Tidning för Svensk Flygledareförening

FLYGLEDAREN

2 2018

Leo Sedov, doktorand vid Linköpings Universitet, belönades med 2017 års LFV innovationsstipendium för sitt arbete med att ta fram metodik och verktyg för att optimera sektorisering i NUAC, den svenska delen av luftrummet. Arbetet genomfördes som en förstudie i samverkan med Trafikverket.

Leo har genom en matematisk modellering tagit fram förslag på sektoriseringar av luftrummet. Dessa sektoriseringar har sedan prövas med operativa experter, via möten med NUAC som gett Leo insikter om att det är ett komplext och svårt arbete med att designa luftrum och att mer arbete behöver göras. I framtiden kan nya krav ställas på hur vi ska utvärdera användandet av luftrummet. Det gäller att operatören och skiftledaren hela tiden har bästa möjliga hjälpmedel att planera resurserna.
Leo Sedov kommer att använda stipendiet till att besöka konferenser inom ämnet för att lära sig mer om flygtrafikledning. Här nedan redogör Leo kortfattat om de projekt man jobbar med för tillfället på Linköpings universitet.

LFV--LiU cooperation: a prime example of industry--academia partnership

According to Martin Rolfe, CEO of NATS (the main Air Navigation Service Provider in the United Kingdom), the currently hottest topics in ATM are Unmanned Traffic Management (UTM), cybersecurity, remotely operated towers (ROT) and new business models. We follow and, in fact, in many cases lead the research trend in our joint effort with LFV.

The cooperation agreement between Linköping University (LiU) and LFV, signed by former LFV Director General Thomas Allard and LiU Vice-Rector Peter Värbrand, was signed to foster both the research and education in the "Flygtrafik och logistik" program. We had the honor to have in our classes many of the currently active ATCOs working in various places in and outside Sweden, including the world's first controller (direct from school) certified for ROT control. The LFV--LiU tandem was not created by chance; rather it is a consequence of highly successful efforts by the government to breathe new life into the run down by the textile industry fall city of Norrköping, to which several governmental institutions (including LFV, Sjöfartsverket, Migrationsverket et al.) were moved from Stockholm and where LiU Norrköping campus was founded.

For a long and narrow country like Sweden, transportation efficiency is of utmost value. Moreover, the relatively low traffic demand levels allows one to actually use the transport resources in an optimal way. Such optimization is at the heart of our research. Below we give some details about our projects:

ODESTA: OPTIMAL DESIGN OF TERMINAL AIRSPACE. In airspace design research, the following two fundamental issues have been addressed extensively from various points of view:
Problem I: Trajectory planning. Given an airspace split into sectors, design flight paths that "conform well" to the sectorization -- do not switch sectors more often than necessary, are cost-efficient, have low environmental impact, etc.
Problem II: Sectorization. Given flight trajectories (historical or projected), decide how to decompose the airspace into sectors so that the traffic is "easy to control" -- the controllers workload between different sectors is balanced, flight handovers are smooth and kept to a minimum for safety reasons, controller-to-controller communication is infrequent, etc.

Previously, trajectory planning and sectorization were considered separately, as two different problems. ODESTA's ambition is to develop a unified approach to airspace design by simultaneously delivering fight paths and sectors configurations. The focus on TMA is prompted by the higher capacity needs: e.g., according to the European ATM Master plan (the main defining document for ATM modernization), already 80 movements per hour created high capacity need in a TMA, while as many as 160 movements per hour led to only medium needs enroute.

CAFEA: CURVED APPROACHES FOR FUEL-EFFICIENT AND ENVIRONMENT-FRIENDLY AVIATION (PENDING). TMA designers must make educated tradeoffs between various conflicting objectives: cost efficiency and noise impact, traffic complexity and airspace capacity, landing rate restrictions and economic considerations. One of the first ODESTA papers looked at the bottlenecks in the current system and singled out route design as the most promising direction for improvement. This turned out to be inline with the efforts of Swedish authorities to decrease noise on approaches to Arlanda. Here, a fundamental tool in fuel saving and noise abatement are arrival routes (STARs) with curved approaches (CA), playing also the central role in Arlanda's environmental permit. CAFEA will develop a precise mathematical framework for optimization of STARs with CA, and design, analyze and implement efficient algorithmic solutions to the problem of constructing fuel-efficient STARs with CA while taking into account the many operational constraints. The algorithms will be used to optimize locations of the entry points to Stockholm TMA and to produce the STARs from the entries to runway thresholds of Arlanda airport.

SWEAO: UPPER AIRSPACE OPTIMIZATION. While TMA designer's task is to create both routes and sectors (see above), the introduction of free routing left only the *sectorization* as the goal in splitting the *enroute* airspace into control zones -- the routes are basically decided by the airlines. The EU-wide initiative of merging countries FIRs into Functional Airspace Blocks (FABs) has not succeeded and would not have been optimal anyway, since boundaries between countries were optimized for anything but air traffic control. For a number of years, we ran a class project with our ATCO students, trying to assess advantages of the Danish--Swedish FAB above our heads -- no clear benefits could be identified (fortunately, no harm either), the reason being the already existing good cooperation between Danish and Swedish ATCOs even before the FAB (thanks, in particular, to the COOPANS partnership). The goal of this project is to determine optimal splitting of the airspace into control areas *ignoring* countries boundaries and take the local expertise to the European level.

Specifically, within the project we developed a new algorithm for optimal splitting of an upper airspace. The algorithm aims to balance controllers' workload between the sectors. To quantify the workload we considered two measures of traffic complexity:

- The *maximum* number of aircraft in the sector over time
- The *average* number of aircraft in the sector over time

We proved that it is always possible to find a split that divides an airspace into two perfectly balanced (i.e. with both KPIs balanced simultaneously) parts, see Figure 1 for an example of a perfect split (for simplicity we removed all turn points from the flight trajectories and enclosed the complicated Swedish FIR boundary into a rectangle). Moreover, our algorithm allows to find *all* perfectly balanced cuts. Currently the task of sectors drawing is delegated to a human airspace designer, as it is an extremely complex process that requires (among other qualities) creativity. This is the reason why our algorithm is intended to just be a *decision support tool* (DST) for a designer. We coded the DST prototype, visualizing *all* perfect splits, so the designer can see where the balanced cuts live and how badly a chosen cut performs (Figure 2).

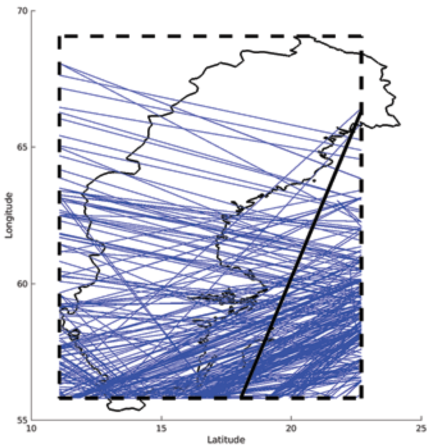

Figure 1 - The optimal split (black) of the airspace (dashed). Blue line segments represent flight trajectories

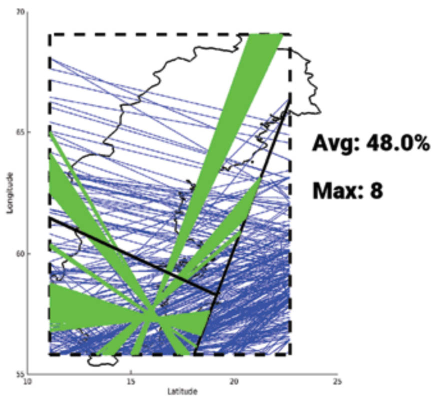

Figure 2 - The prototype of a decision support tool. Green regions represent places, where optimal splits live

TMAKPI (pending). An overreaching approach to handling a large-scale optimization problem (like ATM modernization) is to split it into smaller, tractable subproblems, do the smaller-scale optimization and then smooth interfaces between the solutions. A natural question, arising after application of such schemes, is to assess how well the partly-optimized solutions perform in comparison with the global optimum. In technical terms, this boils down to evaluation of a set of KPIs. An important idea here is that the KPIs should be expressed in terms of comparison to optimal solutions (formally -- as approximation factors), and not be targeted as absolute numbers (a concrete example is the Horizontal Efficiency KPI -- the ratio of flown nmi to the great circle distance; it would be wrong to set targets simply for the number of miles flown). This aspect was missed in the Master plan, which became a major point in the recent special report on SESAR (Single European Sky ATM Research) Joint Undertaking by the European Court of Auditors. TMAKPI aims at understanding how well the system can do (or could have done), comparing the real (or simulated) performance with the best *theoretically possible* KPI values.

CYBSEC: Security and Privacy of Air Traffic Communication. Recent contributions from academic and hacking communities have exploited potential vulnerability of air traffic communication to attacks on some of the currently used technologies; however, not all of these attacks have resonated widely within aviation circles. Within this project we examine the security measures currently adopted in air traffic communication in Sweden, analyse technical characteristics of the wireless ATM communication technologies and examine the possibility of attacks and unauthorised usage. The pre-studies and the follow-up studies will build a bridge between the ATM and research communities in the field of wireless communication security. We will propose a set of potential countermeasures able to defend air traffic control systems and significantly improve the security of air traffic communication networks under the existing real-world constraints.

CAPMOD: Capacity Models for Remote Tower Services. One place where cybersecurity is particularly important is ROT, as the data from remote airport is transferred to the remote tower center (RTC). The main research questions in this project are: How the workload at RTC differs from the workload at traditional towers? How many airports can an ATCO control from one RTC, and how many ATCOs are necessary and sufficient to manage traffic in several remotely controlled aerodromes? Optimal rostering and staff scheduling at RTC will unleash the huge economic potential of the remote services. Our mathematical framework will also include probabilistic modeling for increased predictability of the extra workload due to unscheduled events like extreme weather conditions, military exercise, hospital helicopters, etc. (Interestingly, this large, long-term project spawned from a Bachelor thesis written by our ATCO students---Peter Axelsson and Jonas Petersson---who also coauthored the first research paper on the subject; we couldn't have wished for a better outcome of our teaching activities.)

STAFFLESS AIRPORT (PENDING). Air navigation is only one of the services that can be provided remotely; more generally, it may be of interest to operate an airport stafflessly or with minimum staff. This project will explore such possibilities, looking at the many legal and operational issues (from robotic snowblowing to automatic locks to security checks by the cabin crew) -- what is the absolute minimum cost of an aircraft turnaround?

SAILAS SUSTAINABLE AIRPORTS LOCATIONS. Remote and staffless operations are most called for in remote airports, which crave for lower operational costs. This project addresses another aspect of operations for small airports far away from the capital: low demand and the need for subsidizing the flights to/from the area. One the one hand, there currently exists a trend to exploit the economies of scale by using large airports (and larger aircraft) farther from the populated cities -- this decreases the environmental impact and allows to operate optimal routes (without the need to avoid noise-sensitive neighborhoods and no-fly zones). The opposite trend is also picking up -- flying out of small airports, conveniently reached by ground transportation. SAILAS aims to quantitatively analyse the impact of closing, opening, or moving

an airport in Sweden, under a common framework (as a macro model) for this type of questions. The project is run as a doctoral study at LiU for five years.

UTM-OK: CAPACITY ESTIMATION FOR DRONES. While conventional aviation is becoming remote/unmanned on the *service* side (see above), in the drone world both Remotely Piloted Aircraft Systems (RPAS) and autonomous Unmanned Aerial Vehicles (UAVs) are becoming the reality in the *operations*. Given the projected number of drone flights, capacity estimation for the very low level (VLL) uncontrolled airspace becomes of crucial importance. This project addresses questions like: How much traffic is it possible to have in a certain area (e.g., over a city) before safety is compromised, noise levels are exceeded, communication spectrum is jammed, etc.? Establishing unmanned traffic management (UTM) system is of highest priority to LFV and many international partners (FAA, NASA, US universities) with whom we are tightly collaborating in this project. UTMOK is also a PhD study at LiU.

PBN4UTM (PENDING). Performance-Based Navigation (PBN) is the unifying theme for multiple airspaces used by multi-class vehicles and is a central pillar of the ongoing ATM modernization efforts both within SESAR in EU and NextGen in the US. Its idea is to acknowledge the diversity of the users and airspaces, and provide air navigation services based, in particular, on the equipage level and airspace specifications. Development of PBN for UTM, in order to adopt different regulations in different areas, is a core of airspace integration solutions, as different airspaces may require different capabilities: e.g., users with weaker equipage may not be permitted in the congested urban spaces. Note that in ATM, PBN has to fit into the existing well evolved system, which is a sometimes painful process. To avoid the same type of retrofitting complications in UTM, it is crucial to be proactive and establish PBN for RPAS as early as possible. This project will lay out the algorithmic base towards development of PBN for UTM in VLL urban airspaces. Two specific challenges are *Smart geofencing* (maintain and update efficient representations for the multitude of the airspace constraints imposed by owners, users, authorities, et al.) and *Launch cylinders placement* (find good location where higher-flight-level VTOL traffic, like urban drone taxis, may cut through the lower layers while minimally disrupting traffic in the layers).

FURTHER INDUSTRY COLLABORATION.
Naturally, LiU alone would not be able to manage such a realm of projects. ATM is very human-centric, and our research creates only decision support tools to help professionals in deciding on the best option. We are honored to have representatives from several local and international authorities (LFV, Swedavia, Trafikverket, Transportstyrelsen, EUROCONTROL) as members of the projects reference groups. The industry involvement is vital for us, as the field experts help connecting our mostly (and sometimes very) theoretical investigations to the reality. To make the education road two-way and complement the teaching provided by the university to ATCO students, LFV and LiU started to discuss a new form of cooperation: LiU employees will intern at LFV for a couple of years to get hands-on experience and be tutored by the LFV experts -- so maybe some of our former students get a chance to retaliate at the outgrown researchers for the hard time in classes taught in Sturup. We look forward the continued synergy and more joint projects with LFV.

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