MULTI-UAV PLATFORM FOR INTEGRATION IN MIXED-INITIATIVE COORDINATED MISSIONS

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Abstract: The Apollo system for unmanned air vehicle (UAV) control is described. This is done in the context of the AsasF project from Porto University. Apollo is the UAV controller component of the AsasF control hierarchy. Apollo provides a uniform vehicle interface which is targeted at multi-vehicle operations in a mixed initiative environment allowing the intervention of experienced human operators. Apollo decouples the details of UAV control from the organization of external controllers in the AsasF control hierarchy. Apollo has a layered structure modelled in the framework of dynamic networks of hybrid automata. There is a mission supervisor, a vehicle supervisor and manoeuvre controllers, one per type of manoeuvre.

Keywords: Aircraft control, Aircraft operations, Automata theory, Middleware, networked vehicle system, tracking systems

1. INTRODUCTION

Research and development on autonomous vehicle systems is an emergent area, leaving lots of room for new ideas and projects. Researchers and technology developers are devoting significant efforts to the development of concepts of operation for networked vehicle systems where autonomous underwater vehicles (AUV), autonomous surface vehicles (ASV) and Unmanned Air Vehicles (UAV) come and go and interact through inter-operated networks with other vehicles and human operators. The role of human operators is receiving significant attention in these concepts of operation. This is the reason why researchers and technology developers have introduced the idea of mixed initiative interactions where planning procedures and execution control must allow intervention by experienced human operators. In part this is because essential experience and operational insight of these operators cannot be reflected in mathematical models, so the operators must approve or modify the plan and the execution.

The design and deployment of multi-vehicle systems with mixed initiative interactions in a systematic manner and within an appropriate scientific framework requires an interdisciplinary approach from computation, material, control and communication sciences. The major challenges come from the distributed nature of these systems and from the human factors. This is why we need to couple the development of scientific frameworks with field tests with human operators.

AsasF is an interdisciplinary research and development project for students at the Faculty of Engineering from the University of Porto in Portugal. The main objectives of the project are: 1) to design and build light unmanned air vehicles for coordinated missions; 2) to develop concepts of operation for multi-vehicle systems; 3) to design and build modular controllers for unmanned air vehicles; and 4) to evaluate and test the developments in operational deployments.

At the Faculty of Engineering from the University of Porto (FEUP) there is considerable expertise in the coordination and control of ground, underwater and surface autonomous vehicles. This expertise has been achieved through extensive experimental work in operational deployments. There is also a considerable expertise in task planning and execution control for teams of UAVs. This has been done in cooperation with leading US and EU universities, and also with the Portuguese Air Force Academy. Last year, two teams of FEUP students from NAAM (Group of Aeronautics, Aerospace and Modelling) designed and built two airplanes for the Portuguese Air Cargo Challenge. The AsasF project aims to combine the expertise acquired with airplane design with the existing expertise on the coordination and control of multiple vehicles to develop an innovative program of research and development on cooperative air vehicles. The work presented here makes use of the study in (Almeida *et al.*, 2006) where a first approach to this system is made. The long term objective of this project is the integration of UAVs in a system where air, ground, aquatic vehicles and fixed systems perform coordinated actions in order to achieve a common goal.

This paper describes the Apollo system which implements the UAV control component of the AsasF hierarchical control architecture for UAV systems. The AsasF project builds on expertise, tools and technologies developed at the Underwater Systems and Technology Laboratory (USTL) from Porto University. Researchers at USTL have been designing and building ocean and air going autonomous and remotely operated vehicles with the goal of deploying networked vehicle systems for oceanographic and environmental applications (Sousa *et al*., 2003). The concepts behind the AsasF control architecture are built on experience in the modular design of distributed control hierarchies described in (Sousa *et al*., 2003). AsasF uses the Neptus command and control framework (Dias *et al*., 2005; Dias *et al*., 2006) and the Seaware middleware publish/subscribe framework for distributed real-time systems (Marques *et al*., 2006).

There are several reasons for the use of UAVs in the AsasF project. In European Mediterranean countries, a great concern is raised every summer with forest fires. The potential of UAVs for fire detection is considerable but it has not been fully evaluated in these countries. The surveillance of the Portuguese Economic Exclusive Zone represents another major opportunity for UAVs. Moreover, in the last few years, there has been a trend in the military towards autonomous air vehicles to perform coordinated missions requiring some communicated information among them. Here, UAVs are currently used to perform missions where human intervention is dangerous or complex. In conclusion, there is a significant motivation for the development of UAV expertise in Portugal.

Recent advances in UAV research include one system where in-the-air effective task allocation and collaboration is demonstrated (Ryan *et al.*, 2006). The capabilities displayed by this system include single-user control of a fleet of aircraft, distributed task assignment, and vision-based navigation. Research in (Lee *et al.,* 2003) shows a strategy of path-planning for an UAV to follow a ground vehicle. This ground vehicle may change its heading and vary its speed. Here, the UAV will maintain a fixed airspeed and will manoeuvre itself to track the ground vehicle. (Girard *et al.,* 2004a) uses selected case studies as the motivation to examine emerging results in networked multi-vehicle systems. A hierarchical control architecture for a system that does border or perimeter patrol using UAVs is proposed in (Girard *et al.,* 2004c).

This paper is organized as follows. Section 2 describes the AsasF project. Section 3 presents the Apollo system for UAV control. Section 4 discusses manoeuvre control design in the Apollo framework. Section 5 discusses our approach to multi-vehicle operations in a mixed initiative environment. We discuss the conclusions and future work in section 6.

2. THE ASASF PROJECT

AsasF is an interdisciplinary research and development project for students at the Faculty of Engineering from the University of Porto. The technical objectives are: 1) to design and build light unmanned air vehicles for coordinated missions; 2) to develop concepts of operation for multi-vehicle systems; 3) to design and build modular controllers for unmanned air vehicles; and 4) to evaluate and test the developments in operational deployments. The objectives for the students involved in the project are: 1) to participate in the design and implementation of complex system according to the Systems Engineering Process (IEEE, 1999); 2) to develop team work competences; 3) to work in an inter-disciplinary team with experts in control, computer and communication systems, in composite materials, in vehicle design and in environmental surveys; and 4) to motivate international cooperation and mobility.

The project is run by the students under the supervision of faculty from the mechanical and electrical and computer engineering departments. There are periodic seminars where faculty and invited faculty present the tools and technologies used in the project. There are periodic brainstorming sessions where the major design and implementation questions are addressed. This involves major tradeoffs such as buy-or-develop issues. There are project technical reviews on a semester basis. The project has to conform to the regulations of national projects.

2.1 SYSTEM REQUIREMENTS

The project follows the Systems Engineering Process. In this process, each stage of the systems life cycle is divided in three activities: Requirements analysis; Functional analysis; and Synthesis and design. System life cycle stages range from “System definition” to “Costumer support”, including “Subsystem definition” and “Production”.

Currently the project is in the “Subsystem definition” stage, where all subsystems are integrated and system wide tests are performed. This means that we are not going to make hard demands on the system. Thus, our UAV will have short range and will be manually deployed and landed. The functional requirements for the system at this stage are as follows:

- Minimum payload of 4Kg.
- Modular, flexible, robust and low cost.
- COTS components.
- Autonomous and remote control.
- Video acquisition and real time transmission
- Operational console capable of specifying new waypoints for coordinated flight