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A model of air traffic controllers' conflict detection and conflict resolution

Ein Modell der Konflikterkennung und Konfliktlösung eines Streckenfluglotsen

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Abstract

A model of the mental activities of en route controllers in air traffic control (ATC) is outlined. As an example of the psychological research rendering the basis for this model, the methods and results of an experiment with experienced controllers is sketched which is concerned with conflict detection in ATC. Further, a procedure for conflict resolution is described, supplementing the general model. This procedure is designed to be transformed into a computer based assisting system in ATC. Problems and functions of operator models in the development of new technologies in air traffic management are discussed.

Zusammenfassung

Ein Modell der mentalen Operationen eines Fluglotsen in der Streckenflugkotrolle wird skizziert. Als Beispiel für die psychologischen Untersuchungen, die diesem Modell zu Grunde liegen, werden die Methoden und Befunde eines Experiments zur Konfliktentdeckung herangezogen. Ferner wird eine Prozedur skizziert, welche die Wahl der jeweils geeignetsten Konfliktlösung durch den Lotsen unterstützt. Diese Prozedur soll, unabhängig vom implementierten Fluglotsenmodell, zu einem Assistenzsystem ausgearbeitet werden. Probleme des Einsatzes des Nutzermodells für die Entwicklung neuer Technologien für künftige 'Air Traffic Management Systeme' werden diskutiert.

Keywords: ATC; En route control; Conflict resolution; Operator models; Simulation; Scenarios

Schlüsselwörter: Flugsicherung; Streckenflugkontrolle; Konfliktlösung; Nutzermodell; Simulation; Szenarien

1. Introduction

This contribution pursues two purposes. First, it will outline an extended research program aspiring to develop an elaborated model of air traffic controllers' mental activities. Secondly, it will report on an attempt to determine the most feasible conflict resolution if conflicting trajectories are detected in a given traffic constellation. Both attempts are concerned with en route control in lower airspace, leaving aside the transitions as well to airport approach as to the upper air space.

In 1995 at the onset of our project, it's main purpose was to develop a generalized mental model representing the controllers' conceptions of their momentary mission. This assignment implies parallel processing of multiple tasks, as for instance information retrieval, anticipation of future constellations, conflict detection, and conflict resolution, in a continuously changing environment. Since there existed no antecedent attempts to model multiple cognitive goals in a dynamic situation, we decided to implement our model also as a computer simulation of the controllers' activities in order to keep track of mutual interactions of the numerous tasks. The results of this simulation helped us repeatedly to

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detect inconsistencies or omissions in our conceptual model. We named our model MoFL, according to the German terming *Modell der Fluglotsen Leistungen* (model of air controllers' mental processes).

Later on, our psychological project was integrated into an interdisciplinary research group on air traffic management (Fricke et al. [7]). This new frame of our research gradually diverted our approach from a psychological model of a dynamic mission toward the attempt to develop a tool that might anticipate influences of changing technologies on the controller's awareness, and thus assist the human centred design and the evaluation of new ATC tools. This paper will first outline MoFL as the result of psychological reasoning, based on many experiments with experienced ATC controllers, and show that it's basic assumptions proved to be successful.

In a second section, we will argue that the construction and implementation of a complete and coherent operator model hardly can keep abreast of the technological changes in ATC to be expected in near future, because of the time consuming experiments necessary to specify the information flow in MoFL. For instance, data link communication will dramatically change the controller's scheduling of his activities. Consequently, we supplemented the basic architecture of MoFL by modules which are based on logical reasoning rather than on observations of the controllers' cognitive activities. To illustrate this approach, we will sketch a new procedure for conflict resolution. This procedure might be transformed into an assisting system, independent of MoFL, that calls the most feasible solution for any existing conflict between trajectories.

2. Modelling cognitive activities of air traffic controllers in en route control

Systematic research concerning the tasks and the activities of air traffic controllers started around 1975. We will refer here mainly to studies on en route control. The first approach was systematic task analysis (e.g., Sperandio [18]), and this approach is still contributing to our knowledge (Phillips and Melville [16], Amaldi and Leroux [1], Dittmann et al. [3]) by using mainly systematic observation and interviewing. In these studies the operator's workload (Sperandio [18]) and the distribution of tasks within a team (Vortac et al. [19], Leroux [12]) are important topics.

A number of these studies differentiated specific procedures within the process of air traffic control (e.g., Laval [11], Phillips and Melville [16]), starting thus the construction of a general model of this process. Laval [11] achieved a similar discrimination of parts of the task, as we did, by a logical analysis. The aim of modelling en route control, is directly addressed by Freed and Shafto [6] and by Freed and Johnston [5], including the topic of a computer implemented model of the relevant mental activities. But these contributions rather outline methodological problems than proposing definite solutions. Quite close to a formal model come Kallus et al. [9] and Dittmann et al. [3] by positioning the main components of en route control in detailed flow diagrams of the task.

Some further sources of arguments for the present paper should be named here: Whitfield and Jackson [20] and Mogford [13] emphasize the importance of the controller's *picture* of the situation, which is about equivalent to his *situation awareness*. Boudes et al. [2] discuss the relevance of simulation studies for gaining knowledge about processes in actual air traffic control. A recent review of studies concerning conflict resolution tools is given by Kirwan and Flynn [10].

3. The operator model MoFL

MoFL is primarily a conceptual model, but it exists also as a computer implementation, that simulates the controllers' typical activities during control of a specific air traffic in a given ATC sector (Niessen and Eyferth [14]). The model represents the mental activities of controllers at the radar screen. We decided to model the activities of a single radar controller only, instead of a team of controllers, not only to get a clear definition of the model's topic, but also since it was difficult to recruit expert controllers for our experiments, and since quite often only a single controller was assigned to the observed sector in reality. By running the implemented computer model, the mental activities of an experienced air radar controller in the specified situation are simulated. The computer model catches, according to evaluation studies, most prototype constellations quite well, but it is still far from reflecting the variability of conflict solutions shown by experienced controllers.

Fig. 1 shows the architecture of MoFL. The main components of the model are the seven modules *data selection, anticipation, conflict resolution, update, sector knowledge* and *control*, which comprise several procedures, and the three information processing cycles interconnecting the modules. The centre of the system is the *picture,* a working memory representing the controlled situation, on which the modules operate. The information processing cycle comprises of the *data selection*, selecting momentarily relevant items from the redundant supply of information via radar, flight strips, and head phone communication. Repeated *updates* are part of this cycle, adapting the *picture* to the continuous changes of aircraft positions.

In the second cycle, the *anticipation* cycle, future states of each attention-demanding aircraft or aircraft relation are anticipated separately. If any intervention is necessary, especially in case of an impending conflict, the conflicting partners are combined to an *event* which is marked by a time stamp, indicating the latest term for intervention. In a corresponding process an event may be dismissed from focal attention if the impending conflict is not confirmed, or proves to be settled. In this case the time stamp is