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Editorial

Air traffic management: Challenges and opportunities for advanced control

GUEST EDITORS: Andrea Lecchini-Visintini[1,*,†] and John Lygeros[2]

[1]*Department of Engineering, University of Leicester, Leicester LE17RH, U.K.*
[2]*Automatic Control Laboratory, ETH Zurich, Switzerland*

The operation of Air Traffic Management (ATM) is characterized by a hierarchy of tasks many of which are exceptional benchmarks for any method aiming to tackle complexity. ATM applications offer unique challenges and opportunities for the development of innovative control methods. Increasing levels of traffic are pushing the current ATM systems towards their limits. Therefore, there is also a strong need for more sophisticated tools for ATM applications, which can sustain the safety performance of ATM and accommodate the steady growth of air traffic worldwide. The need for technological improvement in current ATM systems has stimulated high-quality research over the past two decades. In addition, models and simulation tools covering all levels of ATM are being developed, both to test and validate novel methods and to perform risk assessment for existing operations. In this special issue we present a selection of ongoing research, which builds on advanced methodologies in automatic control and signal processing and applies them to problems in ATM. We hope that in the process we will highlight the interesting research problems and challenges arising in ATM and will stimulate follow-on developments in this exciting research area.

The volume comprises six technical papers. In the first paper, Prandini *et al.* [1] consider the problem of evaluating the complexity of air traffic. The aim is to detect in advance the occurrence of congested areas, which would require air traffic controllers and pilots to execute multiple or complex tactical maneuvers to navigate through safely. The work develops a novel probabilistic approach to the problem of airspace complexity, in such a way that the uncertainty in the prediction of future aircraft trajectories can be taken into account.

Uncertainty in aircraft trajectory prediction is also the theme of the paper by Lymperopoulos and Lygeros [2]. The aim here is to use advanced signal processing and state estimation methods to reduce the uncertainty inherent in the trajectory prediction process. The authors present a novel approach in which radar information from multiple aircraft flying in a region of airspace is combined to reduce the uncertainty in the weather forecast and hence improve the prediction of the future aircraft positions. Novel Sequential Monte Carlo algorithms are developed for this purpose, suitable for the high-dimensional problem and the nonlinear aircraft dynamics.

The third paper [3] comes from the developers of Base of Aircraft DAta (BADA). BADA provides an aircraft performance model, a model of the flight management system, and a database of parameters that can be used to instantiate the models for different aircraft types and flight conditions. BADA has been used world wide both in academia and in industry for a wide range of studies in ATM; for example, the filtering algorithms of [2] in the present special issue have been inspired by and have been validated on BADA. In [3] the authors present BADA

*Correspondence to: Andrea Lecchini-Visintini, Department of Engineering, University of Leicester, Leicester LE17RH, U.K.
†E-mail: alv1@leicester.ac.uk

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and the latest achievements in its development, provide examples of studies carried out based on it, and information on how to obtain and use it.

Safety is always the most important concern in ATM. For airborne operations, safety is typically quantified in terms of losses of separation, known as conflicts. The last three papers of the issue deal with the problem of determining aircraft trajectories which prevent loss of separation (conflict-free flight). Idan *et al.* [4] develop an approach in which conflicts are resolved by re-computing new conflict-free trajectories but only for a minimal number of aircraft. It is shown that the resulting conflict resolution algorithms are computationally efficient and suitable to address conflicts which are detected to occur within 20 min in the future.

The paper by Kantas *et al.* [5] presents an approach to the problem of aircraft routing based on the optimization of an expected-value cost. In this approach, the aim is to determine routes which minimize the expected time of arrival to the aircraft destinations and are conflict free with high probability, in the face of uncertainty in the wind forecast. The authors adopt the Sequential Monte Carlo framework to develop a novel optimization algorithm that makes the routing problem tractable.

Finally, the paper by Roussos *et al.* [6] presents a collision avoidance strategy based on Navigation Functions, a methodology originally proposed for collision avoidance and goal attainment in multi-agent robotic systems. The proposed strategy is decentralized by nature and is motivated by future ATM concepts based on autonomous aircraft and self separation. The original robotic methodology is extended to allow for agents whose motion resembles the motion of an aircraft, by preventing instantaneous movement in the lateral and perpendicular directions, as well as high yaw rotation rates.

In summary, the six papers in this special issue highlight different research problems in ATM. They also highlight different approaches to these problems, extending state-of-the-art automatic control and signal processing methodologies. We feel that as a whole the papers in this volume demonstrate the richness of ATM as a research area and as a motivation and application ground for cutting edge results in automatic control and signal processing. We hope that the links highlighted here will serve as further motivation for exciting new developments in this direction.

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