https://doi.org/10.1109/ROBOT.2007.363883

2007 IEEE International Conference on
Robotics and Automation
Roma, Italy, 10-14 April 2007

COLIBRI: A vision-Guided UAV for Surveillance and Visual Inspection

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***Abstract*— UAVs (Unmanned Aerial Vehicles) are becoming more popular for civil task due to their unique flight capabilities. The video shows several capabilities of a platform used as main research testbed of computer vision for unmanned aerial vehicles. Four major research areas are explored in the present work as visual servoing, trajectory planning, power line inspection and stereo-based visual navigation.**

I. INTRODUCTION

Unmanned aerial vehicles have been an active area of research in recent years. Their use in civilian applications for surveillance and inspection continues to grow due in part to the emergence of cheap low-power vision systems. Vision for flight control encompasses a broad range of research areas such as object detection and tracking, position estimation, sensor fusion with inertial navigation and GPS, and multivariable non-linear system modeling and control. An autonomous helicopter is highly suitable for tasks like inspection and surveillance. The inherent ability of the helicopter to fly at low speeds, hover, fly laterally and perform maneuvers in narrow spaces makes it an ideal platform for such tasks. These abilities are particularly useful in structured environments where the features to be tracked are very well understood. The structured nature of features facilitates vision-based state estimation and control. The present video explores a research field in computer vision for UAVs. Four main active research lines are presented: visual servoing, trajectory planning, power line inspection and stereo-based visual navigation.

II. SYSTEM DESCRIPTION

The testbed, COLIBRI helicopter [2], is based on a gas powered model helicopter industrial twin with two stroke engine 52 cc and 8 hp. The platform is fitted with a Xscale-based flight computer augmented with sensors (GPS, IMU, Magnetometer, etc fused with a Kalman filter for state estimation). For vision processing it has a VIA mini-ITX 1.25 GHz computer onboard with 512 Mb Ram, wireless interface and a firewire color camera for acquiring the images. Both Computers runs Linux OS. The ground station is a laptop used to send high-level control commands to the helicopter. It is also used for visualization of image data and communications with the onboard image processing algorithm. Communication with the ground station is via 802.11g wireless ethernet. We implement an existing architecture such as client-server. This architecture is based on TCP/UDP messages which allows embedded application to run onboard of an autonomous helicopter. This common architecture is intended to serve as mechanism to exchange message between processes. The exchange is made through a high level layer which routes the messages to specific processes. The basic functionalities are:

- Define a number of messages to identify the type of information and the destination of these messages. Messages and data structures are defined and then sent to this layer. Different messages for flight control: velocity control, position control, heading, attitude, helicopter state, etc, and for ground processes: type of data sent/received from the ground-based process to/from the onboard vision processes.
- Switch and route the messages depending on the type of information received. For example, the layer can switch between position or velocity control depending on the messages received from an external process.

The visual control system, its visual references and additional external processes are integrated with the flight control through a high level layer using UDP messages. This layer acts as a switch using the API communication explained above. The low-level controller is based on simple PID loops and ensures the stability of the helicopter. This controller has been validated empirically. The higher level controller uses various sensing modalities such as GPS and/or vision to perform tasks such as navigation, landing, visual tracking, etc.

III. FINDINGS

A. Autonomous Hover & GPS Waypoint Navigation

- Flight control software is based on decoupled PID control laws.
- Several controllers in cascade for attitude, velocity and position control.
- External processes can be connected to the flight controller through a software layer which switch and routes the messages.
- Several successful GPS-based landing has been accomplished [2].

B. Trajectory Planning

- Approach based on splines using the Catmull-Rom algorithm [3].
- Trajectories are calculated in real-time allowing changes while is the vehicles is moving. UAV motions constrains are introduced in the algorithm. Generates feasible 3D trajectories which are smooth evading sharp turns and passing through all way points.

C. Visual tracking and Visual Servoing

- 2D Visual servoing for control vertical, lateral and longitudinal [5] displacements of an autonomous helicopter.
- User selected features are tracked using Lucas-Kanade approach. Location of tracked feature is used to generate image-based velocity references for the flight control [6].

D. Power lines & Isolator detection

- Power line detection using a fast version of Hough Transform.
- Once the line is detected isolator are found based on interest point detection & grouping along the line [1].

E. Stereo Vision-Based Navigation

- Altitude estimation using pixel matching and stereo disparity.
- Estimation of helicopter motion parameter in bodyframe: Using pixel tracking (optic flow) and, Iterative Closest Point and Singular Value Decomposition for correspondence an motion estimation [4].

IV. CONCLUSIONS

The UAV field has reached an important stage of maturity in which the possibility of their use in civilian applications is now imaginable and in some cases attainable. We have experimentally demonstrated several capabilities for an autonomous helicopter such as autonomous waypoint navigation, trajectory planning, visual servoing and visual navigation. These features and capabilities are important when tasks like power lines inspection are addressed. We consider the field of computer vision for UAV a promising area where we intend to invest further research for the benefit of the autonomy and applicability of these type of aerial platform, considering that reliability and safety become a major research thrust of our community.

V. ACKNOWLEDGMENTS

The authors gratefully acknowledge the contribution of Spanish Science and Technology Ministry through the grant DPI2004-06624 and Comunidad de Madrid through the grant 3D Visual SLAM. The authors would like to thank to Jorge Leon for support with the flight trials and the ETSII - Universidad Politécnica de Madrid for granting us access to their facilities.

REFERENCES

[1] CAMPOY, P., GARCIA, P. J., BARRIENTOS, A., CERRO, J., AGUIRRE, I., ROA, A., GARCIA, R., AND MUNOZ, J. M. An autonomus helicopter guided by computer vision for overhead power cable inspection. In *5th International Conference in Live Maintenance* (Madrid, Spain, May 2000).

[2] COLIBRI. Universidad Politécnica de Madrid. Computer Vision Group. COLIBRI Project. http://www.disam.upm.es/colibri, 2005.

[3] FISCHER, S., MEJIAS, L., AND CAMPOY, P. Respecting motions constrains in a 3d spline-based trajectory planner for an autonomous helicopter. In *sudmitted to IEEE International Conference on Robotics and Automation 2007* (2006).

[4] MEJIAS, L., CAMPOY, P., AND DOHERTY, P. Stereo vision-based navigation for an autonomous helicopter. In *sudmitted to IEEE International Conference on Robotics and Automation 2007* (2006).

[5] MEJIAS, L., ROBERTS, J., CAMPOY, P., USHER, K., AND CORKE, P. Two seconds to touchdown. vision-based controlled forced landing. In *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems* (Beijing, China, October 2006), p. to appear.

[6] MEJIAS, L., SARIPALLI, S., CAMPOY, P., AND SUKHATME, G. Visual servoing for tracking features in urban areas using an autonomous helicopter. *Journal Of Field Robotics 23*, 3-4 (April 2006), 185–199.