KoMSO Challenge Workshop

"Mathematical Modeling, Simulation and Optimization for Air Traffic Management"

July 14-15, 2016
Lufthansa Systems, Raunheim, Germany

1 Point of Departure

Flight route planning nowadays is faced with growing challenges due to continuous increase of air traffic and mounting strict requirements on safety, efficiency, capacities and environment. To successfully accomplish these challenges, joint efforts of all air traffic management (ATM) stakeholders – air traffic control, network managers, airports, airlines – and academia are necessary.

This workshop served as a platform to discuss a variety of mathematical aspects in air traffic management, including pre-flight route optimization as well as in-flight conflict resolutions. Day 1 offered insight into the flight planning and operation at Lufthansa and was enhanced by practical experience reports of an air traffic controller from DFS Deutsche Flugsicherung and a pilot from Deutsche Lufthansa. The MSO-related presentations on day 2 carved out the mathematical approaches for the stakeholder-specific challenges, where the main aim of the workshop was to foster synergies and collaborations.

2 Challenge Workshop

The challenge workshop "Mathematical Modeling, Simulation and Optimization for Air Traffic Management" was organized by the Committee for Mathematical Modeling, Simulation and Optimization (KoMSO) with financial support from the Federal Ministry of Education and Research (BMBF) via the "Accompanying Networks" project (IMNET) as well as the Zuse Insitute Berlin (ZIB). Local organization was provided by Lufthansa Systems.

The speakers included industry representatives from Lufthansa Systems, Deutsche Lufthansa, DFS Deutsche Flugsicherung, Eurocontrol, Fraport AG, as well as academic representatives from Bundeswehr University Munich, DLR German Aerospace Center Hamburg, DLR Institute of Flight Guidance Braunschweig, Technical University Munich, Università degli Studi Roma Tre/Italy, University of Erlangen-Nuremberg and Zuse Institute Berlin.

In addition, representatives from the following institutions participated in the workshop: Fraunhofer ITWM Kaiserslautern, Heidelberg University, University of Belgrade/Serbia, Technical University Kaiserslautern and École Polytechnique de Montréal/Canada.

3 Major Topics

The discussion concentrated on the question of how mathematical MSO can support ATM in order to

- increase airspace and airport capacity, which will also reduce delays both on the ground and in the air;
- maintain the highest level of safety;
- improve operational efficiency and reduce costs;
- reduce flight emissions, which will make air travel more sustainable and will reduce fuel costs;
- increase predictability, which will improve performance of all ATM stakeholders.

These topics were intensively discussed from the view of different players in ATM (pilots, air traffic controllers, dispatchers, network managers, airport operators, etc).

4 Challenges

Numerous topics for research projects have been identified during presentations and discussions. The participants of the workshop clearly stated that efficient optimization methods exist already that are able to solve some of the problems but that there is a definite need for new optimization approaches. Furthermore, in order to solve practical problems one should develop appropriate mathematical models.

In particular, automated decision support tools for *air traffic controllers* require, among others, the development of

- appropriate optimization problem formulations (4D flight trajectory, restrictions, objectives, model parameters, changes in initial data and weather conditions),
- efficient methods for solving nonlinear optimal control problems with numerous state constraints, taking into account different types of uncertainties (e.g. model predictive control approach),
- user-friendly tools and human-computer interfaces,
- optimal control tools for training and decision support,
- simplified feedback strategies possible for real-time use in practice (as in trucks, see intelligent powertrain control by Daimler)

Flight planning requires development of network optimization methods that

- combine shortest path algorithms with efficient treatment of restrictions (such as traffic flow restrictions that in general make problems NP-hard) and
- include optimal control problems on arcs to describe the dynamics of an aircraft and constraints on fuel consumption, CO2 emission, noise, etc.
- are robust against small and large disturbances,
- are able to treat free flight zones within the network,
- are able to consider departure and arrival flow management.

A big challenge in ATM is the coupling of many flights of competing companies over long time horizons which leads to very large and complex optimization problems which have to be solved fast and reliably.

5 Outlook

All participants agreed that the workshop offered a much-needed platform to raise awareness of the potential of mathematical MSO for ATM. In collaboration with Springer Verlag it is planned to publish a special volume in the series “Lecture Notes in Mobility” (expected publication in April 2017). The participants realized that the two-day workshop was too short to discuss all relevant topics in sufficient detail. It has been suggested to organize a follow-up conference and to investigate possibilities for setting up specific joint research projects.