An interaction metric for an efficient traffic demand management: requirements for the design of data-driven protection mechanisms ('INTERFACING')

Executive summary

Data-driven trajectory prediction methods pave the way not only for a better predictability but also for a true integration at the ATM service system level in which the presently layered ATM planning could exploit the freedom gaps between strategic/pre-tactical (ATFM) and tactical (ATC), to move one step forward to a competitive ATM system in which present ATC resources are used to attend AUs' demands whilst avoiding resource idleness and saturations that foster regulations and/or holdings.

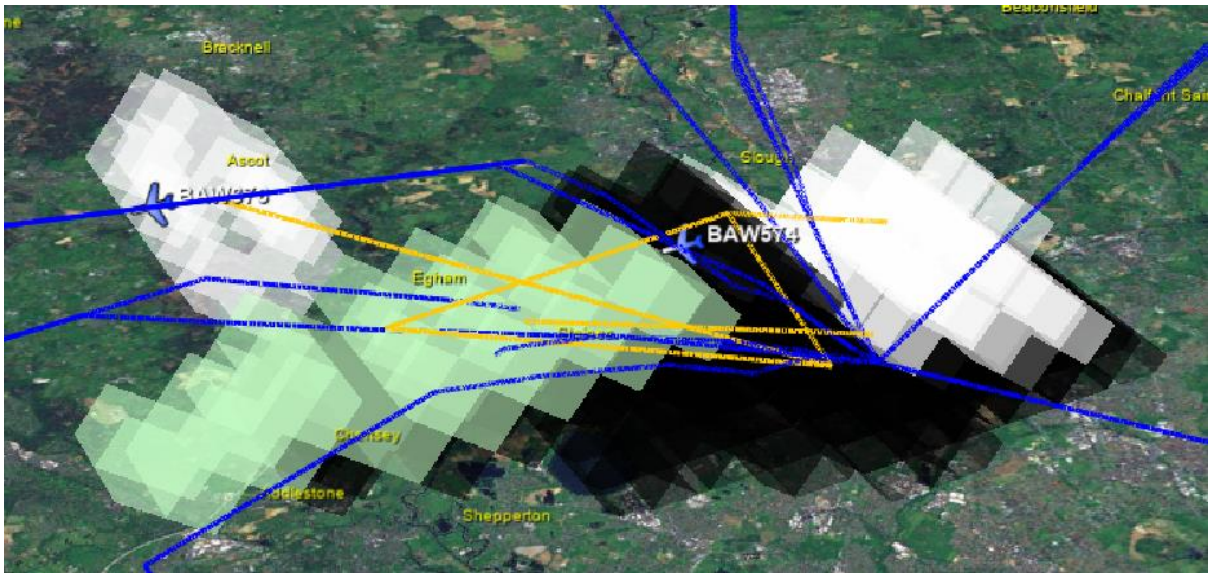
Airspace digitisation opens a window of opportunities to support the modelling of airspace demand **at the micro level by analysing trajectory data** to anticipate the detection of problems/interactions among trajectories that would consume mental effort of ATCs and, in some cases, the implementation of tactical measures. The proper identification of the different interaction zones will facilitate the assessment and exploitation of new ATFCM and STAM mitigation measures in volumes smaller than sectors, providing advantages with respect to conservative measures such as sector capacity regulations, which unfortunately tend to over-constrain the full ATM when more than one regulation is activated.

The granularity of the INTERFACING methodology enables the early detection of precise areas where problems to manage will arise. INTERFACING **proposes a probabilistic framework** to extend the PARTAKE (SESAR ER2 project, GA: No. 699307) data-driven prediction methods for digitisation, trajectory interaction detection and analysis tools and **implements new interaction metrics** to better integrate strategic and tactical information to anticipate ATC problems (i.e. potential co-existence of more than one aircraft in the same airspace volume). These tools are enhanced with a macro level analysis of the interdependencies among interaction zones (distributed through different sectors or spatially concentrated in the same sector) to enable a proper understanding of the spatio-temporal interdependencies among fragmented sector capacity constraints in order avoid the propagation of undesired interaction-zone dynamics through the full ATM system together with the potential upstream and downstream negative effects of capacity regulations.

The project has produced two main outcomes:

- **A formal probabilistic framework for Interaction Zone detection and characterisation**. The following concepts have been formalised in order to assess the airspace state in terms of the Interaction Zones (see figure below):
  - the **Characterisation** of the possible interaction zones that may appear during the analysed period, considering the uncertainty in the trajectory predictions,
  - the **Existence Probability**, which is the probability that these detected interactions zones will finally take place,
  - the **Complexity** of each interaction zone, which is a function of its intrinsic properties and,
  - the existing **Interdependencies** between the detected interaction zones.
- **A Demonstration suite**. The core of the project developments is a library of functional blocks that works as a pipeline, taking the traffic scenario as the main input, along with the algorithm tuning parameters, and producing the results of the interaction zone analysis. The traffic scenario is described by the set of 4DT trajectories using the so6 file format. The analysis results are represented by a complex data structure (using a new format called VisioJSON, which extends from GeoJSON) containing the detected interaction zones, hotspots, their metrics as well as their interdependencies. Two solutions have been implemented for the visualisation of

the INTERFACING analysis results. *AsloEarth* is a visualisation tool created as part of the INTERFACING project to graphically show the objects and metrics produced by the interaction zone analysis. Secondly, a software communication interface for executing the tools from the R-NEST platform, so the ATM community will benefit from the project outcomes through this reference tool.



3D Visualisation of Interaction Zones

On the view of the achieved results, the project has successfully addressed two (expected positive) impacts for ATM:

- **Enhancement of the DCB for the sake of ATC Minimum Intervention**. INTERFACING metrics and the interdependency causal analysis complement and enrich traditional indicators, such as entry and occupancy counts, that participate in the capacity analysis. The Interaction Zones can be framed at sector level, providing a deeper insight on the possible conflicting situation ATC will face. It could be expected that the consolidation of the implemented metrics opens the opportunity to investigate new mitigation measures bridging the gaps between the temporal ATCFM phases, ranging from the LTM to the EAP lookahead with respect to ATC timeframe.
- **Improve transparency and efficiency of DCB network services**. The new metrics and interdependencies provide an insight into the Interaction Zones at trajectory level, so the mitigation measures to remove the interactions can be implemented at trajectory level instead of at sector level. Therefore, an efficiency improvement could be expected since constraints (e.g. a sector regulation) can be transformed into decision variables (e.g. which is the minimum set of flights that should be regulated to reduce the complexity of a given Interaction Zone or Hotspot). Transparency would benefit from the causal analysis at trajectory level since the need to implement certain mitigation measures can be explained from the up & downstream negative effects a given flight or set of flights are causing.

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