Deployment of Multi-agent Algorithms for Tactical Operations on UAV Hardware*[*]

(Demonstration)

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ABSTRACT

Small Unmanned Aerial Vehicles (UAVs) are becoming increasingly popular for tasks such as surveillance or target tracking in various types of tactical missions. Traditionally, each UAV in a mission is controlled by one or more operators. In our previous work we have developed a collection of distributed algorithms that allow one operator to control a whole team of small UAVs.

Here, we report on our successful effort to deploy the developed multi-agent control algorithms to a team of hardware UAVs.

To reduce costs and risk, we first developed the multi-agent control algorithms using simulated approximation of the target environment. Then, we gradually refined the model of the target environment by adding higher-fidelity models of the assets and hardware-in-the loop assets. In the final step, the algorithms were deployed and field tested in a full hardware setting and in a mixed-reality setting, where hardware UAVs are accompanied by a a number of simulated UAVs.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Intelligent agents, Multi-agent systems*

General Terms

Hardware, Deployment, Algorithms, Experimentation, Verification

Keywords

Multi-robotic teams, Deployment on hardware, Unmanned aerial vehicles, Decentralized multi-agent algorithms.

1. MOTIVATION

Currently, small UAVs are used by many countries for Intelligence, Surveillance, and Reconnaissance (ISR) missions. Traditionally, each UAV deployed in such a mission must be controlled by one or more operators. To decrease the cognitive load on the operators and to allow one operator to control more UAVs in the same time, the autonomy of the individual UAVs has to be improved. In result, the focus must shift from the development of a solitary intelligent vehicles to teams of cooperating intelligent UAVs.

Figure 1: Unicorn Unmanned Aerial System from Procerus.

During last year's AAMAS demo session, we presented a simulated application of multi-agent algorithms for tactical missions [4]. In this demonstration, we report on results of a follow-up hardware deployment project. The target environment in this project consists of two Unicorn Procerus UAVs (see Figure 1) in a mixed-reality simulation accompanied by additional simulated UAVs carrying out a tactical mission. The mission can be split into a set of various tasks, which are solved by a collection of problem-specific planners supported by various decentralized algorithms, that individual UAVs use to coordinate the mission execution.

2. DEVELOPMENT PROCESS

Being aware of the costs of carrying out field experiments and the repairs of accidentally crashed hardware UAVs, we have employed a specific incremental development process [2] designed to support the development of multi-agent control algorithms and their incremental deployment to a target hardware platform. This development approach is based on an incremental refinement of the developed system from a fully simulated environment containing only simulated assets towards an environment containing only hardware assets. Firstly, the application is developed in a purely simulated environment usually with only approximated dynamics of the target assets. Afterwards, a higher-fidelity simulation of the target environment is used for validation and the control algorithms are updated accordingly. In the final steps, parts (or all) of the simulated entities are replaced by real hardware assets. Such a gradual approach helps to reveal and fix various types of design flaws in early stages of the development, which is typically cheaper than allowing them to appear during full-featured hardware experiments.

We have adopted a highly modular approach to every element in the system allowing variability in the deployment scheme (details

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[*] Demo video: **http://agents.cz/taf3/aamas13/**

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presented in [3]). We can model the UAV assets in the target environment in four different modes: (i) a simulated asset, (ii) a hardware in the loop asset, (iii) a hardware asset remotely controlled by an algorithm running on the ground, and (iv) a hardware asset controlled by an on-board-deployed algorithm.

The control algorithm for individual UAVs consists of several task-specific planners. Each UAV has at its disposal a planner for surveillance tasks, a planner for tracking tasks, a conflict resolution mechanism and a trajectory planner. Aside is a planner orchestrator component that is responsible for the control of the UAV by means of combining inputs and outputs of individual planners as the particular task or situation requires.

3. USED ALGORITHMS

For trajectory planning we can choose between a simple local-optimization-based method, accelerated A* planner modified for planning in the wind [5] and RRT*-based trajectory planner. As a conflict resolution mechanism we use the asynchronous decentralized prioritized planning (ADPP) scheme [6]. The surveillance planner is based on a decentralized partitioning of the target area with a zig-zag pattern trajectory planner filling the sliced space. For the tracking tasks we have tested several approaches. The simplest one is based on a simple attraction of the nearest UAV towards the last known position of the target. Another one uses a general Distributed Vehicle Routing Problem solver [7] allocating the targets to the participating UAVs in a close-to-optimal manner. The distributed mission task allocation is realized using classical multi-agent algorithms such as leader voting or event synchronization.

Further, we tested a patrolling planner that models the patrolling problem as a zero-sum game in extensive form and executes the strategy found by the method presented in [1].

4. HARDWARE SETUP

The hardware platform consists of a ground-station PC and two off-the-shelf Procerus Unicorn UAVs with Kestrel autopilot. Kestrel autopilot provides sensory data, is capable of autonomous take-off, landing and GPS waypoint navigation and is equipped with 869 MHz radio modem for direct control of the plane and tasking from the ground.

The UAVs were additionally equipped with Gumstix Overo on-board computer connected to the autopilot and communication channels used for execution of tactical and control algorithms and Xbee modem (2.4 GHz) that increases the UAV-to-UAV communication bandwidth and reliability and is used for purposes of cooperation and coordination of the UAVs in the missions.

5. RESULTS AND FINAL REMARKS

In the first experiments we tested the basic system functions such as on-board processing of the telemetry, the control of a single UAV, and communication tests between a UAV and the ground station. In the second step, we focused on the basic control of two UAVs simultaneously and on the measurements of the robustness of UAV-to-UAV communication.

After the communication stacks have been improved and the new conflict resolution algorithms have been tested, the conflict resolution scenario involving two real and two simulated UAVs in a superconflict (a scenario where all UAVs attempt to fly through one point in space) was successfully conducted.

During the final experiment, we tested the distributed mission control of a squadron of two hardware and several virtual UAVs. The missions tested the ability of the UAVs to autonomously execute the cooperative mission while still reliably performing the conflict resolution. The tested scenarios included, e.g., a combined mission of surveillance over a designated area and tracking of an evading ground target, or a mission where n ground targets were tracked by m UAVs, where $m < n$.

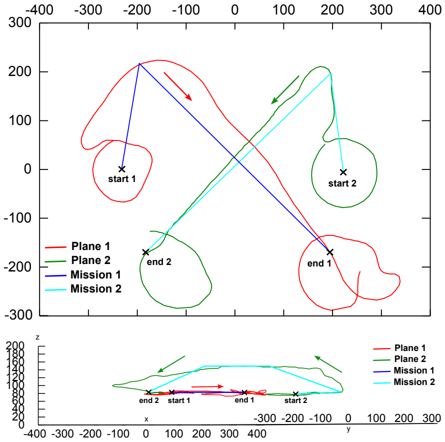

Figure 2: Trace of flights of two airplanes in a conflict scenario.

In result, the experiments verified the function of the tested multi-agent application in realistic conditions. An example trace of one of the scenarios is presented in Figure 2.

We plan to continue the presented research track in the direction of adding additional planners for different tasks in the context of ISR missions, e.g., a flight-in-formation capability or coordinated action for GPS jamming capability - here the challenge is the communication-based position pinpointing by other airplanes in the team that are not affected by the GPS jamming.

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