranks non-parametric test are addressed to explore task load effects on cognitive workload. The fNIRS biomarker between task loads revealed a significant difference (c 2 2 = 7.000, $p = 0.030$, $W = 0.583$), with differences between the easy and medium conditions ($p = 0.028$) and the medium and hard conditions ($p = 0.046$). The use of fNIRS to quantify cognitive workload through neurophysiological and behavioral measures during sequential task loading may help determine a relationship between neural activity and the propensity of an operator to either adjust or disengage with increasingly difficult tasks, forming the basis for personalized training protocols of a specific task load sequence.

Track 2

System Performance

Probabilistic Analysis of Air Traffic in Adverse Weather Scenarios

Eduardo Andrés, Javier García-Heras, Daniel González, Manuel Soler
Department of Aerospace Engineering
Universidad Carlos III de Madrid
28911, Leganés, Spain
eandres@ing.uc3m.es,
masolera@ing.uc3m.es

Tomislav Radišić, Petar Andraši
Department of Aeronautics
Faculty of Transport and Traffic Sciences
Zagreb, Croatia
tradisic@fpz.unizg.hr,
pandrasi@fpz.unizg.hr

Alfonso Valenzuela, Antonio Franco, Juan Nunez-Portillo, Damián Rivas
Department of Aerospace Engineering
Universidad de Sevilla, 41092
Seville, Spain
avalenzuela@us.es

Abstract— The presence of convective cells makes sector demand irregular and not easy to predict, increasing traffic complexity and reducing sector's capacity. In this paper we present a novel, integrated trajectory predictor, which considers multiple sources of meteorological uncertainty at different temporal and geographical scales together with take-off uncertainty. The trajectory predictor is used to calculate the demand, presenting a multi sector traffic assessment of demand (and complexity under convective weather. The combination of probabilistic demand) the assessment of complexity due to weather constitutes the groundwork for the creation of a tool that will enable FMPs a better understanding of complexity in adverse weather conditions.

Designing Recurrent and Graph Neural Networks to Predict Airport and Air Traffic Network Delays

Junzi Sun, Tristan Dijkstra, Constantinos Aristodemou,
Vlad Buzetelu, Theo Falat, Tim Hogenelst, Niels Prins, Benjamin Slijper
Faculty of Aerospace Engineering,
Delft University of Technology,
Delft, the Netherlands
j.sun-1@tudelft.nl

Abstract— In this paper, we propose open machine learning models that can provide airport delay predictions in a network with an error of around or less than five minutes. Due to the complexity of different components of air traffic networks, traditional flight performance model-based predictions fall short when dealing with numerous flights and often are not able to deal with delays that propagate among airports in a network. In this study, we employ three different machine learning models to predict delays at three different scopes: individual flights, airports, and the network of airports. Consequently, we tested three approaches with different levels of complexity, including statistical regression models, recurrent neural networks, and spatial-temporal graph attention neural networks. We conduct experiments for all three types of models using the Eurocontrol research data archive. After training and testing with two years of data covering the top 50 European airports, our models produce prediction errors of around or less than 5 minutes with look-ahead time up to 3 hours. These metrics have shown a significant advancement compared to existing prediction models. We also openly share this model to support open science in aviation.

Integrated Airside Landside Framework to Assess Passenger Missed Connections with Airport Departure Metering

Hasnain Ali∗, Duc-Thinh Pham†, Sameer Alam‡
Air Traffic Management Research Institute,
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
{∗hasnain001 | †dtpham | ‡sameeralam }@ntu.edu.sg

Michael Schultz
Institute of Logistics and Aviation
TU Dresden, Germany
michael.schultz@unibw.de

Abstract— Airport departure metering can contain airside congestion, but it may adversely impact scheduled gate assignments leading to passenger missed connections. Using an integrated landside airside framework, this study aims at evaluating the impact of departure metering on connecting flights and passenger connections. The proposed framework comprises of landside and airside simulators where the landside simulator simulates transfer passenger movements conditioned upon minimum connection time and the airside simulator simulates runway and taxiway movements based on planned operations and available data source. Departing aircraft movements are then metered to reduce taxi and take-off delays under uncertainties. Delayed arrivals and/or departures may lead to conflicts at gate rendering planned gate assignments infeasible or impractical. Using Singapore Changi airport A-SMGCS data, as a case study, it is found that DM may transfer as much as 12 minutes of waiting time from taxiways to gates. This leads to increased gate conflicts which additionally delays the gate-in time of an arriving aircraft by 2-7 minutes on average. Gate reassignments were found to significantly reduce both the number of gate conflicts and arrival queuing time at gates leading to less passenger delays. A minimum connection time of 70 minutes is found sufficient to reduce the probability of missed connections for transfer passengers.

Track 3

Fuel / Emissions / Environment

Climate Optimal Trajectory Planning at Network-Scale: Complexity Assessment Based on Probabilistic Conflicts

Fateme Baneshi, Manuel Soler, Abolfazl Simorgh, Daniel González-Arribas, Eduardo Andrés
Department of Aerospace Engineering, Universidad Carlos III de Madrid, Spain
masolera@ing.uc3m.es

Abstract— Aviation induced climate impact comprises both carbon dioxide (CO2) and non-CO2 effects. Due to the direct dependency on meteorological conditions, the latter can be mitigated using operational strategies, such as aircraft trajectory optimization. However, optimizing individual flights independently is not practical for real traffic scenarios due to the associated interactions and impact at the network-scale. Therefore, the mitigation of the climate impact at the Air Traffic Management (ATM) system requires taking into account networks effects, including demand and capacity balancing, complexity, congestion, and resiliency. In this paper, we aim to explore how the independently climate-optimized trajectories affect the complexity of the traffic patterns and, in particular, the number of conflicts. To this end, we consider a realistic network-scale scenario with around 1000 flights in a free-routing airspace. The lateral routes are optimized for different weightings of operational cost and climate impact, from purely cost-optimal to climate-optimal routing. The optimized trajectories are determined in a probabilistic fashion in order to deal with the uncertainties in meteorological variables that influence both the aircraft dynamics and the climate effects. For the considered scenario, it is shown that the climate optimal routing options increase both operational cost (in terms of fuel consumption and flight time) and the number of conflicts. We find that the increase in the number of conflicts is much higher, in relative terms, than the increase in operating cost.

Estimating Fuel Consumption based on Trajectory Data using Machine Learning Method

Zhuoming Du, Junfeng Zhang*, Honglian Miao, Rong Hu
College of Civil Aviation,
Nanjing University of Aeronautics and Astronautics
Nanjing 210016, China
*zhangjunfeng@nuaa.edu.cn

Abstract— With the increasing concern of global warming, all sectors of society pay more and more attention to carbon emission reduction. To quantify carbon emission, we should first evaluate fuel consumption, the main factor in the carbon production of civil aviation. However, fuel-related information cannot be directly obtained since it concerns the airline's commercial confidentiality. Therefore, this paper proposes a data-driven method to estimate aircraft fuel consumption in the descent phase using ADS_B or radar surveillance information. To validate the proposed method, 160 QAR data of B738 and A320 are collected, using trajectory-related and fuel data to train the model. However, only trajectory-related data is used to test the model. In contrast, the recorded fuel data is used to check the accuracy. At the same time, this paper also uses BADA to build the performance model and set evaluation metrics to compare with the proposed method. Results show that the accuracy of the proposed method is higher than that of the performance model, and the mean absolute error is lower than that of the performance model by more than 30% (19 kg). Furthermore, it is proved that the proposed method has specific stability for different operational environments and keeps a high accuracy when true airspeed is unavailable.

Environmental Impact Optimisation of Flight Plans in a Fixed and Free Route network

Florent Vergnes∗†, Judicaël Bedouet∗, Xavier Olive∗, Junzi Sun‡

∗ONERA – DTIS
Université de Toulouse
Toulouse, France

†École Nationale de l'Aviation Civile
Université de Toulouse
Toulouse, France

‡Faculty of Aerospace Engineering,
Delft University of Technology,
Delft, the Netherlands

florent.vergnes@onera.fr, judicael.bedouet@onera.fr, xavier.olive@onera.fr, j.sun-1@tudelft.nl

Abstract— Efforts to minimize the environmental impact of aviation can be implemented at several levels including electric green taxiing systems, novel propulsion systems, jet fuels, improvements in aircraft efficiency and optimization of climb profiles. In this paper, we address the optimization of flight plans in a route network considering operational parameters and weather forecast. We implement an A* based approach to explore all possible sequences of nodes, altitudes with given wind, temperature and pressure forecasts in order to minimize total flown distance, total burnt fuel, CO2 and non-CO2 emissions, the latter being responsible for two-thirds of aviation radiative forcing. We evaluated our approach on both a network of standard routes and through free route areas, and observed that our optimized flight plans are consistent with those that have actually been filed to be flown in similar weather conditions during December 2021.

Track 4

Trajectory Modeling / Optimization

Optimization of Departure Routes Beyond Aircraft Noise Abatement

Thomas Zeh, Martin Lindner, Judith Rosenow, and Hartmut Fricke
Chair of Air Transport Technology and Logistics
Technische Universität Dresden
Dresden, Germany
thomas.zeh@tu-dresden.de

Abstract— Noise is a significant metric for departing aircraft at lower altitudes in the populated vicinity of an airport. In this paper, we propose a method to combine noise abatement with economic and further environmental objectives leading to an individual multi-objective trajectory optimization in the Terminal Maneuvering Area. For this, an innovative 3D grid is applied in an A* algorithm with a multi-objective cost function to balance noise, wind, fuel, and time costs based on aircraft-type specific performance. The nuisance of noise is evaluated in detail considering population density with assumed noise cost rates, which leads to edge costs including noise during pathfinding. With the sound level LSEL based on the recommended ECAC Doc. 29, the sensitivity of the noise cost rate on the resulting departure path is analyzed in this paper. The developed methodology covers aircraft-specific environmental and socioeconomic trajectory optimization objectives. The results show that even a comparatively low noise cost rate reduces the nuisance for more than 60% of the residents compared to the free optimization. At the same time, the additional fuel burn averages at only 49 kg per flight, and the horizontal flight efficiency reduces slightly from 1.25 to 1.35. The proposed method can be adapted to other airports.

Trajectory Specification to Support High-Throughput Continuous Descent Approaches

Titilayo Fasoro and Hamsa Balakrishnan
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology
Cambridge, MA, USA
{tfasoro, hamsa}@mit.edu

Abstract— Continuous descent approaches (CDAs) have demonstrated the ability to reduce aircraft fuel burn and noise, while trajectory-based operations (TBO) have been shown to improve the predictability and throughput of aircraft flows. Prior work has recognized the difficulty of implementing CDAs in high-density terminal-areas due an increase in uncertainty, which can result in a decrease in throughput. This paper investigates whether increased throughput afforded by trajectory-based operations can be combined with continuous descent approach profiles in order to achieve high-throughput CDA operations. Our proposed method first determines a CDA profile, and then locates waypoints with scheduled time of arrival (STA) constraints along this profile, so as to optimize a combination of throughput and fuel burn. For a representative terminal-area descent profile, we find that it is possible to use intermediate waypoints with STAs to increase the throughput by as much as 64%, while incurring an additional penalty of 5 kg per aircraft.

Impact of Explicit Memory on Dynamic Conflict Resolution

Sarah Degaugue[1,2], Nicolas Durand[2], Jean-Baptiste Gotteland[2]

[1]DSNA-DTI/Innovation domain
1 avenue du Dr-Maurice-Grynfogel
BP 53584, 31035 Toulouse Cedex 1, France

[2]ENAC Lab/OPTIM
7 av. Édouard Belin
31055 Toulouse Cedex, France

{sarah.degaugue, nicolas.durand, jean-baptiste.gotteland}@enac.fr

Abstract— Due to uncertainties in weather conditions, trajectory prediction and constant flight evolution, controlling traffic in a sector is a dynamic problem. Furthermore, when the traffic increases, air traffic control can become a complex dynamic optimization problem difficult to handle by human operators. In the context of offering air traffic controllers intelligent decision support tools adapted to the dynamic nature of traffic, we compare two options to address this issue. Previous work has already used an evolutionary algorithm to solve conflicts at given time steps. In this paper, we compare two different approaches using this evolutionary algorithm. The first one periodically calls an automatic solver, and the second one uses a memory method to guide successive resolutions. In order to choose the more adapted, we test them on different scenarios of continuous traffic. The memory approach can handle higher densities by maneuvering fewer aircraft and inducing lower delays. It is also more stable over time as early planned maneuvers are more likely to comply to effective maneuvers.

Track 5

Advanced Modeling

Scenario-based Strategic Flight Reassignment in Multiple Airport Regions

Ang Li, Mark Hansen
Department of Civil and Environmental Engineering
University of California, Berkeley
Berkeley, CA, USA
angli@berkeley.edu, mhansen@ce.berkeley.edu

Abstract— Airport congestion and delay are subject to many sources of uncertainty including daily variations of airport capacity and demand. Taking advantage of interconnections among airports serving the same metropolitan region help alleviate airport congestion by utilizing excess resources in other airports. This study proposes to shift flights between airports in the same Multiple Airport Region (MAR) to improve regional operational performance. We consider such flight shifting at strategic level. If one airport is consistently congested and another has excess capacity, flights can be reassigned to less congested airport to reduce delay. We identify US MARs based on temporal distance between airports, and characterize spatial-temporal patterns of airport capacity variation within MAR. Then the stochastic flight shift model is formulated as a Mixed Integer Linear Programming (MILP) model to optimize the average total delay and reassignment cost of the flight schedule in the MAR among all possible capacity scenarios. Since the stochastic flight shift model is computationally expensive with high flight traffic intensity, we solve the model in decomposed flight batches. The proposed methodology is applied to New York MAR. Results show that by reassigning flight landing airport and time, the flight delay in the New York MAR could be significantly reduced.

A Runway Exit Prediction Model with Visually Explainable Machine Decisions

Chuan Jie Woo∗, Sim Kuan Goh†∗, Sameer Alam∗, Md Meftahul Ferdaus∗, Mohamed Ellejmi‡
∗ Air Traffic Management Research Institute, Nanyang Technological University, Singapore.
† School of Electrical and Computer Engineering, Xiamen University, Malaysia.
‡ EUROCONTROL Innovation Hub, Brétigny-sur-Orge, France.
sameeralam@ntu.edu.sg

Abstract— A growing number of machine learning (ML) enabled tools and prototypes have been developed to assist air traffic controllers (ATCOs) in their decision-making process. These ML tools can facilitate faster and more consistent decisions for traffic monitoring and management. However, many of these tools utilize models, where machine made decisions are not readily comprehensible to ATCO. Hence, it is pertinent to develop explainable ML model-based tools for ATCO to manage the inherent risks of using ML model-based decisions. This research investigates visually explainable ML models for runway exit prediction for better runway management. Specifically, this research adopts local interpretable model-agnostic explanations (LIME) on XGBoost, where machine-made decisions for runway exit prediction are visualized. XGBoost achieved a classification accuracy of 94.35%, 94.17% and 80.87% on the three types of aircraft studied here, respectively. When the LIME parameters are analyzed, Lime shows the contribution of the features for each aircraft corresponding to a particular runway exit. Furthermore, the visual analysis can inform decision makers about the sources of uncertainty in runway exit prediction. Thus, this work paves the way to explainable ML-based prediction of runway exits, where the visually explainable machine decisions can provide insights to ATCO for effective runway management and planning of arrivals and departures. An interactive interface which visualizes machine decisions for runway exit prediction is also developed as a prototype in this paper.

Assessment of minimum ground time for air taxis based on turnaround critical path modeling

Robert Brühl, Hartmut Fricke
Chair of Air Transport Technology and Logistics
Technische Universität Dresden
Dresden, Germany
robert.bruehl@tu-dresden.de

Abstract— The ground infrastructure for air taxi services has to preserve facilities for electric vertical take-off and landing aircraft, as well as passenger handling. This work examines the handling of eVTOL aircraft during turnaround by identifying the critical path for various charging setups. As a result, we predict the charging time for three possible scenarios based on battery capacity and charging performance. The results of the charging time estimations indicate that it is necessary to install a charging capacity of at least 150 kW at the vertiplaces in order to maintain a reasonable turnaround time for eVTOL aircraft.

Track 6

Safety

Modeling Aircraft Braking Performance and Runway Condition using Machine Learning

Wenxin Zhang, Alexia Payan, David Anvid, HyunKi Lee, Tejas G. Puranik,
Michelle Kirby, Dimitri N. Mavris
Aerospace Systems Design Laboratory
Georgia Institute of Technology
Atlanta, GA, USA
stanleyzhang@gatech.edu, hlee389@gatech.edu, tejas.puranik@gatech.edu, alexia.payan@gatech.edu,
danvid6@gatech.edu, michelle.kirby@ae.gatech.edu, dimitri.mavris@aerospace.gatech.edu

Abstract— The safety of aircraft at landing is among the most important concerns in the aviation industry due to accidents related to runway/taxiway excursions. The relationship between adverse weather conditions, runway conditions, and braking performance has mostly been explored in the literature from a qualitative perspective. However, previous studies have not investigated the development of classification models for aircraft braking performance or runway surface condition by using other prevailing conditions.

In this paper, we describe the creation of classification models for aircraft braking performance and runway surface condition. First, we collect various sources of data such as runway and airport characteristics, prevailing weather conditions, runway condition codes, and pilot reported braking action, and use data fusion to get a coherent set of information. Then, we use the fused dataset to build multiclass classification models from supervised machine learning techniques such as random forest and extreme gradient boost. The results show that it is possible to build data-driven models to infer aircraft braking performance and runway surface condition by using the relevant data such as runway characteristics and prevailing weather conditions. Finally, we identify future avenues for data analysis and research regarding the development of more refined models.

Conflict Resolution with Time Constraints in the Terminal Maneuvering Area using a Distributed Q-Learning Algorithm

Antoine HENRY
ENAC
7 avenue Edouard Belin
31400 Toulouse, France
antoine.henry@alumni.enac.fr

Daniel Delahaye
ENAC
7 avenue Edouard Belin
31400 Toulouse, France
delahaye@recherche.enac.fr

Alfonso Valenzuela
ETSI, Universidad de Sevilla
Camino de los Descubrimientos
s/n
41092 Sevilla, Spain
avalenzuela@us.es

Abstract— With the growing number of flights, more and more conflicts have to be solved in Terminal Maneuvering Areas (TMAs). In order to keep a fluid flow of aircraft arriving on an airport, air traffic controllers use software to help them to solve conflicts and sequence aircraft on runways. This paper faces the sequencing and merging problem using a reinforcement learning algorithm (Q-Learning) in order to measure its performance. This algorithm has been run on a scenario representing a regular day at Paris Charles de Gaulle airport (CDG), and gives satisfying results. Then, it has been benchmarked on heavily loaded scenarios, with more aircraft than the previous ones in order to see the limits of reinforcement learning efficiency. The Q-Learning algorithm can not only solve conflicts on this heavily loaded scenario but it also has a reasonable computational time. By using a Q-learning algorithm in a distributed way, we aim to find an optimized solution on heavily-loaded scenarios without compromising the computational time.

Improving Safety of Vertical Manoeuvres in a Layered Airspace with Deep Reinforcement Learning

Jan Groot, Marta Ribeiro, Joost Ellerbroek and Jacco Hoekstra
Control and Simulation, Faculty of Aerospace Engineering
Delft University of Technology (TU Delft)
Delft, The Netherlands
djgroot@outlook.com, M.J.Ribeiro@tudelft.nl, J.Ellerbroek@tudelft.nl,J.M.Hoekstra@tudelft.nl

Abstract— Current estimates show that the presence of unmanned aviation is likely to grow exponentially over the course of the next decades. Even with the more conservative estimates, these expected high traffic densities require a re-evaluation of the airspace structure to ensure safe and efficient operations. One structure that scored high on both the safety and efficiency metrics, as defined by the Metropolis project, is a layered airspace, where aircraft with an intended heading are assigned to a specific altitude layer. However, a problem arises once aircraft start to vertically traverse between these layers, leading to a large number of conflicts and intrusions. One way to potentially reduce the number of intrusions during these operations is by using conventional conflict resolution algorithms. These algorithms however have also been shown to lead to instabilities at higher traffic densities. As recent years have shown tremendous growth in the capabilities of Deep Reinforcement Learning, it is interesting to see how well these methods perform in the field of conflict resolution. This research investigates and compares the performance of multiple Soft Actor Critic models with the Modified Voltage Potential algorithm during vertical maneuvers in a layered airspace. The final obtained performance of the trained models is comparable to that of the Modified Voltage Potential algorithm and in certain scenarios, the trained models even outperform the MVP algorithm. Overall, the results show that DRL can improve upon the current state of conflict resolution algorithms and provide new insight into the development of safe operations.

Track 7

UAS / UAM / AAM

Route network design in low-altitude airspace for future urban air mobility operations

A case study of urban airspace of Singapore

Zhengyi Wang, Daniel Delahaye
Optim group
Ecole Nationale de l'Aviation Civile
Toulouse, France
{zhengyi.wang, daniel.delahaye}@enac.fr

Jean-Loup Farges
ONERA
Toulouse, France
jean-loup.farges@onera.fr

Sameer Alam
ATMRI
Nanyang Technological University
Singapore, Singapore
sameeralam@ntu.edu.sg

Abstract— The rapid growth of the metropolis leads to the proposal of alternative solutions, including the concept of Urban Air Mobility (UAM). Automated and highly integrated UAM networks have been proved to have great advantages to handle UAM traffic flow with intense density and complexity in the near future. This research addresses designing UAM route networks in low-altitude airspace to minimize noise impact and maximize the efficiency and safety of UAM operations. Singapore's urban airspace is selected for the case study. On the basis of the open-source data of Singapore, the UAM network is designed as a grid-based multi-layer route network that supports two-way traffic. The topology features of the route network are analyzed. To provide alternative travel options for UAM traffic flow, we search for feasible routes between Origin-Destination (OD) pairs by solving k-Shortest Path with Diversity (KSPD) problem that minimizes link costs in terms of noise impact, safety and efficiency. The resulting feasible routes can potentially reduce airspace complexity and can be used for air traffic assignment. In addition, the impact of different parameter settings for link costs on UAM services is explored.

Cost-Aware Congestion Management Protocols for Advanced Air Mobility

Victor Qin and Hamsa Balakrishnan
Massachusetts Institute of Technology
Cambridge, MA, USA
{victorqi, hamsa}@mit.edu

Abstract— Air traffic congestion management has traditionally relied on centralized optimization, which may not be practical for large-scale and on-demand applications. The emergence of advanced air mobility motivates the use of prioritization protocols, similar to rules of the road. We propose a cost-aware backpressure prioritization method for air mobility traffic management protocols, based on the second-price auction. We demonstrate using simulations of several advanced air mobility scenarios that our prioritization method increases economic efficiency and fairness across flights and aircraft operators.

Routing with Privacy for Drone Package Delivery Systems

Geoffrey Ding, Alex Berke, Kwassi H. Degue, Hamsa Balakrishnan
Massachusetts Institute of Technology
Cambridge, MA, USA
{gding, aberke, kdegue, hamsa}@mit.edu

Karthik Gopalakrishnan
Stanford University
Stanford, CA, USA
gkarthik@stanford.edu

Max Z. Li
University of Michigan
Ann Arbor, MI, USA
maxzli@umich.edu

Abstract— Unmanned aerial vehicles (UAVs), or drones, are increasingly being used to deliver goods from vendors to customers. To safely conduct these operations at scale, drones are required to broadcast position information as codified in remote identification (remote ID) regulations. However, location broadcast of package delivery drones introduces a privacy risk for customers using these delivery services: Third-party observers may leverage broadcast drone trajectories to link customers with their purchases, potentially resulting in a wide range of privacy risks. We propose a probabilistic definition of privacy risk based on the likelihood of associating a customer to a vendor given a package delivery route. Next, we quantify these risks, enabling drone operators to assess privacy risks when planning delivery routes. We then evaluate the impacts of various factors (e.g., drone capacity) on privacy and consider the trade-offs between privacy and delivery wait times. Finally, we propose heuristics for generating routes with privacy guarantees to avoid exhaustive enumeration of all possible routes and evaluate their performance on several realistic delivery scenarios.

Track 8

Network Management

Airline Schedule Recovery at Hub Airports including Dynamic Cost Indexing and Re-Routing

Jan Evler, Judith Rosenow, Hartmut Fricke
Technische Universität Dresden
Institute of Logistics and Aviation
Dresden, Germany
jan.evler@tu-dresden.de

Abstract— As decision-support for airline operations controllers, we consider dynamic cost indexing and re-routing (tactical trajectory management) as additional options within an integrated airline schedule recovery model that focuses on turnaround optimization at the airline's hub airport. With dynamic cost indexing or re-routing, negative effects from arrival delays may be mitigated before they would propagate via the aircraft turnaround or crew/passenger transfers onto subsequent flights in the airline network. This paper studies the efficiency of individual and integrated trajectory and turnaround optimization at different tactical look-ahead times on the case study of a small airline network with a hub at Frankfurt Airport.

Flight Rescheduling to Improve Passenger Journey during Airport Access Mode Disruptions

Geoffrey Scozzaro
ENAC, Université de Toulouse
31400 Toulouse, France
geoffrey.scozzaro@enac.fr

Ji Ma
Civil Aviation University of China
300300 Tianjin, China
jma@cauc.edu.cn

Daniel Delahaye
ENAC, Université de Toulouse
31400 Toulouse, France
daniel.delahaye@enac.fr

Eric Feron
King Abdullah University of Science and Technology
Thuwal 23955, Saudi Arabia
eric.feron@kaust.edu.sa

Catherine Mancel
ENAC, Université de Toulouse
31400 Toulouse, France
catherine.mancel@enac.fr

Abstract— Disruptions on airport access mode impact the passenger journey. This paper shows that the impact can be mitigated with a modest tactical rescheduling of flights. Operational constraints related to connecting flights, minimum turn-around time, runway throughput limitations, terminal and taxi network capacities are considered. In order to solve this optimization problem, we implement a simulated annealing coupled with a simulation-based evaluation and a sliding time window. We propose a data-driven approach to simulate the passenger arrival process at the airport. The coordination mechanism has been evaluated on several scenarios with different levels of disruption. New flight schedules and runway assignments obtained after optimization succeed in reducing up to 70% the number of stranded passengers at the airport by only assigning on average a 6-minute delay to the flight set.

Sector Entry Flow Prediction Based on Graph Convolutional Networks

Chunyao Ma∗, Sameer Alam∗, Qing Cai∗, Daniel Delahaye†
∗Air Traffic Management Research Institute, School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
†OPTIM Lab, Ecole Nationale de l'Aviation Civile, Toulouse, France
Email: ∗M180146@e.ntu.edu.sg, {∗sameeralam| ∗qcai}@ntu.edu.sg,
†daniel.delahaye@enac.fr

Abstract— Improving short-term air traffic flow prediction can help forecast demand and maximize existing capacity by tactical air traffic flow management. Most existing studies in flow prediction lacks consideration of the dynamic, structural, and interrelated nature of air traffic flows in the airspace. Therefore, this paper proposes to predict sector entry flows based on graph convolutional networks, which consider the dynamic spatial-temporal features of air traffic from a graph perspective. First, we specify a sector entry flow based on its upstream and downstream sectors. Then, each entry flow is denoted as a node in a graph. The weighted edges between the nodes are learned from a Word2vec model based on air traffic flows among the nodes. With the weighted graph constructed and the temporal flows on the nodes extracted from the flight trajectories, an Attention-based Spatial-Temporal Graph Convolutional Network (ASTGCN) module is adopted to capture spatial-temporal features of recent, daily-periodic, and weekly-periodic flows in the graph. Finally, The outputs from the ASTGCN module based on the three features are fused to generate the final prediction results. The proposed method is applied on 164 sectors of French airspace for one-month ADS-B data (from Dec 1, 2019, to Dec 31, 2019) which includes 158,856 flights. Results show that, the proposed method outperforms the well-established Long short term memory (LSTM) model, and demonstrates better capability in predicting rapid changes in traffic flow and has relatively smaller decrease in prediction accuracy as the prediction time window increases.

Airline Disruption Management with Delay Ledgers

Christopher Chin, Hamsa Balakrishnan
Massachusetts Institute of Technology
Cambridge, MA, USA
{chychin, hamsa}@mit.edu

Karthik Gopalakrishnan
Stanford University
Stanford, CA, USA
gkarthik@stanford.edu

Max Z. Li
University of Michigan
Ann Arbor, MI, USA
maxzli@umich.edu

Abstract— The impact of disruptions may result in reduced capacities at airports, forcing airlines to revise schedules and delay flights. However, due to myriad factors (e.g., passengers who may miss their connections, remaining flights to be performed by an aircraft, high-valued passengers with elite statuses), a delayed flight may be more or less costly to an airline, even when compared to another similarly delayed flight. Currently, identifying optimal slot swaps between airlines requires sharing the airline-specific delay cost of each flight. However, this is not amenable as sharing these private delay costs could reveal sensitive business practices. We propose the use of a procedure called the Delay Ledger (DELED) which enables airlines to identify a set of beneficial slot swaps across a network of airports which guarantees improvements in terms of private delay costs while ensuring that no private flight-specific valuations are shared. DELED is guaranteed to lower airline delay costs, incentivizes truthful airline participation, and supports flexible airline privacy preferences. We evaluate DELED across 30 days with 8 major US airlines, resulting in average reductions in private delay costs of 8-22% per day compared to current approaches.

Excess Delay from GDP: Measurement and Causal Analysis

Ke Liu, Mark Hansen
Department of Civil and Environmental Engineering
University of California, Berkeley
Berkeley, California, United States
liuke126@berkeley.edu
mhansen@ce.berkeley.edu

Abstract— Ground Delay Programs (GDPs) have been widely used to resolve excessive demand-capacity imbalances at arrival airports by shifting foreseen airborne delay to pre-departure ground delay. While offering clear safety and efficiency benefits, GDPs may also create additional delay because of imperfect execution and uncertainty in predicting arrival airport capacity. This paper presents a methodology for measuring excess delay resulting from individual GDPs and investigates factors that influence excess delay using regularized regression models. We measured excess delay for 1210 GDPs from 33 U.S. airports in 2019. On a per-restricted flight basis, the mean excess delay is 35.4 min with std of 20.6 min. In our regression analysis of the variation in excess delay, ridge regression is found to perform best. The factors affecting excess delay include time variations during gate out and taxi out for flights subject to the GDP, program rate setting and revisions, and GDP time duration.

Automated Traffic Scheduling in TMA with Point Merge to Enable Greener Descents

Henrik Hardell
Communications and Transport Systems, ITN, Linköping University (LiU), Norrköping, Sweden
Procedure Design Unit, Luftfartsverket (LFV), Norrköping, Sweden
henrik.hardell@liu.se

Tatiana Polishchuk and Lucie Smetanová
Communications and Transport Systems, ITN, Linköping University (LiU)
Norrköping, Sweden
firstname.lastname@liu.se

Abstract— We present a mixed-integer programming approach for fully-automated sequencing and merging of the arriving and departing traffic within the terminal areas implementing point merge. We assume all the arrivals are performing the most fuel efficient continuous descent operations (descents with idle thrust and no speed-brakes usage), with the exception when the aircraft are flying along the sequencing legs of the point merge system.

On example of a high-traffic scenario at Dublin airport, we demonstrate that our approach provides significant benefits, including increased vertical performance as well as reduced time and distance spent in the terminal airspace, contributing to fuel savings of up to 22%. The analysis is based on the historical ADS-B traffic data obtained from the Opensky Network.

Track 9

Economics / Policy / Equity

Democratizing Aviation Emissions Estimation: Development of an Open-Source, Data-Driven Methodology

Andy G. Eskenazi*, Landon G. Butler+, Arnav P. Joshi‡, Megan S. Ryerson◊

*Department of Mechanical Engineering and Applied Mechanics
University of Pennsylvania
Philadelphia, PA

*Department of Mathematics
University of Pennsylvania
Philadelphia, PA

+, ‡,◊Department of Electrical and Systems Engineering
University of Pennsylvania
Philadelphia, PA

◊Department of City and Regional Planning
University of Pennsylvania
Philadelphia, PA

andyeske@sas.upenn.edu*, landonb3@seas.upenn.edu+, arnavj@seas.upenn.edu‡

Abstract— Through an aviation emissions estimation tool that is both publicly-accessible and comprehensive, researchers, planners, and community advocates can help shape a more sustainable and equitable U.S. air transportation system. To this end, we develop an open-source, data-driven methodology to calculate the system-wide emissions of the U.S. domestic civil aviation industry. This process utilizes and integrates six different public datasets provided by the Bureau of Transportation Statistics (BTS), the Federal Aviation Agency (FAA), EUROCONTROL, and the International Civil Aviation Organization (ICAO). At the individual flight level, our approach examines the specific aircraft type, equipped engine, and time in stage of flight to produce a more granular estimate than competing approaches. Enabled by our methodology, we then calculate system-wide emissions, considering four different greenhouse gases (CO2, NOx, CO, HC) during the Landing, Take-off (LTO) and Climb, Cruise, and Descent (CCD). flight cycles. Our results elucidate that emissions on a particular route can vary significantly due to aircraft and engine choice, and that emission rates differ significantly from airline to airline. We also find that CO2 alone is not a sufficient proxy for emissions, as NOx, when converted to its CO2-equivalency, exceeds CO2 during both LTO and CCD.

AIMing for Equity in Aviation Accessibility: Development of the Aviation-accessibility Integrated Mobility (AIM) Metric

Shriya Karam, Stephanie J. Nam, and Megan S. Ryerson
University of Pennsylvania
Philadelphia, PA 19014
karams@seas.upenn.edu, namsteph@sas.upenn.edu, mryerson@design.upenn.edu

Abstract— As federal spending and planning for air transportation infrastructure looks to prioritize access for disadvantaged populations, aviation systems planning metrics that measure accessibility at the individual-level are necessary. Existing metrics, from the mobility-driven metrics focused on efficiency and on-time performance to geographic accessibility focused on connectivity, lack the detail of the multiple, interlocking constraints that limit potential travelers (especially lower income travelers) from executing their agency and accessing the aviation system. We seek to develop a methodology, resulting in new analysis metrics, to quantify accessibility on an origin-destination basis based on individual constraints, time and cost-based impedance, and aviation travel supply. We develop and apply our Aviation-accessibility Integrated Mobility (AIM) metric to empirically model relative accessibility based on traveler-specific constraints, accounting for individual-level sensitivity to travel costs and propensity to travel by ground access modes. We illustrate how equity-focused variables can change the calculus and geographic distribution of accessibility by applying the AIM to our case study region: Philadelphia, Baltimore, and Newark metropolitan areas, a region with significant socioeconomic disparities, to diverse markets. Our findings indicate that incorporating individual constraints greatly influences the calculation of accessibility; additionally, we find that transportation supply and service characteristics alter the distribution of accessibility. Our model supports a national map of accessibility and potential policy recommendations to expand traditional federal airport infrastructure projects, such as targeted air service enhancement.

Benefits of Shifting Passenger Traffic from Air to Rail

A Case Study of California High-Speed Rail

Kaijing Ding, Lu Dai, Mark Hansen
Institute of Transportation Studies
University of California, Berkeley
Berkeley, CA, USA
kaijing@berkeley.edu, dailu@berkeley.edu, mhansen@ce.berkeley.edu

Abstract— This study provides a method to quantify the benefit of shifting passenger traffic from air to high-speed rail (HSR) from the perspective of flight delay cost reduction. We first estimate the number of flight reductions for airport origin and destination pairs based on the HSR ridership forecast provided in the California High-Speed Rail 2020 Business Plan, and then distribute these flight reductions to quarter hours. After that, Lasso models are applied to estimate the impact of the reduced queuing delay of SFO, LAX and SAN on the arrival delay of national Core 29 airports. Finally, these delay reductions are monetized using aircraft operating cost per hour and the value of passenger time per hour. We apply several different variations of this approach, for example, considering delay at all 29 Core airports or just the major California airports, different scenarios for future airport capacity and flight schedules, and different percentiles of a probabilistic forecast for future HSR ridership. We ultimately arrive at delay cost savings of $51-88 million 2018 dollars in 2029 and 235-392 million 2018 dollars in 2033.

Doctoral Symposium

Chair: Seth Young

Identifying Aviation Operation Types Using Flight Trajectories

Zhuoxuan Cao
Department of Civil and Environmental Engineering, and Institute for Systems Research
University of Maryland
College Park, MD, USA
zcao1235@umd.edu

David J. Lovell
Department of Civil and Environmental Engineering, and Institute for Systems Research
University of Maryland
College Park, MD, USA
lovell@umd.edu

Abstract— Aiming to provide accurate capacity estimation for small airports, this study proposed a set of logic to identify various flight operations using an Automatic Dependent Surveillance – Broadcast (ADS-B) dataset, which was collected based on a proposed data collection scheme. Trajectory smoothing techniques are first deployed to eliminate the high-frequency noise. Then the peaks and troughs in the trajectories, as well as other features, are identified. Based on the processed trajectories and extracted features, six operations are sequentially identified.

Development of QGIS tools to aid in airport operations modeling using ADS-B data

Employing custom plugins for flight data evaluation and validation

Aishwarya Bokil
Dept. of Computer Science and Engineering
The Ohio State University
Columbus, OH, USA
bokil.6@buckeyemail.osu.edu

Seth B. Young (Adviser)
Dept. of Civil, Environmental, and Geodetic Engineering Center for Aviation Studies
The Ohio State University Columbus, OH, USA
young.1460@osu.edu

Abstract— As part of a wider research project to develop aircraft performance metrics that aid in capacity modeling of small airports, a python-based "plug-in" to the QGIS geographic information system software has been developed. The plug-in facilitates this analysis through the search and graphical display of flights from locally collected automated dependent surveillance - broadcast (ADS-B) data. This tool aids in the analysis, classification, and segmentation of flight operations. The plug-in has been found to be a useful tool towards developing machine learning models to automatically analyze flights for their operational performance as it pertains to airport capacity.

Toward Real-Time Stochastic Conformal Anomaly Detection in Terminal Airspace

Hong-Cheol Choi
School of Aeronautics and Astronautics
Purdue University
West Lafayette, IN, USA
choi642@purdue.edu

Inseok Hwang
School of Aeronautics and Astronautics
Purdue University
West Lafayette, IN, USA
ihwang@purdue.edu

Abstract— The continuously increasing demand for air transportation calls for reliable data-driven methods such as anomaly detection to enhance safety in aviation systems. Although data is inherently imperfect and corrupted by noise, which is a critical issue for real-time applications, it was rarely considered in previous works. In this paper, we propose Stochastic Conformal Anomaly Detection (SCAD) which can explicitly consider the uncertainty in data and provide the probability distribution of the $\boldsymbol{p}$-value (an indicator for anomalies). This information could be beneficial for situational awareness in a real-time manner. The proposed algorithm is demonstrated with real air traffic surveillance data.

A Multi-Branch Convolutional Neural Network for Predicting Airport Throughput – Using ATL Airport as Case Study

Huang Feng
Dept. of Civil and Environmental Engineering
University of South Florida,
Tampa, U.S.
fengh@usf.edu

Yu Zhang
Dept. of Civil and Environmental Engineering
University of South Florida
Tampa U.S.
yuzhang@usf.edu

Abstract— There is extensive research in quantifying how convective weather effects section and airfield capacity at the tactical and operational levels. However, how convective weather in TRACON (terminal radar approach control) and terminal areas affects the airfield efficiency has not been well studied. Convective weather reduces airspace capacity and disrupts normal operations. It forces the rerouting of aircraft, elongates their flying time, and may affect airfield efficiency in terms of utilization of runway capacities. This research proposes to leverage the learning-based method to predict airport throughput and take Atlanta International Airport as the case study to demonstrate the proposed method.

Improving Conflict Prevention in Constrained Very Low-Level Urban Airspace, U-Space

Andres Morfin Veytia, Joost Ellerbroek, and Jacco Hoekstra
Control and Simulation, Faculty of Aerospace Engineering
Delft University of Technology, The Netherlands
{a.morfinveytia, J.Ellerbroek, J.M.Hoekstra}@tudelft.nl

Abstract— The rate of urbanization is expected to continue increasing [1]. This has led to an interest in using drones and air taxis for urban transportation in place of the current methods, which often lead to road congestion. In most places urban air operations will happen above buildings. However, in many cities with large skyscrapers it may not be efficient to fly above buildings as it would add travel distance. For these cases, aircraft will have to operate in constrained airspace (above roads and between buildings). There is still a knowledge gap for operating in constrained very low-level urban airspace [2]. Most studies attempt to improve the safety in constrained airspace with strategic or tactical conflict resolution. But this may not be enough to ensure safety in highly-dense urban environments. The restriction of heading maneuvers by buildings substantially limits the solution space for conflict resolution. Therefore, conflict prevention with airspace design can be an important tool for improving airspace safety. In a layered airspace, turn layers can be used so that turning aircraft do not create bottlenecks for cruising aircraft that may be behind it. However, merging conflicts can occur when these turning aircraft attempt to re-enter cruising layers. These are typical in both orthogonal (New York) and non-orthogonal (Paris) street networks. Non-orthogonal street networks can also create merging conflicts because it is not always possible to segment cruising aircraft at intersections. This work will propose two conflict prevention doctoral research experiments that aim to reduce merging conflicts. The first will use three different layering techniques to reduce merging conflicts created by turn layers. The second will focus on merging conflicts that are typical of non-orthogonal networks.

Conflict Prevention, Detection, and Resolution in Constrained Very Low-Level Urban Airspace

Călin Andrei Badea, Joost Ellerbroek, Jacco Hoekstra
Faculty of Aerospace Engineering
Delft University of Technology
Delft, The Netherlands
{C.Badea, j.ellerbroek, J.M.Hoekstra}@tudelft.nl

Abstract— The interest for using small aircraft for missions in urban airspace is growing for applications like parcel deliveries. Research shows that conventional airspace structure and conflict detection and resolution techniques are not suitable for maintaining a high level of safety in constrained urban environments, especially when aircraft are restricted to flying within the limits of the road network. The problem at hand becomes even more complex when factoring in cities with topologically organic street networks, thus increasing the probability of crossing and merging traffic flows. Preliminary results show that such networks induce the detection of false-positive conflicts when using classical state-based conflict detection, decreasing the effectiveness of conflict resolution. Velocity-obstacle based conflict resolution methods were able to improve airspace safety, but require further development in order to handle conflicts in such an unpredictable and constrained environment. Thus, the doctoral project at hand seeks to develop and research improved methods for conflict prevention, detection and resolution in constrained, urban, very low-level urban airspace.

Exploration of On-Demand Urban Air Mobility: Demand Forecast, Infrastructure Location and Capacity Identification, and Vehicle Fleet Size Design

Zhiqiang Wu
Dept. Civil & Environmental Engineering
University of South Florida
Tampa, U.S.
zhiqiangwu@mail.usf.edu

Yu Zhang
Dept. Civil & Environmental Engineering
University of South Florida
Tampa, U.S.
yuzhang@usf.edu

Abstract— Traffic congestion has been one of the leading sustainability issues in transportation around the world. The emerging concept urban air mobility (UAM) is expected to provide a new solution by making use of the three-dimensional airspace to transport passengers and goods in urban areas. Among different constraints and challenges for promotion and commercialization of UAM, we will focus on optimal infrastructures location identification, facility capacities and aircraft fleet size design and analyze corresponding transportation system performance as well as impact from uncertainties.

Airspace Design and Conflict-free Flight Planning for Urban Air Mobility

Hualong Tang
Civil and Environmental Engineering
University of South Florida
Tampa, USA
hualongtang@usf.edu

Yu Zhang
Civil and Environmental Engineering
University of South Florida
Tampa, USA
yuzhang@usf.edu

Abstract— Urban air mobility (UAM) is envisioned to move to highly automated and high-density operations in low altitude urban airspace in the future. Third-party service providers, rather than the legacy air traffic control, are anticipated to provide traffic management for hundreds of thousands of flights. This paper aims to develop methods to support pre-departure flight planning services for medium to high-density UAM operations that can be employed by service providers. We propose a layered airspace topology and subsequent route network construction method based on previous studies to accommodate the unique needs of conformance to airspace constraints such as buildings, obstructions, and restricted airspaces. Based on the proposed airspace structure, strategical approaches, flight level assignment plus departure delay, are applied to deconflict aircraft. Experiments are conducted to investigate the sensitivity of operating cost to three key cost parameters (electricity price, crew hourly rate, and maintenance hourly rate). The tradeoff between the operating cost saving from departure delay and delay cost to passengers with varying flight level vertical separation and departure delay bound (maximum departure delay allowed) is explored to provide insights to service providers.

Assessing and Modelling Climate Optimal Flights Using Open Surveillance and Remote Sensing Data

Esther Roosenbrand, Junzi Sun, Irene C. Dedoussi, Daphne Stam, Jacco Hoekstra
Faculty of Aerospace Engineering
Delft University of Technology
Delft, The Netherlands
{e.j.roosenbrand, j.sun-1, I.C.Dedoussi, D.M.Stam, J.M.Hoekstra}@tudelft.nl

Abstract— Sustainability is the biggest challenge facing the aerospace industry today. With the global number of flights expected to rise, the climate impact of aviation will continue to increase. Current research states that the rerouting of aircraft through wind-optimization for the purpose of fuel usage minimization and emission reduction is an effective sustainability contribution. However, these routing models only optimize for minimum fuel burn, not necessarily minimum climate impact. Flying efficiently through wind fields could mean flying through regions with higher climate impact, for example, where warming contrails are formed. This potentially forfeits the advantage of the reduced emissions from the wind-optimized route. By bringing together fields such as satellite remote sensing, atmospheric science and aircraft surveillance data, a climate optimized free routing model can be made. This paper creates a climate optimized free routing airspace model by incorporating knowledge from the aforementioned fields and existing wind-optimization models with AI and open-source tools.

Enabling Safe and Efficient Separation through Multi-Agent Reinforcement Learning

Jan Groot, Joost Ellerbroek, Jacco Hoesktra
Control & Simulation, Faculty of Aerospace Engineering
Delft University of Technology
Delft, The Netherlands
djgroot@outlook.com, J.Ellerbroek@tudelft.nl, J.M.Hoekstra@tudelft.nl

Abstract— Over the next decades, it is expected that the number of unmanned aerial vehicles (UAVs) operating in the airspace will grow rapidly. Both the FAA (Federal Aviation Administration) and the ICAO (International Civil Aviation Organization) have already stated that aircraft operating autonomously or beyond their operators' line of sight are required to have detect and avoid capabilities. At higher traffic densities these avoidance maneuvers can, however, lead to instabilities within the airspace, causing emergent patterns that lead to knock-on effects that can harm the safety of the operations. It might be possible to formulate a cost function that encapsulates global safety, rather than individual safety, stimulating both safety and stability. One method that lends itself for optimizing such a cost function is cooperative Multi-Agent Reinforcement Learning (MARL). It has been demonstrated that MARL can be used for optimization in both competitive and cooperative (or even mixed) environments, however, when applied in a completely decentralized manner, stability issues often arise. It is therefore proposed to investigate the application of MARL for a well-known centralized domain, ATC for manned aviation. This doctoral paper breaks down the proposed research project into 4 independent phases that individually contribute to the knowledge of applying MARL for ATC.

Data-Driven Optimization of Airside Operations Under Uncertainty

Hasnain Ali
Air Traffic Management Research Institute,
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
hasnain001@ntu.edu.sg

Sameer Alam
Air Traffic Management Research Institute,
School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
sameeralam@ntu.edu.sg

Abstract— Airport taxi delays adversely affect airports and airlines around the world leading to airside congestion, increased Air Traffic Controllers/Pilot workload, and adverse environmental impact due to excessive fuel burn. Airport Departure Metering (DM) is an effective approach to contain taxi delays by controlling departure pushback timings. The key idea behind DM is to transfer aircraft waiting time from taxiways to gates. This work proposes model free and learning-based DM using Deep Reinforcement Learning (DRL) approach to reduce taxi delays while meeting flight schedule constraints. This study casts the DM problem in a Markov decision process framework that uses taxiway hotspot features to effectively represent the spatial-temporal evolution of airside congestion state. The learnt policy leads to a reduction of approx. 44% in taxi out delays and 22% in total fuel consumption. However, DM may adversely impact scheduled gate assignments leading to gate conflicts and passenger missed connections. Using an integrated landside airside framework, this study also aims at evaluating the impact of DM on connecting flights and passenger connections. As copious amount of data becomes easily available, our ability to learn, draw insights and obtain actionable knowledge using past operations data is a pre-requisite for establishing data driven airport operations.