Obstacle Avoidance for Small Uninhabited Aerial Vehicles Using Computer Vision

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Introduction

Small unmanned aerial vehicles (UAVs) can operate in hazardous environments, are unconstrained by human endurance, and are cheaper to operate than manned aircraft. These benefits have inspired civil and commercial applications such as search and rescue, disaster relief, wildfire protection, crop dusting, and traffic monitoring. However, due to increased air traffic and unmapped stationary objects, collisions between UAVs and other objects are possible. Currently UAVs have no inherent capability to avoid obstacles while in midair. The purpose of this research is to develop an obstacle avoidance system for use on small, fixed-wing UAVs. In order to detect and avoid obstacles, computer based vision algorithms will be implemented with an automatic flight control system. Images of obstacles are captured using forward facing, externally mounted cameras. Obstacles will include moving and non-moving objects within the flight path of the UAV, which will be detected through the use of optical flow and feature-tracking methods.

Airframe

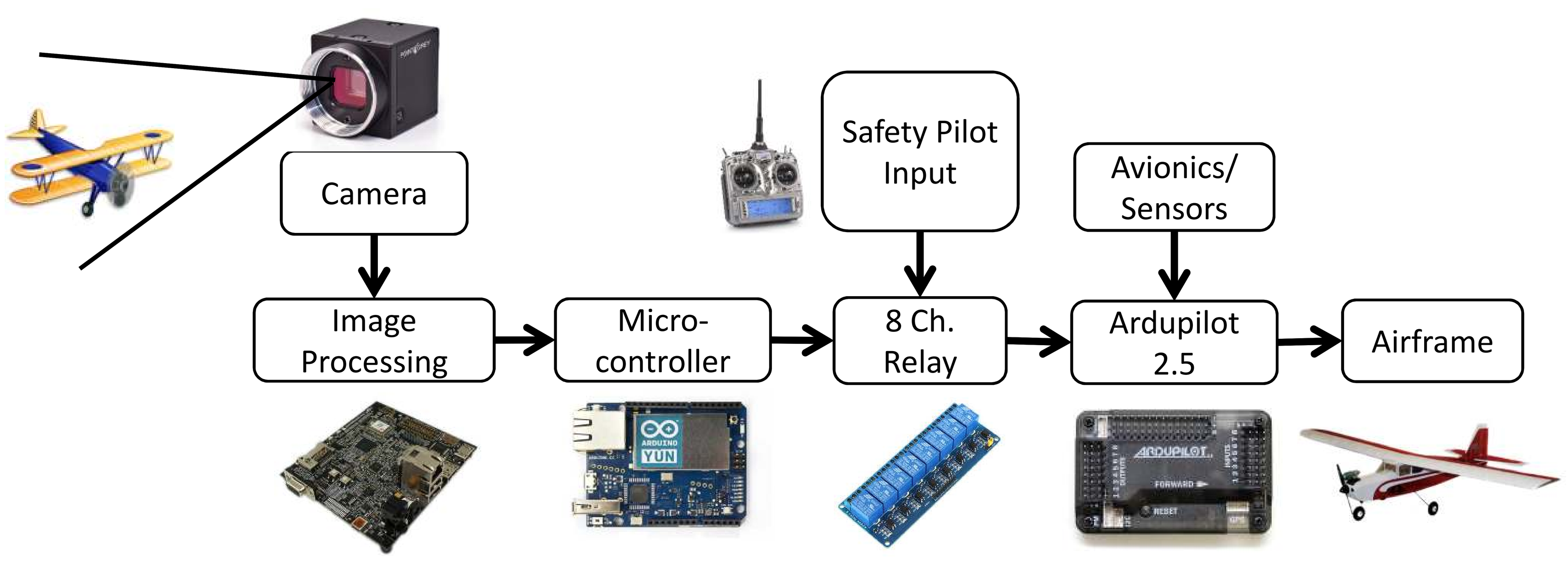
For the development of this obstacle avoidance system the chosen aircraft is the Sig Kadet Senior shown below. This is the perfect airframe as it is easy to control due to its high wing configuration and it provides enough lift to carry the required sensors. It has a span of six feet and can carry a net load of eight pounds.

Sig Kadet Senior

Methods

The overall system functionality is broken into three parts: autonomous flight, object recognition, and avoidance commands. While in autonomous flight, the aircraft is under the control of the ArduPilot Mega 2.5. Also during flight, the camera is collecting images and sending them to the onboard image processor, which filters and analyzes the images. If the processor detects an object in the images, it will begin to track it. As objects begin moving towards or are already in the flight path of the UAV, they are immediately tracked and upgraded to obstacles. When this happens, the processor sends an avoidance command to the microcontroller, which in turn will calculate the amount of control surface deflection required to move the UAV away from the obstacle.

System Architecture



Results

System testing was performed in two stages. First there was a ground test. The aircraft was placed on a workbench and the onboard computer was powered. Objects were placed in front of the vehicle, as they would during flight, and the electro-mechanical servos reacted by moving the control surfaces. After this test was successful, then a test flight took place. Here the optical flow software was tested. The data recorded was retrieved and analyzed. The picture below shows results similar to the ones obtained in this test.

Computer Vision Code Output

Conclusion

All three individual systems have been tested and are working, with the aircraft and autopilot having been flown and tuned for autonomous navigation. The computer vision code has also been tested on manual flights while the avoidance algorithm has successfully sent commands from a laptop computer to the Ardupilot Mega 2.5. Full-system ground tests, with single moving and stationary targets, have been conducted and the aircraft's attempted maneuvers and control surface deflections are as anticipated. More ground tests, such as moving objects from multiple directions, and multiple stationary objects, are required to ensure the system will respond appropriately in all circumstances. Once the system has been thoroughly evaluated flight test will begin. This project has laid the ground work for a more robust and comprehensive obstacle avoidance systems and will continue to be built upon in the years to come.

References

- He, Z., Iyer, R. V., et al, "Vision-Based UAV Flight Control and Obstacle Avoidance", *Proceedings of American Control Conference*, Minneapolis, Minnesota, June, 14-16, 2006.
- Call, R., Brandon, "Obstacle Avoidance for Unmanned Aerial Vehicles", *Thesis for Bringham Young University*, Idaho, United States, December 2006.
- DIY Drones, "Arduplane", https://code.google.com/p/ardupilot-mega/wiki/home?tm=6
- OpenCV Pyramid tutorial, http://docs.opencv.org/trunk/doc/py_tutorials/py_feature2d/py_shi_tomasi/py_shi_tomasi.html
- Computer Vision Introduction, http://www.comp.nus.edu.sg/~cs4243/lecture/motion.pdf
- Vision Class Reference, http://www.mathworks.com/help/vision/ref/vision.pointtrackerclass.html
- Arduino Help and References, http://arduino.cc/en/Reference/HomePage#.UyaNEfldXwE

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