AGENTFLY: A Multi-Agent Airspace Test-bed*

(Demo Paper)

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ABSTRACT

The contribution presents a multi-agent technology in the domain of the air-traffic control of several autonomous aerial vehicles (manned as well as unmanned). The system has been validated mainly by the collision avoidance (CA) tasks. Several cooperative and non-cooperative CA methods have been integrated in the system to validate and compare their properties in the scalable experiments. The AGENTFLY system is suitable also for the developing and testing of algorithms for the collective flight control. The operation of the underlying multi-agent system has been integrated with freely available geographical and tactical data sources. The system provides real time 2D/3D visualization and also the web-access component.

Categories and Subject Descriptors

I.2.11 [**Computing Methodologies**]: Artificial intelligence—*Multi-agent systems*; I.6 [**Computing Methodologies**]: Simulation and modeling

General Terms

Algorithms, Experimentation, Verification

Keywords

agent-based collision avoidance, autonomous aircrafts, multi-agent simulation

1. AGENTFLY DESCRIPTION

The AGENTFLY is a software prototype of the multi-agent technology deployment in unmanned aerial vehicles air traffic control supporting the *free flight concept* [3], [2] – an approach to the autonomous routing of the aircraft and continuous self-optimization of the flight trajectory complemented by the distributed CA mechanisms. The system demonstrates the readiness of multi-agent technology for the distributed, flexible and collision-free coordination among heterogenous autonomous aerial assets with potential to fly a higher number of aircrafts, decrease requirements for human operators and allow a flexible combination of cooperative and non-cooperative CA.

All aerial assets in the AGENTFLY are modeled as the asset containers hosting multiple intelligent agents. Each container is responsible for its own flight operation. The operation of each vehicle is specified by its mission – a sequence of time-constrained way-points. The operation is tentatively planned before the take-off without consideration of possible collision with other flying objects. During the flight performance, the software agents hosted by the asset containers implement the See & Avoid capability [1]. The responsible agent monitors the airplane neighbor and detects possible future collisions on its current flight trajectory. If the collision is detected the appropriate collision avoidance method is invoked, see the Figure 1.

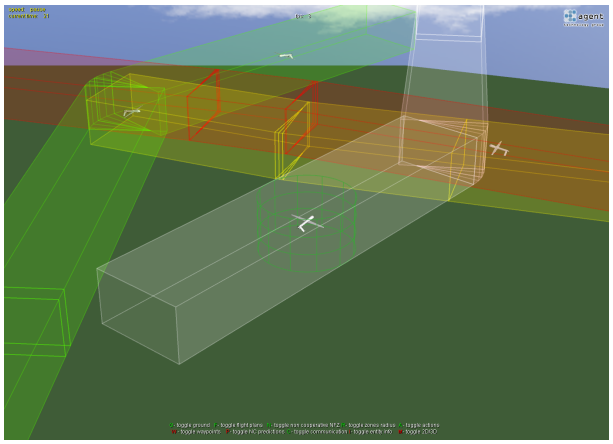

Figure 1: AGENTFLY real-time internal state visualization.

The AGENTFLY provides a simulation that is very close to the real domain. It provides full three-dimensional space simulation supporting also the limited communication range. The available air space for each airplane can be restricted by the terrain surface and several no-flight zones kept in various structures - octant trees, height maps and composed elementary objects. The physical flight model allows smooth three-dimensional flight with velocity changes. The system supports validation algorithms for real-time control – airplane

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is still flying during the negotiation and planning changes. The detailed description of the air domain covered by the AGENTFLY system is described in [5].

The AGENTFLY is a JAVA system build on the top of the **$\mathcal{A}$-globe** multi-agent platform [4]. The **$\mathcal{A}$-globe** provides a flexible middle-ware supporting seamless interaction among heterogenous software, hardware and human actors. The **$\mathcal{A}$-globe** outperforms the available multi-agent integration environments by its ability to model rich environments in distributed host configurations, Figure 2.

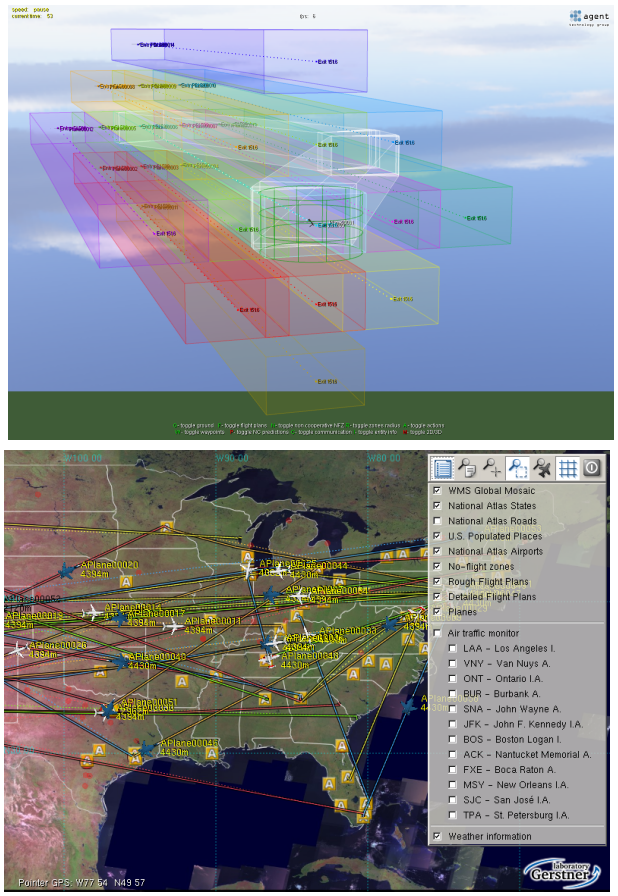

Figure 2: AGENTFLY integration with freely available external geographical and tactical data sources.

The AGENTFLY provides four distinct CA algorithms linked by a flexible mechanism managing the autonomy of individual assets and selecting the best CA strategy in real time:

Rule-based CA is a domain dependent algorithm based on the Visual Flight Rules defined by FAA. Upon the collision thread detection, the collision type is determined on the basis of the angle between the direction vectors of the concerned aircrafts. Each collision type has a predefined fixed maneuver which is then applied in the replanning process.

Iterative peer-to-peer CA deploys multi-agent negotiation theories (Monotonic Concession Protocol with the Zeuthen Strategy) aimed at the finding the optimal CA maneuver. The software agents on each asset generate a set of viable CA maneuvers and compute costs associated with each manoeuver (based on e.g. the total length of the flight plan, time deviations for mission way-points, altitude changes, curvature, flight priority, fuel status, possible damage or type of load). The agents negotiate such a combination of the manoeuvres that minimizes their joint cost associated with avoiding the collision.

Multi-party CA extends previous algorithm by allowing several assets to negotiate about collective CA avoidance maneuvers. This algorithm minimizes the effects of CA maneuvers causing conflicts in future trajectories with others. While requiring more computational resources, this strategy provides more efficient free-flight collision free trajectories.

Non-cooperative CA supports collision avoidance in the case when the communication among airplanes is not possible. Such a situation can arise e.g. when on-board communication devices are temporarily unavailable or when an asset avoids a hostile flying object. This algorithm is based on modeling/predicting the future airspace occupancy of the non-cooperative object and representing it in terms of dynamic no-flight zones. Based on this information, the algorithm performs continuous replanning.

The *collective flight* components in the AGENTFLY system provide the capability for the automatic synchronization of the group of independent airplanes. Each airplane flies following the way-points specified in the mission. There can be a special task to fly via the specified corridor synchronously with others in the flight formation. The airplanes participating in the group perform the selection of the rendezvous location at the corridor entrance. If at least one of the airplanes is delayed due to any reason, others must wait for it applying the holding orbit at the rendezvous location. The composition formation phase is initiated when all airplanes are ready. This phase includes the negotiation about position in the formation pattern depending on the airplane types, finding of the exact contact time and plan of detailed collision-free flight plans to establish formation. The implementation utilizes the social dominance concept providing robustness in an unstable environment. There is not apriori selected leader responsible for the group management and the leader is designated using the dominance concept.

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