Monitoring of Vessel Traffic using AIS Data and ALOS Satellite Image

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***Abstract*—Advanced Land Observing Satellite (ALOS) was launched for earth observation and there are more than 6 million scenes of archives including coastal areas during period of five years. Nowadays, the number of AIS (Automatic Identification System)-equipped ships is increasing for maritime safety and monitoring vessel traffic. This study proposes a methodology for monitoring of vessel traffic by matching AIS data to ALOS images. We collected both ALOS images and AIS data in the Straits of Malacca and Singapore on 4th May 2010. The purpose of this paper is to acquire the knowledge about monitoring of vessel traffic by satellite images with simultaneous acquisition of AIS data.**

Keywords-component; AIS;ALOS;GIS;Ship detection

I. Introduction

The Advanced Land Observing Satellite (ALOS) was launched for earth observation of global land coverage and so on. ALOS acquired more than 6 million scenes of archives including coastal areas during period of five years. The wealth of satellite imagery is noticeable for investigating monitoring methods such as ship detection in coastal area. Nowadays, the number of AIS (Automatic Identification System)-equipped ships is increasing under the international convention for the Safety of Life at Sea (SOLAS) by the International Maritime Organization (IMO). The AIS is automatically providing navigation information to other ships and coastal authorities to improve the maritime safety and efficiency of navigation, the protection of the marine environment. An analyzing AIS data is also an effective solution for monitoring of vessel traffic in real time. The authors have focused attention on ALOS images with AIS data to examine monitoring methods in the Straits of Malacca and Singapore. In this paper, an approach for recognizing and classifying various ships in satellite images is presented.

II. ALOS Imagery With Simultaneous Acquisition of AIS Datebase

This study proposes a methodology of vessel identification in coastal environments by matching AIS data to ALOS images. We collected ALOS images and AIS data in the Straits of Malacca and Singapore on 4th May 2010. In this chapter, our study area, AIS Database, and ALOS are introduced.

A. Vessel Traffic in Straits of Malacca and Singapore

The Straits of Malacca and Singapore are geographically important and are used as a gateway for many commercial vessels. More than 70,000 vessels traverse the strait per year from year 2006 to 2010. The high vessel traffic coupled with the narrowness of the Straits is existing navigational hazards. Monitoring of vessel traffic is an important application for safe navigation of the strait. Fig.1 shows the example of vessel trajectories by AIS analysis in the Straits of Malacca and Singapore.

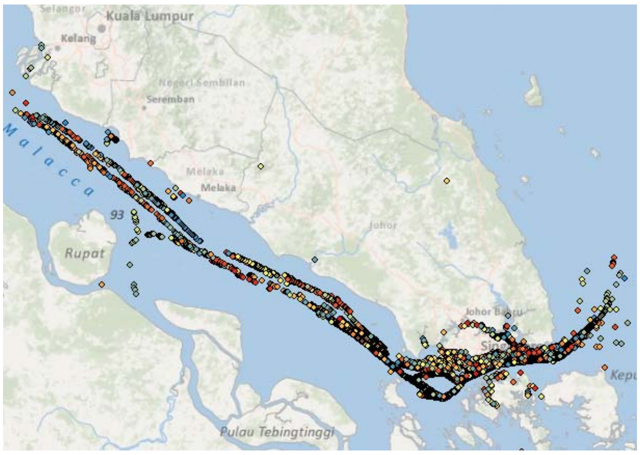

Figure 1. Vessel trajectories in the Straits of Malacca and Singapore. (C)GEBCO, NOAA, National Geographic, DeLorme, and ESRI.

B. AIS Database

The IMO requirements mandating that certain ship classes to be equipped with AIS devices capable of automatically providing navigation information to other ships and coastal authorities are set forth in Regulation 19 of the SOLAS Chapter 5. AIS receivers are installed at Kobe University and cooperating universities [1] [2]. AIS data has been collected and stored in the same server. We collected AIS data around the acquisition time of ALOS and converted vessel position (latitude and longitude) into geospatial information data with detail of each vessel (MMSI, ship types, speed, length, and many other parameters). Summary of AIS data on 4th May 2010 are summarized in Table I.

TABLE I. Summary of AIS data on study area

Local time	**11:00 - 12:00**
# of ships	1115
under way using engine	356

C. ALOS Image

The Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) on board of the ALOS is a panchromatic radiometer with 2.5m spatial resolution. We used the PRISM images of Straits of Malacca and Singapore that was acquired in three directions mode (40km x 35km) on 10 May 2010 in descending pass (11:37:05 in local time) and the pointing angle was -1.09 degree with 2.5m ground spatial resolution. Fig.2 shows coverage of experimental area in the Straits of Malacca and Singapore. We extracted ships structure within white line on ALOS images.

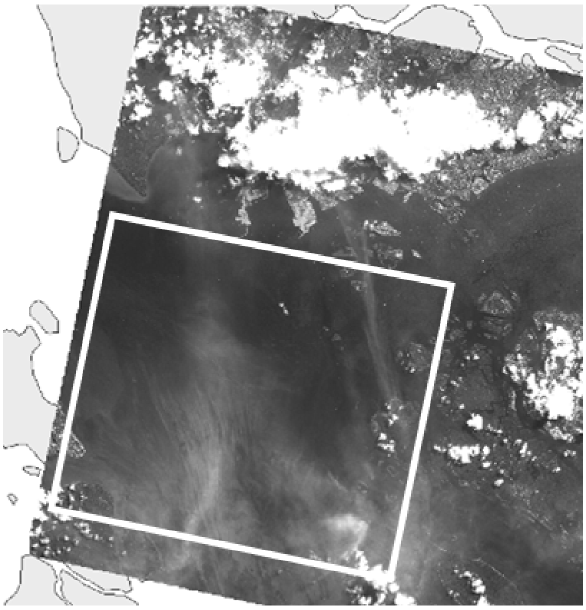

Figure 2. ALOS PRISM over the Straits of Malacca and Singapore on May 10, 2010 at 11:37LT (Local Time) (C)PASCO / Included Material (C) JAXA

III. METHODOLOGY

We evaluated the most suitable methodology to identify vessel from ALOS and AIS database. We extracted vessel structure from ALOS images with AIS data by using GIS (Geographic Information System) in the Straits of Malacca on 4th May 2010. It should be noted that this process would enable to classify various length vessels with AIS-equipped or AIS-unequipped. Then, we compare between a length of each vessel from satellite images and AIS data as actual measurement value. In this chapter, the focus is on ship-LOA (Length over All) measurement using GIS.

A. Filtering process of AIS data

Several methods were used for extracting ships on ALOS images. More specifically, vessel trajectories of experimental area were filtered by using spatial search function of GIS. Fig.3 shows that the filtered vessel trajectories within the space of experimental area (red line). The trajectories seem to indicate vessel traffic, but we more filtered vessel trajectories around acquisition time of ALOS. Fig.4 shows extracted ships with the vessel trajectories from AIS database while three minutes of acquisition time of ALOS.

This process would enable to simplify for recognizing ship structure with AIS-equipped or AIS-unequipped on ALOS images.

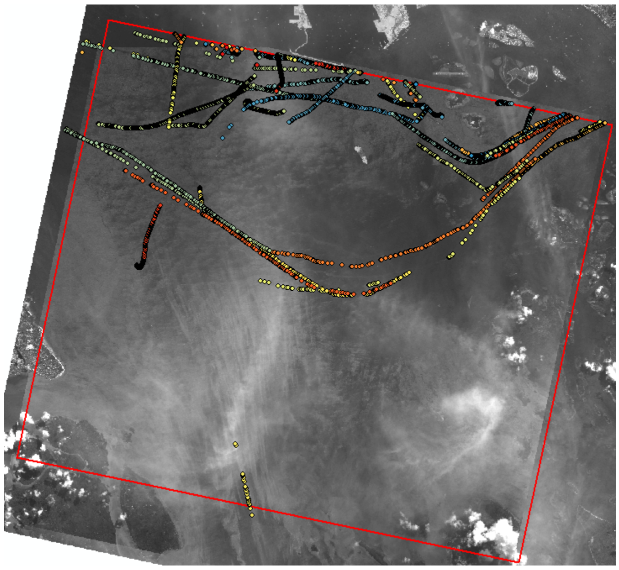

Figure 3. Vessel trajectories in experimental area on May 10, 2010 from 11:00 to 12:00LT at 1:250,000 scale.

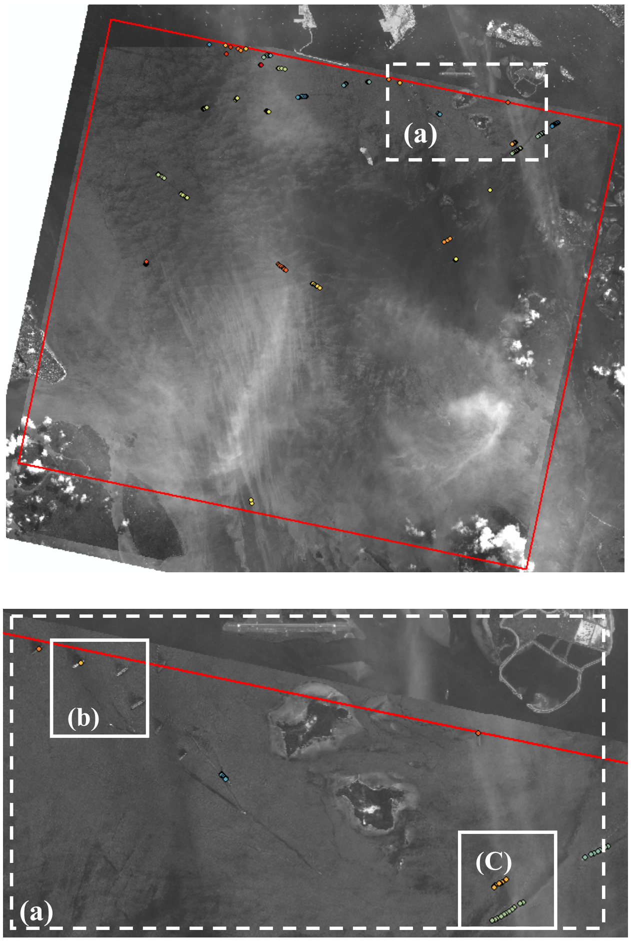

Figure 4. Vessel trajectories in experimental area on May 10, 2010 around acquisition time (from 11:36 to 11:38LT) of ALOS at 1:250,000 scale.

B. *Vessel straucture with simultaneous acquisition of AIS*

Several vessel with AIS-equipped or AIS-unequipped are extracted from ALOS imagery. It should be noted that all ships are not equipped with AIS, but the satellite image would be enable to make observation of vessel with AIS-unequipped even small ships. Fig.5 and Fig.6 shows example of extracted ships. Vessels with simultaneous acquisition of AIS data can get some information from AIS message. Vessels without AIS data would estimate the length, width and course on ALOS imagery using GIS.

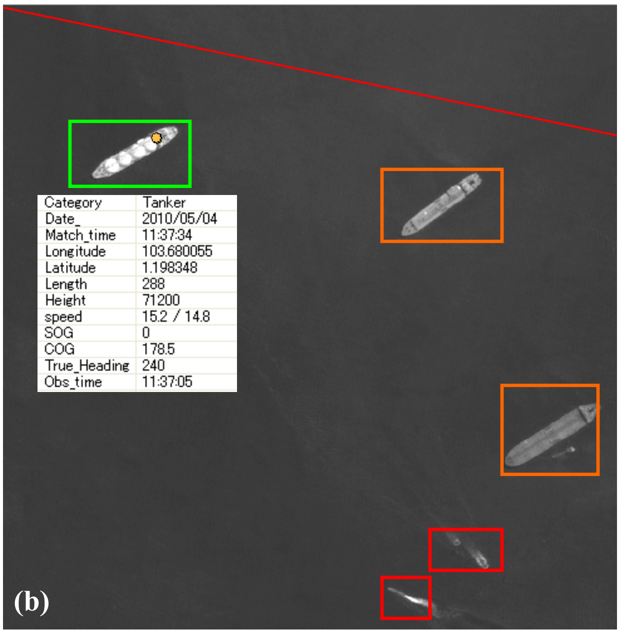

Figure 5. Extracted ships marked with colored square in experimental area (b) at 1:10,000 scale. (Red) Moving small ships without AIS information. (Orange)Anchored vessel without AIS messages. (Green) Anchored vessel with AIS data (yellow point).

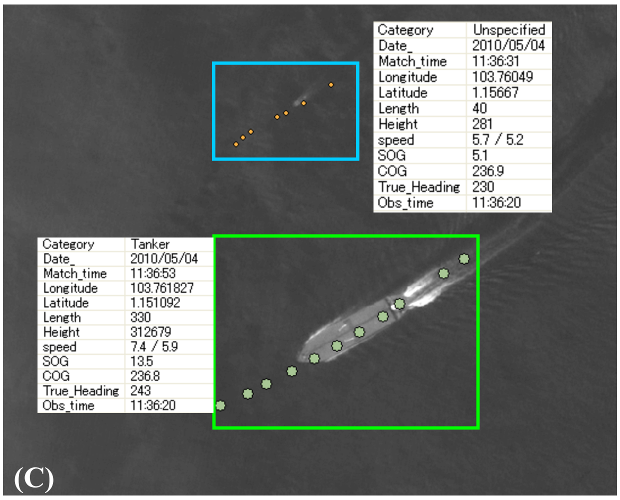

Figure 6. Extracted ships marked with colored square in experimental area (C) at 1:10,000 scale. (Blue) Moving small ship with AIS data (orange trajectory) and AIS information. (Green) Moving vessel with AIS data (green trajectory) and AIS information.

C. *Measurement of LOA (Length over all)*

The LOA observed in the ALOS imagery is obtained from those spatial points (bow and stern) of the vessel structure and the measurement was done using GIS calculation tool. We compared the LOA of each vessel with the length from AIS as actual measurement value. Fig.7 shows example of extracted ships. Our methodology is to extract vessel structure from ALOS with AIS data by using GIS. This process would enable to recognize and classify various length vessels with AIS-equipped or AIS-unequipped.

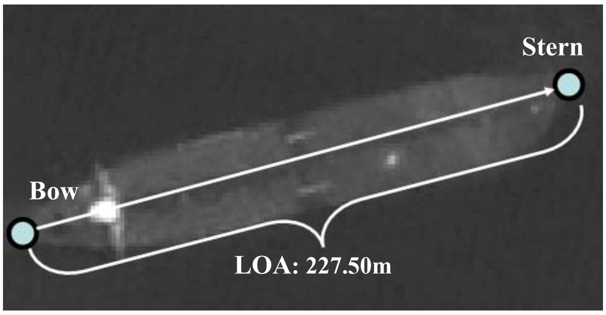

Figure 7. Center line of vessel be measured from ALOS imagery

IV. ACCURACY AND VALIDATION

In order to validate the matching and estimate the accuracy, length determination from satellite imagery has been evaluated.

A. *Matching results with AIS data*

All of the results are summarized in Table II and Table III. From the results, we found a total number of 82 ships, the almost target features consisted of AIS-unequipped, but other ships were categorized 38 ships with AIS-equipped in experimental area. It can be seen that the greater number of ships without AIS was within 110m. The results show that we can classify vessels structure from ALOS imagery into categorized vessels.

TABLE II. CLASSIFIED LISTS FROM MATCHING RESULT

Category	# of ship	Percentage (%)
Tug	4	5
Cargo	8	10
Tanker	24	29
Other	1	1
Unspecified	1	1
Unequipped	44	54
Total	82	

TABLE III. CLASSIFIED LISTS FROM MATCHING RESULT

	AIS-equipped		AIS-unequipped	
Size	**# of ship**	**Percentage (%)**	**# of ship**	**Percentage (%)**
0～65.5	6	16	22	50
65.5～110	6	16	18	41
110～173.5	6	16	1	2
173.5～300	16	42	3	7
300～	4	11	-	-
Total	38		44	

B. Accuracy of LOA estimation from ALOS imagery

All of the measurement results are summarized in Table IV. From this result, we found a total number of 38 ships with AIS data and the measurement accuracy of LOA was within RMSE 7 m in experimental area. The results show that we can measure LOA of more than 65.5 m vessels within RMSE 6 m from the satellite image itself.

TABLE IV. SHIP LENGTH MEASURED IN ALOS IMAGES AGAINST LENGTH REPORTED BY TERRESTRIAL AIS (32 DATA PAIRS).

Length(m)	*# of ships*	*Residual error (m)*	*Error rate (%)*	*RMSE(m)*
0～65.5	6	5.07	14.87	7
65.5～110	6	2.23	1.84	6
110～173.5	6	2.38	1.84	3
173.5～300	16	0.36	0.07	4
300～	4	1.98	0.60	2

Fig.8 shows relation of residual error between LOA measured in ALOS images and length reported by AIS. As a result, we achieved measurement accuracy of almost ships within 7m, but residual error of 2 ships ranged from 11m to 16m.

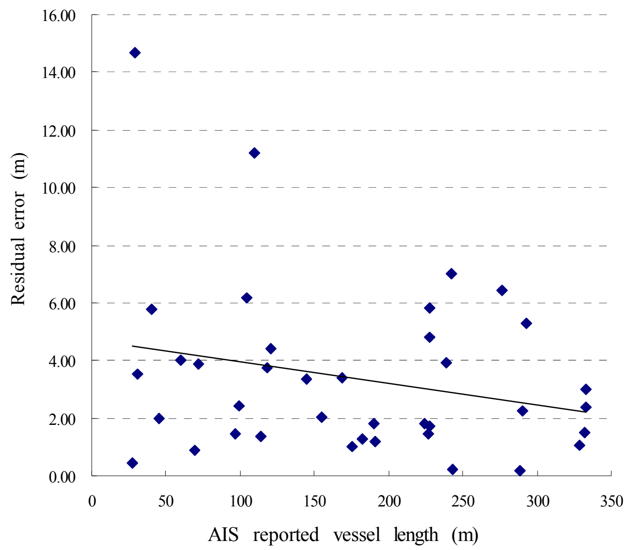

Figure 8. Relation between ship length measured in ALOS images and length reported by AIS (32 data pairs)

V. CONCLUSION

In this paper, AIS and ALOS acquisitions have been analyzed in order to assess the potential to be used for monitoring of vessel. It was used to evaluate the performance of ship detection and length estimation from satellite imagery compared to reference data derived from AIS data. Although the evaluation shows the challenges of vessel monitoring with satellite imagery in terms of error rate, the vessels information from these results show a good agreement with the AIS data as reference data. Our research suggests that our methodology might be effective for maritime monitoring by using satellite image with simultaneous acquisition of AIS data.

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