Urban Post-Disaster Search and Rescue Solutions with Unmanned Aircraft Systems

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Abstract

This manuscript proposes solutions to the problems given in an international competition (iMAV2014), which involves micro air vehicles in urban post-disaster search and rescue missions. Solutions to all four mission elements of the competition which include real-time map stitching, low altitude navigation, indoor navigation and roof-top perching are described in this manuscript. The proposed solutions are tested and realized in the competition with actual flights.

Keywords: Search and rescue, unmanned aircraft systems, flight control

1. Introduction

In the recent years, unmanned aerial vehicles (UAVs) play major roles in many military and civilian applications, especially in aerial reconnaissance, search and rescue, and area exploration. While sensors and processors are getting smarter and smaller in size, micro-UAVs, or more commonly known as MAVs, are introduced to replace the large scale UAVs. These MAVs are more suitable for short missions such as indoor surveillance [1, 2].

In September 2014, the Mavlab from TU Delft has organized the International Micro Air Vehicle (iMAV) competition, which was held in Delft, the Netherlands. The competition consists of a single mission that combines both outdoor and indoor mission elements.

The first mission element requires the MAVs to survey a village and then build an aerial map based on the images taken by the MAVs. Several obstacles on the major roads of the village are then identified on the aerial map. Second mission element requires the MAVs to navigate from houses to houses in the village, and to identify the house numbers and victims in the houses. Third mission element comprises indoor navigation in a 2-storeys building. The MAVs are required to navigate from room to room while the ground operator will identify objects in each room. The last mission element requires the MAVs to land on the rooftop of the building and to observe a panel displaying digits on the opposite building.

This manuscript describes the method and algorithm used by the team from the National University of Singapore (NUS) in participating and winning the iMAV 2014 competition. In addition to the four mission elements in the competition, a standalone MAV carrying high gain wireless router is introduced by the team to act as the data and video link relay to all the MAVs used in the four missions. The manuscript is divided into 6 sections. Introduction of the iMAV competition is made in this section. Solutions to each of the mission elements using MAVs are described in Section 2, 3, 4 and 5 respectively. Concluding remarks are made in Section 6.

2. Real-Time Map Stitching

The first mission element requires the MAV to fly above the post-disaster village, at the same time to take high resolution aerial photos. The photos are then stitched together to form a complete map of the village.

A downward facing camera is installed on the MAV. To realize fully automatous flight and onboard image stitching, two on-board processor layers are designed. One is used for automatic flight control which includes take-off, GPS waypoint tracking and landing. The other processor is used for the vision algorithm captures and stores onboard images at 5 Hz speed. Given the village area to be covered in the competition, a sweep pattern path is generated online automatically from the GPS coordinates to maximize the image coverage. Once the designated flight path has completed the last waypoint, the flight control processor will trigger the vision processor to start the image stitching process with the recorded on-board images. With such intelligence, the image stitching task can be done in-flight and the result is ready to be rendered to the ground control station once the MAV returns home

3. Optical Flow Aided Outdoor Navigation

The second mission element requires a quick inspection of houses to check whether there are possible trapped victims. The MAV is required to navigate to each house, take pictures and recognize house numbers.

In order to complete the tasks, the MAV is set to operate below rooftop height to obtain better images of the house. This renders the GPS signal not consistently available. To solve the problem, a specific navigation solution is proposed. Optical flow is used as the main state estimation method while GPS signal is utilized as the waypoint guidance. The velocity estimated with optical flow is transformed to global frame and then fused with the acceleration measurement in a Kalman filter [3]. As this conventional method of position estimation is prone to drifting, the absolute GPS position is used to guide the MAV to the desired location. With this method, the MAV is able to fly to the absolute waypoints eventually.

4. Lidar-Based Indoor Navigation

In this mission element, the MAV is required to penetrate and navigate in a building with unknown structure and obstacles, at the same time to observe and identify objects inside the building.

One of the main challenges in this task is to obtain the MAV ego-motion in an environment where GPS is totally unavailable. To solve this problem, a 30-meter scanning laser range finder (Lidar) is utilized, where the motion of the MAV is estimated based on feature matching between consecutive Lidar scans. Corners, lines and end points of line segments are extracted by the split-and-merge algorithm to be treated as distinctive geometric features which favor the matching. An orthogonal structure of the indoor environment is assumed, which decouples rotational motion estimation from translational motion. This leads to a more accurate result and faster processing, where it can be run on-board at 25 Hz.

Besides motion estimation, an obstacle detection and avoidance algorithm is realized for robust and safe indoor navigation. A real-time path generation algorithm is implemented, which updates the MAV trajectory reference based on the targeted waypoint and obstacles detected by the Lidar sensor.

5. Vision Guided Rooftop Landing

The final mission element of the competition requires the MAV to perch on a roof-top, while video survey a number panel placed opposite the building.

To tackle this task, two color cameras were installed to the MAV. One of the color cameras is used for the land point detection and poses estimation while another one is used for surveillance. The algorithm for roof-top landing employs the vision guidance mechanism. The relative distance between the MAV and a pre-defined marker is used to guide the MAV for precise landing.

The marker consists of several cascaded shapes. As long as at least one shape is detected, the vision algorithm will use perspective-n-point (PnP) algorithm to calculate the relative distance and relative poses between the marker and the MAV. An adaptive threshold algorithm is developed to handle the changes in light intensities for outdoor environment.

6. Conclusions

Solutions to the mission elements in the iMAV competition are proposed in this manuscript. Our team from the NUS has taken part in the competition and realized our solutions on actual flights. All mission elements are carried out in fully autonomous mode, where no human interference occurs during the missions. The overall result places the NUS team as the champion of the competition.

References

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