Verification and validation of the graph-based airspace model

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Europe, and especially the European Union, is one of the most densely populated areas on the Earth. Because of the high mobility of people living in Europe, a very complex and extensive transport system has been created in its area, including the air transport system. In 2017, almost 10.5 million IFR flights were performed in Europe. Not taking into account the decrease in the number of flights because of the COVID-19 pandemic, 19.5 million IFR flights are expected in Europe in 2040. Such a large number of air operations requires a suitably advanced technical and organizational infrastructure.

Historically, Europe consisted of the number of states that did not form homogeneous political, economic and demographic systems. It also affected the different air traffic and airspace organization in each country. The process of creating the Single European Sky - SES was initiated by the European Commission in 2000 with many legislative activities and then research and development activities under the SESAR (Single European Sky ATM Research) program, established in 2007. Despite the actions taken in Europe, the ATM (Air Traffic Management) system is fragmented and dominated by domestic entities with a monopoly on the provision of ATM services. The low performance of the system is caused by the functional division of airspace according to national borders, which still applies to some extent. The border division of airspace has made the European ATM system a kind of mosaic of national ATM systems.

One of the solutions developed under the SESAR program is the change in the rules of planning and performing flights. Currently, in many places in Europe flights are still planned along fixed or conditional airways. However, this method does not make it possible to connect the route start and endpoints most beneficially. The new route planning method gives some freedom in selecting the aircraft flight trajectory. Therefore, this type of flight planning is known as free route, and the airspace in which it is possible to plan flights is called Free Route Airspace (FRA).

To fully use the advantages of the FRA space, the planned routes should be optimized. However, this requires the development of the necessary models and algorithms, such as aeroplane model, airspace model, flight route model and the algorithm of flight route optimization.

The proposed model of airspace is a graph with a structure reflecting the most important features as well as restrictions applicable in it. The concept of the new airspace model allows the aircraft user to report only the entry and exit points from the airspace sector.

The trajectory in the graph is described by piecewise line based on many nodes and edges connecting them. The nodes of the graph are described by geographic coordinates, and the position of the aircraft is determined by the height and time at the route nodes. The nodes of the graph, however, are not treated as waypoints (WPs), but only define the initial shape of the flight path. This route is processed in the following stages to "straighten" it, with the condition of minimizing waypoints, without significantly reducing the quality of the result. Only the final version of the route ("straightened") will be used to submit the flight plan.

The subject of the work was to determine the parameters defining the airspace model in the form of a graph, among which the distances between nodes are among the most important. The distances were initially selected based on surveys conducted among pilots and air traffic controllers. Then, the airspace model was used to model the route planned using traditional methods with the assessment of the quality of the route modelling. The validation consisted of conducting a series of test flights on an FNPT II class flight simulator to demonstrate the feasibility of the route planned in the airspace graph model.