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Constructing an Index of Difficulty for Air Traffic Control Using Proximity Parameters

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Abstract

In this paper, we propose an approach to constructing an index of air traffic control difficulty based on exponential functions of proximity parameters of aircraft pairs, i.e. the time to closest point of approach and miss distance. The index is given by single value between 0 and 1 in order to simplify its presentation, such as in a heat map. The approach deals with the mapping of aircraft trajectory information onto proximity parameters and the derivation of the real-valued index in [0, 1]. The approach consists of the following steps: 1) Formulation of the concept of a difficulty index calculated from the trajectories of a pair of aircraft at a given time; 2) Determination of an objective function which evaluates the projected difficulty; and 3) Derivation of the difficulty index as a function of the trajectory information and model parameters. This paper briefly describes the method of mapping and some results from numerical calculation examples using the proposed method.

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Keywords: Air Traffic Control; Index of Difficulty; Proximity

1. Introduction

The modernization of air traffic management (ATM) systems is proceeding globally with the introduction of technologies such as air-ground datalink, automatic dependent surveillance and performance-based navigation. With these systems, ATM is expected to shift from the current airspace-based operations paradigm to trajectory-based operations (TBO) [1], with trajectory information becoming the basis of the future ATM. In TBO, it may be useful

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to identify areas of airspace with expected high demand, "hot spots", based on planned or predicted trajectory information. To detect such potential hot spots, comprehensive indices associated with safety [2,3,4,5] and airspace complexity [6] will be required for airspace design and ATM-related studies.

The air traffic controller is expected to play a role even in highly automated future ATM systems. For controllers, the difficulty of handling air traffic depends partly on the circumstances of potential close-proximity encounters between pairs of aircraft; specifically, on their relative positions and relative velocity vectors. Each such proximity event increases controller workload by a degree that may be associated with the severity and the time to the potential proximity event. These quantities can be modelled by the time to the closest point of approach (CPA) τ and the miss distance m_c. Controller workload, or the difficulty of handling a potential proximity event, may increase as the projected time horizon or miss distance become smaller. We therefore propose that a comprehensive index of difficulty can be constructed from a combination of appropriate functions of these proximity parameters.

In this paper, we propose an approach for constructing a difficulty index based on exponential functions of the proximity parameters. The index is given by single value between 0 and 1 in order to simplify its presentation, such as in a heat map. The approach deals with the mapping of trajectory information onto the proximity parameters and the construction of a real-valued index in [0, 1]. This paper briefly describes the method of constructing the index and some numerical examples calculated by the proposed method.

Nomenclature

$\vec{R}_r = (x, y, z)$ relative position vector and its components

$\vec{V}_r = (v_x, v_y, v_z)$ relative velocity vector and its components

$\overrightarrow{d(t)} = (x + v_x t, y + v_y t, z + v_z t)$ relative distance vector at projected time t and its components

$R_H = (x^2 + y^2)^{1/2}$ relative horizontal distance

$V_H = (v_x{}^2 + v_y{}^2)^{1/2}$ relative horizontal velocity

$R_r (\equiv |\vec{R}_r|)$ relative distance

$V_r (\equiv |\vec{V}_r|)$ relative speed

2. Concept of Difficulty Index

2.1. Air traffic controller tasks

The primary aims of air traffic control are to prevent collisions and to maintain a safe, orderly and expeditious flow of traffic. Air traffic controllers achieve this by providing instructions, advisories and other information to aircraft within a given volume of airspace. As well as the amount of traffic being handled, controller workload seems to be associated with the "complexity" of the airspace which depends partly on the traffic flow characteristics. The difficulty of handling air traffic depends partly on the circumstances of potential close-proximity encounters between pairs of aircraft; specifically, on their relative positions and relative velocity vectors. Each such proximity event increases controller workload by a degree that may be associated with the severity and the time to the potential proximity event. These quantities can be modelled by classical parameters used in collision avoidance systems; that is, the time to the closest point of approach (CPA) τ and the miss distance m_c. The difficulty of handling a potential proximity event, and hence its associated workload, may thus vary according to the projected time horizon and the miss distance; roughly speaking, workload or difficulty increase as the projected time horizon or miss distance become smaller. We therefore propose constructing a comprehensive index of difficulty from a combination of appropriate functions of these proximity parameters.

2.2. Index of difficulty

A difficult situation can be essentially described in terms of proximity parameters such as m_c and τ. The following characteristics are desirable for a practical index of difficulty: