Determining Position of Ship with UAV Multi-sensory Data at Marine Area

High Resolutions Sensor (Optical, Microwave, LIDAR, UAV)

Hyoungseok Ryu, Kyoungah Choi, Impyeong Lee

[1]Lab for Sensor & Modeling, Department of Geoinformatics, University of Seoul, Seoulsiripdaero 163, Dongdaemun-gu, Seoul 02504, Korea;
E-Mail: {youmam123, shale, iplee}@uos.ac.kr

Abstract: Every year, at marine area, a lot of accidents and illegal fishing work are take place. In order to alleviate human life and property damage being occurred thereby, remote monitoring means are required. Among these, UAV (Unmanned Aerial Vehicle) is a platform that is economical and has excellent temporality compared with other monitoring means like satellite, radar, manned aerial vehicle. In order to determine position of ship that is main marine monitoring object, multi-sensor system of UAV may be used. In this study, by using such system, a method of determining ship position is intended to be suggested. Ship position is determined by using collinearity equation after determining image position in global coordinates through image and GPS/IMU data pre-processing and georeferencing process. Suggested method was applied to test data acquired from the ocean. Ship position was determined as 4.773m at altitude of 200m, 9.761m at altitude of 350m, 14.150m at altitude of 500m. It is considered that by using suggested method, ship positioning is able to be fully performed by using UAV and it is expected that ship monitoring could be performed effectively at marine area.

Keywords: Ship Positioning, UAV, Marine Surveillance, Georeferencing, Multi Sensor, System Calibration

1. INTRODUCTION

According to statistic data made by Korea Ministry of Oceans and Fisheries, for the recent past 9 years, 14603 cases of marine accident were taken place in Korea and human life damage of 3296 persons were occurred. In particular, for the recent past 2 years, marine accident over 2000 cases was taken place for the first time as 2010 cases of accident were occurred in 2015 and 2307 cases in 2016. Due to geographical features, as marine accident is highly likely to involve human life damage, urgent rescue operation is required. In addition, as illegal fishing work over 2,000 cases is taken place every year in Korea, economic damage is entailed. If this trend persists, human life and property damage in the future would become significant social loss. Therefore, in order to alleviate this damage, monitoring marine accident or illegal fishing work is essentially required and constant monitoring shall be performed so that decision making of the relevant institution responding to accident would be supported at the time of occurrence and it is important to identify damaged area, scale and position of relevant ship.

Ship monitoring is performed in diversified ways at present including aerial platform based monitoring like satellite, aircraft, visual monitoring by coast guard or navy and marine radar, AIS. For constant monitoring, platform having excellent temporality and economic efficiency. Monitoring by using artificial satellite or manned aircraft has restriction of big temporality and economic efficiency and AIS is not suitable for small ship as it is a system applied to large ship over min. 300t and marine radar is unable to identify ship position precisely as its definition is low. On the other hand, in case of UAV based marine monitoring, as its operation cost is cheaper than manned aircraft or satellite and required manpower is fewer than visual monitoring personnel, monitoring of high frequency is possible. In addition, as it is operated by autonomic flight, it has an advantage of being able to acquire image data having high ground resolution at low altitude stably. Therefore, it is efficient to use UAV when monitoring ship.

When sensor data acquired from UAV system determines EO (EO) parameters (position/attitude) information of image by using georeferencing technique, location information of points represented in image could be determined. Georeferencing is a process of calculating EO parameters of UAV acquired by GCP (ground control point), GPS/IMU acquired by survey based on collinearity equation (Choi and Lee, 2009). In georeferencing, there are direct georeferencing that determines image position by establishing geometric relation between camera sensor and GPS/IMU sensor and BBA (Bundle Block Adjustment) based indirect georeferencing that determines EO parameters by using over 2 sheets of image and GCP. In the marine area, as it is hard to acquire conjugate point between GCP and image, direct georeferencing technique that could determine EO parameters of image by using camera sensor mounted on UAV and GPS/IMU sensor only was adopted. As accuracy of direct georeferencing is affected not only by sensor performance but also by accuracy of mount parameter showing a relation image sensor and GPS/IMU sensor, system calibration is required for more precise positioning (Lee et al, 2012). As a related researches, there are a research that performed system calibration for direct georeferencing (Cramer and Stallmann, 2002), a research that evaluated accuracy of the result of performing direct georeferencing for EO parameters by data acquired through multiple sensors (Song, 2005), a research that determined ground position by using direct georeferencing without GCP and evaluated determined accuracy (Chiang et al, 2012). In this study, direct georeferencing is intended to be performed by using system calibration and ship position is intended to be determined by using georeferenced image.

In this study, for economic and efficient ship monitoring, ship positioning method is suggested by determining EO parameters of image and projecting image in sea surface based on sensor data of UAV. In Chapter 2, a methodology for ship positioning is suggested and in Chapter 3, test result comprising data acquisition, test result, accuracy verification will be handled.

2. METHODOLOGY

Ship positioning methodology is intended to be induced by applying two stages of image georeferencing and ship positioning for the data acquired by multi sensor system of UAV as shown on Fig. 1. At image georeferencing stage, an image having adjusted EO parameter is generated by calculating EO parameters of image precisely. At ship positioning stage, position is calculated by projecting image in sea surface based on collinearity equation and acquiring ship image point in projected image.

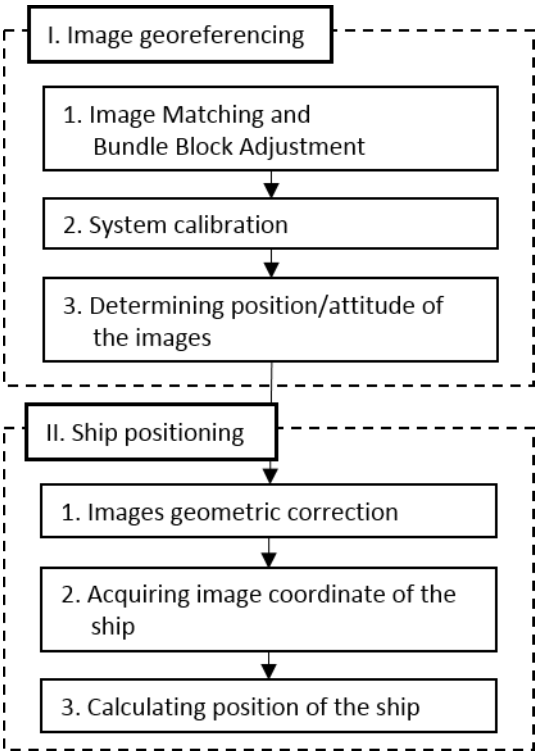

Figure 1. Flow-chart of Ship positioning process

2.1.IMAGE GEOREFERENCING

In order to determine EO parameters of image precisely, direct georeferencing technique shall be performed. This technique is used for calculating EO parameters of camera at the time when image is acquired and it is progressed in the following stages. 1) Acquire precisely adjusted presumed EO parameters of image by performing image matching and BBA using image, GPS/IMU data, GCP input data, 2) perform system calibration that estimates mount parameters showing a relation between GPS/IMU data and adjusted EO parameters, 3)direct georeferencing process reflecting system calibration result to GPS/IMU data whenever individual image is acquired.

(1)IMAGE MATCHING and BBA

In order to explore EO parameters of image, image matching and BBA shall be performed for image acquired from UAV multi sensor system, GPS/IMU data, GCP. According to Kim et al (2017), image matching is a process of detecting conjugate point that is the same ground point being shown in different images and defining relative relation among images. Image matching comprises (1) a process of detecting image key point, (2) a process of describing information of such key point, (3) a process of searching conjugate point by comparing information of key point. According to McGlone (2004), BBA is a mathematical process of adjusting and calculating ground point coordinates by using more than 2 sheets of image, EO parameters of image, ground control point.Bundle adjustment is performed based on collinearity equation that image projection center, one ground point, image point applicable to ground point exist in one line. Result value by performing BBA is a rotation matrix that converts adjusted EO parameters, its reference coordinate system to starting point of camera coordinate system from starting point of ground coordinate system. Adjusted EO parameter shows a value presumed to be position/attitude of camera.

(2)SYSTEM CALIBRATION

System calibration is a process of determining mount parameter showing a geometric relation between camera and GPS/IMU. This geometric relation is represented by motion vector for starting point between camera coordinate system and GPS/IMU system coordinate system and rotation angle of each axis among coordinate systems and it could be represented as relative relation of individual coordinate system. Therefore, mount parameter to be determined by system calibration is mount parameter showing geometric relation between GPS/IMU coordinate system and camera coordinate system.

(3)DIRECT GEOREFERENCING

Image georeferencing is a process of adjusting image attitude value by directly applying georeferencing technique to an image acquired from UAV multi sensor system. Attitude values of GPS/IMU data being acquired simultaneously with image converts to rotation matrix form so that multiplication would be enabled. Attitude value of individual image could be adjusted by multiplying rotation matrix being determined by the result of system calibration to converted rotation matrix and converting calculated rotation matrix to attitude angle.

2.3.SHIP POSITIONING

Stage of determining actual position of ship comprises 3 methods. (1) Project an image to mean sea surface by using collinearity equation, (2) Acquire image point by detecting ship in image, (3) calculate ground coordinate of ship by matching ground point coordinate being recognized as same position as image point with relevant image point coordinate. Collinearity equation means that image projection center, ground point and image point corresponding to ground point exist in one linear line.

Geometric correction is performed for mean sea level by assigning image pixel value to determined coordinate after calculating ground point coordinate followed by applying collinearity equation to image projection center, image point and ground point corresponding to image point. For ship positioning, image point coordinate of ship shall be acquired. Background region could be obtained through matching with UAV image after constructing template library for the marine area to be observed in advance and by utilizing grabcut algorithm that is a background removal technique in image, ship detection could be performed in UAV image (Xu Chao, 2014). Adopted image point coordinate is acquired by selecting image point of ship center located at centroid in ship polygon centroid being obtained from ship detection. Obtained image coordinate could be calculated by corresponding to ground coordinate being previously calculated through geometric correction.

3. EXPERIMENT RESULTS

3.1.DATA ACQUISITION

(1)TEST SITE

Spatial range of this study is southern coast of Yeonmyeong port located at Yeonhwari, Tongyoung City, Gyeongnam, Korea and by targeting the region of app. 1.4km x 0.5km based on Yeonmyeong port as take-off place, a research was carried out. In the place around Yeonmyeong port, several ships are operated in view of features of port area and it is characterized by islands and marine structures like aquaculture farm. Photographing by using UAV in the target region was performed during the period from September 22 to September 23, 2016.

(2)SYSTEM SPECIFICATION

UAV is classified into fixed wing aircraft and rotorcraft depending on wing shape and in case of fixed wing aircraft, as its weight is light, long flight is possible but due to limited payload, equipment to be mounted is restricted but in case of rotorcraft, flight time is short due to its heavy weight but equipment payload is relatively free. In this study, rotorcraft was chosen as payload of a certain level is required for mounting several sensors. In addition, compared with electric UAV that is seriously affected by climate and humidity due to use of gasoline fuel, it has an advantage of constant flight time. Shape and specification of UAV being used in this study is as shown on Fig. 3 and Tab 1.

Table 1. UAV specification

Engine	32HP, 2cycle, Gasoline
Maximum flight time	1 hour
PayLoad	30 kg max
Nominal aircraft speed	Up to 50 km/h
Radio link range	Up to 5 km

As sensor system, multi sensor system comprising optic camera, GPS/IMU sensor was adopted and camera specification is as shown on Table 2. Optic camera could acquire HD image having ground resolution below 8.5cm at an altitude below 500m. GPS/IMU is apx-15 and when acquiring data based on SPS (standard positioning service), a data having position accuracy of 1.5-3.0m and attitude accuracy of app. 0.3 degree could be obtained.

.

Table 2. Optical camera specification (Sony A7 II)

Resolution	6000 x 4000 pix
Pixel size	5.97 μm
Focal length	35 mm
Ground Resolution (500m)	8.5 cm

3.2.IMAGE GEOREFRENCING RESULTS

In this stage, loading parameter is estimated through pre-treatment process and EO parameters of image are determined precisely by performing image georeferencing through determined loading parameter. Loading parameters are motion vector and rotation matrix that are relation between GPS/IMU coordinate system and camera coordinate system through system calibration. However, in view of features of marine monitoring, under the assumption that motion vector is not present as distance between two systems is considered to be minimal, a relation will be established only for the attitude. Image matching BBS were performed by selecting 9 sheets of image photographed in 200m flight by targeting port area, 9 sheets in 350m flight, EO parameters of UAV being synchronized with photographed time and 12 GCPs as experiment input data. Its result has shown that 21.8cm RMS was represented for 5 CP. attitude difference was precisely determined by performing system calibration for determined EO parameters and GPS/IMU data and determined rotation angle is as shown on Table 3.

.

Table 3. Calculated results of the mounting paramter (Rotation matrix)

Mounting parameter	-0.0231	-0.9996	-0.0160
	0.9997	-0.0233	0.0098
	-0.0102	-0.0158	0.9998

3.3.SHIP POSITIONING RESULTS and ANALYSIS ACCURACY

Ship detection and its positioning were performed and for accuracy analysis of determined position, a research was performed for the ship displayed on 200m, 350m, 500m image. Each set was classified based on frequency of consecutively detecting ship by each altitude and at every set, ship positioning was performed and by showing position information visually when analyzing the result, visual analysis was performed qualitatively and it was analyzed quantitatively by showing a difference between determined ship position and actual ship position as average, SD (Standard Deviation), RMS (Root Mean Square). As GPS receiver is mounted at a specific location, not ship center, there was a limitation for existing ship detecting technique that detects ship center and so, ship image coordinate was obtained manually. Classified ship position was determined by image coordinate having pixel unit.

Frequency of consecutively detecting ship in 200m, 350m, 500m flight was 2, 3, 3 times (total 8 times) and in case that same ship was shown persistently in consecutive image, it was selected as set. By reflecting image coordinate of detected ship into an image projected to average sea surface, absolute position of ship was calculated. In order to verify accuracy of calculated position coordinate, positioning technique was applied to all the images in which ship was detected. Table 4 shows average of X axis, Y axis, SD, RMS for the difference between ship position detected by each altitude and position determined by GPS signal. Average of ship position difference shows declination of determined position and SD means deviation degree among position difference. In addition, RMS shows average size of position difference.

As a result of calculating ship position by using 200m image data, it was represented to be most similar to position information of GPS. In particular, declination of X axis, SD, RMS were determined as 0.245m, 1.343m, 1.365m and in Y axis, 3.67m, 2.73m, 4.57m. In 350m, X axis declination was 0.43m, SD 5.65, RMS 5.67m and additionally total RMS was 9.76m that was very low precision compared with 200m image data. In case of 500m image data processing result, X axis declination was represented as 2.394m, Y axis 2.33m and SD of X, Y axis was represented as 4.98, 12.82 and RMS of X, Y axis 5.52m, 13.03 and total 14.15m. It could be confirmed that in all the altitude, RMS difference value in Y axis rather X axis was significantly represented. Table 5 shows average, SD, RMS for the difference between ship position determined by each altitude and position being represented by GPS signal. As RMS was represented as 4.77m in 200m, 9.76m in 350m, 14.15m in 500m, it could be confirmed that RMS value tends to get bigger in proportion to altitude value.

Table 4. Positioning results of the ship per diretion.

Flight height	Set	Ship detection count	Mean		Standard deviation		RMS	
			X (m)	Y (m)	X (m)	Y (m)	X (m)	Y (m)
200m	a	9	0.03	5.80	1.09	2.40	1.09	6.28
	b	11	0.42	1.93	1.50	1.45	1.55	2.41
	a+b	20	0.25	3.67	1.34	2.73	1.37	4.57
350m	c	10	-6.33	-4.52	2.06	1.36	6.65	4.72
	d	16	2.63	9.54	4.45	2.03	5.17	9.75
	e	24	1.78	1.24	5.24	7.58	5.54	7.68
	c+d+e	50	0.43	2.74	5.65	7.46	5.67	7.95
500m	f	19	-0.62	-15.78	2.34	2.88	2.42	16.04
	g	12	4.01	19.12	7.64	2.36	8.63	19.26
	h	26	3.85	-2.41	3.65	2.67	5.31	3.60
	e+f+g	57	2.39	-2.34	4.98	12.82	5.52	13.03

Table 5. Positioning results of the ship per flight height.

Flight height	Mean (m)	Standard deviation (m)	RMS (m)
200m	4.14	2.37	4.77
350m	9.34	2.83	9.76

500m	12.34	6.82	14.15

4. CONCLUSIONS

Through this study, UAV based ship positioning methodology was suggested. In order to verify actually measured data based methodology, GPS information of detected ship was acquired. EO parameters of image was determined by performing georeferencing with data acquired by using UAV. By projecting image to sea surface using determined EO parameters and sea level, ship position represented in image was determined. Ship position RMS was determined as 4.55m in 200m, 9.76m in 350m and 14.15m in 500m. In marine environment where object is limited and view opened, a result of ship positioning is considered to have enough accuracy of being able to perform marine monitoring. Through this, it is judged that ship monitoring could be performed effectively through UAV in the marine environment.

5. ACKNOWLEDGEMENTS

This work was supported by the Building Wide Integrated Surveillance System of Marine Territory project (2015006741) funded by Republic of Korea government and ministry of Oceans and Fisheries.

6. REFERENCING

Chiang, K., Tsai, M., and Chu, C., 2012. The Development of an UAV Borne Direct Georeferenced Photogrammetric Platform for Ground Control Point Free Applications. Sensors, 12(7), pp.9161-9180.

Cramer, M., Stallmann, D., 2002. System Calibration for Direct Georeferencing. International Archives of Photogrammetry Remote Sensing and Spatial Information Sciences, 34(3/A), pp.79-84.

Choi, K., Lee, I., 2009. Image Georeferencing using AT without GCPs for a UAV-based Low-Cost Multisensor System. The Journal of the Korean Society of Surveying Geodesy, Photogrammetry and Cartography, 27(2), pp.249-260.

Kim, H., Choi, K., Lee, I., and Yun, H., 2017. Rectification of Smartphone Image Based on Reference Images for Facility Monitoring. Korean Journal of Remote Sensing, 33(20), pp.231-242

Lee, J., Choi, K., and Lee, I., 2012. Calibration of a UAV Based Low Altitude Multi-sensor Photogrammetric System, The Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography, 30(1), pp.31-38.

McGlone, C., 2004. Manual of Photogrammetry, 5th Edition, ASPRS, Bethesda, Maryland, USA, pp.847-870.

Song, S., Moon, J., and Roh, E., 2010. Development of Flight Control System for Close Range Surveillance UAV. Korea Association of Defense Industry Studies, 18(2), pp.242-261.

Xu, C., Zhang, Z., and Feng, Z., 2014. BgCut: Automatic Ship Detection from UAV Images. The Scientific World Journal, vol. 2014, article ID 171978, pp.1-11.