Modeling behavior and performance of air traffic controllers using coloured petri nets

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Abstract

Airport infrastructure is often unable to grow at the same rate as the steadily growing volumes of air traffic and ground controllers face increasing workloads, because they have to deal with more aircraft in the same time. This can be counteracted by making changes to the system or system conditions, e.g. by implementing computerized supporting systems. Simulations are needed to investigate the impact of changing system conditions on the human operator. In addition to modeling the airport traffic control system in general, it is also necessary to model the cognitive processes and behavior of the ground controller. Based on basic guidelines for the development of cognitive simulation, an approach for the development of a coloured Petri net model of aerodrome air traffic control is presented.

Keywords: Task Analysis, Aerodrome Air Traffic Control. Coloured Petri Nets.

Introduction

Facing steadily growing volumes of air traffic, ground controllers encounter increasing efficiency demands and excessive workloads as they have to deal with more aircraft in the same time. At the moment the aviation industry is one of the safest modes of transport. Following Hollnagel, Woods and Leveson (2006) it is the inherent resilience of the system that makes it safe. In aviation it is the variability of human performance which enables air traffic controllers (ATCOs) and pilots most of the time to act in a safe way and to take the right action at the right time (Stroeve, Everdij & Blom, 2011). Above all ATCOs are responsible for the safe and efficient handling of air traffic where they regularly have to reach a tradeoff between efficiency and thoroughness if they are to be successful (Hollnagel, 2009). With increasing air traffic this tradeoff has to be shifted towards efficiency, which can lead to erroneous actions and increasing numbers of incidents and accidents. This effect can further be influenced by so called performance conditions, which are by definition a set of environmental, personal and systemic variables which can alter the possibility of erroneous actions (Center for Chemical Process Safety, 1994). To help ATCOs conduct their tasks safely and efficiently, changes to the system or system conditions will be introduced, e.g. by implementing computerized supporting systems like A-SMGCS (Advanced Surface Movement Guidance and Control System; EATMP, 2005). For the investigation of the impact of changing system conditions on the human operator a model of the human behavior and performance is needed.

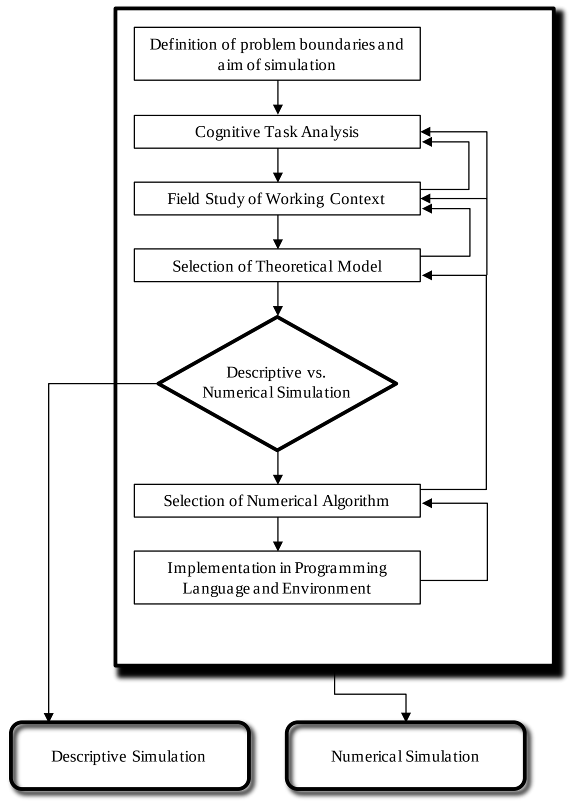

Figure 1: Basic guidelines for the development of cognitive simulation (Cacciabue, 1998).

Development of cognitive simulation

Following the basic guidelines for the development of cognitive simulation given by Cacciabue (1998) shown in Figure 1, the first step is the definition of the problem boundaries and aim of the simulation. For modelling purposes it is not only necessary to model the airport traffic control system in general, it is also necessary to model the cognitive processes and behavior of the ground controller. An essential requirement for this is exact knowledge about the tasks of ground controllers.

Cognitive task analysis and field study of working context

The second and third steps are a (cognitive) task analysis and a field study of the working context. Existing task analyses were reanalyzed in terms of their focus and methods for several sites across Europe, including analyses by EUROCONTROL (Buck, Biemans, Hilburn & Van Woerkom, 1996; Tavanti & Bourgois, 2006), German Air Navigation Services (DFS; Human-Factors-Consult, 2009) and Royal Air Force Institute of Aviation Medicine (Cox, 1994). Through these analyses, a widespread illustration of the tasks of the ground controllers has been generated and a model of the action phases of the ground controller based on action regulation theory has already been introduced elsewhere (Smieszek, Huber & Jürgensohn, 2011). Several main tasks and sub-tasks are described in further detail and a prototypical action sequence is created which will form the basis for the model construction. The review of task analysis will be validated with the help of expert interviews and field studies in two airport control towers of the Berlin airports.

Theoretical Model

The fourth step, as proposed by Cacciabue (1998), is the selection of a theoretical model, which in this case will be the contextual control model (COCOM) developed by Hollnagel (1993). Within this framework it is assumed that all human behavior is essentially influenced and the choice of the next action is determined by the actual context as it is also proposed by the situated cognition approach (e.g. Brown, Collins & Duguid, 1989).

Selection of numerical algorithms and implementation in programming language

To gain a numerical simulation, the final two steps are the selection of numerical algorithms and the implementation in programming language. For this purpose the framework of Coloured Petri Nets is chosen. Coloured Petri Nets is a language for the modeling and validation of concurrent and distributed systems and other systems in which concurrency plays a major role (Jensen & Kirstensen, 2009). It provides both a graphical representation and a mathematical description of the modelled system. Firstly a Coloured Petri Net will be constructed which models the normal process of aerodrome air traffic control. Afterwards Fuzzy Logic (Zadeh, 1965) terms will be introduced to include the influence of several performance conditions on the operation of the system. With the help of the Petri Net model the investigation and evaluation of the impact of system changes on human behavior and performance will be possible.

Conclusion

Due to the dramatic changes in the air traffic control sector especially the growing traffic levels it is necessary to study the effects of changing system conditions on cognitive processes and the behavior of aerodrome air traffic controllers. This can be done by using models and simulations. An approach has been presented which will provide a model and simulation both of the airport control system and cognitive processes and the behaviour of the tower controller based on Coloured Petri Nets. The theoretical framework is provided by the contextual control model (Hollnagel, 1993). This describes how the context influences the behavior of the individual. This framework will be the basis for the Coloured Petri Net model which will provide the insight to the question how controllers will behave under changing system conditions.

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