IMPROVEMENT OF AUTOMATIC COREGISTRATION OF MULTISENSOR ORTHOPHOTOS GENERATED FROM UNMANNED AERIAL VEHICLE USING EDGE SHARPENING

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KEY WORDS: Multi-sensor, Unmanned Aerial Vehicle, Co-registration, Unsharp Masking

ABSTRACT: The images acquired by multi-sensor on the Unmanned Aerial Vehicles (UAVs) have very high resolution (VHR) and are utilized as basic data in various fields. To utilize these images together, orthophoto should be generated based on the acquired UAVs images, and ground control points (GCPs) data acquired through the global navigation satellite system (GNSS) survey should be collected. However, it takes a lot of manpower and time to obtain GCP data every time it is acquired. Also, since sensors mounted on UAV have different properties of acquired images and there are limitations on collecting GCPs. Therefore, in this paper, we propose a methodology to improve the accuracy of automatic co-registration by improving the quality of multi-sensor orthophotos generated based on images acquired from UAVs using unsharp masking method. The image quality affects the extraction of matching points (MPs) used for automatic co-registration. Accordingly, we extracted MPs using phase correction after improving the quality of the reference and input images by utilizing unsharp masking method. And then, co-registration was performed using MPs extracted by proposed method, and the efficiency of the proposed method was verified through visual and quantitative analysis. As a result, we confirmed that the accuracy of automatic co-registration can be improved by using the proposed method.

1. INTRODUCTION

The imagery acquired from unmanned aerial vehicles (UAVs) have become popular as a next-generation platform in the field of remote sensing as they are periodically able to acquire higher spatial resolution images compared to imagery acquired from existing satellites and aircraft. In addition, UAVs can be equipped with various sensors, so it can acquire various kinds of data. In general, images acquired from UAVs are processed to generate an orthophoto to be used for applications in the remote sensing field. However, the specification for each sensor is different, and geometric errors occur between the orthophotos generated by the external environmental factors at the time of image acquisition. Therefore, in order to efficiently use the UAV imagery acquired from different sensors, co-registration must be performed (Han et al., 2019).

To generally perform co-registration of images acquired from UAVs, air-photo targets are firstly installed in a study area before the image acquisition of the UAVs. Global navigation satellite system (GNSS) survey is performed based on the installed air-photo targets to obtain ground control points (GCPs) data. Then, the GCPs data is input to the air-photo targets represented in the acquired images when the orthophoto is generated, and the coordinates of all the acquired images are converted into actual ground coordinate values. However, each time it takes a lot of manpower and time to acquire the GCPs data and input them into the image. Thus, a necessity is emerging for automatic co-registration to make the coordinate information of multi-temporal images the same GCPs data (Aicardi et al., 2016).

Automatic co-registration is performed the process of extracting and matching features without manual intervention and is divided into area-based matching and feature-based matching methods (Zitova and Flusser, 2003). Although the feature-based matching method is known to be suitable for very high resolution (VHR) images, there are several limitations on matching between images with different properties (Han et al., 2011). On the other hand, phase correlation, one of the area-based matching methods, is known to be able to perform matching between images with different properties effectively (Han et al., 2019).

The quality of image is one of the most important factors for using them (Pu et al., 2014). The VHR images are acquired with sensor mounted on UAVs, but sometimes blur images were acquired due to the movement of platform and external environmental factors (Ribeiro-Gomes et al., 2016;Samad et al., 2013). In particular, the blur images affect orthophotos quality, which may affect the extraction of matching points MPs for using to perform co-registration. Therefore, in this paper, we propose an automatic co-registration methodology of multi-sensor orthophotos using unsharp masking method and phase correlation method. First, using unsharp masking method, quality of multi-sensor orthophotos is improved. Then, we extract the MPs using phase correction, remove the outlier, and compose the transform model to perform co-registration. Finally, the efficiency of the proposed method was verified by analyzing accuracy using visual and quantitative methods.

2. STUDY SITE AND TEST DATA

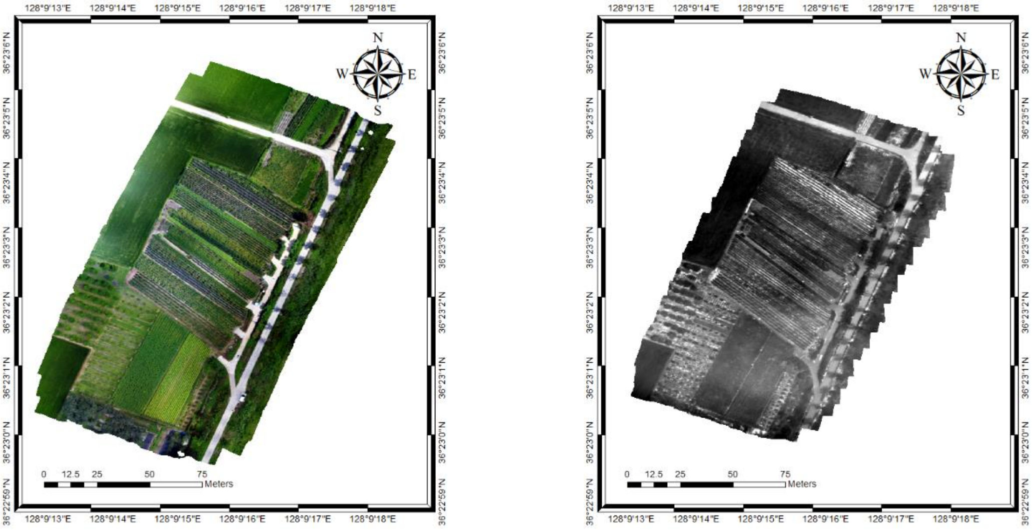
The study site was selected as the agricultural area of Sangju, Gyeongsangbuk-do, located in South Korea as shown in figure 1. Before the acquisition of multi-sensor UAV images, air-photo targets were installed in the study site and GNSS surveying was conducted on the air-photo targets to acquire GCPs data. The multi-sensor UAVs images were acquired by mounting the thermal infrared sensor Zenmuse XT in the Inspire-1 and the optical sensor Zenmuse X4S in the Inspire-2. The specification for UAVs and sensors used to acquire multi-sensor UAVs images were shown in Table 1.

Figure 1: Study site (Sangju, Gyeongsangbuk-do, South Korea).

Table 1: Specification for the UAVs and sensor.

Optical image acquisition equipment				**Thermal image acquisition equipment**			
Inspire-2		Zenmuse X4S		Inspire-1		Zenmuse XT	
							
Weight	3,440g	Sensor	Optical	Weight	2,935g	Sensor	Thermal
Flight altitude	≤2500m	Resolution	5472×3648	Flight altitude	≤2500m	Resolution	640×512
Flight time	27min	Focal Length	8.8mm	Flight time	18min	Focal Length	13mm
Speed	≤94km/h	Weight	253g	Speed	≤79km/h	Weight	270g

Both optical and thermal images were acquired around 11 a.m. under the same photographing conditions at an altitude of 30m, sidelap of 80% and an overlap of 80%. As a result, a number of 174 optical images and 205 thermal images were acquired. We generated multi-sensor orthophotos using Agisoft Photoscan based on the acquired multi-sensor UAVs images and GCPs data. The GCPs data was input to the optical orthophoto (as a reference image), whereas GCPs data was not input to the thermal orthophoto (as a subject image). As a result, the generated optical and thermal orthophotos were shown in Figure 2 and detailed information was shown in Table 2.



(a) (b)

Figure 2: Multi-sensor orthophotos: (a) optical orthophoto (reference image), (b) thermal orthophoto (subject image).

Table 2: Information of multi-sensor orthophotos.

Dataset	Optical orthophoto	Thermal orthophoto
Acquisition date	2019. 08. 01	
Scene size	21462×15501 pixels	3902×2884 pixels
Spatial resolution	Approximately 1cm	Approximately 4cm
The number of GCPs data	10	No GCPs

3. METHODOLOGY

The flowchart of the proposed method is shown in Figure 3. The optical orthophoto was used as reference image and the thermal orthophoto was used as subject image. First, The MPs were extracted using phase correlation method after improving the orthophoto quality by applying unsharp masking method, one of the representative image enhancement methods, to the reference image and the subject image. Since the extracted MPs contain outliers, outliers were eliminated by using affine transform coefficients and root mean square error (RMSE). The automated co-registration was performed by applying the MPs from which outliers were eliminated to the affine transform model.

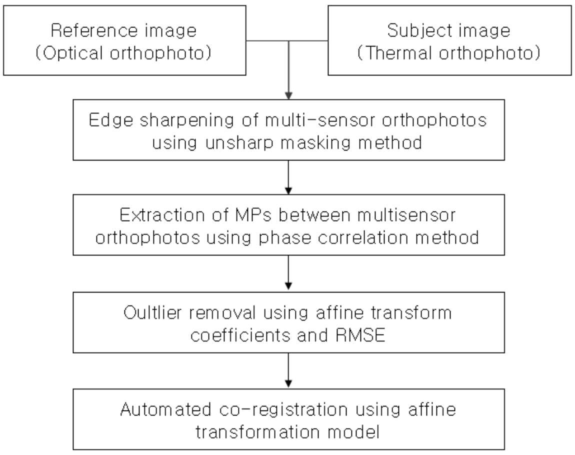


Figure 3: Flowchart of the proposed method.

3.1 Edge sharpening using unsharp masking method

The unsharp masking method is one of the representative image enhancement methods that improves the quality of the image through edge sharpening. In this method, the edge sharpening is performed by subtracting the low-pass filtering component from the original image using Equation (1).

$$g(x, y) = f(x, y) + K(f(x, y) - f'(x, y)) \qquad (1)$$

where $g(x, y)$ represents the enhanced image with unsharp masking method, $f(x, y)$ represents original image, K represents the constant, and $f'(x, y)$ represents low-pass filtering component from the original image.

3.2 Co-registration using phase correlation

The Phase correlation, which is known to be suitable for multi-sensor images co-registration, was used to extract the MPs after enhancing the edges of the reference and subject images using the unsharp masking method. The phase correlation is a method of estimating the amount of translation, rotation, and scale information between two images by using mobility properties in the frequency domain through Fourier transform and is defined as Equation (2) (Han and Choi, 2015). In this study, we extracted the MPs between the reference and subject images using only the translation information of the phase correlation.

$$\mathrm{C} = \left| F^{-1}\left(\frac{F(I_{sub}(x, y))}{F(I_{ref}(x, y))}\right) \right| \qquad (2)$$

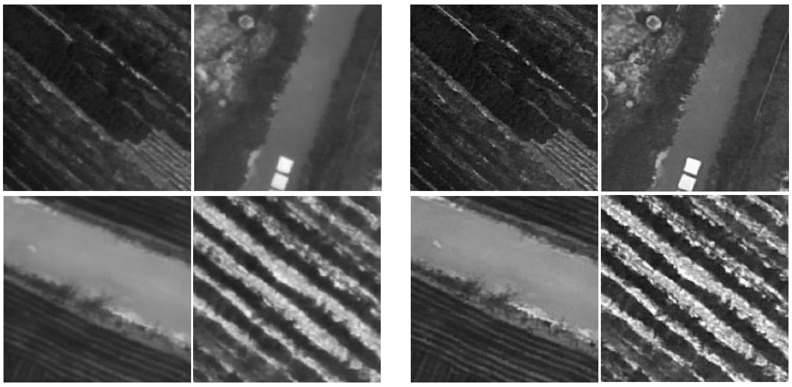
where C represents the phase correlation, F and F^{-1} represent 2-D Fourier and 2-D inverse Fourier transformations, and $I_{ref}(x, y)$ and $I_{sub}(x, y)$ represent reference image and subject image.

The MPs extracted using the phase correlation method should be eliminated because they contain outliers. Therefore, to eliminate outliers, we estimated the affine transform coefficients using the extracted MPs, and then estimated the RMSE to judge the distance difference between the MPs of the reference image and the MPs of the subject image. The MPs with the largest RMSE among the extracted MPs lower than a specific threshold were determined as outlier and eliminated. Then, the process of removing outliers was performed repeatedly to estimate the final affine transformation coefficients, which are used for the co-registration.

4. RESULTS

In order to improve the accuracy of automatic co-registration between multi-sensor orthophotos using the method proposed in this study, we applied the proposed method step by step. First, to improve the quality of the multi-sensor orthophotos, we applied unsharp masking method to reference and subject image. As a result, we confirmed through Figure 5 that the blurring of the reference image and the subject image was eliminated and the edge was enhanced, meaning the orthophotos quality is improved.

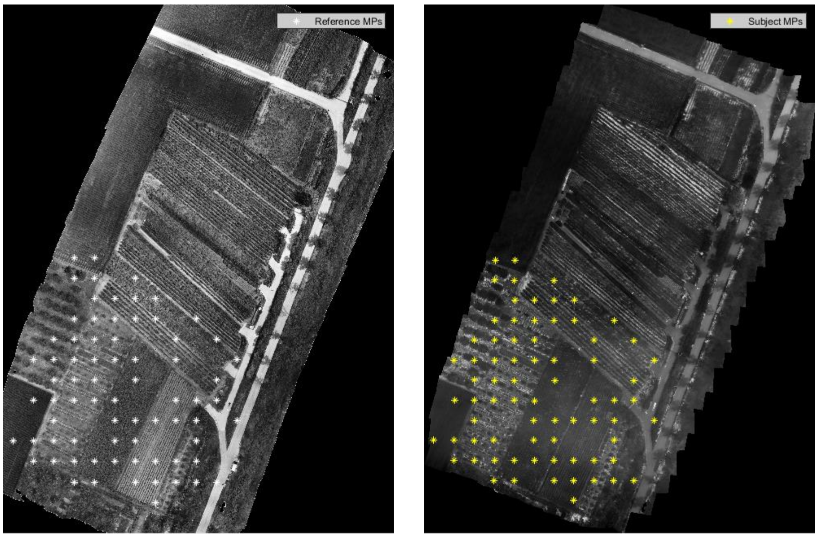
(a) (b)



(c) (d)

Figure 4: Result of applying the unsharp masking method: (a) reference image, (b) reference image with edge enhanced, (c) subject image, and (d) subject image with edge enhanced.

The MPs were extracted by applying phase correlation to the reference and subject images which were processed by the unsharp masking method. At this time, the red band image and subject image of the reference image were used to extract MPs. Then, affine transform coefficients and RMSE were used to eliminate outliers included in MPs. Finally, the extracted final 73 MPs are shown in figure 5.



(a) (b)

Figure 5: Extracted MPs after outlier removal: (a) reference image, (b) subject image.

To perform co-registration, we estimated affine transform coefficients using MPs from which outliers were eliminated. And, the co-registration was performed using the estimated affine transform coefficients. To evaluate the efficiency of the proposed method, we conducted comparative analysis with the case of using only phase correlation. First, we generated a mosaic image as shown in figure 6 to perform visual analysis. When co-registration was performed using the extracted MPs using only phase correlation, the geometric errors were slightly improved compared to the raw image (Figure 6(b)). On the other hand, when co-registration was performed using extracted MPs by the proposed method, we confirmed that the geometric errors were significantly improved compared to the case using only phase correlation (Figure 6(c)). Subsequently, we estimated correlation coefficients (CC) values, one of the representative similarity measurement methods, between the raw image and the co-registered image to perform the quantitative analysis. The estimated CC values were shown in Table 3. The CC values and co-registration accuracy are proportional, the higher the CC values, the higher the co-registration accuracy. The CC value between images before co-registration was estimated as 0.246, and CC value, when co-registration was performed using only phase correlation, increased to 0.335. And, when co-registration is performed using the proposed method, the CC value was estimated as 0.502, the highest value. As a result, we were able to improve the accuracy of automatic co-registration between the multi-sensor orthophotos using the proposed method.

(a) (b) (c)

Figure 6: Mosaic images of automatic co-registration result: (a) raw image (b) phase correlation (c) proposed method.

Table 3: CC values of the co-registration results.

Method	**CC**
Raw image	0.246
Phase correlation	0.335
Proposed method	0.502

5. CONCLUSIONS

In this study, to improve the automatic coregistration between multi-sensor orthophotos, we applied a phase correlation-based co-registration approach together with an unsharp masking method. Through the results of this study, we confirmed that the accuracy could be improved when co-registration was performed by utilizing MPs extracted by improving the quality of multi-sensor orthophotos. Unfortunately, the unsharp masking method characteristic causes information loss if edge sharpening of multi-sensor orthophotos consisting of complex objects is performed. Also, the MPs used in this study are weak in rotation and scale because only translation is considered. In a future work, we will develop an adaptive image quality improvement method that takes into account multi-sensor orthophotos characteristics based on the unsharp masking method. Furthermore, we will consider both rotation and scale information when extracting MPs between multi-sensor orthophotos using phase correlation.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (2017R1C1B2005744).

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