THE DEVELOPMENT RESEARCH OF THE FISHING BOAT DISTINCTION TECHNIQUE BY SATELLITE-ONBOARD HIGH RESOLUTION OPTICAL SENSOR
— DISTINCTION TECHNIQUE USING IKONOS DATA —

T. MORIYAMA[1], H. TAMEISH1 [2], J. SUWA[3], S. KANNO[3],
Y. SUGIMORI[3], T. OSAWA[3] AND M. KOIWA[4]

Abstract

This paper describes the vessel distinction algorithm by using radiance silhoutte algorithm for IKONOS data. Although original TKONOS image has high spatial resolution about 1 m, it is difficult to identify whole feature of the vessel. The newly developed algorithm named "Radiance Silhoutte Analysis Algorithm" can estimate entire length, full width and bridge location of the vessel in high accuracy. By using targeted vessels, it is evaluated the algorithm has sufficient accuracy for vessel distinction. The research also covers synthetic collation decision by using vessel type axtraction algorithm.

Keyword: IKONOS image, SPOT, ALOS image, high resolution image alogarithm, nearest neighbor interpolation, cubic convolution interpolation

I. Introduction

The fishing boat operation surveillance system has been the important subject of development of fisheries, due to poaching by the foreign fishing boat in the 200-nautical mile economy exclusive offshore zone in Japan in recent years. Poaching in the territorial waters in Japan by the foreign fishing boat occurs frequently especially in the East China Sea circumference ocean space, thus the counter measure is hurried.

Conventionally, although fishing boat operation surveillance corresponded mainly under the surveillance by the patrol boat of the Fisheries Agency, it is not easy to supervise the vast ocean only by vessel, so that the other effective surveillance systems are urgently needed. The past studies of the elementary system by satellite were carried out in Japan titled "Study on the detection of the position and the speed of a vessel using stereo-viewing of JERS-1 optical sensor(OPS)" by Remote Sensing Technology Center (RESTEC) and "Technical development on the management system of the fishing boat using DCS" by Japan Fisheries Information Service Center (JAFIC). However, for the moment, in the field of control of fishing boats or common vessels by remote sensing, there is no example of research on utilization of the system.

In this research, we studied the fishing boat discernment technique by the optical sensor (IKONOS) and the microwave sensor (SAR). Although a high resolution optical sensor was excellent in the ground resolution in general, when taking the field-of-view interception (surveillance obstacle by the cloud and the thick fog) by the weather, the ability declined extremely. However, the ground resolution of high resolution optical sensor such as IKONOS (US), SPOT (France) and the ALOS sensor soon launched by JAXA (NAS-

1 Remote Sensing Technology Center Japan.
2 Japan Fisheries Information Srvice Center.
3 Center for Remote Sensing and Ocean Sciences, the University of Udayana.
4 Mitsubishi Space Software Co., Ltd.

DA) will be very high with 10m, and since furthermore they will have several cm resolution in the case of the reconnaissance satellite for military affairs. These new optical sensors will be very effective in the fishing boat discernment technique.

II. High resolution Image algorithm

The high resolution analysis algorithm for which the fishing boat discernment technique was asked from the space performs vessel detection automatically from a high resolution satellite image (IKONOS image), and performs collation discernment of a vessel from the trimmed image of the detected vessel. This was composed of the vessel identification algorithm created for high resolution image of the vessel detected using vessel detection algorithm, and vessel collation identification algorithm. The processing block diagram of two comprehensive algorithm is shown in Fig. 1.

First, the "vessel detection algorithm" consists of the following five algorithm: 1) the compensation algorithm of a vessel position, 2) land area removal algorithm, 3) vessel discernment algorithm, 4) bow direction presumption algorithm, and 5) vessel full length and full width estimation algorithm, and performs detection and discernment for a vessel from image data using such basic technology (Moriyama et al., 2003). On the other hand, "vessel collation discernment algorithm" performs automatically trimming from the image data of the vessel detected by vessel detection algorithm, the analysis of a image, and a collation decision. As shown in Fig. 2, luminosity peak detection, form extraction, and the judgment of a vessel and a noise (clouds and wave head) are performed in "3) vessel discernment algorithm" part, and Principal Component Analysis in "4) bow direction presumption algorithm" part in the flow of processing of "vessel detection algorithm".

1) The application of the high resolution image algorithm

The images of the coastal waters of Tsushima and Tokyo bay were analyzed as a example of the application of the high resolution image algorithm. The results of the vessel detection algorithm applied to the high resolution image data (IKONOS images) are shown in the following. Fig. 3 is the example of the application of the vessel detection algorithm to the satellite image taken at the

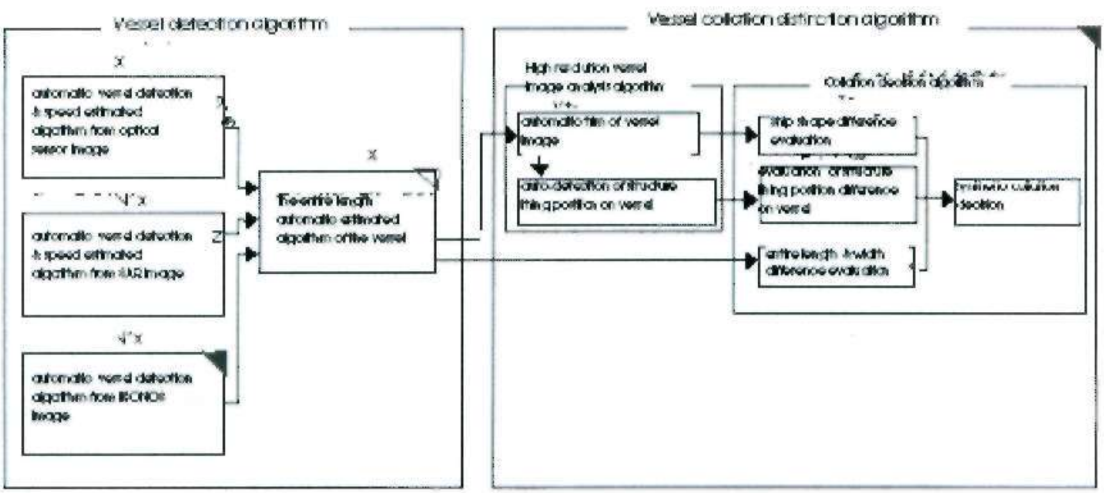

Fig. 1. Processing block diagram of two comprehensive algorithm.

Fig. 2. The flow of vessel detection algorithm.

coastal waters of Kami-tsushima. Fourteen vessels were detected by the vessel detection algorithm.

Fig. 4 is the example of the application of the vessel detection algorithm to the satellite image taken at the Tokyo Bay. Thirteen vessels were detected by the vessel detection algorithm. Fig. 5 shows the vessels whose right values of the entire length and width had already known among all vessels detected from the IKON OS image taken at Tokyo bay by the vessel detection algorithm. The estimated values of the entire length and width detected by the vessel detection algorithm were

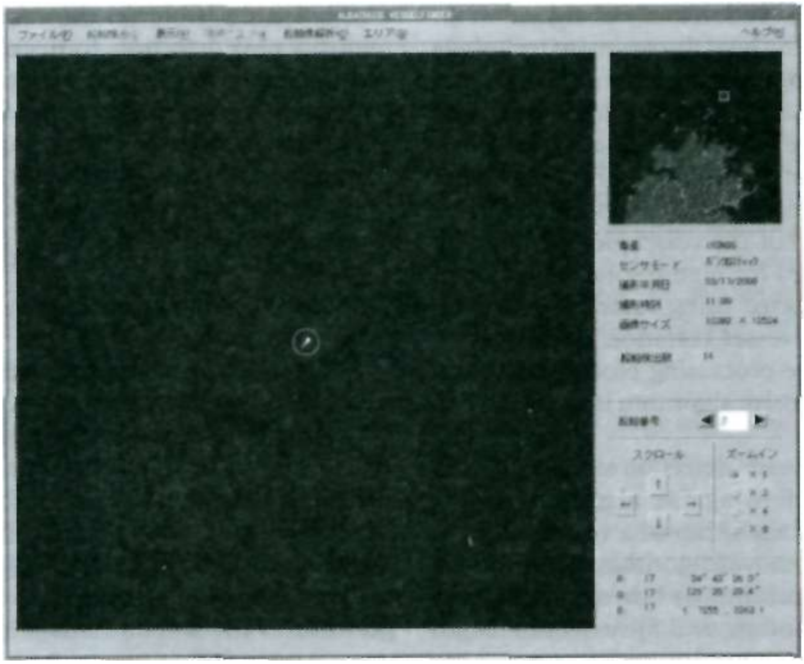

Fig. 3. Application of the vessel detection algorithm to the satellite image took at the coastal waters of Kami-tsushima

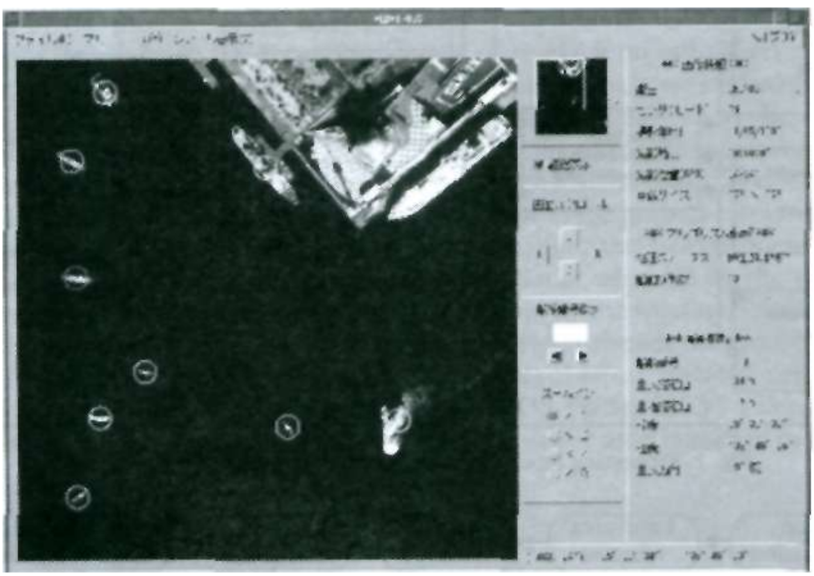

Fig.4. Application of the vessel detection algorithm to the satellite image taken at the Tokyo Bay.

compared with the right value of the entire length and width of the vessels (Fig. 6).

From this figure, it can be find that the tendency of over estimation of entire width of the vessel and to estimate entire length a little small. The following factor can be thought as this cause.

(1) The extent (it influences the direction which grows large both in entire length and width) of the vessel figure due to radiance saturation.

(2) The error (as for the entire length, it is small, and influences the direction which grows large as for the entire width) of a result of direction estimation.

The error of the estimated all entire length and width values was about 3% to the right values, and this precision satisfied the purpose of development of this algorithm in case of this analysis.

2) The application of the vessel collation distinction algorithm

Next, an example the application of the vessel collation distinction algorithm developed in the present study is shown here. The vessel collation identification system was composed of two algorithms such as the high resolution vessel figure analytic algorithm and

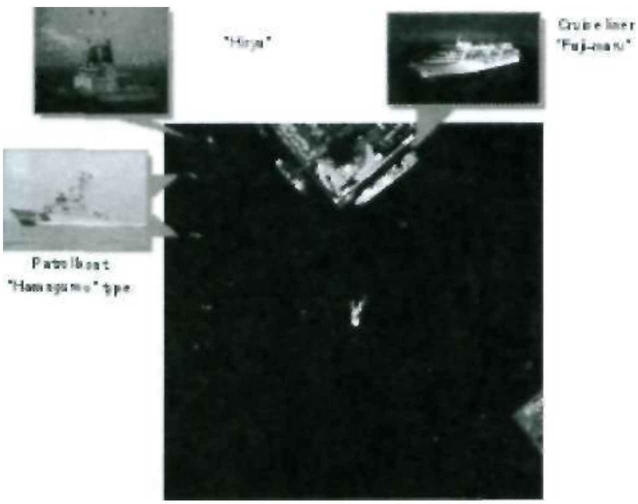

Fig. 5. The result of vessel detection algorithm and true value.

	Entire Length (m)			Width (m)		
	Estimated Length	True Value	Error	Estimated Width	True Value	Error
Hiryuu	36	35.1	+0.9	15	12.2	+ 2.8
Hamagumo type	34	35	-1	8	6.3	+ 1.7
Hamagumo type B	34	35	-1	7	6.3	+ 0.7
Fuji-maru	163	167.4	-4.4	28	24	+ 4

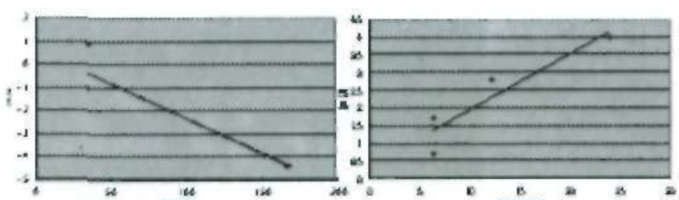

Fig. 6. Automatic presumption of the full length and width of the vessel from an IKONOS image (Tokyo Bay).

the collation decision algorithm. Therefore, the high resolution vessel figure analytic algorithm applied to the detailed analysis of the trim of the vessel figure detected by the vessel detection algorithm and the image. Then the evaluation of the vessel figure and a synthetic collation decision were analyzed by the collation decision algorithm based upon the above result. This synthetic collation decision was to evaluate similarity between two vessels.

Generally the similarity of the size and the form of the vessel were highly based on the fishing kind and this similarity changed by the nationality of the fishing boat. Therefore, it was possible that the fishing kind, the nationality and so on were judged by accumulating the size of the vessel, the form and so on in the database. In this study, the parameters of the size of the vessel, the form and a structure thing on the ship were defined, and the similarity was evaluated by these parameters. Here, the high resolution vessel figure analytic algorithm was composed of the vessel image trimming algorithm and the automatic detection algorithm of the structure thing on the ship. The vessel image trimming algorithm trimed the vessel figure detected by the above

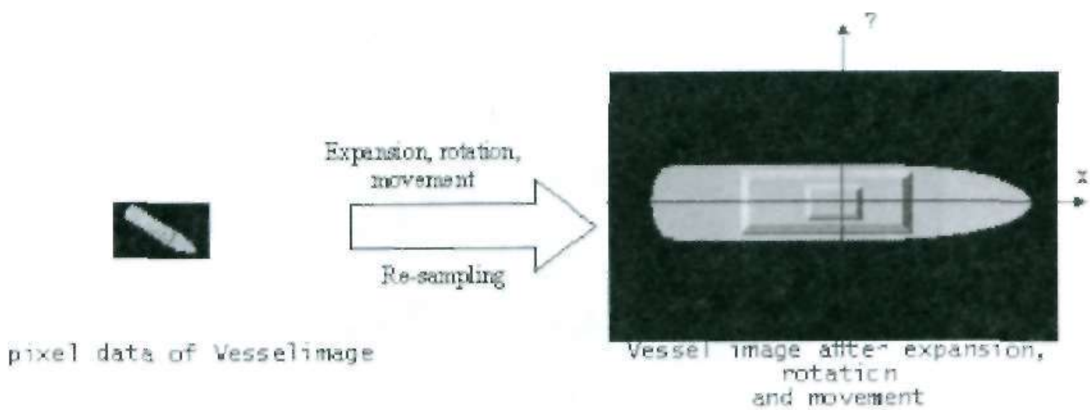

Fig. 7. Vessel image trimming algorithm.

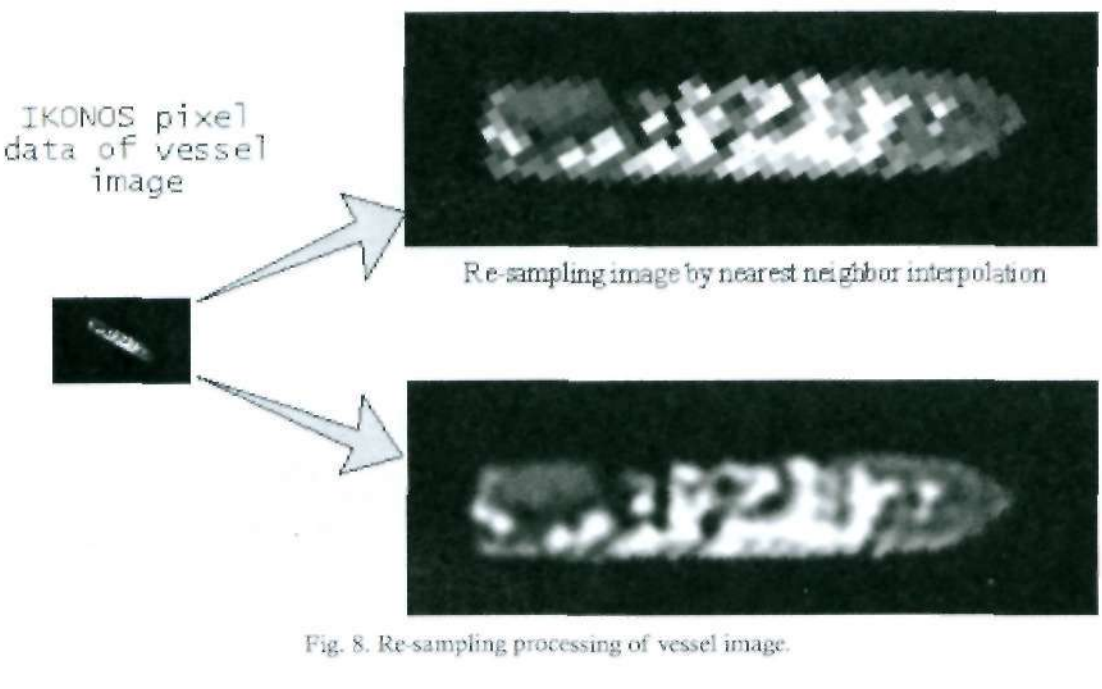

Fig. 8. Re-sampling processing of vessel image.

vessel detection algorithm automatically as a pre-processing (Fig. 7). This pre-processing simplified processing after that.

First, the latitude and the longitude of the vessel (the position of the center of gravity of the vessel), the direction (center axis direction), and the entire length and width were detected by the vessel detection algorithm (Moriyama et al., 2003). The pixel data of a vessel were trimmed inside the work station during the detection process. The trimmed vessel figure is turned to complete a direction after it is expanded and the center of gravity of the ship was moved to the origin. Consequently, the vessel figure was standardized, and the remaining processing became easy, and moreover a more precise analysis became possible. As satellite images were girded arrangement data, re-sampling (re-arrangement) of the image was necessary for rotation, expansion, movement operations, (a) Nearest neighbor interpolation and (b) cubic convolution interpolation were introduced here as typical technique of re-sampling (Fig. 8).

(a) Nearest neighbor interpolation
- Original image data are not broken.
- Algorithm is easy.

(b) Cubic convolution interpolation
- Smoothing effect on an image can be obtained.
- Edge effect on a image can be obtained.

Comparing the evaluations of structure

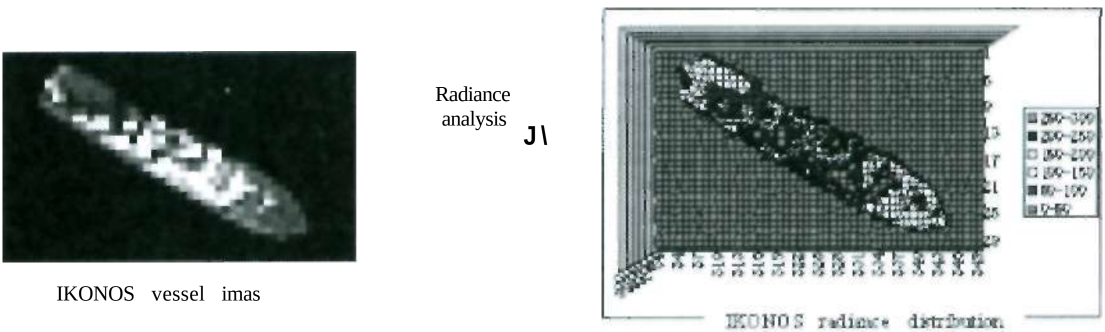

Fig. 9. Radiance distribution.

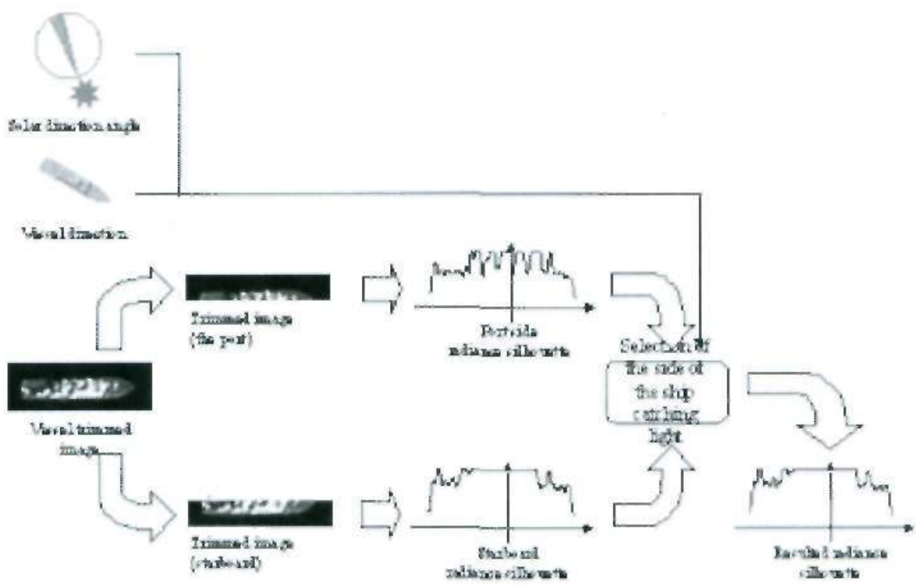

Fig. 10. Radiance silhouette analysis.

things on the ship and ship form by two techniques, the cubic convolution interpolation was more suitable than the nearest neighbor interpolation for the precise evaluation. Therefore, the trimmed vessel image obtained by re-sampling using the cubic convolution interpolation was indicated in another window (Fig. 9).

Next, the automatic detection technique of positions of the structure things on the ship is mentioned. Structure things on the vessel are effective to indicate the characteristics of the vessel. The algorithm of the automatic detection of positions of the structure things on the vessel detects a position on the vessel of the structure thing (a bridge, etc.) on the vessel. Generally, the distribution of light and shade (radiance) in the vessel image indicates the shadow created by structure things on the ship which interrupts solar light. Then, analyzing the radiation distribution in this vessel image, the structure thing creating it can be detected. The method which detects a structure thing by radiance analysis based on this idea is called radiance silhouette method.

As a result of confirming a vessel figure (entire length: 10m-50m class) in the IKONOS image with the eyes as shown in Fig. 9, though a structure thing on the ship was confirmed, the outline was not vivid, and a structure thing on the ship was grasped as a difference of radiance of each pixel in vessel figure. Though the radiance was comparatively equal, as for pixels of the deck part, it indicated that a change in the radiance was remarkable in bridge part as a result of radiance analysis of the vessel figure. This seems to be the reflections of a mast, an antenna, etc. in bridge and their shadow made this change in the radiance. Like this, the distribution of the radiance in bridge is thought to change by a shadow's changing by the season, the photography time (solar altitude), the position (latitude) of the vessel and the direction (heading angle) of the vessel greatly. Therefore, the detection method which is hardly taken from the influence of a change in a shadow of the structure thing on the ship is necessary.

Three methods including the correlation rating system method, the outline extraction method and radiance silhouette analysis method were examined as a detection method of the structure thing on the ship, and radiance silhouette analysis method was decided to be adopted (Table 1). The radiance silhouette method plotted the maximum radiance at each point in the x coordinates of the trimmed image. Since the radiance distribution of the structure thing on the ship had more strong characteristics at the solar light receiving side of the ship, the trimmed image was divided with a center line of the vessel, and radiance silhouette at the side which caught solar light, which was used for the detection of the structure thing on the ship (Fig. 10). Fig. 11 explains how to judge a position of a bridge from radiance silhouette. As radiance peak in the territory where a struc-

Tablel. Onboard structure detection system.

Method	Outline	Evaluation
Correlation Evaluation	The template of the structure thing and correlation evaluate a vessel figure on the vessel, and a structure thing is detected on the ship.	Correlation value with the template is inappropriate because it changes on the ship greatly due to the change in the shadow in structure thing.
Outline Extraction	The outline of the structure thing is grasped on the ship by the edge extraction and so on.	A structure thing doesn't have the clear outline on the ship of the vessel of 10-15 m class, and inappropriate in the actual IKONOS image.
Radiance Silhouette Analysis	Radiance Silhouette of the vessel is formed and a structure thing is detected by this on the ship.	Radiance Silhouette hardly takes the influence of the shadow in structure thing on the ship.

ture thing existed on the ship appears continuously, it was possible that the longest connection area was judged as a bridge by segmentating radiance silhouette using the threshold. Because the most suitable threshold varied in radiance level of the image and the size of the vessel, the threshold was set up for each vessel by the threshold control algorithm shown in Fig. 12.

The example of the application of the high resolution image analytic algorithm

The result of the radiance silhouette analyses to the small fishing boats anchored around Kamakura and Enoshima area in Kanagawa Prefecture is introduced. Fig. 13 (a) is the image after applying the high resolution image algorithm and Fig. 13 (b) is the after applying the radiance silhouette algorithm. These figures indicate that the entire length and width, the trimmed image by the nearest neighbor interpolation, and the trimmed image by the cubic convolution interpolation of the Tohkichi-maru No. 10 during the anchorage.

Table 2 shows the result of the estimation of the length of the structure thing on the vessel in Enoshima area. The estimated length of the structure thing on the vessel was larger than the true value because of the extent of

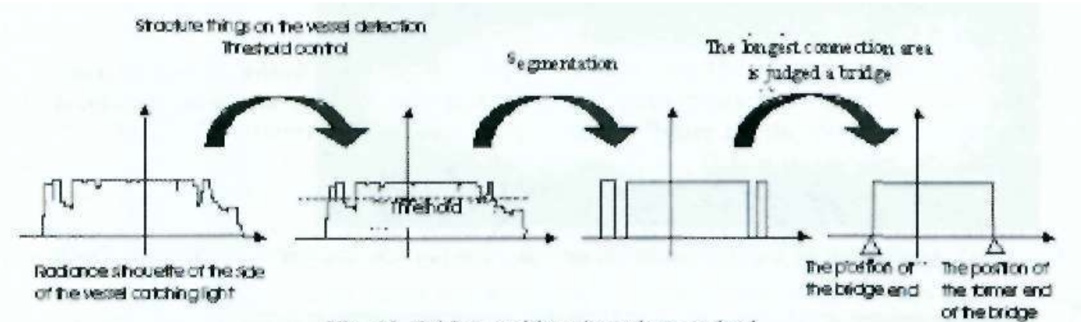

Fig. 11. Bridge position detection method.

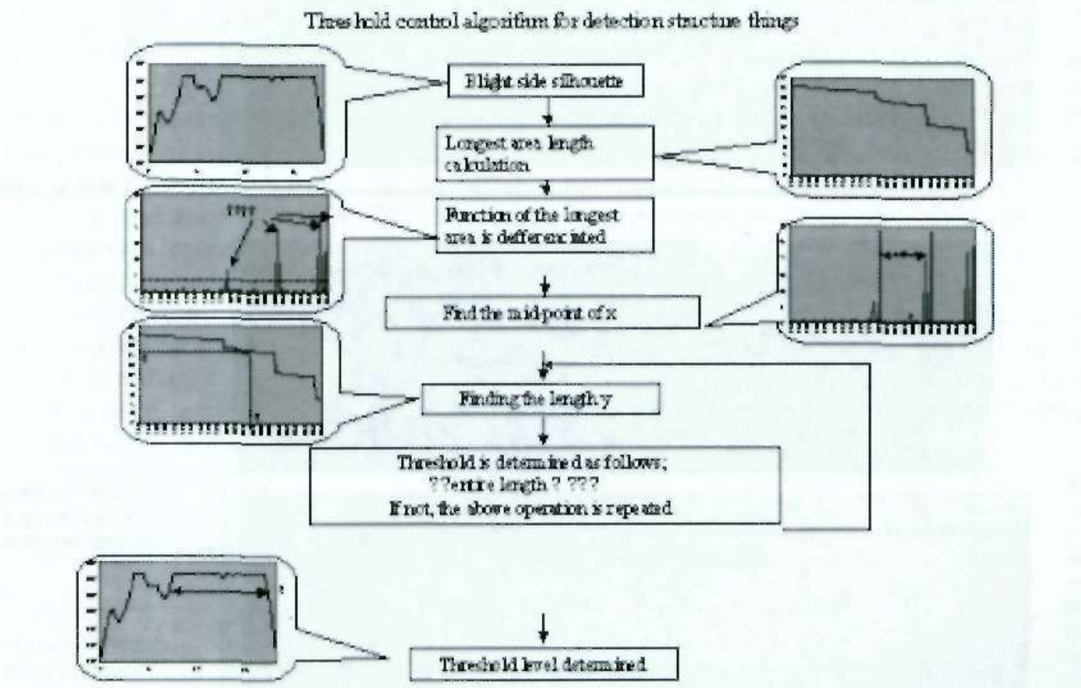

Fig. 12. Onboard structure detection threshold control algorithm.

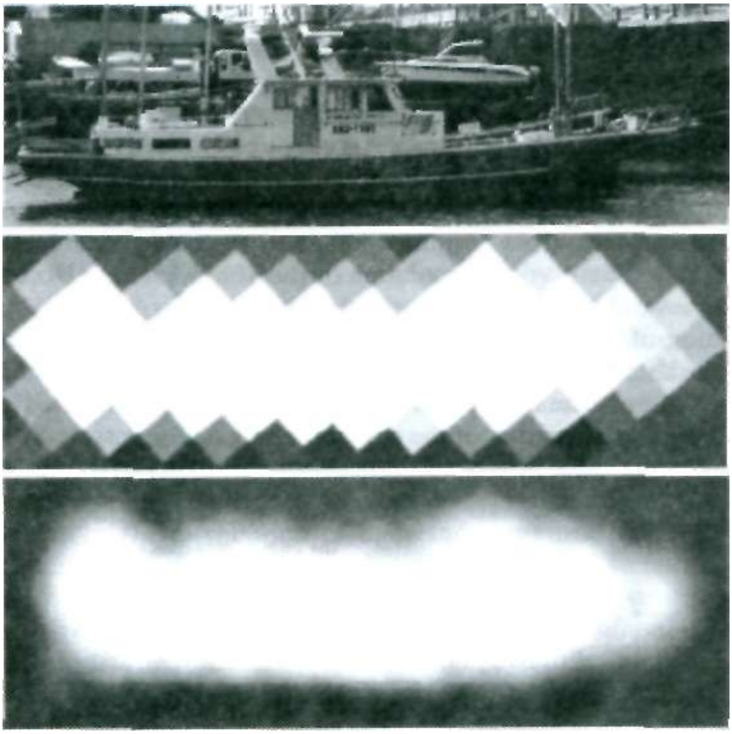

Fig. 13 (a). Application of high resolution image algorithm (around Enoshima, Katasebashi bridge).

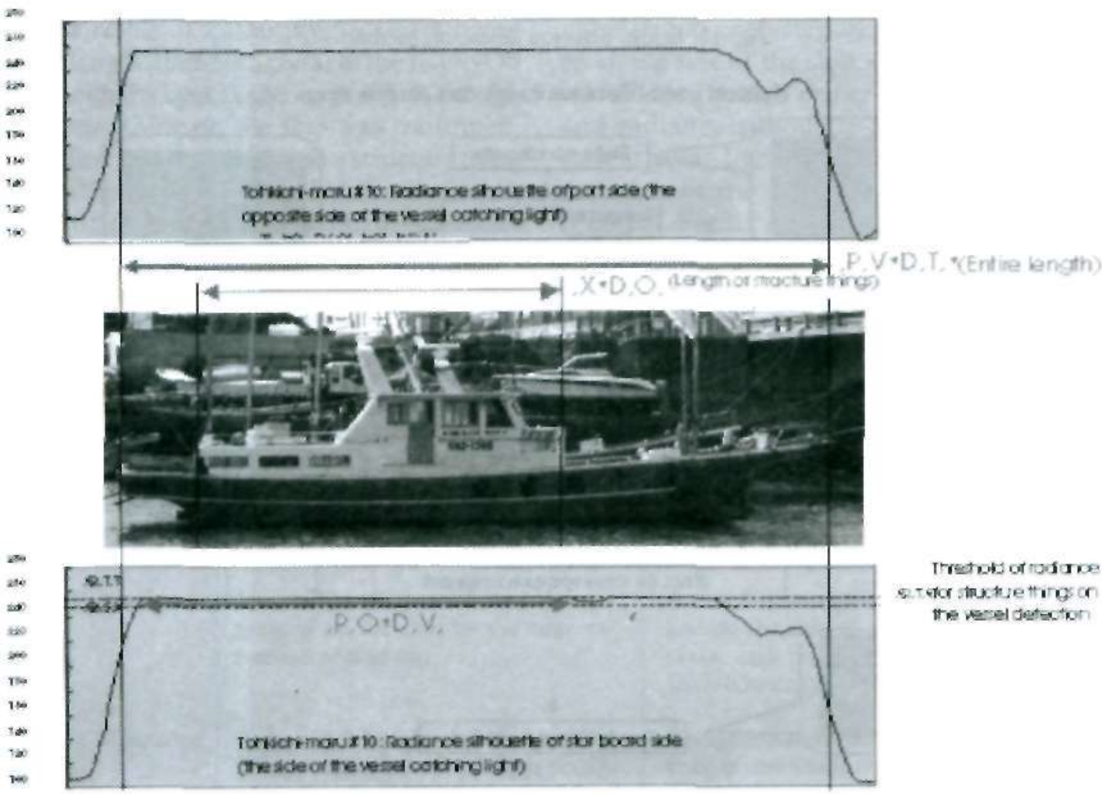

Fig. 13 (b). Radiance silhouette analysis.

the figure due to radiance saturation. Because the dispersion (standard deviation) of the error was small enough in comparison with the offset (average error), it was possible that the precision of the estimation increased with reducing an average error from the estimation of the structure thing length.

Next, collation decision algorithm was composed of three evaluation algorithms including the ship style difference (inconsistency partial area) evaluation, the arrangement difference evaluation of the structure thing on the vessel and the entire length and width difference evaluation, and the synthetic collation judgement. For this evaluation, the standardized parameters as the indexes of the above three evaluations were defined.

(i) The ship type (the contour of the ship) detected from the vessel figure was evaluated with the ship style difference (inconsistency partial area) evaluation. In this algorithm, the ship type was defined as the area which was extracted as the part of the vessel from the trimmed vessel figure. When the center of gravity was aligned and that territory was piled up, the difference in ship patterns could be estimated by finding the area of the part of the inconsistency. However, since the area of the part of the inconsistency was in proportion to the size of the vessel itself, to evaluate an inconsistency area was standardized regardless of the size of the vessel.

(a) As the offset of the extent of the figure due to radiance saturation was canceled when two images of the same vessel were compared, it did not need to take that into consideration.

(b) The dispersion of the extent of the figure due to radiance saturation independent of the size of the hull, but depended on the character (resolution, etc.) and image processing algorithm.

Therefore, under the condition that the sensor and the image processing algorithm were constant, the inconsistency area of two images of the same vessel was in proportion to the length of the outline of the vessel figure. Therefore, the standardized index was proposed as follows.

[The standardized parameter which shows a difference in ship pattern]
= [Inconsistency area/the length of the convex parcel of the agreement part]

When the image of the same vessel was compared, the value of the upper formula was not based on the size of the hull, and it approached a certain fixed value decided by the sensor and the image processing algorithm. And, obviously this value increased when the vessel figure of the different ship form was compared. When the length of the outline of the vessel figure was made, the length of a smooth curve to pass through between the inner dimension and the external dimension of the part of the inconsistency are shown in Fig. 15, it could be approximated in the length of the convex parcel of the agreement part. Consequently, this value was available as a standard for the ship form difference evaluation, and the standardized parameter which showed this difference in ship pattern is called " standard ship form difference". This difference in standard ship pattern was evaluated with ship pattern difference evaluation.

(ii) Evaluation of the difference in the arrangement of structure thing on the vessel

The absolute value of the front-back position of the difference in structure things of two vessels was evaluated with the evaluation of the difference in the arrangement of structure thing on the vessel.

(iii) Entire length and width difference

Table 2. Estimation of the length of the structure thing on the vessel.

	Estimated (m)	Truth (m)	Error (m)
Hamagumtype A	22.2	20.2*	+ 2.0
Hamagumtype B	19.5	16.5	+ 3.0
Tokichi-maru No. 10	10.7	9.0	+ 1.7
Tokichi-maru No. 15	10.4	8.9	+ 1.5

evaluation

The absolute value of the difference in the entire length and width of two vessels was evaluated by the entire length and width difference evaluation.

(iv) Synthetic collation decision (Fig. 16)

This decision aimed at evaluating similarity between two vessels by using each evaluation of the previous item (i) - (iii). From the items (i) - (iii), two vessels were judged whether it was the same shape or inconsistent.

3) Collation experiment as a case study

The results of two examples of case study experiments analyzed by the algorithm developed in this study are shown as follows.

(A) Tokyo Bay - collation of Hamagumo-type A and Hamagumo-typc B -

The difference in standard ship form, the difference in entire length and width and the

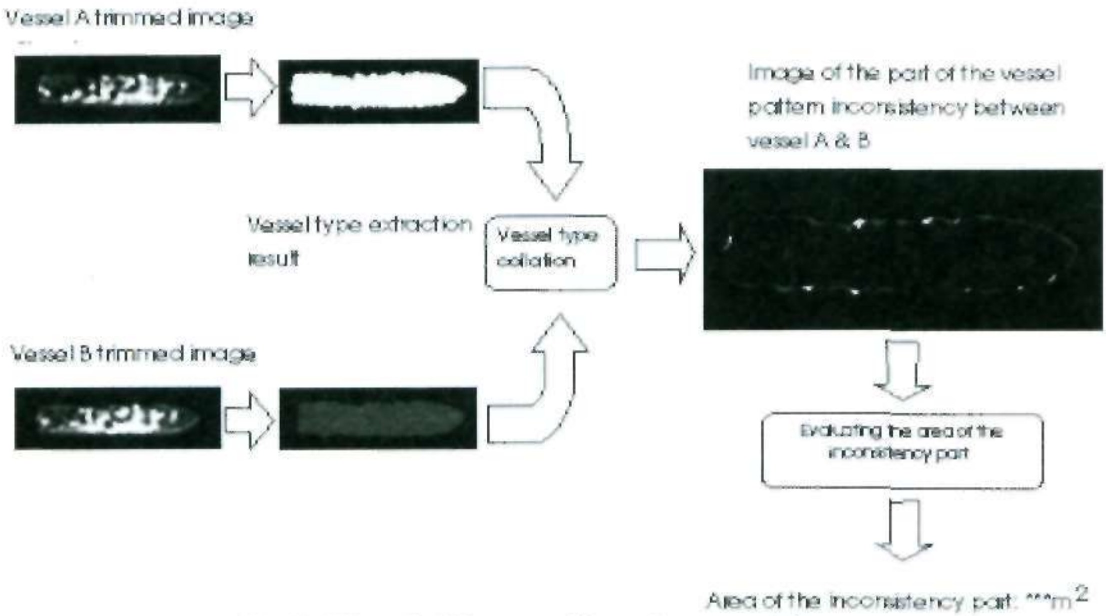

Fig.15. Ship style difference and inconsistency partial area.

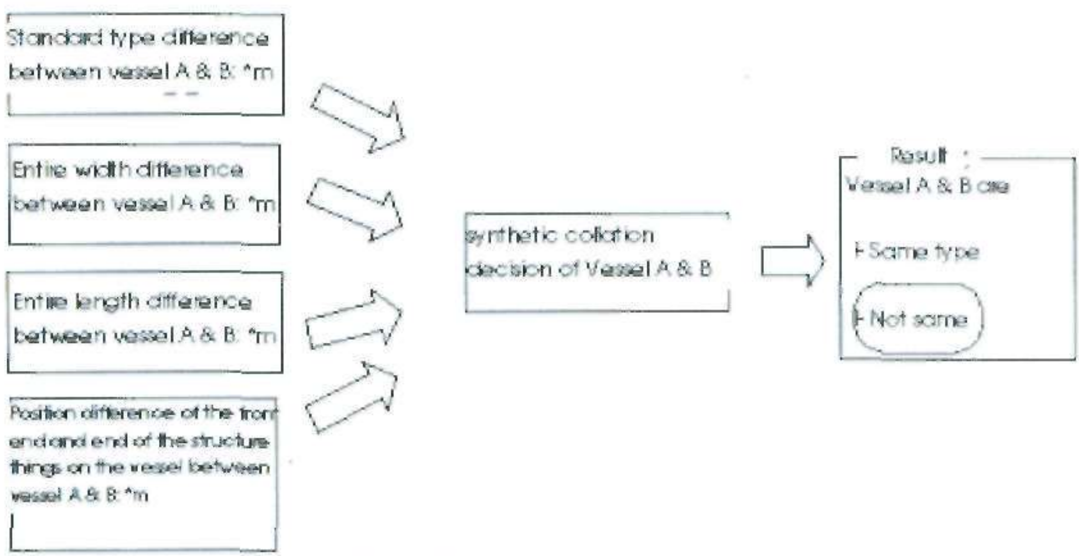

Fig. 16. Synthetic collation decision.

Case study 1: Collation of Hamagumo type A and B

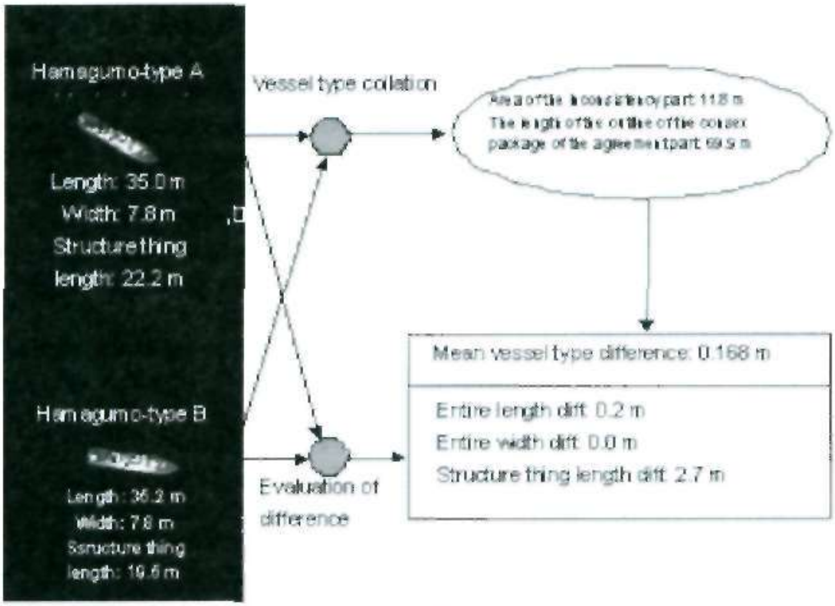

Fig. 17. Case study #1 (Tokyo Bay).

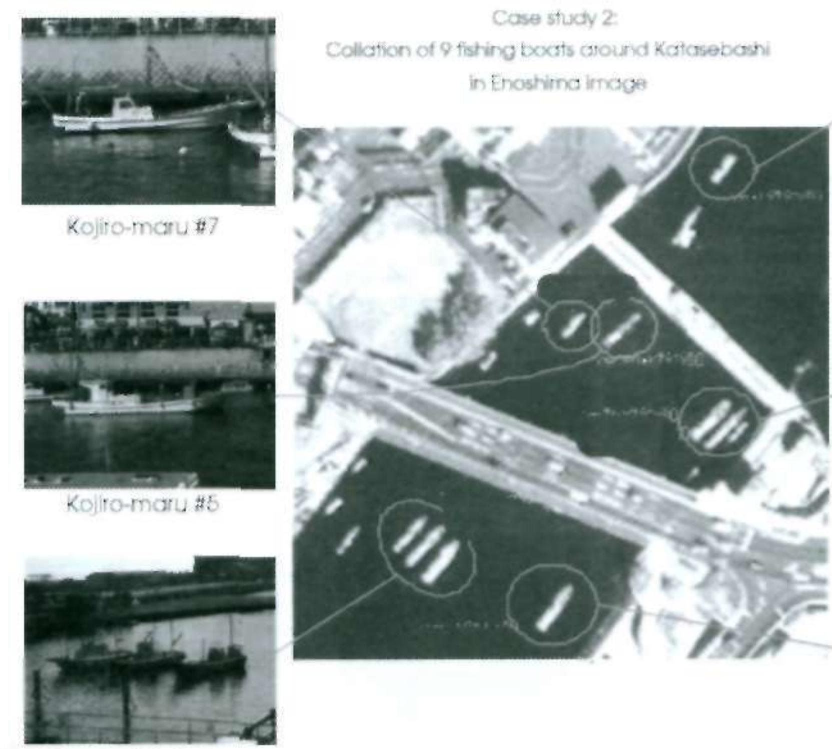

Fig. 18. Case study #2 (Enoshima).

difference in structure thing length were calculated for the vessel which was known as the same type as Hamagumo. The vessel collation decision algorithm was applied to the two Hamagumo-type vessels extracted from the Tokyo bay image, then each evaluation parameter was calculated (Fig. 17). Both the differences in the standard ship pattern and the differences in the entire length and width were within lm, which were good results, comparing with the pixel size of lm in the original image.

On the other hand, the difference in structure thing length was a little large value of 2.7m.

(B) Enoshima -collation of nine fishing boats-

The difference in standard ship form, the difference in entire length and width and the difference in structure thing length were calculated for the vessel which was not the same type but a form had a resemblance, and the relationship between the similarity and the difference in standard ship form and the difference in entire length and width was examined. Fig. 18 indicates the vessel around Katase-bashi bridge in the image of Enoshima. The result of collation of these nine vessels is shown in Table 3 (The difference in structure thing length is not evaluated because the structure things of some vessels cannot be detected). When the conditions judged the same shape vessel were defined as "the standard ship pattern difference <0.3" and "the entire length and width difference < 0.3", the combination example of the "same shape" vessel is shown with the vessel photograph and each parameter in Fig. **19.**

III. Conclusions

The results in the present study from the two examples of case studies analyzed by the high resolution analytic algorithm and vessel detection algorithm using the high resolution

Fig. 19. Combination example of the "same shape" vessel.

satellite data such as IKONOS arc as follows:

The size and the form of two vessels are as similar as the difference in standard ship form and the difference in entire length and the width between the two vessels are small. Therefore, the same shape vessel can be judged from the difference in standard ship form and the difference in entire length and the width. However, the difference in structure thing length isn't always small even if the difference in standard ship form and the difference in entire length and the width of the vessel is small. These results demonstrate that the collation of the vessel can be judged by using the algorithm for the high resolution image developed in the present study.

Reference

Eldhuset, K: "An automatic ship and ship wake detection system for space-bone SAR image in costal region", IEEE transaction on Geoscience and Remote Sensing, Vol. 34, No. 4, pp. 1010-1019,1996.

Flett, D., Youden, J., Davis, S., Randell, C, Arkett, M: Detection and discrimination of iceberg and vessel using RADARSAT Synthetic Aperture Radar", Ship Detection in Costal Water Workshop Agenda, Canada, 2000.

Foulkes, S. B., Booth, D. M: "Ship detection in ERS and RADARSAT imagery using a self-organising Kohonen Neural Network", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Lin, L. L.,Kwoh, Y. L.,Khoo, V: Ship and ship wake detection in the ERS SAR imagery using computer-imaged algorithms", Proc. International Geoscience and Remote Sensing Symposium (IGARSS' 97), Singapore, 1997.

Kourti, N., Shepherd, J., Verbrgh, J: "Fishing boat detection by using SAR imagery", Ship Detection In Coastal Water Workshop Agenda, Canada, 2000.

Olsen, R. B., Vachon, P. W, Wahl, T: "Vessels Detection Using Imagery, Current status and some view for future", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Robertson, N., Bird, P., Brwonsword, C: Ship surveillance using RADARSAT scan SAR image", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Vachon, P. W, Campbell, J. W M., Bjerkelund, C. A., Dobson, F. W, Rey, M. T: "Ship Detection by RADARSAT SAR: Validation of detection model prediction", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.