ROAD SURFACE IMAGE MOSAICKING FROM NADIR VIDEO CAMERA ON UAV USING OPTIMIZED RESIZING-ROTATING NEIGHBOR FRAME

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ABSTRACT Due to the platform altitude uncertainty of Unmanned Aerial Vehicle (UAV) for road surface surveying, the road surface image mosaicking from UAV video camera will always appear the image distortion. The easy way to solve this problem, it can use the information of UAV location to correct the image frame before the combination process. Unfortunately, the result of this technique depends on the accuracy of the positioning system which is more expensive for the high accuracy positioning system. In this paper, we propose the algorithm to mosaic the road surface image from a nadir video camera that does not need the high accuracy of the positioning system. The information about platform speed and direction are used to estimate the overlap area of image frame pairs. After that, the bicubic interpolation and matrix rotation are employed to resize and rotate the current image frame. To searching the optimized image frame, the least square error of the current and previous image frames is applied. The results show that the lane line is smooth and has no distortion. Moreover, the resulting image can also be used to analyze the road surface damage.

1. INTRODUCTION

Compared with the satellite, using Unmanned Aerial Vehicle (UAV) has many benefits such as it is lower cost than others, the payload sensors can measure precisely both spatial resolution and elevation. Moreover, it can be developed as the autonomous system which can be controlled by a few operators. However, the environment in the low altitude more affects the stability of the platform. This problem influence to the payload measurement, especially the optical imaging, LiDAR and etc. Image mosaicking is a method that constructs a single continuous composite image formed by piecing together two or more overlapping images (Wolf and Dewitt, 2000). In the road surface survey, the imaging stability is necessary because the accuracy and precision of the imaging system are decreased which is direct effects to the mosaiced image quality. The information on the platform often used to correct these effects. In the past, we tried to generate the UAV mosaic image for testing the feasibility to apply the UAV for the road survey. But we had problems from the limitation of a low-cost sensor. Figure 1 shows the mosaic image of our previous works. We can see, the distortion on the mosaic image (on the right hand near the car) due to the UAV platform failed to maintain the altitude

Figure 1. The UAV mosaic image in our previous works.

In this paper, we propose the algorithm to mosaic the road surface image from a nadir video camera. This algorithm based on the least square error of neighbor frame images. This paper is organized as follows. The related works are summarized in section 2. After that, the proposed method is described in section 3. The experimental results and discussions are presented in section 4. Finally, the conclusion is given.

2. RELATED WORKS

Although the image from UAV based platform is more benefits such as low cost, high resolution, short revisit time and more flexible mission. There are have some issues as it has a smaller view than other platforms. Therefore, the image mosaicking of UAV image is a critical task (Xing et al., 2010). Several researchers have proposed the techniques to mosaic the image from UAV. Zheng et al. (2017) proposed a weight A* algorithm to select optimal seam-line in orthoimage mosaicking of UAV imagery. It consists of 4 steps as generating the initial seam-line, detecting the edge diagram, relocating the conjunction nodes, and refining the initial seam-line. Liu et al. (2011) proposed the fast image mosaicking for UAV imagery with an integrated GPS/INS/Vision system. Xing et al. (2010) proposed a two-step optimization method to mosaic the UAV sequence image. Ren et al. (2017) presented the method to mosaic the multispectral images from UAV. An information entropy-based evaluation method was employed to select the optimal band for feature matching. Xu et al. (2016) proposed the image mosaicking method for UAV imagery that was inspired by the non-rigid mesh deformation. The objective function consists of two terms as a feature correspondence energy term and a regularization term. Rojas et al. (2017) presented the technique to plan and create the 2-D maps by using the image mosaicking with multiple geo-referenced aerial images. He applied this technique to monitor the rice field. Camargo et al., (2010) proposed the algorithm for constructing the super-resolution mosaicking from the recoded video. This algorithm based on the Levenberg Marquardt method and used the Hubert prior to deal with the ill-conditioned inverse problem and to preserve edge.

3. PROPOSED METHOD

In this section, the proposed method and our algorithm for mosaicking the road surface image from UAV will be described. The assumption that the UAV camera will be always pointing along nadir. It can rotate and translate following the UAV platform. From this assumption, the neighbor image frame from the UAV camera will be expressed in figure 2. The relationship between both images depends on three parameters as the shift position, relative orientation, and image scaling. Thus, if we can estimate all parameters correctly, the image from both neighbor frame will be similar. The least-square error is employed to consider the difference of image feature. It can be expressed as the following equation.

$$\{\Delta x, \Delta y, \Delta\theta, s\}_i = \min\left[\left\| I_i\left(x+\Delta x, y+\Delta y, \theta+\Delta\theta, s\right) - I_{i-1}\left(x, y, \theta\right)\right\|\right] \tag{1}$$

Where I_i is the considering image frame,
I_{i-1} is the previous image frame,
$\Delta x, \Delta y$ are the frame shift distance in x and y axis,
$\Delta\theta$ is an angle difference of the image orientation,
s is the scaling factor.

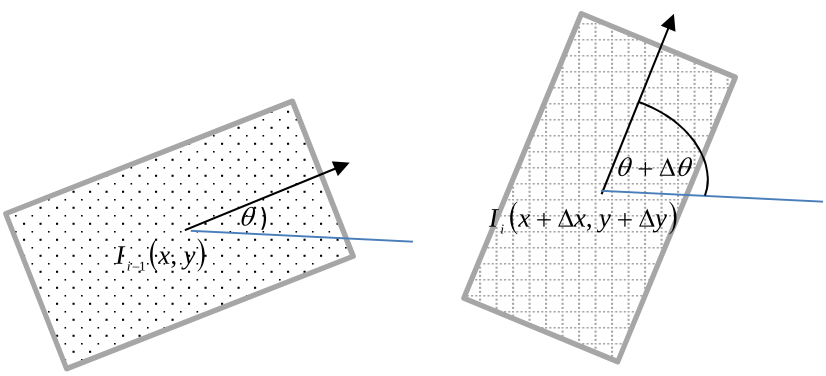

Figure 2. Illustrate the relationship between the image frame

The algorithm of our proposed method is started with information about the UAV platform. The acceleration in 3-axis was used to estimate the shift distance between the current and previous frame. The magnetic field strength in 3-axis was employed to determine the orientation of the platform which can be used to calculate the angle difference. The altitude from height measured sensors such as LiDAR or barometer is applied to find the scaling factor. This parameter is used to resize the image before mosaicking. After that using (1) to determine the accuracy version of such parameters. Finally, all parameters are employed to adjust and construct the mosaic image. The angle difference is used to rotate the image which can be calculated from

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\Delta\theta & -\sin\Delta\theta \\ \sin\Delta\theta & \cos\Delta\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{2}$$

The scaling factor is used to up or downscale the considering image. In this paper, we employ the bi-cubic interpolation to rescale the image.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

We applied this method to mosaic the image from UAV in the previous works. The area that had a high distortion in figure 1 is considered. The results are demonstrated in figure 3 which present frame by frame image processing. We can see, the mosaic image of the road surface is maintaining the correct size of road surface damage. Moreover, the lane line is near the straight line. However, the artifact of lens correction has appeared in the image border. Figure 4 shows the results when the UAV changes the direction of motion. The results show that the lane line in the center of the mosaic image is also close to the straight line. However, it has many artifacts in the image border too.

(a) before lose altitude

(b) while falling

(c) after returning to normal state

(d) mosaic image of a damage road surface

Figure 3. The mosaic image in the time that temporary UAV falling.

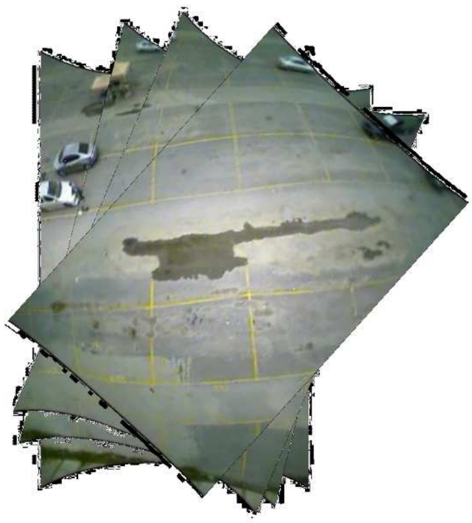

Figure 4. Mosaic image when the UAV change motion direction

5. CONCLUSIONS

In this paper, we propose the algorithm to mosaic the road surface image from a nadir video camera. The information about platform acceleration, direction and altitude are used to estimate the coarse parameters for preparing the image before mosaicking. The scaling factor is used to resize the image by using the bicubic interpolation. The difference angle of platform orientation is employed to rotate the image. To searching the optimized image frame, the least square error of the current and previous image frames is applied. The results show that the lane line is smooth and has no distortion. Moreover, the resulting image can also be used to analyze the road surface damage.

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