A SURVEY OF MULTI-AGENT SYSTEMS USED FOR AIR TRAFFICCONTROL

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INTRODUCTION

- **Purpose:** Explore why air traffic control is an ideal system for agent oriented implementation
- Free Flight system
- Present two important components of the Free flight system
- Air Traffic Flow Management
- Conflict resolution
- Conclusions

ATC CHALLANGES

AIR TRAFFIC CONTROL CHALLANGES

- The growing air traffic since the 1990s.
- ATC was mainly relying on human resources to resolve the traffic management
- FAA estimates put weather, routing decisions and airport condition induced delays at 1,682,700 h in 2007, resulting in a staggering economic loss of over $41 billion, and in 740 million gallons of fuel being wasted. [Agogino and Tumer, 2012]
- Intelligent air traffic flow management is one of the fundamental challenges facing the Federal Aviation Administration (FAA) today.

WHY MULTI AGENT SYSTEMS?

- ATC systems have geographically and functionally distributed elements, subsystems which have a high degree of autonomy and highly dynamic environment.
- The system is very complex, each decision can affect other unexpected parts of the environment.
- Decentralised systems are more effective, can adapt more easily.
- Multi-agent systems can solve system conflict with different policies: negotiation, competition, cooperation.

SOLUTION: FREE FLIGHT SYSTEM

- With the appearance of GPS and ADS-B devices the automation of ATC has become more and more possible.
- NASA introduced the concept of Free Flight systems to solve this problem.
- Free Flight system allows pilots to choose their own routes, altitude and speed and essentially gives each aircraft the freedom to self-optimise.
- The goal is to create a decentralised system by using on-board equipment which allows aircrafts to share some of the workload, such as navigation, weather prediction and aircraft separation, with ground controllers.

ELEMENTS OF FREE FLIGHT SYSTEMS

- Air traffic flow management: the regulation of air traffic in order to avoid exceeding airport or air traffic control capacity in handling traffic, and to ensure that available capacity is used efficiently
- Conflict resolution: resolving the problems of two aircraft trajectories meeting in the future

AIR TRAFFIC FLOW MANAGEMENT

Currently relies on a centralised, hierarchical routing strategy that performs flow projections ranging from 1 to 6 hour.

We will discuss an agent oriented system from [Agogino and Tumer, 2012]

COMPONENTS OF ATFM

- Agents
  - If we used aircrafts as agents the system would become too big
  - Researchers use individual ground locations throughout the airspace called ’fixes’ as agents. Each agent is then responsible for any aircraft going through its fix.

COMPONENTS OF ATFM

- Agent actions
  - **Miles in trail (MIT)**: controls the distance aircraft have to keep from each other wile approaching a fix.
  - **Ground delays**: controls how long aircraft that will eventually go through a fix should wait on the ground. With this action, congestion can be reduced if some agents choose ground delays and others do not, as this will spread out the congestion.
  - **Routing**: controls the routes of aircraft going through its fix, by diverting them to take other routes that will (in principle) avoid the congestion.

COMPONENTS OF ATFM

- Agent learning
  - The agents use reinforcement learning to improve the system.
  - Each agent has its own reward function which they need to maximise.
  - The agents use the ϵ-greedy learning algorithm.
  - Chooses the action with the highest table value with probability 1 - ϵ and chooses a random action with probability ϵ.

$$V(a) = (1 - \lambda)V(a) + \lambda R$$

ATFM EXPERIMENTS

- Agent learning
  - The researchers use a simulation tool called FACET (Future ATM Concepts Evaluation Tool) to test theirs system.
  - The effectiveness of the system is then calculated based on the linear combination of the amount of congestion and air traffic delay.
  - The agents take independent actions that maximize the system evaluation function G(z).

$$G(z) = (B(z) + \alpha C(z))$$

where B(z) is the total delay penalty for all aircraft in the system, and C(z) is the total congestion penalty.

CONFLICT RESOLUTION

First we we'll explore Distributed problem solvers for ATC [Cammarata et al., 1988]

- Each aircraft is an agent
- Goal: move from point A to B which can lead to shared coflicts
- Conflict arises when aircrafts enter each other's protected zone.
- Agents resolve these conflicts through distributed problem solving

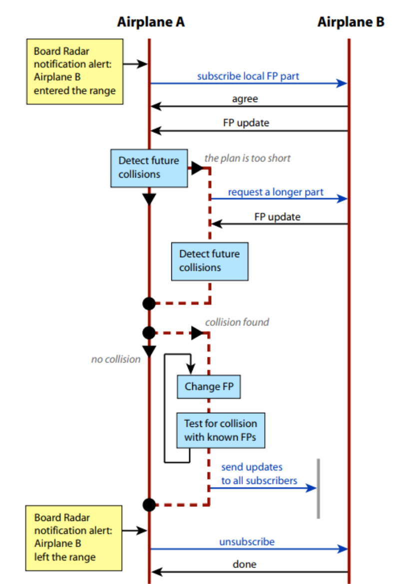
CONFLICT RESOLUTION

- Each system implements the information distribution policies where the information should be sent to other aircraft selectively
- An agent is selected to perform the evaluation, create a new plan and execute it. It that's not enough other agents replan as well until conflict is resolved.
- Usually the agent with the most degree of freedom is the chosen planner.
- The most knowledgeable agent can also be a planner.
- Task sharing policy

Autonomous Agents for Air-Traffic Deconfliction
[Pěchouček et al., 2006]

- The aircraft are modeled by agent containers hosting several agents
- The aircrafts have multiple information specific zones: Communication, Alert, Safety and Collision zones.
- The deconfliction can happen by cooperative or non-cooperative negotiation.
- When agents enter each other's communication zones they subscribe to the other's flight plan updates.
- At each update conflict detection is made

AUTONOMOUS AGENTS FOR AIR-TRAFFIC DECONFLICTION



Agents use a rule based system to modify their flight plan.

The goal is to guarantee minimal future conflicts

The flight plans can be described by waypoints and timestamps at which the airplane arrives to that specific waypoint. Using these the flight planner generates the path consisting of segments and elements.

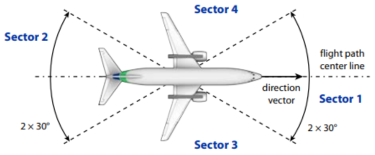


Figure 3: Identification of the collision type

- **head-on collision**, both of them turning to the right.
- **rear collision**, it has to change its flight plan so that it turns to the right and passes the front airplane without endangering it.
- **side collision (right)**, The aircraft A needs to slow down its speed.
- **side collision (left)**, aircraft A changes its flight plan by increasing its flight speed so that it passes the collision point before the airplane B.

CONCLUSION

- ATC and ATFM are very well suited for agent oriented implementations.
- Agent oriented Free flight system are easily adaptable and improve the problems of delays and fuel waste.
- We already have some good results in this automatization task, but we still need to improve it.

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