Chapter 4
Cooperative Decision Making Under Air Traffic Conflicts Detection and Resolution

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ABSTRACT
A number of probabilistic methods for aircraft conflict evaluation are presented. The analytical method is shown. The probability method that enables taking into account the features of stochastic dynamics of motion and the new compositional method of conflict probability evaluation are proposed. The feature of this method is that analytical solution is made using the predicted uncertainty areas of each aircraft position separately, making it possible to manage the position uncertainty and to apply for a wider range of scenarios. The multi-criteria decision-making for conflicts resolution is discussed. Optimality criteria and constraints for conflict resolution are defined. The generic multi-criteria model of conflict-free trajectories selection and the methods of resolution of two- and multi-aircraft conflicts have been developed. These methods provide the synthesis of conflict-free trajectories using different aircraft maneuvers according to criteria of flight regularity, economy, and maneuvering complexity using the multi-criteria dynamic programming.

BACKGROUND
Regardless of steady increasing of the automation level in the air traffic management (ATM) systems, the final decision-making remains with the air traffic controller (ATCO). Being in the flight control loop, ATCO significantly affects the integral characteristics of the air navigation services system. The human factor is revealed to a large extent with increasing the intensity of air traffic, when the number of potentially conflict situations also increases, that lead to significant delays in air traffic, an increase in the probability of dangerous approaching and aircraft collisions in the air.

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The main task of the air traffic control (ATC) is to avoid mid-air collisions and collisions with obstacles in the maneuvering area, as well as to regulate air traffic taking into account meteorological conditions and flight restrictions. Air traffic safety is ensured by complying with established safe separation standards (minima).

The solution of the problem of preventing potential conflict situations is carried out in two stages. At first, the threat of a conflict between the aircraft must be detected, and its danger must be evaluated. Then some optimal actions are taken to eliminate the threat.

According to the new concepts, the development of ATM systems involves using of more advanced decision-support tools, including the artificial intelligence components, where the central place is given to the detection and prevention of conflict situations.

The development of ATM systems in the area of integrating of digital data transmission systems, improving surveillance methods, artificial intelligence tools and automation enables to apply the strategy of cooperative decision-making under air traffic conflicts detection and resolution. Cooperative decision-making requires the availability of all necessary relevant information that should be available to the parties involved in the decision-making process, i.e. to the controllers and the pilots. The new qualities of the cooperative decision-making provide a more reliable assessment of air traffic situation and control.

METHODS OF CONFLICT DETECTION AND CONFLICT PROBABILITY EVALUATION

It is considered (Babak et al., 2006; Bakker et al., 2001; Blin et al., 2000; Blom et al., 2001; Kuchar & Yang, 2000; Paielli & Erzberger, 1997; Prandini et al., 2000) that probabilistic methods of conflicts evaluation are more advanced and promising compared to geometric methods. They enable to take into account the probabilistic nature of the flight process because of the influence of numerous disturbances, and at the same time take into account the controllability factor and the features of the applied navigation modes.

However, the well-known probabilistic approaches and methods (Blom et al., 2001; Paielli & Erzberger, 1997; Prandini et al., 2000) have significant limitations. These methods are usually quite complicated, and their algorithmization and computer realization require substantial simplifications.

The methods of conflict detection and evaluation considered in this section relate to a group of methods based on stochastic uncertainty prediction of aircraft location due to their deviation from the flight plan. The proposed methods enable to predict stochastic uncertainties of aircraft location not only on straight flight paths, but also in maneuvering areas, as well as to use the information about stochastic dynamics of motion.

General Statement of Conflict Detection and Conflict Evaluation Problem

In air traffic management systems the evaluation of relative position of the aircraft is performed in a unified coordinate system. Let us consider Cartesian coordinate system $Oxyh$. The axis $Ox$ and $Oy$ are located in a horizontal plane, the axis $Oy$ is directed to the north, and the axis $Oh$ is directed vertically (Figure 1).
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