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AIRobots: Innovative Aerial Service Robots for Remote Inspection by Contact

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Abstract— **This video presents experiments conducted within the final review meeting demonstration session of the AIRobots project. AIRobots started at 2010 and the final review meeting took place on 22 of March, 2013. The presented experiments cover a wide area of the challenges related with aerial industrial inspection. In particular, multiple test-cases related with both vision-based and contact-based inspection and in general physical interaction are shown. It is highlighted that these experiments were recorded live during the project demonstration and evaluation process.**

I. The AIRobots experience

AIRobots aimed to address the challenge of aerial service robotics for industrial inspection using advanced vision sensors and innovative configurations and control strategies that enable aerial physical interaction and inspection through contact. In order to thoroughly examine this challenging scenario, different unmanned aerial vehicle (UAV) configurations were considered from the project partners. In particular, a ducted–fan UAV was designed at University of Bologna, a Coaxial–rotor UAV was developed at the Swiss Federal Institute of Technology (ETH Zurich), while commercial quadrotors were also utilized from ETH Zurich, University of Naples and University of Twente. It is noteworthy that towards the end of the project, a new 'double ducted–fan' configuration was also developed through the combination of two ducted–fan prototypes in order to create a novel kind of system with fully actuated longitudinal dynamics.

Towards the goal of active physical interaction, two of the aforementioned vehicles, namely the double ducted–fan [1] as well as the Coaxial–rotor UAV [2, 5] were optimized to achieve safe and robust physical interaction. The double ducted–fan is equipped with an aerial manipulator [4] developed at University of Twente, while the Coaxial–rotor UAV is equipped with force sensors. Both vehicles implement controllers to achieve safe physical interaction and minimize the undesired effects of elastic collisions. Specifically, the double ducted–fan makes use of an impedance controller [3], while the AIRobots Coaxial–rotor UAV implements a hybrid predictive controller to ensure stable transition from free–flight to in–contact dynamics [2].

As expected for an industrial inspection mission, the aerial robots have to be able to autonomously perceive their environment. The AIRobots consortium particularly focused on the problem of autonomous indoor flight based on tight stereo camera – inertial measurement unit integration. As a result the ETH SLAM sensor was developed [6]. This module greatly imporved the motion estimation capabilities of a quadrotor. As experimentally shown, the vehicle is able to autonomously estimate its pose while inspecting a boiler mock–up environment. In addition, an online reference trajectory generator that provides the inspection path as well as obstacle avoidance capabilities was implemented based on the work of the AIRobots partners at University of Naples.

In brief, AIRobots approached the problem of aerial industrial inspection through vision and contact. The most important parameters including the mechanical robustness of the vehicles, the potential advantages and disadvantages of different flying concepts, the control laws towards safe physical interaction as well as the sensorial systems and navigation algorithms that can provide advanced autonomy were investigated. The experimental test–cases shown in this video were demonstrated successfully live in front of the project reviewing committe. Although, the problem of aerial physical interaction and autonomous operation inside industrial environments cannot be considered as solved, there is strong indication that AIRobots paved the way for further improvements at the academic and the industrial level.

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References

[1] Marconi, L.; Naldi, R., "Control of Aerial Robots: Hybrid Force and Position Feedback for a Ducted Fan", IEEE Control Systems, Aug. 2012.

[2] K. Alexis, C. Huerzeler, R. Siegwart, "Hybrid Modeling and Control of a Coaxial Unmanned Rotorcraft Interacting with its Environment through Contact", 2013 International Conference on Robotics and Automation (ICRA), Karlsruhe, Germany, pp. 5397-5404.

[3] Lippiello, Vincenzo, and Fabio Ruggiero. "Cartesian impedance control of a UAV with a robotic arm", IFAC Symposium on Robot Control. 2012.

[4] Keemink, A. Q L; Fumagalli, M.; Stramigioli, S.; Carloni, R., "Mechanical design of a manipulation system for unmanned aerial vehicles," ICRA, 2012

[5] K. Alexis, C. Huerzeler, R. Siegwart, "Unmanned Coaxial Rotorcraft Force and Position Control for Physical Interaction through Contact", 2013 21st Mediterranean Conference on Control and Automation (MED), Platanias-Chania, Crete, Greece, pp. 179–84.

[6] J. Nikolic, M. Burri, J. Rehder, S. Leutenegger, C. Huerzeler, R. Siegwart, "A UAV system for inspection of industrial facilities", IEEE Aerospace Conference 2013, 2013, pp. 1-8.