An Effective Surveillance System in Narrow Area Using Two Small UAVs

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ABSTRACT

In recent, to overcome the monitoring area limits of fixed surveillance systems moving systems that utilize small UAVs have been studying. In this paper, we propose a moving surveillance system that is able to operate a real monitoring on the narrow or small area where buildings stand close together. Based on the experimental results about the pre-planned simulation path, we founded the proposed system shows some efficiency performances.

Keywords: Surveillance, Moving, Small UAVs and Narrow Area.

1. INTRODUCTION

In recent, studies for utilizing multiple UAVs to detect, recognize, and track objects.[1-3] Also planning, simulation and control of activities of small UAVs have been presented.[4-6] And surveillance and trajectory are very important factors in fields of small UAV's applications.[7-8] When a fire or an occasional accident is happened in a narrow specific area between buildings, we are faced with necessity of a system to be able to observe and monitor the scene immediately. If we get the real-time information related to the scene, we can cope with the situation immediately and easily. In order to represent a variety of information for the scene, two small UAVs are needed and one of them is for reconnaissance and the other is for surveillance, and also, an integrated user interface system composed of map marking, image displaying, and graphical viewing modules. Especially, in case of occlusions that the reconnaissance vehicle is behind a building and it is not observed, we cannot inspect the states such as the position or the direction of the vehicle. Therefore, a graphic system to present the situation graphically is necessary. This system calculates the azimuth and the elevation angle from the latitude, longitude, and altitude data of the surveillance UAV and indicates the current location of the surveillance UAV using the calculated angle data.[9] And if we mark the current position on the presentation map in real time, we can visually detect and monitor the surveillance UAV in the behind of the building. Also if we use the images from the reconnaissance UAV that is hovering at high position on air and interlink with the integrated visual system that is composed of the graphic system, the representation map, and the image display system, we will be able to detect and manage the accidental or suspicious situation. In this paper, we illustrate the background, structure, and operations of our proposed system and present the experimental results.

2. BACKGROUND

2.1 Mission Planner

There is an efficient simulation tool to be able to test the pre-palled flight path before the real flight experiment and it is Mission Planner provided by Microsoft. This Mission Planner is a ground control station for small UAV like a quad-copter. Using this Mission Planner we can setup, configure, and tune the related vehicle for optimum performance and also it is possible to plan, save, and load autonomous missions into the autopilot with simple point-and-click way-point entry on Google map, and then we can download and analyze the mission logs created by the autopilot. In this study, we used this mission planner to simulate the pre-flight operation in a narrow area on Google map and to earn an simulated flight path and the related flight data before implementing our surveillance system. Figure 1 shows an example of the waypoint autopilot planning using Mission Planner.

Figure 1. An example of the waypoint autopilot planning using Mission Planner

2.2 Small Flight Vehicles

To compose our surveillance system we need two small vehicles - one is for reconnaissance and the other is for surveillance. These fly simultaneously at low and high position from ground. The reconnaissance vehicle moves along the pre-defined path and operates the reconnaissance mission using two cameras equipped in the forward and under directions on itself. The surveillance vehicle detects the operational situation of the former vehicle at more high position using the under directional camera. To operate these missions we used two AR Drones 2.0 provided by Parrot Company. Figure 2 is the appearance of the small UAVs – A. R. Drone 2.0 – used to experiments of this paper.

Figure 2. Appearance of the small UAVs, A.R. Drone 2.0

2.3 Graphical Direction Viewer

If the reconnaissance vehicle is to be positioned behind one of the buildings and it gets out of the visual area, we cannot detect the vehicle's current situation. But if the azimuth and elevation angles are calculated from the flight information - altitude, longitude, and latitude and are presented in the graphics system, the vehicle's current situation can be graphically presented. This graphic direction viewer is made by the graphical language - Open GL. 3.0. Figure 3 represents the procedure of modeling the graphic viewer to show the direction angles.

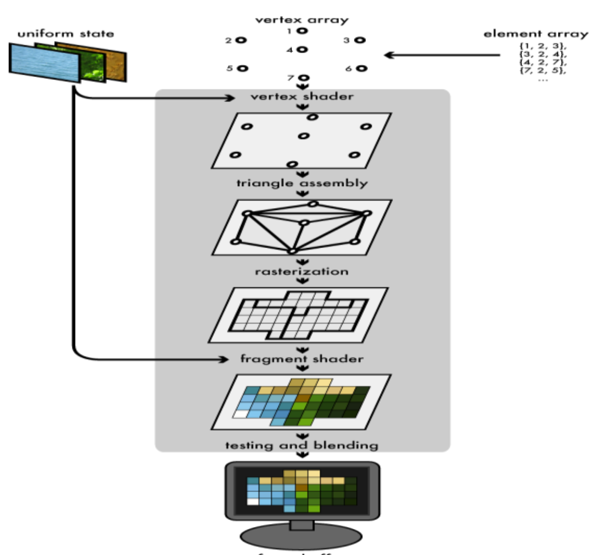

Figure 3. The procedure for modeling our graphic viewer to show the reconnaissance vehicle’s direction angles.

2.4 Marking Map

In order to compare the simulation path and the real experimental result path we need a map for marking the paths. Portal companies such as Google or Daum provide the mark-possible APIs to facilitate this, and they also provide the road and satellite image map to mark the paths. We used these maps provided from Daum.

3. SURVEILLANCE SYSTEM

Figure 4 shows schematically the organization of the surveillance system proposed and implemented in this paper.

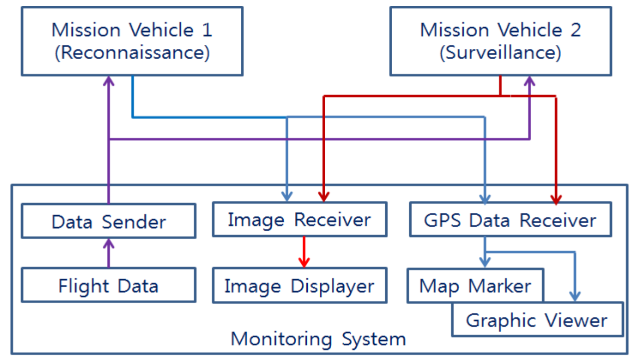

Figure 4. Structure of the proposed surveillance system

As figure 4 illustrates, the surveillance system has fairly simple missions of seven modules as follows.

1) Vehicle 1

Vehicle 1 has a mission to carry out reconnaissance and it moves along the pre-defined path on a narrow area buildings stand close together. Also it takes a picture the front scenery at the current location using a camera equipped on itself and transmit the image to the control station on the ground.

2) Vehicle 2

Vehicle 2 has a mission to keep watch the flight situation of the vehicle 1. it prevents for vehicle 1 to come into conflict with buildings or obstacles. And also it takes a picture downwards to the ground with the vehicle 1 and transmits the image from the under directional camera to the control station. And it receives the modified path information from the ground station and then modifies its path not to conflict with the buildings or obstacles.

3) Flight Data Sender

This module sends the simulated path data to the vehicle 1 so that it flies according to the paths and also sends the modified path data to change its path.

4) Image Displayer

This module takes a role to display the images transmitted from the two vehicles. We can look how things stand on ahead using image from vehicle 1 and detect the state of the vehicle 1 using the image from vehicle 2.

5) Map Marker

Map Marker shows the flight path operated from starting point to the current point on the road and the satellite maps. By using this map marker we can realize the current location of the vehicle 1.

6) Graphical Direction Viewer

This module is necessary to assume the location of vehicle 1 and detect the direction toward vehicle 2. The azimuth and the elevation angles are calculated by the fight data - longitude, altitude, and latitude - transmitted from it while vehicle 1 is flying. Figure 5 is a coordinate system to calculate the two directional angles from the flight information using equation (1).

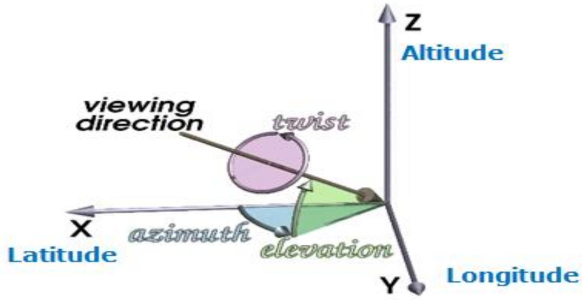

Figure 5. Coordinate system to calculate the direction angles

$$\Delta X = (\lambda_V - \lambda_A) \times Scaler_{Lon}$$

$$\Delta Y = (\phi_V - \phi_A) \times Scaler_{Lat}$$

$$AzimuthAngle = \tan^{-1}\left(\frac{\Delta Y}{\Delta X}\right) \quad (1)$$

$$ElevationAngle = \tan^{-1}\left(\frac{h_V - h_A}{r_A\sqrt{\Delta X^2 + \Delta Y^2}}\right) \quad (1)$$

Here ϕ, λ, and h indicate indexes for latitude, longitude, altitude respectively.

7) Ground Monitoring Station

This station sends the simulated path data to vehicles, gathers the flight and image data from the vehicles, calculates the direction angles, modifies the path data and sends it to vehicles, and makes a continuous view and displays the images.

Figure 6 shows the mission diagram of the proposed system using the six modules.

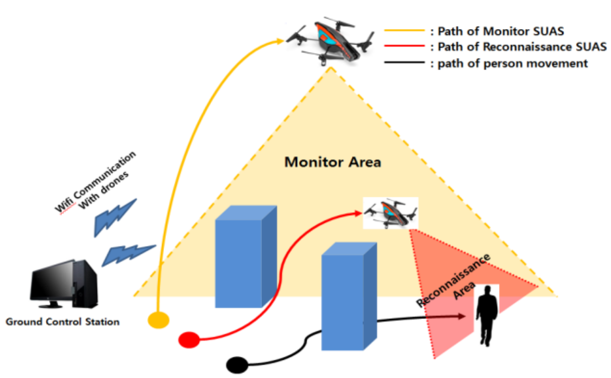

Figure 6. Mission diagram of the proposed surveillance system

4. EXPERIMENTS AND RESULTS

4.1 Experiments

We ran the following experiment procedure to test the performance of the proposed system.

1) Install a simulation flight path from the Mission Planner and operate the craft along the path and extract the flight data such as longitude, altitude, and latitude.

2) Operate the two vehicles through the simulated path using the flight information extracted from Mission Planner.

3) display the flight and image data transmitted from the two vehicles on the road and satellite image viewer.

4) Simultaneously, represent the directional angle characteristics on the graphic viewer.

In order to show the flight data, the operating path, images, and direction angles in same time, we have to synchronize these data in time. The flight data is extracted at frequency of 5 Hz and the images are of 30 Hz, and we synchronized these different frequencies to the image rate of 30 Hz. And we shared these two different types of data to two processors and processed their missions. The related diagram and the pseudo code are presented figure 7 and 8 respectively.

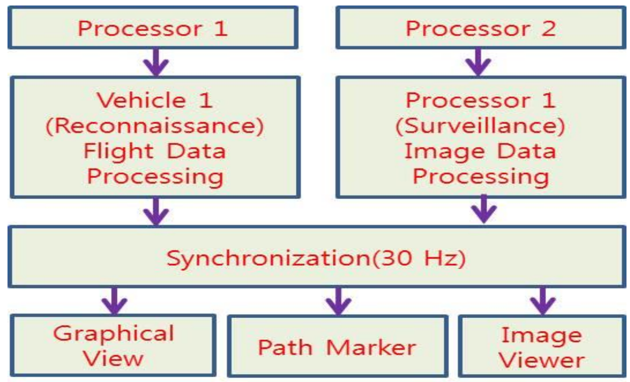

Figure 7. Block diagram for processing the flight and image information.

```
Thread_1 (Flight Data Display Thread)

Thread_1(NavData nav)
{
            pthread_mutex_lock(var);
            Display nav data;
            pthread_mutex_unlock(var);
}

Thread_2 (Image data Display Thread)

Thread_2(VideoData video)
{
            pthread_mutex_lock(var);
            For i=1 to max_nav_HZ / max_video_HZ)
                        Display video data
            pthread_mutex_unlock(var);
}
```

Figure 8. Pseudo code for sharing the flight and image data

4.2 Results

Figure 9 shows the simulation path drawn by the flight data from Mission Planner, and it represents a narrow area where several buildings are close to each other.

Figure 9. Simulation path extracted from Mission Planner

Figure 10. GUI of the proposed surveillance system

Figure 10 shows the results of using the proposed system with two flight vehicles and it presents GUI of our system that simultaneously represents the experimental results such as road map, satellite map, the current state image of the vehicle 1 shot from the camera of vehicle 2, and the graphical direction angle. In image viewer, the small circles reveal the current location of the vehicle 1. And the vehicle paths are marked on the road map and satellite image map. In this figure, we could found that these paths are fluctuated and was far out the simulated path greatly and this maybe because their values from GPS are slightly changed according to time and location.

5. CONCLUSIONS

In this paper, we present the moving surveillance system that be able to carry out reconnaissance and maintain surveillance at narrow and small area using two small flight vehicles. Although the small vehicles are very sensitive to wind, we found the possibilities that the moving surveillance mission has an effective advantage in the field of surveillance based on the experimental results. In future, we will study object tracking using reconnaissance vehicle and interconnect it with this system.

6. ACKNOWLEDGEMENT

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