SPACE-BASED OCEAN SURVEILLANCE AND SUPPORT CAPABILITY

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ABSTRACT:

The use of satellite remote sensing in maritime safety and security can aid in the detection of illegal fishing activities and provide more efficient use of limited aircraft or patrol craft resources. In the area of vessel traffic monitoring for commercial vessels, Vessel Traffic Service (VTS) which use the ground-based radar system have some difficulties in detecting moving ships due to the limited detection range. A virtual vessel traffic control system is introduced to contribute to prevent a marine accident such as collision and stranding from happening. Existing VTS has its limit. The virtual vessel traffic control system consists of both data acquisition by satellite remote sensing and a simulation of traffic environment stress based on the satellite data, remotely sensed data. And it could be used to provide timely and detailed information about the marine safety, including the location, speed and direction of ships, and help us operate vessels safely and efficiently. If environmental stress values are simulated for the ship information derived from satellite data, proper actions can be taken to prevent accidents. Since optical sensor has a high spatial resolution, JERS satellite data are used to track ships and extract their information. We present an algorithm of automatic identification of ship size and velocity. This paper lastly introduce the field testing results of ship detection by RADARSAT SAR imagery, and propose a new approach for a Vessel Monitoring System(VMS), including VTS, and SAR combination service.

KEY WORDS: Virtual Vessel Traffic Control, RADARSAT/SAR, Ship Detection, VTS.

1. INTRODUCTION

For about the 15 years after 1951, synthetic aperture radar (SAR) technology remained almost exclusively within the domain of military reconnaissance, but by 1965 ocean scientists were already advocating the use of "present day radar technology to give a complete description of the sea state"[1]. After several years of SAR applications research in both the United States and Europe, the U.S. National Aeronautics and Space Administration (NASA) launched the first civilian spaceborne SAR in 1978. Even in its unexpectedly brief 98 days, the Seasat SAR(1.275 GHz, HH-polarization) revealed marvelous patterns of winds, waves, and current features over the ocean never before seen in such abundance and scope[2),3)].

The potential of SAR for Earth science commercial and civil applications is being advanced by several satellite systems, including Shuttle-based SAR flights (SIR [Shuttle Imaging Radar]-A (1981, L-band, HH) , SIR-B(1988, L-band, HH), SIR-C/X-SAR1(1991/1992, L-,C-,X-band, HH/VV/HV/VH)) and the European Space Agency's (ESA's) ERS-1(1991) and ERS-2(1995) (Table 1). Significant contributions are also being realized from Japan's JERS-1, Canada's Radarsat-1(1995) and ESA's Advanced Synthetic Aperture Radar (ASAR)(Envisat, 2002). Future systems such as Radarsat-2 and Japan's Ministry of International Trade and Industry (MITI) SAR-2 and Phased Array type L-band Synthetic Aperture Radar (PALSAR), an instrument proposed for the Advanced Land Observing Satellite (ALOS), promise to add even more data and processing knowledge to the global pool of SAR experience.

SAR has the capability to detect both stationary and moving ships on the ocean. Ships are good microwave reflectors, or hard targets, in a sense acting as radar corner reflectors. They return a large portion of the incident energy back to the SAR sensor and may appear in the SAR imagery as relatively bright points or elongated bright blobs. Due to this strong hard target behavior, the location of fishing fleets can be easily determined using SAR imagery. Successful SAR detection of ships depends, nevertheless, on the size and type of vessel, the prevailing wind speed conditions, the SAR resolution used and the viewing angle [4),5),6),7)].

With the increasing importance in monitoring ship traffic in both coastal and ocean waters, an automatic detection of ships, wakes, and ship velocity is very desirable. By using land-based radar, Vessel Traffic Service (VTS) has been developed and applied in waterways around ports. The control of ships near coasts is currently supported by VTS radar but it is restricted because of available information limitations. In addition to that, the coverage of monitoring ships by the traditional VTS is limited to the bay area or the approach from the sea to a harbour. There is a requirement for improving the VTS to be able to cover areas where radar coverage is almost impossible to achieve.

A VTS and SAR combination service, therefore, could be an alternative proposal to expand vessel-monitoring coverage to ocean waters. The objective of this paper is to present the results of field experiment in detecting ships using RADARSAT-1/SAR File mode. VTS-radar data was used to validate the ship position obtained from

SAR imagery and to obtain a vessel code. Because the detection depends on the ship size and type, the incidence angle, and the sea state such as wind speed and wave height, in-situ data were measured and pictures of ships were taken aboard a ship.

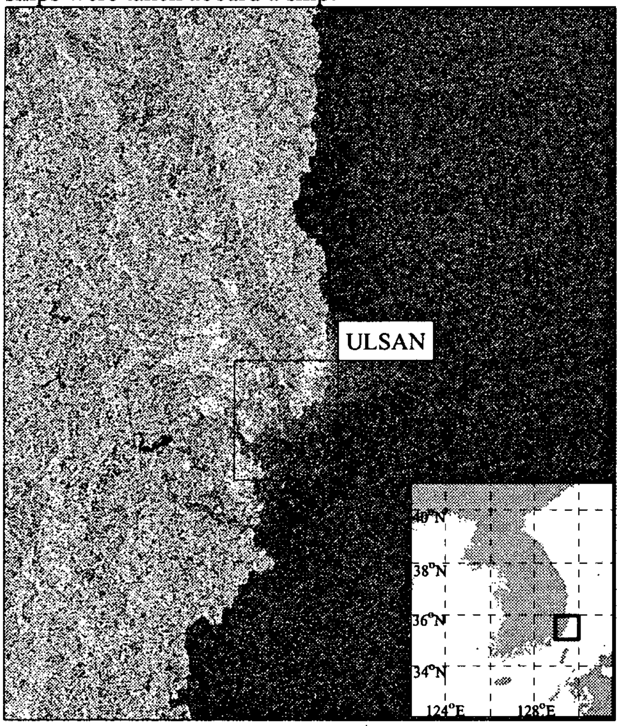

Figure 1. RADARSAT image, Ulsan Bay–centered East Coast of South Korea, June 19, 2004.

Table 1. Data Descriptions and Weather Conditions

Specification of RADARSAT SAR	Acquisition Time/Center (LT)	June 19, 2004 06:19:07	August 6, 2004 06:19:01
	Mode	Fine/Descending	Fine/Descending
	Incidence Angle (Deg)	41.21	41.21
Weather Conditions	Wind	2.6-3.2m/s, NW	0-0.4m/s, NW
	Wave	Calm	Calm

2. Data

1) SAR Image Data: Fine Mode

RADARSAT-1 satellite SAR data were acquired on June 19 and August 6, 2004 and processed at the Korea Earth Observation Center (KEOC) as shown in Fig. 1 and Table A. SAR image is calibrated to geophysical (sigma naught) values of radar cross section (RCS) even if data numbers (DN) on these detected images can be viewed as indicating relative radar backscatter intensities. Wind data was acquired from Hwaamchu station (Fig. 2). During the first SAR data acquisition, northwest winds, with speeds from 2.6 m/s to 3.2 m/s were recorded, and during the second acquisition there was below 0.4 m/s winds.

2.2 Validation Data

Validation data includes ship name, call sign, latitude/longitude position, ship size and type, and ship photographs from the scene.

- Automatic Identification System (AIS) GPS ship position
- Vessel Traffic Service (VTS) data: vessel code, radar image
- ship photographs from the scene

The vessels tracked by the Ulsan-VTS during the SAR acquisition are shown in Figs. 3 and 4, and listed Tables B and C.

1. SHIP DETECTION ALGORITHM

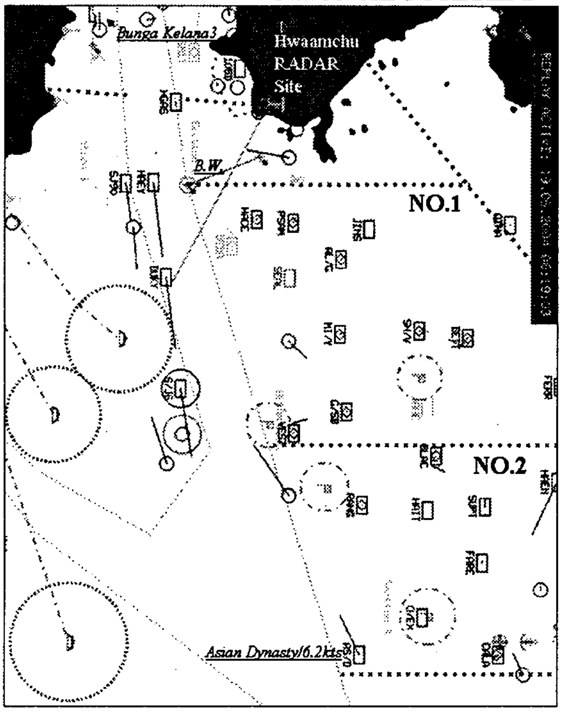

Figure 3. VTS-Radar based ship locations and codes: June 19, 2004

Table B. Ship Information: June 19, 2004

Ship Name	**Ship Code**	**Length(LOA, m)**	**Breadth(m)**	**Depth(m)**	**Type of ship**
HANYANG ACE	HACE	78	13	7	Petroleum Product Tanker
PACIFIC SAMBU	PSAM	84	14	8	Chemical Tanker
DE DA	DEDA	90	16	8	Towing Tug
ALPHA GAS	AL/G	93	16	7	Liquefied Gas(LPG) Tanker
SEA LINE	SEAL	70	12	6	General Cargo
SUPERTEC	SUPT	185	32	16	General Cargo
HAE NAM	HAEN	60	10	5	Petroleum Product Tanker
ASIAN DYNASTY	AS/D	193	32	20	Car Carrier
BUNGA KELANA 3	_Alongside_	236	42	21	Oil Tanker

The proposed structure of the detection algorithm is illustrated in Fig. 5. The principle of the detection algorithm is based on the theoretical considerations and practical experience, and the algorithm use a processing chain consisting of calibration, land masking, thresholding, point positioning, labeling technique, morphological erosion, morphological dilation, morphological bridging, and attribute-extraction.

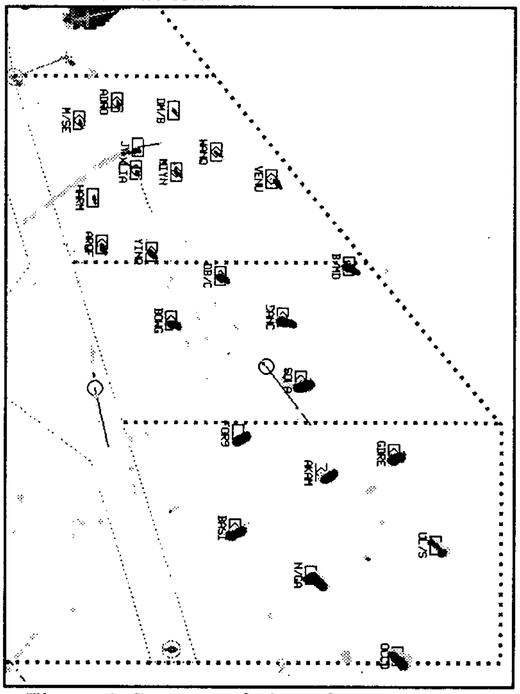

Figure 4. Same as of Fig. 3 for Aug 6, 2004

Table C. Same as of Table B for Aug 6, 2004

Ship Name	Ship Code	Length(LOA, m)	Breadt h(m)	Dept h(m)	Type of ship
Morning Sea	M/SE	79	14	6.7	Chemical Tanker
Harmony	HARM	68	11.6	5.7	General Cargo
Ocean Concord	OCCD	237	42	19.5	Petroleum Product
Navios Galaxy	N/GA	216	32.2	19.3	General Cargo
Akama	AKAM	174	32.2	19.1	Petroleum Product
Global Dream	GDRE	154	26	11	General Cargo Ship
Solar Oceania	Sola	162	27.2	13.4	General Cargo Ship
Formosa Nine	FOR9	167	30	14.2	Chemical Tanker
Danchi	DANC	171	32	14	Petroleum Product
Bunga Melati Dua	B/MD	168	30	15	Petroleum Product
DB Coral	DB/C	111	19.5	10.2	Chemical Tanker
Wanquanhai	WANQ	96	15.2	8.4	Petroleum Product
Venus Gas	VENU	84	15	7	Liquefied Gas(LPG)
Mi Yeon	MIYN	92	14.6	7.4	Petroleum Product
Basic Arron	BASI	182	32.2	16.5	General Cargo
Dongmyung Best	DM/B	73	13.6	7.7	General Cargo
Xin Liang	XLIA	85	16.2	7.2	General Cargo
Adoracion	ADRO	78	12.8	5.8	Chemical Gas
Pacific Crystal	P/CR	312	58	29.5	Crude Oil
Fine Hana	FH	62	10	4.5	Petroleum Product
Ju Yeon	JY	98	15.2	7.5	Petroleum Product
Yinquan	YINQ	105	16.4	7.8	Petroleum Product

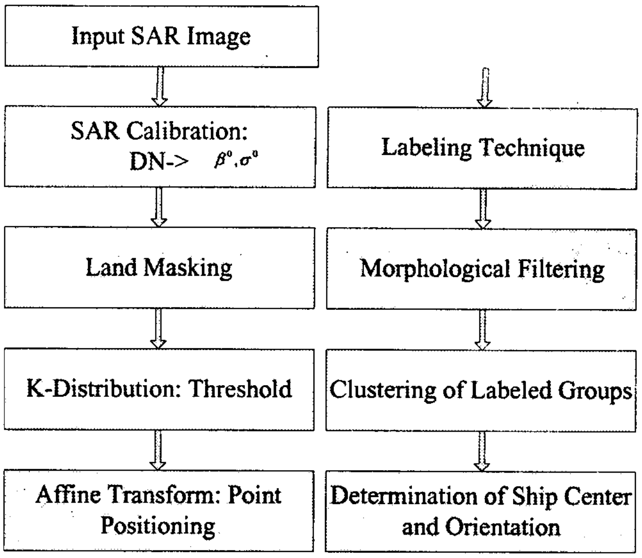

Figure 5. Flowchart of the proposed algorithm

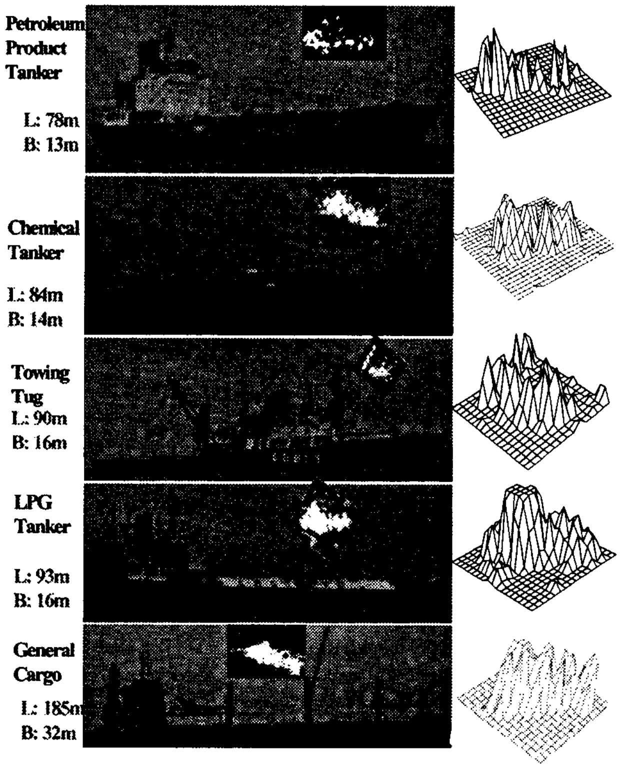

Figure 6. Vessel classification by RADARSAT Fine mode image (June 19, 2004): from left vessel information, photo, scattering locations of the vessel, and 3d intensity values.

The proposed structure of the detection algorithm is illustrated in Figure 5.

2. VALIDATION RESULTS

4.1 Case Study 1: Aug 6, 2004

Vessels at anchorage No. 1 and No.2 as shown in Fig. 3 are identified in SAR image (Fig.6). Breakwater (B.W. in

Fig. 3) is also not seen in the image, but the two lighthouses at each end of the breakwater appear as a bright dot.

Figure 6 shows an interpretation example of an extracted region containing a vessel signature.

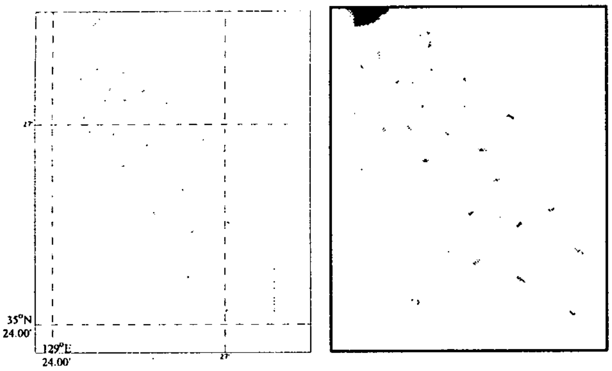

Figure 7. 23 vessels in anchorage from AIS positions (left) and RADARSAT candidate target positions (right): Aug 6, 2004.

4.2 Case Study 2: June 19, 2004

The validation process is straightforward, requiring comparison of ship validation positions with RADARSAT candidate target positions. As a validation data, 23 vessels in anchorage were selected, because their positions show hardly variation with time and are reported to VTS center using AIS. Figure 7 represents the locations of 23 vessels and RADARSAT-detected ship targets. Figure 8 is the superposition of the ship targets transmitted by AIS to VTS center (Fig. 7 left image) and the potential ship targets identified by SAR imagery. The SAR data detected all targets that were reported to VTS. In a portion of ships, a large discrepancy in position appears, but that is why the SAR-ship position is calculated as a centroid of potential ship area, and an AIS transmitter is installed on bridge.

3. CONCLUDING REMARKS

In this paper, we introduced a ship detection technique and its validation result. The main advantage of the method is that the difference of light intensities between a ship and the sea can be obtained quickly and automatically without human intervention.

Two fine imagery of Ulsan Port under calm condition were used to detect stationary ships at anchorage and reveals 100% accuracy for merchant vessels with a variety of types.

6. ACKNOWLEDGEMENTS

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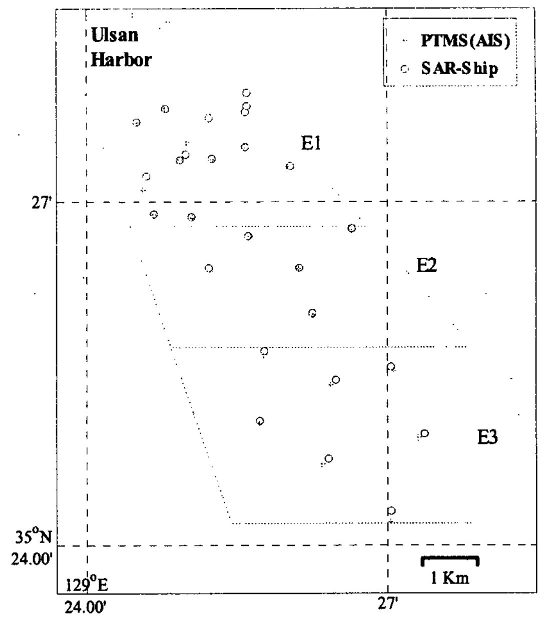

Figure 8. Collocated RADARSAT and AIS(VTS) targets.

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