ABSTRACT

In the recent years, the Unmanned Aerial Vehicles (UAVs) have become increasing interests for different civilian applications. The high-resolution video image, on one hand, brings us clarity and details of the behavior and characteristics of the earth surface features, on the other hand, presents new challenges in data processing. For example, how do we generate ortho-image from high-resolution UAV video images because the video data contain large redundant information due to a high sampling rate and the UAV has inherent characteristics of inconsistent and unstable flight parameters such as flying velocity, attitudes and altitude. This paper presents our theoretical analysis and experimental results for optimizing the re-sampling rate in order to speed up the generation of the video ortho-image. This algorithm is based on analysis of UAV exterior orientation parameters (EOPs) in each imaging epoch and video lens distortion characteristics as well as mapping accuracy of different scale. The model has been established for these relationships based on a test field located in Picayune, Mississippi. Our experimental results indicate that the resample rate is directly correlated with EOPs including three position elements and rotation elements of exterior orientation parameters, flying velocity and requirement of accuracy for different mapping scale.

INTRODUCTION

UAVs are playing more and more important role in many civilian applications, for example disaster monitoring, surveillance, and response. The orthoimages generated from the UAV-based video can be recognized as a supplement or alternative maps on which the decision-makers can add, register and compile other geo-spatial data, quickly derive high-precision 3-D geo-locations of objects and measure the geometry of such as wildfire (e.g., wildfire scopes, disaster areas), tree parameters (e.g., crown diameters, canopy closure) (Zhou and Li, 2005, Sheng et al., 2003). Because of a huge volume of data in UAV-based video, one has to re-sample the video data in order to fast generate the UAV-based data product to response the time-critical disasters. On the other hand, because of irregular flying trajectory of UAV due to remote control operation, A uniform resample rate for UAV-based video resampling will be not practicable. For this reason, This paper has explored how we resample UAV-based video data on the basis of analysis of the UAV exterior orientation parameters (EOPs) of each imaging frame epoch and video lens distortion parameters as well as mapping accuracy requirement of different scale. We established a model which presents the optimizing relationship among flying path, resample interval and orthoimage accuracy. This would be greatly helpful to fast generate orthoimage without losing the accuracy of orthoimage.
DATA PREPARATION

The experiment area is located in Picayune, Mississippi approximately 3.9 km×3.6 km. The reference data is USGS DOQQ and DEM (Fig. 1). The resolution of USGS DOQQ is 1 meter, while the cell size of the USGS DEMs is 10 meters. Because the two coordinate system and map projection are not the same, we uniform to a WGS84 coordinate system.

We collected UAV-based video data using AOSI UAV in cooperation with the Air-O-Space International L.L.C. (AOSI), which developed the small unmanned aerial vehicle (UAV) complete with a standard GPS, GPS waypoint capability, real-time color video imaging and high-resolution data recording and down link system. Figure 2 shows architecture of the UAV system and integration of multi-sensors, such as GPS, INS and video camera, which are used to collect the video images stream, UAV location and attitude (i.e., GPS and INS data). Data collection started from 17:03:24 UT through 17:07:08, the video image stream sampling rate is 30 frames each second, position and attitude reference data collection rate is one data epoch every two second, the flight height is approximately 700 feet. The size of video images is 720 pixel × 480 pixels, and the ground resolution is 0.2 m. Figure 3 is the first frame of image video stream. The GPS and INS data recorded in the text file (Table 1).

![Figure 1](image1.png)

(a) USGS DOQQ, and (b) USGS DEM in the experiment field.

![Figure 2](image2.png)

(a) General view of the AOSI UAV, and (b) integrated sensors of GPS, INS and camera.
Table 1. Part EOPs values from GPS and INS

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<th>Time</th>
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<th>Ys</th>
<th>Zs</th>
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**FLIGHT TRAJECTORY ANALYSIS AND RESAMPLING OF VIDEO DAT STREAM**

With the collected data of GPS and INS, we plot the UAV's three-dimensional trajectory and its two-dimensional (2D) trajectory (Fig. 4), as well as its attitude changes of omega, phi and kappa in Figure 5. As observed from Figure 3 through Figure 4, two significant jumps in the direction of flight have been happened: each is a U turn, where the Kappa values are very large. In addition, a great jump in flying height happened, but its phi and omega changes are small. From Figure 5c, we understand that the changes of Kappa value would give rise to a small sidelap, change of and omega and phi will cause the non symmetric distortion in two image margins, the change of flying height give rise to the different resolution, and change of direction of flight will result in significant overlap. In order to minimize the number of video frame, but not losing the accuracy, we will have to analyze the relationship between the resample rate and these flying parameters. Obviously the attitude angles are the most important factors being taken into account when we make decision on the resample rate. The experiment data is selected from 17:03:26 through 17:05:02 UT for orthorectification and image mosaic.
Because the original sampling rate of the UAV video stream is 30 frames per second, the overlaps almost reach over 99%. Thus, so huge volume of data makes rapid and real-time data processing very difficult, as a result, the quick response to time-critical event become impossible. Thus, the reduction for redundant information from original video image stream is prerequisite to real-time data processing. With the analysis of UAV's fly height, attitude changes, and flying trajectory above, we can resample the video stream at a non-uniform rate depending on the changes of these parameters. For example, there is a dramatic change of Kappa angle between 0 and 20 seconds, and two abrupt changes in the direction of flight, thus, the resample rate should be high. With the selected video image stream from 17:03:24 to 17:05:02, the resample rates vary from 6 frame to 18 frame per second. Figure 6 is the resample rate chart.
ORTHIMAGE GENERATION AND ACCURACY EVALUATION

Orthoimage Generation

A UAV-based video image stream processing is developing in our research group. In order to compare the accuracy orthorectification between traditional method and the developed method in our research group. This paper only report the method and accuracy that we implemented manually. The basic procedures include:

1. Analyze the UAV flight parameters and their changes, and determine the reasonable resample intervals at different times,
2. Separate the video image stream into frame-to-frame image sequences using Pro. Premier software in accordance with the analyzed results from Step 1,
3. Select at least 6 ground control points (GCPs) on each frame, and measure their photo coordinates and the corresponding geodetic coordinates using ERDAR/IMAGINE software,
4. Calibrate the lens distortion of camera, and correct the distorted images,
5. Orthorectify the images using 2nd polynomial equation, and
6. Mosaic the orthorectified images.

For forest area, because it is hard to find out the ground feature points as GCPs, we applied the orthorectified images as reference image and seek for the "second level of GCPs". Figure 7 is a comparison between the traditional 2nd polynomial model and the orthorectification models that our research group is developing using VC++. As seen, the accuracy from our method is largely improved, but traditional method seems to still remain the large distortion due to video camera. When the orthorectification to all frames is implemented, the following is to mosaicck these orthorectified frame into a mosaic. We used the ERDAS/IMAGINE software to carry out the mosaic, and the result is depicted in Fig. 8.

Figure 7. The orthorectified images for the same image using (a) the 2nd polynomial model, and (b) the orthorectification methods that we are developing.
**Accuracy Assessment**

Because the low accuracy of orthoimage does not make any sense to any applications (Wang and Ellis, 2005; Zhou and Li, 2000; Cheng and Toutin, 2001), we will have to evaluate the accuracy of orthoimage that we generated using UAV-based video image. General speaking, there are two way for accuracy assessment. One is using the ground control points measured by GPS, and then comparing their geodetic coordinates. The other method is directly comparing the geodetic coordinates between the orthorectified images and the reference images. Here we adopted the second method.

Selecting four types of terrain: forest, urban, mountain, and flat areas, we choose 63 points, of which 21 points locate in forest area, 21 points locate in urban area, and 21 points locate flat area. By measuring, comparing and data processing, we got the mean square error of ±1.5 m.

**CONCLUSION**

High resolution orthoimages can be used as the basic map to help the decision-makers to make the spatial analysis and spatial planning. This paper has presented some key problems of orthoimage generation from the UAV video image stream, including data collection, data processing, flying trajectory analysis, resample rate analysis and accuracy evaluation. The investigation results show that (a) UAV video images are suitable for generation of high resolution orthoimage. On the condition that the UAV video image, DOQQ and DEM/DSM have the same spatial resolution, accuracy of orthorectification image can be better than 1.5 meter, (b) UAV video images have very big redundant data, this can be largely reduced by resample based on UAV flight analysis, (c) Generation of orthoimages can be improved a lot by using the auto-production of orthoimage from the UAV video image stream.

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