GEOREFERENCING OF UAV IMAGES FOR SHIP DETECTION IN MARITIME SURVEILLANCE

Hyoungseok Ryu[1], Kyoung-h Choi[1], Impyeong Lee[1]

[1]Lab for Sensor & Modeling, Department of Geoinformatics, University of Seoul - Korea
E-Mail: {youmam123, shale, iplee}@uos.ac.kr

KEY WORDS: Georeferencing, UAV, Maritime Surveillance

ABSTRACT: Continuous acquisition of precisely georeferenced images of the marine area is necessary to prevent and handle accidents and illegal activities on the sea. Precisely georeferenced images can be obtained through post-processing of high resolution images by using sensors' External Orientation (EO) parameters and Ground Control Point (GCP) coordinates. Surveillance of ocean areas from satellite and radar images has limitations such as low resolution, lengthy acquisition time and high expenditure. Using UAV systems, we can collect high-resolution images at low cost while have no confidence in terms of accuracy caused by a little number of GCP (e.g.: ships, land such as island) and the performance of mounted GPS/INS sensors. In this study, we apply georeferencing techniques on the UAV high-resolution images and verify the accuracy of the georeferencing results. Adopted georeferencing method is based on the bundle adjustment where initial EO parameters determined by GPS/INS data are adjusted with GCP coordinates and image points produced by an image matching process. The georeferencing results are verified by comparing them with ground truth which can be acquired by Check Point (CP). If the accuracy of the results is satisfying with demands for marine surveillance, we can employ the UAV systems and the image georeferencing technique to monitor marine accidents and illegal activities.

1. INTRODUCTION

According to a statistics made by Ministry of Oceans and Fisheries-Republic of Korea, in South Korea between 2009 and 2015, per year, an average of 1621 marine accidents took plac. In addition, each year two thousand or more illegal fishing activities were carried out (Ministry of Oceans and Fisheries 2016). In order to minimize such damage, it is required to continuously monitor and control maritime accidents and illegal marine activities. It is crucial to quickly and accurately localize damaged area, when any illegal action appears. Therefore, to support organizations responsible for making decision, periodic observations should be performed. For this reason it is important to detect position of the accident as well as illegal ships.

In order to monitor coastal zone, various methods can be used. One of them is the direct observation carried out by specialists. This approach can be effective for areas near shore, while for more distant areas, remote measurements may be more appropriate. This opens a wide range of applications for marine monitoring and surveillance from satellite, airborne or submarine platforms to which sensors such as cameras or radars can be attached. Although images acquired from satellite, radar or manned aircrafts cover wide-area, they cannot acquire high resolution data. Radar resolution does not distinguish the presence of small vessels closed to shore. This problem arises when belligerent, relatively small warships (like fast attack boats), which might participate in illegal activities, try to take advantage of this situation and avoid being detected by the surveillance system (Dimitriou 2013).

To ensure effective monitoring, use of satellite or airborne platforms is required. Since monitoring of marine area based on Unmanned Aerial Vehicle (UAV) is carried out on lower altitude than the satellites and manned aircraft, the high resolution sensor data can be acquired stably. In addition, satellites and manned aircraft generate high cost and low resolution data, so UAV is on the rise for constant maritime surveillance. Previous study on the analysis and application indicates about the need of the applicable maritime surveillance system for South Korea in terms of security (Jeong et al 2014). In order to reconnaissance, intelligence-gathering and targeting, UAV is used in more than 50 nations (CIA drones over Pakistan 2009, pp.1). In Taiwan, to more efficiently supervise ships activities, data from UAV were added to already existing monitoring system which resulted in a reduction in illegal activities in the ocean

(Liang 2009). In Europe, European Maritime Safety Agency (EMSA) and the European Space Agency (ESA) selected Tekever for the Rapsody project. Tekever will confirm the value of using UAV in search and rescue missions, and in monitoring pollution and oil spills from ships (Pocock 2015).

Georeferencing is processed in order to precisely determine the position of ship in obtained images. Georeferencing is process of adjusting EO and GP based on collinearity equation using UAV position/attitude acquired from GPS/INS data and GP coordinate determined during surveying (Choi and Lee, 2009). However, in the maritime environment, cause limit about the number of GP using by image matching and measurement.

This research is necessary to carry out a ship detection on images. System that detects ships on images is constructed in four approach. First, sensor data acquisition part including camera and GPS/INS. The next step is to calculate Image Points (IPs) coordinates from obtained images. That is followed by georeferencing, where we determine EO of the image that contain ship from position/attitude data by GPS/INS. Last, this section is ship position decision that is determining GP position using by IP coordinate and EO. This study determines EO through georeferencing at the third stage using sensor data obtained in the first step, and then executes a part of step for determining the position of ground point of the fourth stage.

This paper is organized as follows: First we explain experiment methodology applied in this study, Aerial Triangulation (AT) based on Bundle Block Adjustment (BBA). Then, we present two georeferencing results, one is the georeferencing result of the stably performed BBA. The other is the considered outcome in marine environment. We confirm result how much effectively test is. So we verify georeferencing result in maritime environment. Finally, we conclude effect of this experiment.

2. EXPERIMENT METHODOLOGY

This chapter contains a contents to AT on the basis of BBA (Mcglone 2004). Precise georeferencing of this study is applied AT based on BBA of UAV images. In this section, it is carried out in (1) AT based on BBA, (2) Determining initial value of GP-and-EO, (3) Estimating GP-and-EO based on Least Squares.

2.1. AT based on BBA

AT is one of image processing method in a mathematical way to adjusting EO of image and GP coordinate using GCP, more than two images and image's EO. BBA that is one of means is based on collinearity equation that is existing image perspective center, one of the GP and one the IP that is corresponding with GP. Tie Point (TP) that is presented at individual image gets a string of collinear line that is called bundle. Each bundle estimates image EO and GP coordinate using by collinear lines which sharing same GCP (Mikhail et al 2001).

In order that is no trouble to conduct BBA, is needing five or more common points. However, it is hard to secure GP because area is almost the whole sea. So procuring TP and GCP from Vessels, floating structures such as farms, costal topography appear intermittently at the ocean observation image, can be somewhat insufficient in terms of the number and accuracy.

2.2. Determining initial value of GP-and-EO

Since relationship among Interior Orientation (IO) of the image, EO, IP, and GP coordinate that is corresponding with IP is nonlinear, two condition is needed to precede operation. One is linearization using by Taylor series, the other is initial value of IO, EO and GP coordinates. We assume IO that is calibrated, decide IO value as a constant. We calculate EO and GP initial value. Initial value of the EO is set GPS/INS data at image acquisition time. And then, insert the measured value of the IP and initial value of the EO as the collinearity condition and then generate a several extended lines. This lines is contacting lines with collinear lines at the TP. However, because EO and IP have errors, collinearity lines can't meet one point. So we decide initial value of GP to calculate minimizing distance to convergence from individual collinearity lines using by Least Squares.

2.3. Estimating GP-and-EO

At performing BBA, we compute EO and GP that minimize what is sum that is adding square of difference and plugging in EO and GP as IP coordinates and collinearity equation. In order to obtain normal matrix, we apply Least Squares for Gauss-Markov Model, but we need effective method because normal matrix size is grow up at appling Least Squares. Normal matrix consists of relative EO matrix, GP matrix and association matrix with EO and GP. Because GP matrix is presented from 3-by-3 block diagonal matrix, we can effective calculating inverse matrix. Inverse matrix can be converted to reduced normal matrix. Reduced normal matrix is expressed in band matrix, in case of several image, band size is greatly decreasing. If we are adjusting EO and GP until convergence, can get result of adjusted EO position·attitude and GP coordinates.

3. EXPERIMENT RESULT

We set the input data value and then generate simulated input data through simulating for georeferencing. So we can perform two experiment of georeferencing. This chapter is progressed as follow: (1) Simulating input data like flight conditions and sensor accuracy and etc. Simulator generate simulated input data such as GP, EO and IP. (2) Set 1 presents georeferencing result based on BBA in having averagely five or more TP to confirm algorithm quality. (3) Set 2 shows georeferencing result of considered maritime environment.

3.1. Simulated input data

In order to georeferencing for UAV images, first, we need camera specification and IO value such as camera perspective center coordinate and focal length, and information of flight mission. Flight mission information is construct of mission area, altitude, ratio of length and breadth overlapping. Number of image is determined by altitude, perpendicular and horizontal overlapping and mission area size. Then, we decide GP how generate GP about number of GP and distribution. Finally, Simulated input data can be get to perform simulating using these data. Common input data and Simulated input data of Set 1, Set 2 is presented Tab. 1, Tab 2. Visualization of Set 1, 2 GP, EO position and image distribution is expressed in Fig. 1, Fig. 2.

Table 1. Common input data information

List	Value	List	Value
IO(mm)	(0, 0, 55mm)	Number of image	147
Pixel size (mm)	(5.967, 5.975)	Mission area (km^2)	2 (2km x 1km)
Pixel count	(6000, 4000)	EO position accuracy (m)	20
UAV velocity (m/s)	11.1	EO attitude accuracy (deg)	5
Mission altitude (m)	500m Mean Sea Level (MSL)	GCP accuracy (m)	1
Image overlap (%)	70	Image point accuracy (pix)	3
Image sidelap (%)	30		

Table 2. Simulated input data of individual Set

List	Set 1	Set 2
Number of Check Point	50	
Number of Ground Point	200	100
Number of Image point	954	469
Ratio of image points per image	6.5	3.2
GP distribution shape	uniformity	centralization

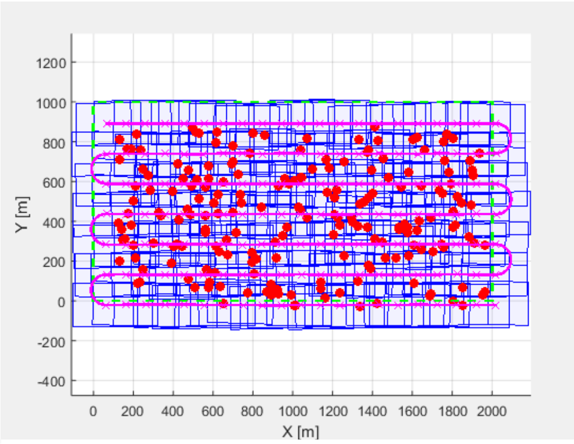

Figure 1. Set 1 EO position, GP, image distribution

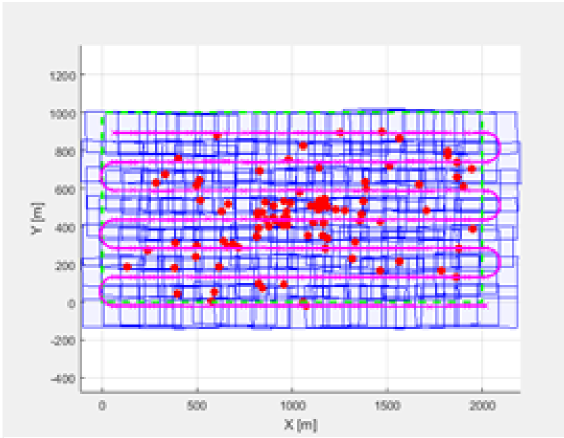

Figure 2. Set 2 EO position, GP, image distribution

3.2. Results

We performed five cases of georeferencing using simulated data. Each case of conducting direct-georeferencing, giving EO constraints, giving that and GCP constraints that is given 10, 30, 50 constraints in each case. After georeferencing, EO of images and GP same as TP have accuracy like to Tab. 3. Last case have a most good result using constraints EO of images with 50 of GCP

Table 3. Result of Set 1, 2 average RMSE

Set 1 Constraints	$\overline{GP}$ (m)	$\overline{EO}$ pos (m)	$\overline{EO}$ att (degree)	Set 2 Constraints	$\overline{GP}$ (m)	$\overline{EO}$ pos (m)	$\overline{EO}$ att (degree)
Nothing	59.71	19.43	4.95	Nothing	53.18	20.93	4.88
Only EO	5.47	9.40	1.44	Only EO	20.65	16.91	3.09
EO, GCP (n=10)	4.54	9.49	1.46	EO, GCP (n=10)	19.63	16.91	3.09
EO, GCP (n=30)	0.93	8.79	1.36	EO, GCP (n=30)	10.89	16.45	2.95
EO, GCP (n=50)	0.52	8.70	1.36	EO, GCP (n=50)	9.05	16.35	2.92

In case of Set 1, GP distribution is a uniformity like land environment, georeferencing is performed stably because TP is shown in the number of 6.5 per image averagely. The last case result shows GP, EO position·attitude as 0.52m, 8.7m, 1.36˚. Although EO and GCP have a not good accuracy, we can estimate position precisely inner 1m accuracy in fourth, fifth case. But, Set 2 GP distribution is a centralization such as assumed island, so located outskirts images have a not enough TP beside central area. That means is lower adjustment computing than middle region. In case 3, Georeferencing is performed using 0.22 of GCP per image on average. Comparing to case 2, the difference with GP is 1.02m and EO is almost same. In case 5, compare with case 1, GP is 44.18m and EO is 4.58m and 1.96˚. We confirm results of variety condition in georeferencing.

4. CONCLUSIONS

This paper is verifying georeferencing based on BBA in maritime environment. We perform simulation if island or floating structure is located in center district. We conduct georeferencing under bad EO accuracy. Consequently, we confirm variety RMSE catching up with GP position and EO position/attitude. Though we obtain high accuracy result too hard when we secure not enough number of GP, we expect improve adjustment result if we select some image that have enough number of presence of TP.

In the marine environment, jurisdiction does not need high precisely accuracy. So we think that georeferencing method can ship detection on the image. Consequently, Georeferencing is expected to contribute to effective surveilling and handling the accident and illegal activities in maritime surveillance

5. ACKNOWLEDGEMENTS

This work was supported by the Building Wide Integrated Surveillance System of Marine Territory project (1525004602) funded by Republic of Korea government and Ministry of Oceans and Fisheries

6 .REFERENCING

Choi, K., Lee, I., 2009. Image Georeferencing using AT without GCPs for a UAV-based Low-Cost Multisensor System.
CIA drones over Pakistan, 2009. The drones of war. Starategic Comments, Vol. 15, issue 4, pp.1
Dimitriou. G., 2013. Integrating Unmanned Aerial Vehicles into Surveillance Systems in Complex Maritime Environment. Thesis, Naval Postgradutate School, Monterey, Califonia, pp.6
Jeong, J., Choi, K., Lee, I., 2014. Applcation Plans through Case Analysis of Maritime Surveillance Systems Using UAVs. Korea Society of Surveying, Geodesy, Photogrammetry, and Cartography Conference Materials 2014, pp.205-209
Liang. Y. F., 2009. More Advanced UAV introduced to Boost marine Monitoring Capacity. Environmental Policy Monthly, Vol. XII, issue 6, pp.9-10
McGlone. J.C., 2004. Manual of Photogrammetry, In: ASPRS, Bethesda, Maryland, USA, pp.847-870.
Mikhail, E.M., Bethel, J.S., McGlone, J.C., 2001. Introduction to Modern Photogrammetry, edited by John Wiley & Sons, New York, pp.119-123
Ministry of Oceans and Fisheries, 2016. national statistics, Retrieved September 1, 2016, from http://kosis.kr/statHtml/statHtml.do?orgId=146&tblId=DT_MLTM_5352&lang_mode=ko&vw_cd=MT_OTITLE&list_id=116_12320&conn_path=I4
Pocock. C., 2015. European Maritime Agency Demo for Portuguese UAV, Retrieved September 12, 2016, from http://www.ainonline.com/aviation-news/defense/2015-11-05/european-maritime-agency-demo-portuguese-uav