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ScienceDirect

Procedia Engineering 187 (2017) 420 – 424

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Scientific Conference Transbaltica 2017:
Transportation Science and Technology

The Concept of Initial Air Traffic Situation Assessment as a Stage of Medium-Term Conflict Detection

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Abstract

Key decisions in the air traffic control system are supported by various technical systems. The most important include conflict detection and resolution (CD&R) systems. The main subject of this paper is a medium-term conflict detection system (MTCD). An excessive number of false alarms is one of the major functional problems of these systems in current implementations. They make the whole idea of CD&R systems less effective. The aim of this study is to present the concept of the system for the initial assessment of the overall level of complexity of the traffic situation. It should become the first stage of the MTCD system algorithm. The paper presents a general scheme of the model to assess the traffic situation based on fuzzy sets theory, and more specifically on the theory of fuzzy inference systems. Choosing this type of the model is justified by the lack of precise and well-defined relationships between the factors influencing the traffic situation complexity and its assessment, which is largely subjective. The paper discusses the input and output linguistic variables and briefly presents the results of simulation experiments conducted with the use of fuzzy inference system implemented in the SciLab environment. Experiments have confirmed the effectiveness of this solution and indicated the possibility of its inclusion in the MTCD system algorithm as a first stage. This will improve the MTCD software behavior with respect to alerting a controller about a detection of the conflict and supporting him/her by the development of proposals for its solution.

Peer-review under responsibility of the organizing committee of the 10th International Scientific Conference Transbaltica 2017

Keywords: air traffic control, medium-term conflict detection, fuzzy inference system, conflict detection and resolution, transport safety

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Peer-review under responsibility of the organizing committee of the 10th International Scientific Conference Transbaltica 2017
doi:10.1016/j.proeng.2017.04.395

1. Introduction

Air traffic control systems are complex sociotechnical systems. A human – an air traffic controller (ATCo) is supported by numerous technical systems. They include conflict detection and resolution (CD&R) systems. Their main task is detection of conflicts, which we define as events of loss of minimum separation between the aircraft. Another task is assisting the ATCo in finding the way of resolving a conflict situation. In this paper we deal only with the first of these tasks.

CD&R systems are created for different planning horizons. This paper is concerned with medium-term conflict detection (MTCD) systems, with planning horizon of about 15–20 minutes [1, 2]. Their general principle of operation is based on trajectory prediction according to one of several possible models, detection of possible collision points and alerting the ATCo.

Excessive number of false alarms is the fundamental functional problem of MTCD systems. A big difficulty in predicting the trajectory and future locations of the aircraft are the most common causes. The trajectory may be subject to deviations caused by the interaction of many factors of a random character.

Focusing controller's attention on non-existent or negligible conflicts is the main negative effect of false alarms in MTCD systems. Negligible, because very often the ATCo is aware of the conflict, and there is still enough time to resolve the situation without any complications.

The aim of this paper is to create an outline of a method for initial overall assessment of the traffic situation, so that MTCD systems algorithms can be modified in order to reduce the number of false alarms. In our opinion, the response of the system when it detects a medium-term conflict between a pair of aircraft should depend on the overall assessment of the situation in the control sector. In the case of straightforward situation – a decision about warning the ATCo can be postponed, giving the ATCo a chance to notice and resolve the problem, possibly this may allow more reliable estimation of the future position of the aircraft. In case of a complex traffic situation – immediate ATCo warning is necessary, because a delay could lead to a safety hazard.

2. The principles of MTCD systems operation

Both the detection and methods of resolving conflicts are as reliable as accurate is the model for trajectory prediction. Prediction models differ from each other mainly by the way of determining the position of the aircraft. There are three main prediction models: nominal, worst-case and probabilistic [4].

Some CD&R systems, having discovered a conflict, propose the ways to resolve it. Kuchar & Yang [4] and ICAO [3] discuss in detail possible approaches. Broadly, they consist in performing one or more maneuvers of: a change of heading, a change of the flight level or a speed change. A situation when two aircraft trajectories intersect and it is predicted that collision is possible is an example of a situation where a change of heading can be used. In this case, one of the aircraft may change the course by a small angle. Another solution in such a situation may be changing the speed which causes the aircraft to reach the conflict point at different times. Also changing of the flight level is a very common way of resolving the conflict used by ATCos. It is necessary to consider various effects of maneuvers planned by MTCD systems, including the possibility of new, induced conflicts [7].

3. A fuzzy system for traffic situation assessment

3.1. General structure of fuzzy inference system

The idea behind the fuzzy set theory was to describe the phenomena and concepts having imprecise and approximate character. Methods based on classical set theory are not able to solve complex issues of this nature.

A fuzzy set will denote a set of pairs

$$A=\{(x,\mu_A(x))\};\ x\in X\ , \tag{1}$$