ECAI 2012
Luc De Raedt et al. (Eds.)

doi:10.3233/978-1-61499-098-7-1019

AGENTFLY: Multi-Agent Simulation of Air-Traffic Management

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The current air-traffic management (ATM) system involves thousands of people, a majority of them being human controllers [5]. Controllers organize the flow of air-traffic to safely maintain airplane distance and plans for assigned airspace sectors. The capacity of ATM depends on many factors, such as availability of air traffic control (i.e., each controller can handle only limited number of airplanes), current or forecasted weather condition, availability of airspace and capacity of airport facilities. An issue occurs at peak hours when the current ATM system reaches its limits. Boeing has predicted [7] that the number of cargo flights will triple within the next 20 years. The U.S. Federal Aviation Administration (FAA) estimates [1] that the U.S. National airspace (NAS) and the weather caused 606,500 delays (513,420 hours of delays) in 2008, leading to unnecessary fuel consumption and increased atmospheric pollution.

To handle increasing traffic, there is a need to modernize and automate ATM tools to help human controllers handle high amounts of traffic. Such new advanced functions would lower the cognitive load of controllers, maintain safety (e.g., minimize near miss situations) and increase efficiency (i.e., optimize consumed energy and thus minimize pollution caused by growing traffic). The Next-Generation Air Transportation Systems (NextGEN) [4] program is designed to coordinate the evolution of ATM systems to satisfy future growth of air-traffic without losing efficiencies with the aviation community. Many interesting concepts are prepared in NextGEN, but before they can be implemented into daily usage they have to be rigorously evaluated under realistic conditions through simulation. The most precise ATM simulations are carried out within human-in-the-loop (HITL) simulations [2] where human interaction is integrated into the simulation model. Such simulations usually run in real-time and thus the test cases must be limited in duration and scope of the studied airspace portion. New concepts have to be studied within large-scale scope (whole European air space or whole U.S. NAS) as minor local delays can potentially cascade into large regional congestions [8]. It is not possible to perform such large-scale HITL study as it requires integration of thousands of people providing ATM services into the simulation.

The AGENTFLY system is a large-scale high-fidelity distributed multi-agent simulator [9]. Recently, the system has been extended with a precise emulation of the human controller operation workload model and human-system interaction. The overall goal of extended AGENTFLY is to provide a platform to study new ATM concepts and perform high quality scenario analysis to handle future air-traffic growth. The multi-agent approach [11] has been chosen for its natural mapping of system elements to autonomous intelligent agents – pilots and air-traffic controllers are simulated as agents. Pilot agents fly simulated airplanes based on performance models from Base of Aircraft Data (BADA) [6] in simulated airspace. The controller agents emulate interactions with available ATM tools and communicate via simulation radio links with pilot agents, see Figure 1.

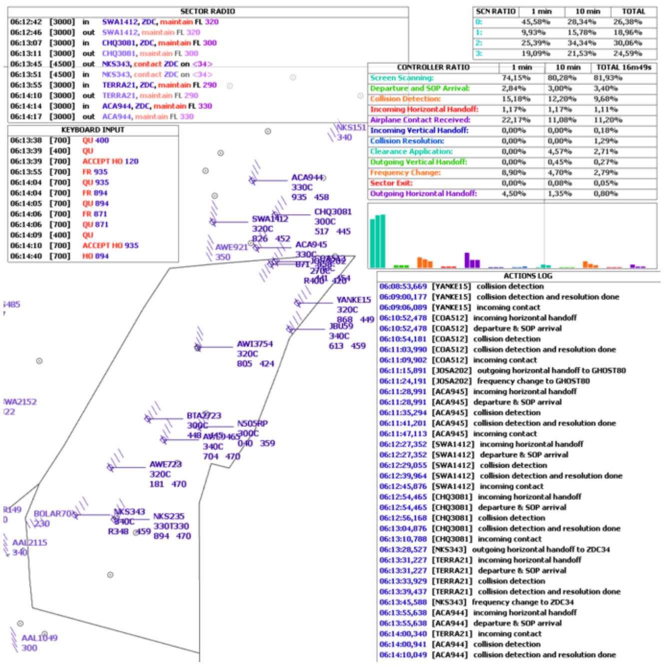

Figure 1. Modeled radar display and controller model actions of the sector ZDC 54 in U.S. NAS.

The current AGENTFLY version supports modeling of the en-route human controller models emulation controller operation and workload models. The workload model is based on Multiple Resource Theory (MRT) [10]. MRT proposes that the human controller have several different pools of resources that can be tapped simultaneously. Cognitive resources are limited and a supply and demand

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[2] AGENTFLY has been supported by the Federal Aviation Administration (FAA) under project numbers DTFACT-10-A-0003 and DTFACT-08-C-00033 and by the Czech Ministry of Education under grant number 6840770038. The underlying AGENTFLY system was supported by the Air Force Office of Scientific Research, Air Force Material Command, USAF, under grant number FA8655-06-1-3073. The views and conclusions contained herein are those of the author and should not be interpreted as representing the official policies or endorsements, either expressed or implied, of the Federal Aviation Administration, the Air Force Office of Scientific Research, the U.S. Government or the Czech Government.

problem occurs when the individual performs two or more tasks that require the same resource. The controller must process information sequentially if tasks require the same pool of resources or in parallel if the task requires different resources. The controller operations are emulated through the Visual, Cognitive, Auditory and Psychomotor (VCAP) workload model [3]. The visual and auditory components in the model are external stimuli. The cognitive component describes the required level of information processing. The psychomotor component describes required physical actions.

The en-route controller duties are modeled as actions organized in dependency chains and procedures. The operation procedures branch actions into several chains which are executed under the specified circumstances. Each particular action defines which components from the VCAP model it requires, its duration and its priority. An action can be performed if its predecessor(s) is completed and the respective VCAP components are available at that moment. When two or more actions are ready for execution at the same time, the action with the higher priority is selected and others are postponed until they can be processed. The action-decomposition and processing is implemented using combined time-stepped (simulation of airplanes movement, weather, radar systems, etc.) and event-driven (VCAP modeling) simulation. The simulation can be executed in real-time (suitable for demonstration or HITL simulation) or in faster-than real-time (perform fast evaluation in as fast as possible mode).

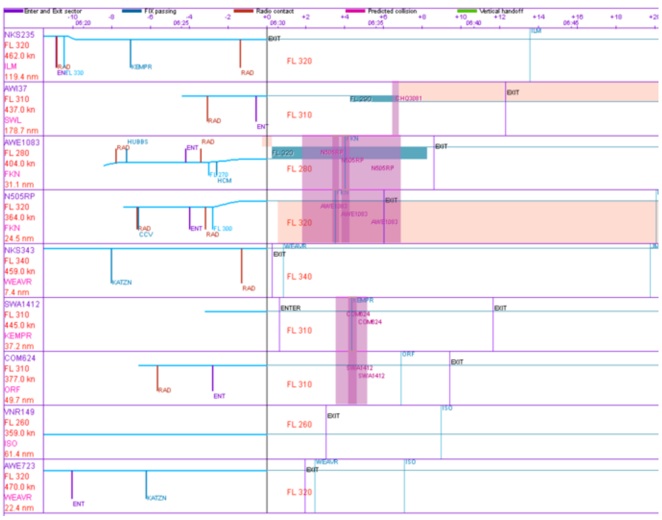

Figure 2. Controller's mental flight model used for its cognitive tasks.

Beside emulation of controller and pilot operations, AGENTFLY also emulates ATM tools supporting en-route controller operation. The current systems uses a simulated radar display system based on ERAM, see Figure 1 - the En-Route Automatization Modernization is a computer system that displays the sector map, airplanes positions with linked textual information containing key flight data and provides an access to electronic flight strips. The visual stimuli and psychomotor actions are sensor inputs of the controller model and are connected to the ERAM model. The high-fidelity controller model includes the inability to scan and monitor the entire ERAM display. Internally, the radar display is partitioned into several regions and the controller's focus cycles among these regions – the time spend in the region depends on the complexity of performed visual stimuli and selection of the next regions is based on the priority model. All parameters are configured from external configuration files. These parameters are configured based on the configured study. For the validation of the the simulator, there have been configured a flight scenario developed by the U.S. Federal Aviation Administration that is based on the real data. In this scenario there were studied the operation of radar controllers in few adjacent en-route sectors. In this scenario all model parameters have been set based on values determined by the FAA Human Factor Laboratory during HITL simulations with real human radar controllers.

The controller model performs cognitive actions only based on information obtained from the available ATM tools and it doesn't have access to the internal states and plans of other components in the system. For tasks working with the airplane flight trajectories (e.g. handoff, conflict detection and resolution), the controller model builds a mental flight information model for each flight which is updated based on the processed external stimuli taken from the radar display, see Figure 2. This mental flight model also integrates controller predictions and uncertainness. Uncertainness is modeled in three different dimensions: (i) lateral flight execution, (ii) vertical flight execution and (iii) time when a change should occur.

AGENTFLY simulator includes precise sector radio communication model where interferences are considered too. Transmitted voice messages are formatted according to international standards and is followed by acknowledgement transmitted by the receiver. A message sender monitors radio channel and if there is no acknowledgement until timeout, the voice message is repeated again. The sector radio is a half-duplex medium where only one participant can transmit at a time. It can happen that two or more participants can start its transmission at the same time even there is modeled mechanism where a participant first checks whether the communication channel is free.

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