Application Form / Workshop Description

Session Title:

Aerial robots physically interacting with the environment.

Organiser(s):

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Motivation and objective:

Aerial robotics has experienced a significant development in the last 10 years. The main methods, technologies and applications have been related to sensing and information exchanges of the aerial robots with objects in the environment, with ground stations as well as between several aerial robots. Recently, new applications that involve physical interactions such as load transportation and inspection are being researched and new methods and technologies have been developed. Thus, the AWARE project developed a system for load transportation and deployment by one or several coupled aerial robots transporting the same load. The AIRobots project is developing innovative aerial service robots for remote inspections by contact. In the recently launched ARCAS integrated project, the challenge is to go further away in this trend by involving cooperative assembly and manipulation by several aerial robots. In this workshop we plan to present some of the results already obtained and to point to what is needed for this ambitious objective.

Approach:

The workshop will consist of 6 presentations of 15 minutes dealing with different concepts related to aerial robots physically interacting with the environment and a round table discussion to summarise the presented results and to derive conclusions and follow-up.

The presentation and contents are the following:

1. *"Aerial robots interacting with environment: modeling and control, the first experience". K. Kondak, M. Bernard, I. Maza, M. Schwarzbach and A. Ollero.*

This presentation is devoted to modeling and control challenges posed by physical interaction with aerial robots based on small size helicopters interacting between them and with the environment. First, the load transportation problem will be considered. The model and control methods for one and multiple helicopters transporting a load will be presented. We will also present the obtained results in the transportation and deployment of a single load by means of one and three helicopters in the AWARE project. Then, we will analyze the manipulation problem by means of an autonomous helicopter equipped with a mechatronic device and present the first results.

2. *"Aerial manipulation". F. Forte, M. Fumagalli, A.Q.L. Keemink, R. Naldi, A. Torre, S. Stramigioli, R. Carloni and L. Marconi*

In this talk, we will present the mechatronic design and control architecture of unmanned aerial vehicles interacting with a remote environment. The innovation of the overall prototype

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lies on the use of a 6 DOFs parallel robotic manipulator, onboard an underactuated ducted-fan flying vehicle, to physically interact with environments and perform versatile tasks at unreachable locations for humans. The first experiment presents the results of keeping the manipulator at a desired position, while the aerial vehicle is freely moving. The controller relies on a joint-space position controller of the manipulator and a position controller of the aerial vehicle. The second experiment presents the results of the interaction of the manipulator with a vertical wall. The manipulator is impedance controlled and the aerial vehicle is position controlled.

3. *"Aerial Robotics Cooperative Assembly System". The ARCAS Integrated project. A. Ollero, K. Kondak, B. Siciliano, R. Alami, I. Maza, A. Sanfeliu, W. Naumann and E. Zwicker.*

In this presentation we will summarise the motivation, objective, structure and first achievements of the new Integrated Project Aerial Robotics Cooperative Assembly System (ARCAS) which is the first integrated project on Aerial Robotics funded by the Cognition and Robotics Unit of the European Commission. The ARCAS project proposes the development and experimental validation of the first cooperative free-flying robot system for assembly and structure construction. ARCAS will provide integrated and consolidated scientific foundations for flying robot perception, planning and control. In particular, ARCAS will produce a framework for the design and development of cooperating flying robots for assembly operations. The following three ARCAS experimentation scenarios will be described: 1) indoor testbed with 10 autonomous quadrotors and the VICON system for positioning; 2) outdoor experimentation scenario with autonomous helicopters with manipulation and assembly capabilities; 3) Advanced free-flying simulation by using an experimental setup based on multiple robot arms to emulate the dynamics of the free-flying objects. The application of the system to inspection and maintenance tasks will be also analysed.

4. *"Workspace incompatibility for bilateral teleoperation of unmanned flying vehicles". B. Siciliano, C. Hurzeler, V. Lippiello, A.Y. Mersha, R. Naldi, J. Nikolic and M. Saveriano*

Abstract: In this talk, we will address the problem of workspace incompatibility for bilateral teleoperation of underactuated flying vehicles. In particular, we will present two different haptic teleoperation controllers. The first one is based on a kinetic scrolling position mapping. The algorithm provides high precision and enables the teleoperation of aerial vehicles in unbounded workspace in a fast and intuitive manner. The second teleoperation controller is based on a switching state mapping between the master and the slave devices. The algorithm is an effective tool that bridges the gap between rate-based telecontrol, which addresses the workspace incompatibility and kinematic dissimilarity of master and slave systems, and pose-based telecontrol, which is required for precise operations. Simulation and experimental results validating the applicability and effectiveness of the proposed algorithms are also presented.

5. *"Sensor Fusion and Environment Awareness in the AIRobots project". C. Hurzeler, V. Lippiello, A.Y. Mersha, R. Naldi, J. Nikolic and M. Saveriano*

In this talk we will present the achievements on sensory data acquisition and fusion as well as on the environment awareness and modeling currently developed in the AIRobot project. We start from a low-level inertial data elaboration and filtering algorithm, based on Kalman filter, explicitly addressing the mechanical vibration issue. Hence, a (stereo) visual egomotion estimation algorithm, which is based on the fusion of inertial data also for the image feature matching step, is described and experimentally validated. Moreover, a new visual egomotion estimation algorithm, that makes use of a Pareto-optimization method for the visual-inertial data fusion, is presented and experimentally validated as a valid alternative to a classical extended Kalman filtering. Then, a solution for the estimation of the absolute velocity by fusing mono-camera visual data and inertial measurements is described

and experimentally tested. Hence, the development of a high-level cognitive navigation support, endowing the system with an advanced environmental awareness in order to autonomously accomplish high-level operations, is addressed at two levels: 1) system safety; 2) system autonomy. With respect to the first level, the methodologies and the hardware/software modules developed allow the real-time reconstruction of a low-level point-cloud map (similar to a 3D occupancy map) of the surrounding unknown environment on the basis of visual measurements provided by the developed stereo visual system. The second level regards the semantic map reconstruction and scene interpretation. Starting from the low-level occupancy map provided by the previous modules, a high level of scene abstraction and interpretation is achieved resulting in an object-based map representation.

6. *"Fixed wing aerial robot with deployable ground robot for soil sampling". Guillermo Heredia, Jesús Martín and Luis de Paz.*

Abstract: In this talk we will present the design of an Aerial Robot System for environmental monitoring and sampling, composed of a fixed wing UAV which carries a ground robot that can be deployed for soil sampling and site inspection. The ground robot has sensors for inspection and an arm that can take soil samples. Then, the ground robot can return to the aerial robot and reattach to it, so that the samples can be taken back to the base station. Once it is deployed, both robots make up a multi-robot cooperating system, in which all the available information is used to increase reliability and performance of the robots. Multi-robot fault detection has been implemented using ground robot visual tracking information, captured from a UAV-mounted camera, as redundant external ground robot pose estimation. Ground robot networked control that allows recovery of the robot by the UAV in case of partial or total sensor failure has also been implemented, using the visual tracking information transmitted through the communication channel as position estimation for the ground robot navigation feedback loop. Experimental results of both cases are also presented.

Agenda of the workshop:

08:30 – 08:35 Introduction by the moderators

08:35- 08:50 "Aerial robots interacting with environment: modeling and control, the first experience", K. Kondak

08:50- 09:05 "Aerial manipulation", L. Marconi

09:05- 09:20 "Aerial Robotics Cooperative Assembly System". The ARCAS Integrated Project, A. Ollero

09:20- 09:35 "Workspace incompatibility for bilateral teleoperation of unmanned flying vehicles". S. Stramigioli

09:35-09:50 "Sensor Fusion and Environment Awareness in the AIRobots project". B. Siciliano

09:50-10:05 "Fixed wing aerial robot with deployable ground robot for soil sampling". G. Heredia

10:05-10:30 "Round Table Discussion"

Speaker(s):

The list of the speakers in the same order than corresponding presentations is the following:

1) *K. Kondak, Dr.-Ing. habil. Institute of Robotics and Mechatronics DLR, ARCAS senior scientist*
2) *L. Marconi, Professor, Università di Bologna, AIRobots coordinator*
3) *A. Ollero, Scientific Director of FADA-CATEC and Professor at the University of Seville, ARCAS coordinator*
4) *S. Stramigioli, Professor, University of Twente, AIRobots senior scientist,*
5) *B. Siciliano, Professor, Università di Napoli, AIRobots senior scientist,*
6) *Guillermo Heredia, Professor at the University of Seville, ARCAS senior scientist*

How can participants contribute to, and prepare for, the workshop?

Reading documents related to aerial robotics and particularly to load transportation, manipulation and structure construction.

A visit to the sites of the projects AWARE, AIRobots and ARCAS (to be finalised before the Workshop) is desirable

Further information:
Links to publications, websites…

http://www.arcas-project.eu
http://www.aware-project.net
http://www.airobots.eu

Relevant publications will be linked.

Planned follow-up:

The results of the discussions and interactions will be used to progress in aerial robotics and to promote synergies between running European projects, such as ARCAS and AIRobots. Also the suitability of new projects will be analysed including new application possibilities.

The launching of new initiatives including summer schools and workshops will be also analysed.

The presentations will also generate publications in Conferences, Journals and Book Chapters.

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