UAV-BASED LARGE SCALE PRECISE OUTDOOR OBJECT RECONSTRUCTING SYSTEM

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Abstract: Nowadays, there is a growing demand for 3D reconstruction of large scale outdoor object and in order to deal with it, this paper proposed a new solution. Taking the advantages of UAV's motility and flexibility, we set the route for a hexacopter to fly around an object, use binocular camera to capture key frames, compute and store them on an airborne platform, which also performs Simultaneous Localization and Mapping(SLAM) and sends the model back to the ground station. Implementing the system, we utilize MinnowBoard Turbot platform as ground station providing GUI and showing the result of feature points reconstruction, while mounting the Genuino 101 platform to get information from some of the sensors and send message to the flight controller in order that our copter can avoid obstacle automatically. We also applied Intel J1900 to perform 3D online reconstruction store all images for further precise reconstruction. The structure of the system is fully implemented with stable performance.

Key Words: Hexacopter, Large Scale Precise Outdoor Object 3D Reconstruction, ORB-SLAM, Flying Route Planning, Ultrasonic Obstacle Avoidance

1 System Description

1.1 Functional Overview

Our system provides two ways of object reconstruction. One is manual mode, that is, the hexacopter flies around an object based on the order of the remote control. The other is automatic mode in which the copter follows the route decided by the ground station. When flying, the binocular camera ZED captures key frames of the object and saves them in J1900, a processor applied on the copter. The processor performs quick 3D reconstruction using ORB-SLAM and transmits the result to ground station via 4G-LTE on time. After completing the task of reconstruction or receiving a call-back signal, the hexacopter will return to the start point and land automatically. We can copy the key frames out of J1900 and then get precise 3D reconstruction result using PC or other processor with higher performance. Compared with shooting videos by ourselves, using hexacopter saves not only time, cost but also human resource and we can also get pictures from where we cannot reach such as skyscrapers and deep mountains.

1.2 System Architecture

Our system uses the MinnowBoard Turbot platform as the ground station and the Genuino 101 as coprocessor on the hexacopter. The ground station receives real-time reconstruction results via 4G-LTE and copter's flight status parameters from Pixhawk and at the same time, sends back control commands. With the help of ultrasonic model, the Genuino 101 board can fulfill the function of obstacle avoidance. Besides, we mount Intel J1900 platform on the hexacopter in order that we can store the key frames and then perform 3D reconstruction online. It is quite a strong processor which enables us to get pretty good online results.

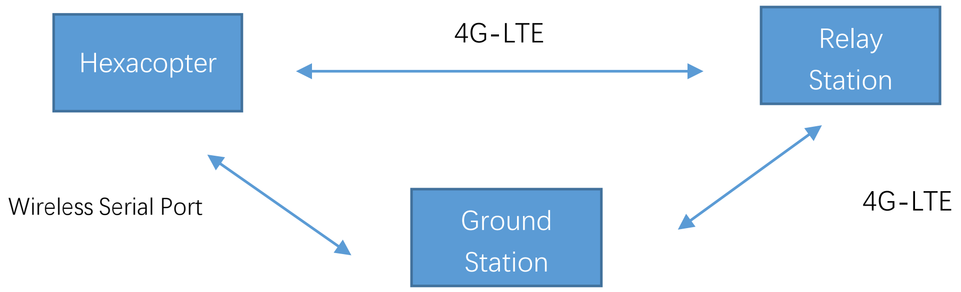

Figure 1-1 System Abstract Architecture Diagram

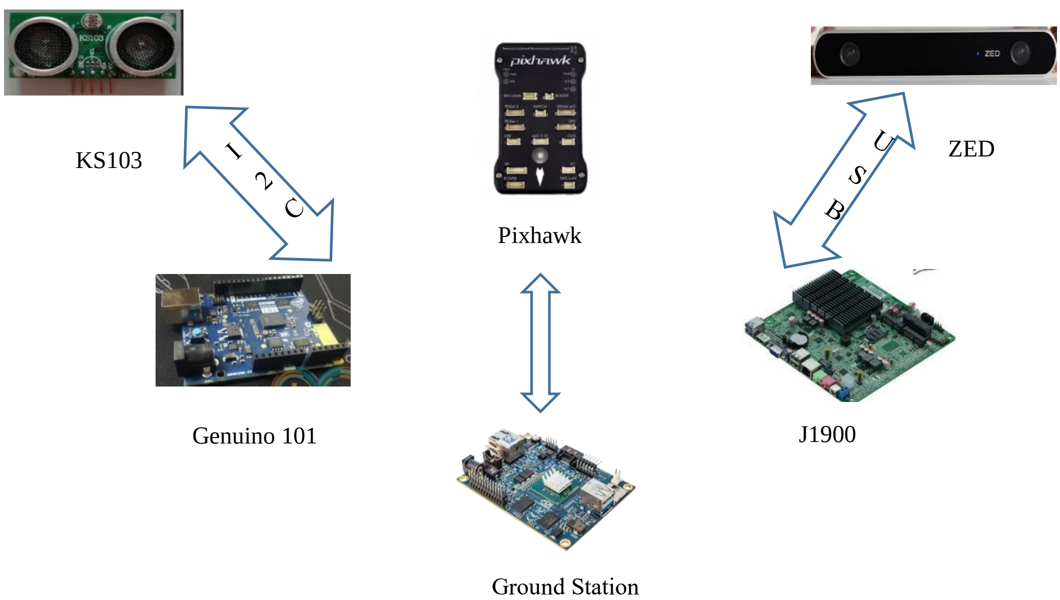

Figure 1-2 Device Diagram

2 System implementation

2.1 Hexacopter Flight Control System

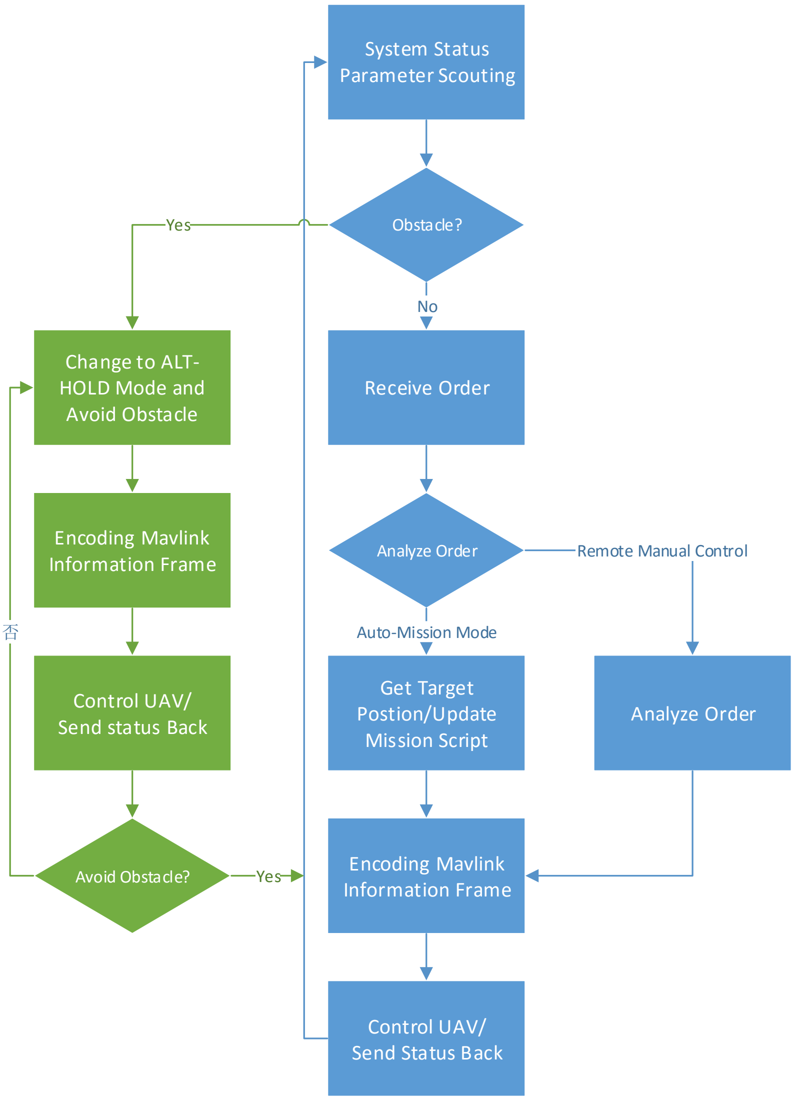

Figure 2-1 Flight Status Diagram

The core of the flight control system is the Pixhawk flight controller. The controller receives orders sent from ground station and controls the movement of hexacopter. Under normal circumstances, the hexacopter can fly autonomously after setting target position, but when it encounters obstacles in the near, the copter will take appropriate avoidance strategies with the help of Genuino 101 coprocessor. In this case, the control of the copter can also be handed to the ground station, requesting for human control. On the MinnowBoard Turbot platform which is used as ground station, we have a joystick that can change the pose of the copter.

We take advantage of ultrasonic sensors to realize the obstacles avoidance, since the ultrasonic sensors' detecting distance is far enough to meet our requirements. The Genuino 101 coprocessor communicates with the Pixhawk controller and the latter will keep the copter away from obstacles.

2.2 3D reconstruction

Key frames are captured through binocular camera ZED, saved and computed in J1900. First of all, we need to calibrate the camera on the ground to make sure the key frames and point clouds it captured are correct. Once taking off, we will no longer be able to calibrate it. Next, J1900 collects video stream and corrects skewness caused by binocular photographing. After correction, it will compute feature points and motions and build online feature points map afterwards using ORB-SLAM. On the one hand, the result of reconstruction will transmit to the ground station through 4G-LTE relay station and we can see them on the monitor which is placed on the ground. On the other hand, key frames with pose information of the camera has been stored in J1900 and when the hexacopter land successfully, we can copy the key frames to our PC to perform off-line intensive reconstruction.

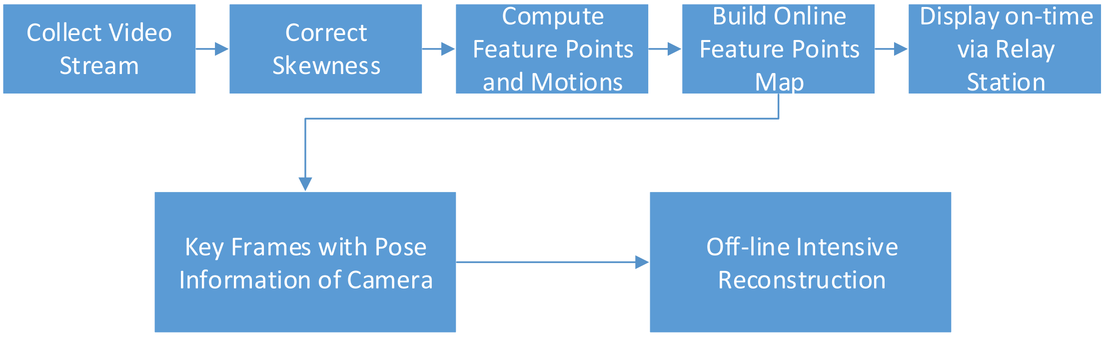

Figure 2-2 3D Reconstruction Procedure

2.3 Ground Station Design

The ground station consists mainly of four functions: parameter display, route planning, remote control and reconstruction result displaying. Parameter display is for showing the current flight status parameters; route planning is for generating flight scripts to control the flight of the hexacopter; remote control converts the keyboard keys to corresponding commands to control the copter and reconstruction result displaying is for visualizing the feature points map the camera captured. The ground station is designed by ourselves, based on python and Qt creator.

Figure 2-3 Ground Station

3 Testing Result

3.1 Route Planning Test

Figure 3-1 Planned Route **Figure 3-2 Actual Route**

After we plan the route on the UI of ground station, the hexacopter takes off and begins to fly around the Yifu building. As is shown above, the actual route is quite similar with that we have planned. Also, the route also illustrates that flying-back-home functions well!

3.2 Remote Controlling Test

Figure 3-3 Remote Control

When flying, we try to change the previous route by clicking the direction button on the UI. Although the copter responds a little bit slowly, it does follow that direction!

3.3 3D Reconstruction Test

The last function we test is the core function-3D reconstruction. We choose the sundial in our school. After setting correct route, the hexacopter takes off and flies around the sundial. We successfully received real-time reconstruction model which is shown in figure 3-4. Restrained from the performance of J1900, we can't perform intensive reconstruction online, but actually the real-time reconstruction results are better than what we have expected. At last we take out all the key frames stored in J1900 and perform off-line 3D reconstruction and get the result shown in figure 3-5 and figure 3-6. All of these results illustrate that our system works extremely well and there is no doubt that the future of UAV based 3D reconstruction is brighter than ever before!

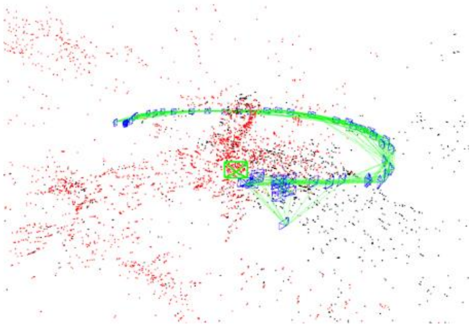

Figure 3-4 Real-time Reconstruction

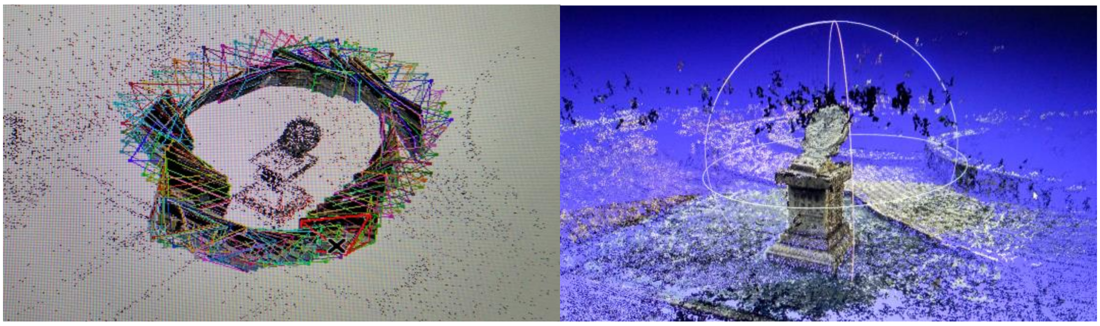

Figure 3-5 Off-line Reconstruction

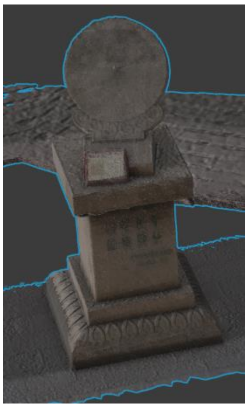

Figure 3-6 Off-line Reconstruction Result

4 Conclusions

Thanks to the UAV's features of flexibility and maneuvering, it is brilliant to combine it with 3D reconstruction. On the one hand, we make full use of UAV, and on the other hand, this system can be used in numerous circumstances such as digital backup of historical sites, disaster investigation, city construction and planning and so on. What's more, with the development of 3D printing, the reconstruction result becomes substantiated and more vivid and thus can be used in wider field.

Our system is divided into two main parts, one is the hexacopter and the other is the ground station. In the hexacopter part, the Genuino 101 board is attached to the copter, controlling the flight. In the ground station part, we take advantage of the MinnowBoard Turbot, which is easy to carry and demonstrates excellent performance.