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COMETS: A Multiple Heterogeneous UAV System

Aníbal Ollero(1), Günter Hommel(2), Jérémi Gancet(3), Luis-Gonzalo Gutierrez(4) , D.X. Viegas(5), Johan Wiklund(6) and M.A. González(7).

(1) AICIA- Escuela Superior de Ingenieros, Univ. Sevilla (Spain), aollero@cartuja.us.es.
(2) Prozeßdatenverarbeitung, Technische Universität Berlin (Germany), hommel@cs.tu-berlin.de
(3) LAAS-Centre National de la Recherche Scientifique (France), jgancet@laas.fr
(4) GMV S.A., Madrid (Spain), lgutierrez@gmv.es
(5) ADAI, Universidade de Coimbra (Portugal), xavier.viegas@dem.uc.pt
(6) Dept of EE, Computer Vision Laboratory, Linköping University (Sweden), jowi@isy.liu.se
(7) Helivisión S.L. (Spain), p_mace@ono.com

Abstract

The COMETS system integrates multiple heterogeneous Unmanned Aerial Vehicles for missions such as surveillance, monitoring, mapping and search. Currently both helicopters and airships have been integrated. The paper summarizes the main characteristics of the COMETS architecture, the control centre, and the perception system in which detection, monitoring and terrain mapping functions are currently being integrated. Furthermore, the paper present results of the General COMETS forest fire experiments conducted in Portugal, in May 2003.

1 Introduction

There are many applications in safety, security, and rescue robotics in which ground vehicles have significant inherent limitations to access the desired locations due to the characteristics of the terrain and the presence of obstacles that cannot be avoided. In these cases aerial vehicles are the only way to approach the location to get information or even to perform some actions such as the deployment of instrumentation. Moreover, the benefit of the cooperation of multiple robots, or autonomous entities in general, in the above mentioned applications has been pointed out by several authors in the last years (see for example [1]).

This paper presents the COMETS system for the cooperation of multiple heterogeneous unmanned aerial vehicles. Fire detection and monitoring are particularly addressed in the COMETS project. The next section will introduce the main characteristics of the COMETS system. Then, the architecture and main components of COMETS will be shortly summarized.

2 The COMETS system.

COMETS is a system that integrates multiple heterogeneous Unmanned Aerial Vehicles for missions such as surveillance, monitoring, mapping and search. Currently both helicopters and airships have been integrated in COMETS.

Figure 1 shows a general picture of the COMETS system. The system exploits the complementarities of different UAVs in missions where the cooperation of several autonomous vehicles is valuable due to the requirements regarding the necessary coverage and the different characteristics of the vehicles. Furthermore, this approach leads to redundant solutions offering more fault tolerance and flexibility when comparing with the use of a single UAV with long endurance flight and important on-board capabilities. The system also allows the cooperation between robotic aerial vehicles and remotely piloted vehicles. This approach takes benefit from the expertise of human operators in missions where the full autonomy is very difficult to achieve. The first Mission Application of COMETS is fire detection, alarm confirmation, localization, and monitoring. In May 2003 the first general field experiments of COMETS took place near Coimbra (Portugal). Two helicopters and one airship participated in these experiments, which have been used to design the COMETS system but also pointed out its possibilities for safety, security and rescue robotics.

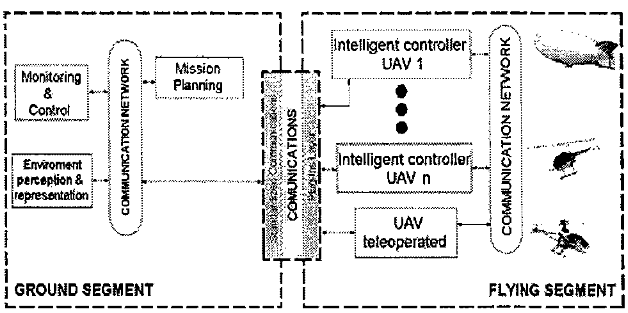

Figure 1. The COMETS system

Figure 2 shows the flight of two helicopters (Marvin and Heliv) and one airship (Karma) that participated in the above mentioned experiments.

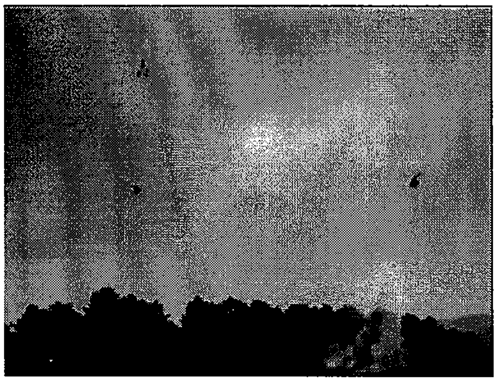

Figure 2. Multiple UAVs flight in COMETS

In these flights the UAVs transmitted images of the fire from different positions.

Marvin (see Figure 3) is an autonomous helicopter developed by the Real-Time Systems & Robotics Group of TU Berlin [2]. The helicopter is driven by a 2-stroke engine: it has a strap-down IMU, a compass, an ultrasonic rangefinder, a DGPS and a microcontroller for flight control. It also carries a high-resolution digital photo camera and a PC-104 for image acquisition, fire and temperature sensor for fire detection and two redundant radio links for telemetry, commands and image transfer. An earlier state of the system has won the International Aerial Robotics Competition 2000 held by AUVS.

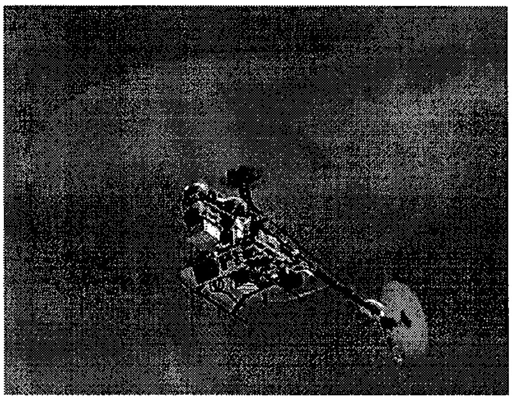

Figure 3. MARVIN autonomous helicopter

Karma is a $18m^3$ electrically propelled airship developed at LAAS (Laboratoire d'Architecture et d'Analyse des Systèmes). It is equipped with the necessary sensor to implement autonomous flight, and carries a wide baseline stereovision bench [3].

The Heliv helicopter is the result of the evolution of a conventional remotely piloted helicopter of HELIVISION which has been transformed by the Robotics, Vision and Control Group at the University of Seville by adding sensing, perception, communication and control functions [4]. In the above mentioned experiments HELIV had an infrared camera and a visual camera (see Figure 5).

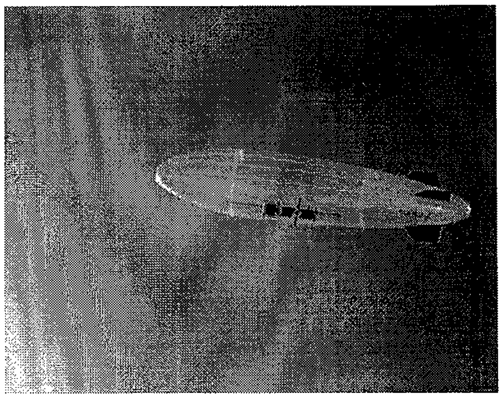

Figure 4. The airship Karma.

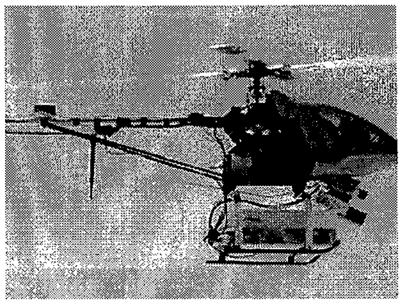

Figure 5. The HELIV helicopter.

3 The COMETS Missions

The following Missions have been considered in COMETS.

1) Detection/Alarm Confirmation, Localization and Evaluation.

The objective is to detect a particular event (i.e. potential fire), and, if the alarm is confirmed, perform the localization in a map and generate a danger measure based on the estimated severity and localization. The use of multiple UAVs is valuable due to coverage, detection, and the ability to confirm the alarm and to provide better estimations of the position and potential danger.

2) Monitoring.

In this case the objective is to provide images and measures of the monitored event, taking into account the dynamic evolution of the event and the possibility of environmental changes that may occlude the visibility, such as the smoke. The application of multiple UAVs is valuable due to the interest of cooperative perception from multiple locations to decrease uncertainty and improve human perception in the control center.

3) Terrain Mapping.

The ability to perform a high resolution 3D map of the affected area is very valuable in many safety, security and rescue related robotics applications. This map could be also used to plan and execute other Missions. The application of multiple UAVs is related to the coverage and reduction of mapping time. Furthermore it could be possible to have one UAV (e.g. the airship) obtaining global views for mapping and another UAV, such as an helicopter, improving the quality of the 3D map in critical areas by means of detailed views (obtained when hovering).

In all the above mentioned Missions co-operative perception is an important issue. Co-operative perception techniques are useful to increase the precision on the location of an event, decrease the false alarm ratio in event detection, and improve the measurements obtained in monitoring missions.

4 The COMETS architecture

The COMETS architecture is shown in Figure 6. This architecture consists of the three following segments:

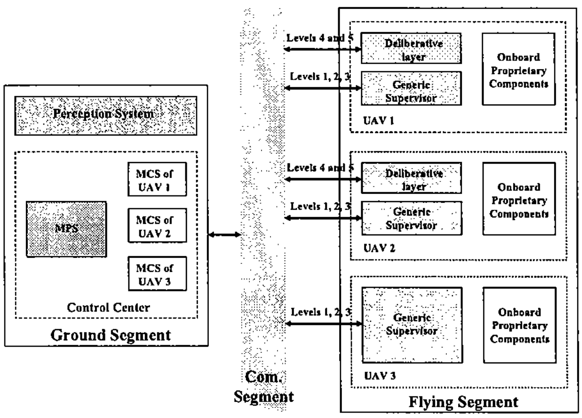

Figure 6. COMETS architecture.

1) The Ground Segment includes the Mission Planning System (MPS), the Monitoring and Control System (MCS), and the ground part of the Perception System.

2) The Flying Segment encompasses all the UAVs.

3) The Communication Segment provides software that supports communications between the different components of the COMETS system.

Each UAV in the Flying segment is endowed with:

It Onboard Proprietary Components, that gather the various functions specific to the UAV (flight control, data acquisition, possible data process).

A Supervisor defined according to a generic scheme, that interfaces the UAV with the other COMETS sub-systems (ground segment and other UAVs) and controls its activities.

A deliberative layer when the UAV has autonomous decisional capabilities.

The Communication segment is described in [5].

5 The COMETS Control Center

The Control Centre is implemented on the Ground Segment. The MPS developed by GMV is devoted to define and create multi-UAVs mission plans, to control centrally the execution of these plans execution and to re-plan if necessary. The MCS, also developed by GMV, remains the state and monitors each UAV, receives information from the perception system, and sends alerts, warnings, failures, re-planning triggers and stop notifications. It provides the users with the interfaces to monitor and control each UAV. Then, a complete and user-friendly GUI has been developed. The Control Centre also encompasses the ground part of the perception system, which performs perception processing for the UAVs that do not have on-board processing capabilities, and collects the perceptions from multiple UAVs (co-operative perception).

The COMETS Control Center includes a teleoperation station for the guidance of remotely piloted vehicles. Figure 7 shows the information depicted in the teleoperation station in the fire monitoring experiments.

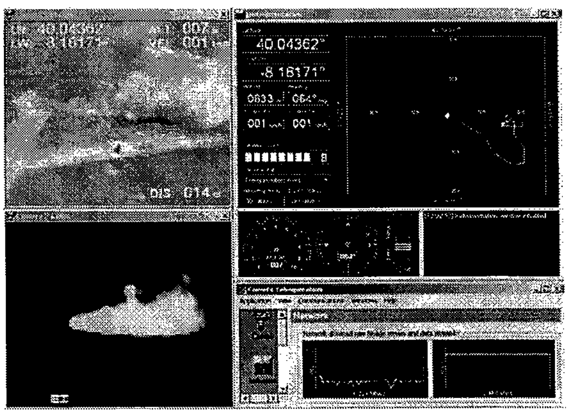

Figure 7: Teleoperation experiment

6 THE PERCEPTION SYSTEM

The Perception System has the Application Independent Image Processing (AIIP) subsystem with several functions for aerial image processing and computer vision applications, and the following application subsystems:

1) Detection of alarms, confirmation, localization and evaluation (DACLE). This function is performed by the DACLE subsystem. It is based on the images transmitted by the different UAVs of the COMETS system. The images are processed by the AIIP which has image stabilization and geo-location functionalities to obtain the alarm position. Both infrared images and visual images are used for fire detection.

2) **Event Monitoring.** It is implemented in the Event Monitoring System (EMS). The EMS also makes use of the AIIP scene image stabilization function and then, constructs a 2D / 3D model of the event in the image plane. For the case of forest fires, this model includes fire front width and flame height and the fire is automatically geo-located. Furthermore, EMS computes the fire rate of spread and the flame height and transmits all this information to the Ground Control Center to be used for forest fire fighting. Figure 8 presents the results of the stabilization procedure and EMS processing for fire segmentation. The fire-base is printed in blue, while corresponding height points are printed in red.

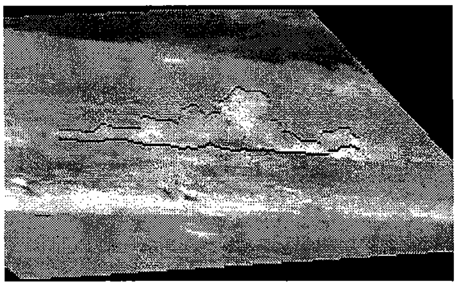

Figure 8: Stabilization and EMS results.

3) **Terrain Mapping**. It is performed by the Terrain Mapping System (TMS). It consists in providing an update of the initially available cartographic files of the area over which the UAVs are operating, in order to provide up-to-date information at a higher resolution than initially available. It involves 3D data perception which is carried out by means of both stereovision and sequences of monocular images.

7 CONCLUSIONS

This paper has presented the main characteristics of the COMETS system for the cooperation and control of multiple heterogeneous Unmanned Aerial Vehicles. COMETS has been designed to accomplish detection, monitoring and terrain mapping missions by exploiting the complementarities of different UAVs. Thus, helicopters have high manoeuvrability and hovering ability, and are therefore suited to agile target tracking tasks and inspection and monitoring tasks that require to maintain a position and to obtain detailed views. Airships have less manoeuvrability, but can be exploited to provide global views or as communications relays, they also offer graceful degradation in case of failures.

Furthermore, the COMETS architecture has been designed to integrate heterogeneous UAVs in terms of on board decisional capabilities, possibly ranging from fully autonomous aerial systems, to conventional radio controlled systems with just minimal on-board capabilities required, to record and transmit information. COMETS also incorporates control and perception functions to perform the above mentioned Missions. The first General COMETS experiments pointed out its possibilities for safety, security and rescue robotics. Several videos and other results of the experiments can be seen in the COMETS web site **(http://www.comets-uavs.org).**

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