Supporting Air Traffic Flow Management with Agents

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Abstract

Air traffic flow management is an inherently complex decision making process that involves a variety of entities. We propose an agent-based system to facilitate mutually beneficial air traffic management decisions, and identify challenges that must be met for its implementation.

Introduction

Airline flights generally follow structured traffic streams that are limited in the number of flights they can safely accommodate. When the airspace capacity drops below the demand (e.g., due to weather) or when traffic exceeds the available capacity, air traffic controllers must reduce the traffic on the impacted stream to acceptable levels. Air traffic flow management, therefore, involves careful planning and re-planning, requiring controllers to react and anticipate developments in a dynamic system in order to keep traffic flowing without compromising safety.

Current State of Traffic Flow Management

The Air Traffic Control System Command Center (ATCSCC) manages the traffic flow in the airspace over the continental United States, which is further subdivided into twenty regions, each under the control of an Air Route Traffic Control Center (ARTCC). Each ARTCC has a Traffic Management Unit (TMU) that is responsible for managing the flow of air traffic in its airspace. Each airline has an Airline Operations Center (AOC) that coordinates with the ATCSCC and TMUs, representing the airline's interests in the traffic management process. Under ideal conditions, the ATCSCC and TMUs would be able to safely manage traffic flows while minimizing flight delays as well as maximizing airline operating efficiency. However, a lack of adequate planning and impact assessment tools, limited coordination with the airlines, and overall high workload hinder the ability of the ATCSCC and TMUs to make optimal decisions. As a result, they often choose mitigating actions aimed at maintaining safety and simplifying the traffic flow management task, but at the cost of more efficient airline operations.

Distributed Air/Ground Traffic Management

As air traffic is expected to triple by 2025, the air traffic management community has proposed various new paradigms for future operations. Our research stems from the Distributed Air/Ground Traffic Management (DAG-TM) (NASA 1999) concept of operations and its possible incorporation into the Next Generation Air Transportation System (NGATS). The collaborative traffic flow management (CTFM) elements of the DAG-TM concept of operations were refined through extensive field observations and interviews at several ARTCCs and AOCs (Idris et al. 2006). In this paper, we focus on the enhancing coordination between the TMUs and the AOCs.

Agents in Air Traffic Flow Management

Air traffic controllers and airline personnel are limited resources in air traffic management. To compensate for their scarcity, intelligent agents can be employed both in simulations (in lieu of human operators) and in actual operations (assisting their human counterparts).

Validating the Concept of Operations

As in any critical system, changes to the air traffic system should be validated before deployment. In aviation R & D, this usually starts with "fast-time" simulations, where both the system and its human operators are simulated with automation. Later, human operators replace the automated stand-ins in higher fidelity "real-time" simulations.

The CTFM concept of operations includes assistive agents who work with their human counterparts. As such, a fast-time simulation may include both stand-in software agents and these assistive agents. Stand-in agents that are particularly adept at their role could lead to changes in the concept of operations: tasks originally planned for humans could be delegated to such agents.

Assistive Agents in CTFM Operations

The CTFM concept of operations recommends enhancing coordination between TMUs and AOCs. The current modes of communication between the TMU and AOC are primarily synchronous (e.g., teleconferences). However, the demands of operating in a real-time environment are significant and preclude spending a great deal of time in

communications, resulting in a loss of efficiency. Assistive agents can handle portions of this communication process, enabling less intrusive, asynchronous forms of communication or even automating some negotiations entirely. Agents can broadcast information (e.g., airspace demand, impact assessments, scheduling decisions) to cooperating parties, distilling and presenting information to the user. They can act as a proxy for the user, presenting policy or preference information, or take their place in negotiation. Finally, when appropriate, they can assist the user in decision-making, or be granted the authority to make certain decisions without human involvement.

Research Issues

Agents show great potential to facilitate more efficient air traffic management, but a variety of challenges must be met for their successful deployment.

Supporting Communication

Our primary focus is to facilitate better coordination between the TMU and the AOC through more effective communication. Time constraints prevent the human users from addressing this themselves; agents do not face the same restrictions, but present different challenges.

Modeling Users and Preferences. A comprehensive understanding of the involved entities, both organizations and individuals, will be required to create effective assistive agents and accurate fast-time simulations. The representation should be easily understood yet powerful enough to capture business models, environmental constraints and user intents. Are the processes and relevant human behavior understood well enough to be emulated by agents in the fast-time simulation?

Effective Communication Modes. The alternative forms of communication must be carefully considered for each information transaction. Under what circumstances is a static policy (i.e., preferences) sufficient? How and when is it appropriate to notify or interrupt a user?

Information Integration, Translation & Interpretation. A user's agent must be able to combine, refine, and filter communicated information in order to reduce the user's cognitive overhead. This requires an understanding and mediation of the different languages used by the various entities involved – concepts used by one agent will relate but not exactly match that of another; different parties may use different terminology and approach traffic management differently. The agent must use reasoning to re-express information in terms that are best understood by the user.

Delegation and Shared Control

Field observations indicated that TMU workload inhibited the communication needed for optimal decisions. Agents can reduce this workload by sharing the task burden.

Full Autonomy. Any task that can be completely automated offers the greatest gain to the offloaded user, but care must be taken when automating critical actions. What tasks can the agent perform independently without jeopardizing safety, and how can this be demonstrated?

Mixed Initiative. Other tasks may be completed by the user alone, the agent alone, or jointly. Though often safer than pure autonomy, shared activities have other control issues. Cooperation is more complex than independent activity and the agent must not counteract user actions.

Knowledge Acquisition

Implementing and adapting a system of agents for air traffic management will be knowledge intensive. Some of this knowledge can be elicited from experts, but this is not always practical, and some knowledge is difficult even for experts to articulate or realize.

Learning from Historical Data. When available, historical data can serve as a basis for developing models of human behavior, either manually or through machine learning methods. Environmental conditions and inputs from other persons form the attribute space, from which the correct decision could be learned.

Adapting to Changing Conditions. Just as learning can be used to set up the initial model, it can also be used by the agent to adapt to the simulation. This gives the agent the ability to both adapt to situations different than in the historical data as well as to correct errors in its model.

Conclusion

Today's air traffic management system is a high-stakes, complex system that has maintained a remarkable safety record. Part of this safety record has come at the cost of increased operating efficiency, a trend that is expected to increase in the future. Assistive agents can help reverse this trend by supporting better communication between collaborating parties, thus leading to improved decisions. However, several technical obstacles must be overcome for such agents to be effective: supporting minimal and effective communication; sharing control; and building and refining models based on historical data and experience.

Acknowledgements

We would like to thank Karl Bilimoria and Richard Keller.

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