Joint Use of Optical and SAR Data for Ship Detection

Gintautas Palubinskas, Peter Reinartz, Stephan Brusch and Susanne Lehner
Remote Sensing Technology Institute
German Aerospace Center DLR
Gintautas.Palubinskas@dlr.de

Abstract
The German Aerospace Center DLR and DigitalGlobe have been engaged in a modest R&D project to investigate complementary uses of Earth Observation (EO) and Radar data. Coordinated collections of TerraSAR-X and WorldView-1 data during July-August 2009 have been acquired. The near real time alerting/maritime situational awareness application has been tested. The imaging was performed within the same day. The low resolution, large swath radar image was used to detect ships and provide tip-off for high resolution EO imaging which in its turn provides alerts of on-going activity or actual ship ID/type. Data over Bandar Abbas, Iran and Persian Gulf have been acquired and analyzed. DLR own software SAINT was used for ship detection in radar images. The size and heading of a ship is estimated automatically. The velocity of a ship is estimated interactively using a radial velocity component, obtained from an azimuth displacement in radar image, and ship heading. Extracted information is used to predict ship position at the optical image acquisition time in order to provide an alert. First preliminary results are presented.

Keywords
Ship detection, speed estimation, route prediction, TerraSAR, WorldView-1, fusion

1 Introduction

For alerting and/or maritime situational awareness applications it is important the near real time acquisition of remote sensing data. Further interest is in detection of ships which are not covered by AIS in order to provide on-going activity or actual ship ID/type. Radar sensors are very suitable for these purposes due their daytime and weather independence and large coverage areas [2]. Optical sensors usually exhibit smaller swathes, but higher resolution thus making them more suitable for classification and identification tasks. Thus a joint radar and optical data collection can complement each other very well: radar data perform ship detection and give tip-off for optical imaging, optical data perform classification and identification. This paper presents an example of such joint radar (TerraSAR-X) and optical (WorldView-1) data collection and shows its potential for alerting and/or maritime situational awareness applications.

2 Methodology

This section first describes how a ship is detected in a radar image. Further its speed is estimated using azimuth displacement and finally the estimated position of a ship is predicted after some time amount, e.g. during the next data acquisition.

2.1 Ship detection in radar image

First, preprocessing including calibration, geolocation and land masking is performed on the radar image. Then, the ship detector implemented in DLR own software SAINT **(**SAR AIS (Automatic Identification System) Integrated NRT Toolbox) [1] is applied. It is based on the

CFAR (constant false alarm rate) detection with moving background window, Gaussian distribution assumption for an amplitude and adaptive threshold for a target detection

$$A_{Target} > \mu_B + \sigma_B \cdot c \;\Rightarrow\; \text{Target detected},$$

where A_{Target} is amplitude of a target, μ_B and σ_B is background mean and standard deviation, respectively and c is a constant factor, e.g. 6. Additionally, position (latitude, longitude), ship length and ship heading angle are derived.

2.2 Speed estimation

From the previously derived ship heading angle and at present still interactively measured azimuth displacement the ship speed can be calculated as

$$v = \frac{\Delta d \cdot v_{sat}}{R \cdot \cos\alpha \cdot \sin\theta},$$

where Δd is azimuth displacement, v_{sat} - satellite speed, R - slant range distance for a target, α - angle between speed vector and radial speed component, θ - incidence angle.

2.3 Position prediction

Given distance from a start point on Earth‘s surface and ship heading destination point is found in the following way

$$lat_2 = \text{asin}\left[\sin(lat_1)\cdot\cos\left(\frac{d}{R}\right) + \cos(lat_1)\cdot\sin\left(\frac{d}{R}\right)\cdot\cos(\beta)\right]$$

$$lon_2 = lon_1 + \text{atan2}\left[\sin(\beta)\cdot\sin\left(\frac{d}{R}\right)\cdot\cos(lat_1)\,,\ \cos\left(\frac{d}{R}\right) - \sin(lat_1)\cdot\sin(lat_2)\right],$$

where start point is (lat_1, lon_1), destination point – (lat_2, lon_2), d – distance travelled = speed * time, R – Earth‘s radius, β – ship heading angle. These formula account for the curvature of the Earth.

3 Data

TerraSAR-X and WorldView-1 data over Bandar Abbas, Iran and Persian Gulf have been acquired. Several characteristics of two sensors are compared in Table 1.

Table 1 Comparison of some TS-X and WV-1 characteristics

Sensor **Parameter**	**TS-X SM**	**WV-1**
Orbit	Desc/Asc	Desc
Viewing angle	20°-45°	±45°
Azimuth resolution (m)	3.3 (single pol.)	0.5 (nadir)
Ground range resolution (m)	3.5-1.7 (20°-45°)	0.5 (nadir)
Swath width (km)	30	17.6 (nadir)
Max contiguous area (km x km)	30x1650	60x110 (mono)
Revisit frequency	2.5 days	1.7 days at 1 m GSD
Scan direction	normal	normal, forward, reverse

Two scenes of TS-X (see Fig. 1 for footprints) were processed and analysed in the next section.

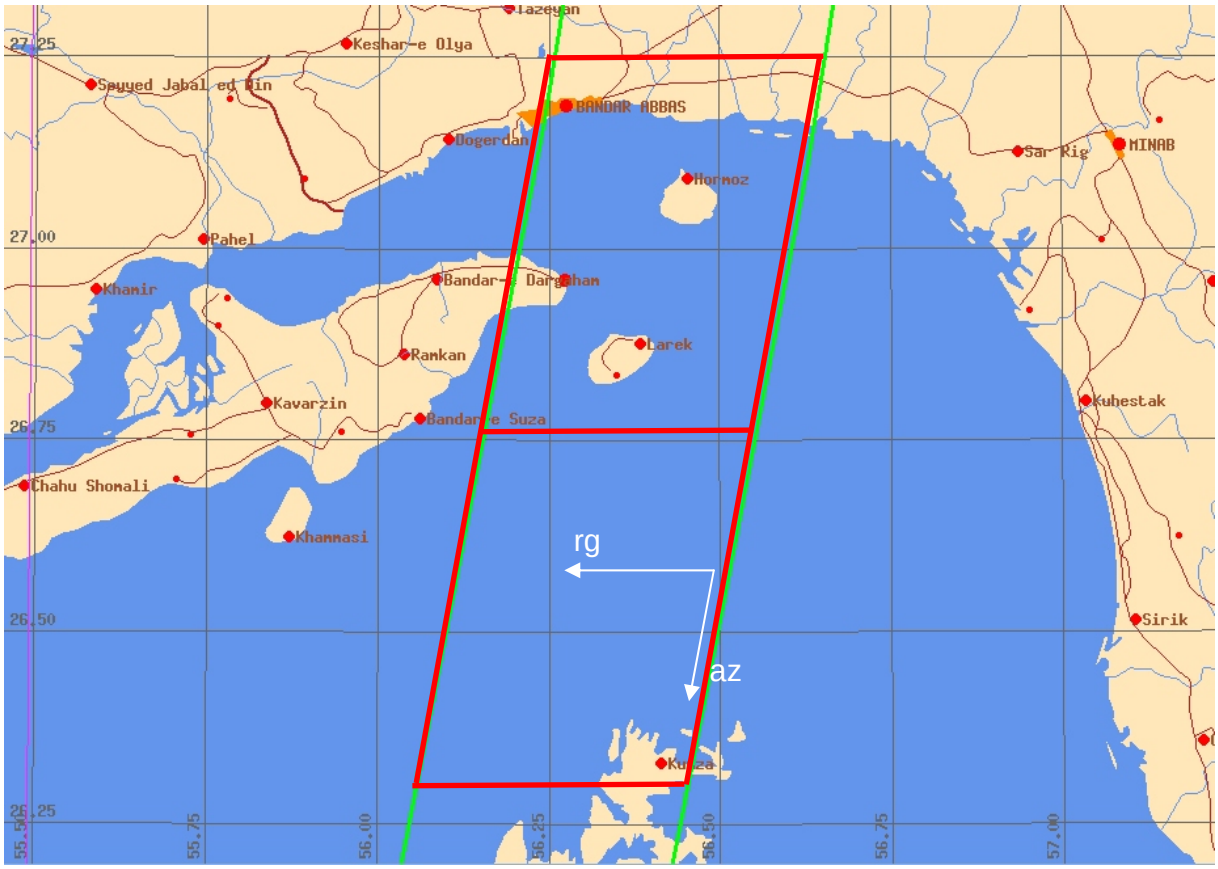

Fig 1 Footprints of two TS-X scenes (red boxes)

Acquisition area of WV-1 imagery is shown in Fig. 2.
The schedule of the TS-X and WV-1 data collection was the following:

TSX Image Time:	24-Jul-2009 02:22:07 (UTC)
Neustrelitz 2. DL Time:	24-Jul-2009 05:02:28
Minutes Before Plan:	35
WV1 Plan Time:	24-Jul-2009 05:37:47
WV1 UL Time:	24-Jul-2009 07:07:47
WV1 Image Time:	24-Jul-2009 07:33:53
Earliest WV1 DL Time:	24-Jul-2009 08:42:19

After the downlink of a radar image, the SAR processing usually takes about 1 hour and ship detection about 15 minutes for a scene size of 30x50 km^2.
Parameters of acquired scenes are summarized in Table 2.

Table 2 Parameters of acquired scenes

Sensor **Parameter**	**TS-X**	**WV-1**
Image time (local time)	24-Jul-2009 05:22:07	24-Jul-2009 10:33:53
Mode	StripMap	PAN
Look angle	21.3°	49.5°
Polarization	HH	-
Product	MGD	L2A
Resolution (m)	3.5 gr x 3.0 az	1.23 gr x 1.07 az

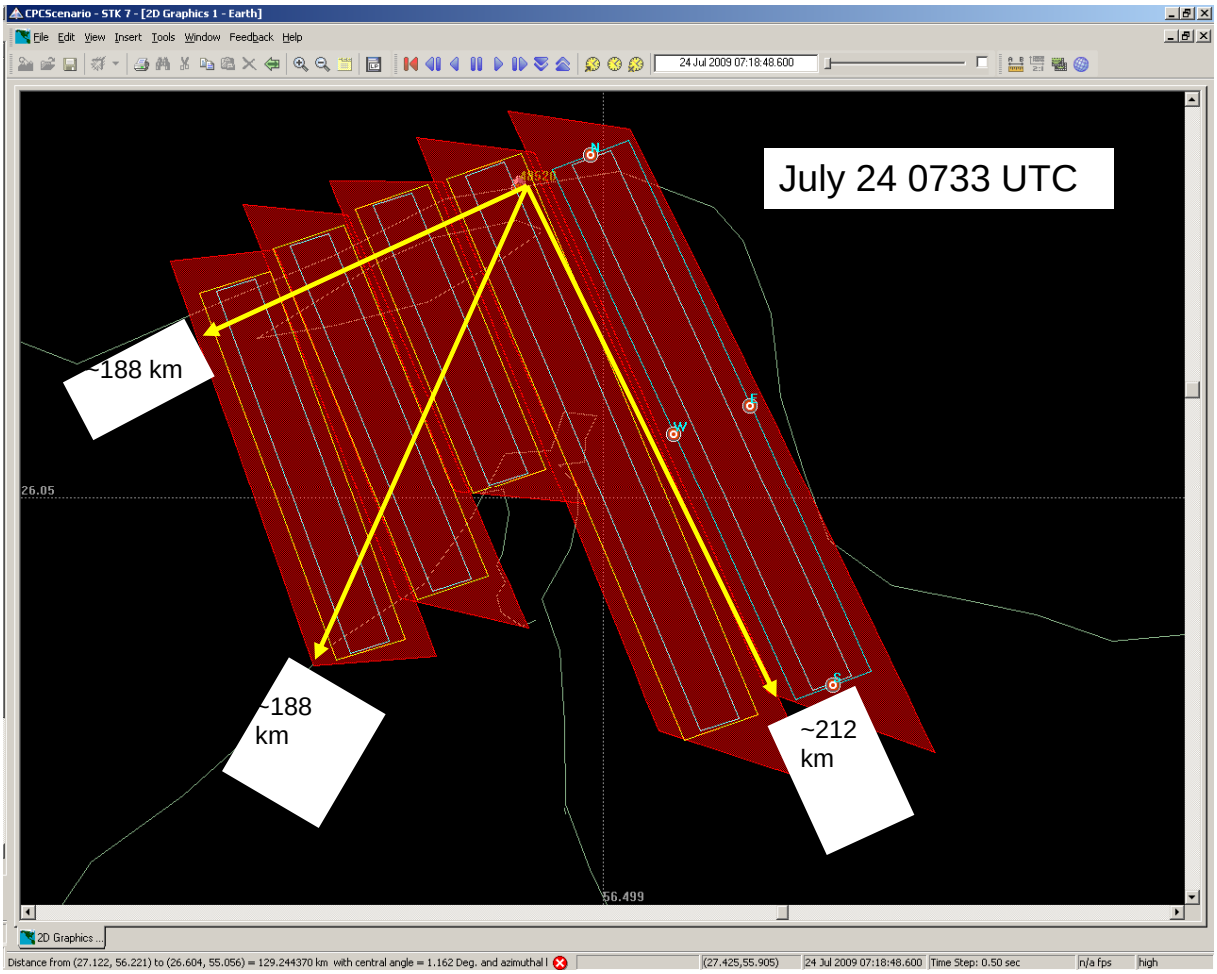

Fig 2 Acquisition area of WV-1 imagery (© DigitalGlobe)

4 Experiment

First, ship detection is performed in radar image. Detected ships (red circles) are presented in Fig. 3. There are several moving ships and a lot of false alarms. Ship No. 1 was selected for a tracking experiment. Parameters derived for this ship from radar ship detection are compared with reference data (AIS) in Table 3. Quite good correspondence is observed.

Table 3 Ship parameters from TS-X and AIS

Sensor **Ship parameter**	**TS-X**	**AIS**
Length (m)	215	182
Heading	234°	235°
Speed (knots/h)	13	14

Further, from the start position, ship heading and speed the destination position of a ship is predicted after about 5 hours (see Fig 3, red pin and red dashed line). This predicted position is deviating from the position of this ship in optical image (Fig. 3, green pin) mostly due to the change of the ship heading during the travel. A priori knowledge of a ship route could increase the accuracy of the prediction considerably. Nevertheless this experiment showed the potential of the fusion of different sensors.

Conclusion

TerraSAR-X StripMap imagery with about 3 m resolution result in relative small imaged areas 30x50 km^2. Ship size, heading and speed can be detected but classification is difficult. ScanSAR mode can be used for larger coverage area. Methods for an automatic speed estimation using split looks and focussing with FM rate are still under investigation [3].
WorldView-1 images under 1 m resolution can classify both small and large ships and in some cases identify them.
For an alerting or maritime awareness missions the local time difference between the current radar and EO satellites of about 5 hours makes tip-off and tracking difficult in high density traffic regions. A priori knowledge about ship routes can be useful for more accurate ship position prediction.

Acknowledgment

The WorldView-1 images have been acquired and processed by DigitalGlobe in the framework of a joint R&D project.

References

[1] Ship detection software SAINT **(**SAR AIS Integrated NRT Toolbox), DLR.

[2] S. Brusch, S. Lehner, E. Schwarz, and T. Fritz, „Near real time ship detection experiments“, Proc. OceanSAR 2009, Herrsching, Germany, 2009.

[3] M. Soccorsi, and S. Lehner, “Ship and currect speeds from TerraSAR-X”, Proc. OceanSAR 2009, Herrsching, Germany, 2009.

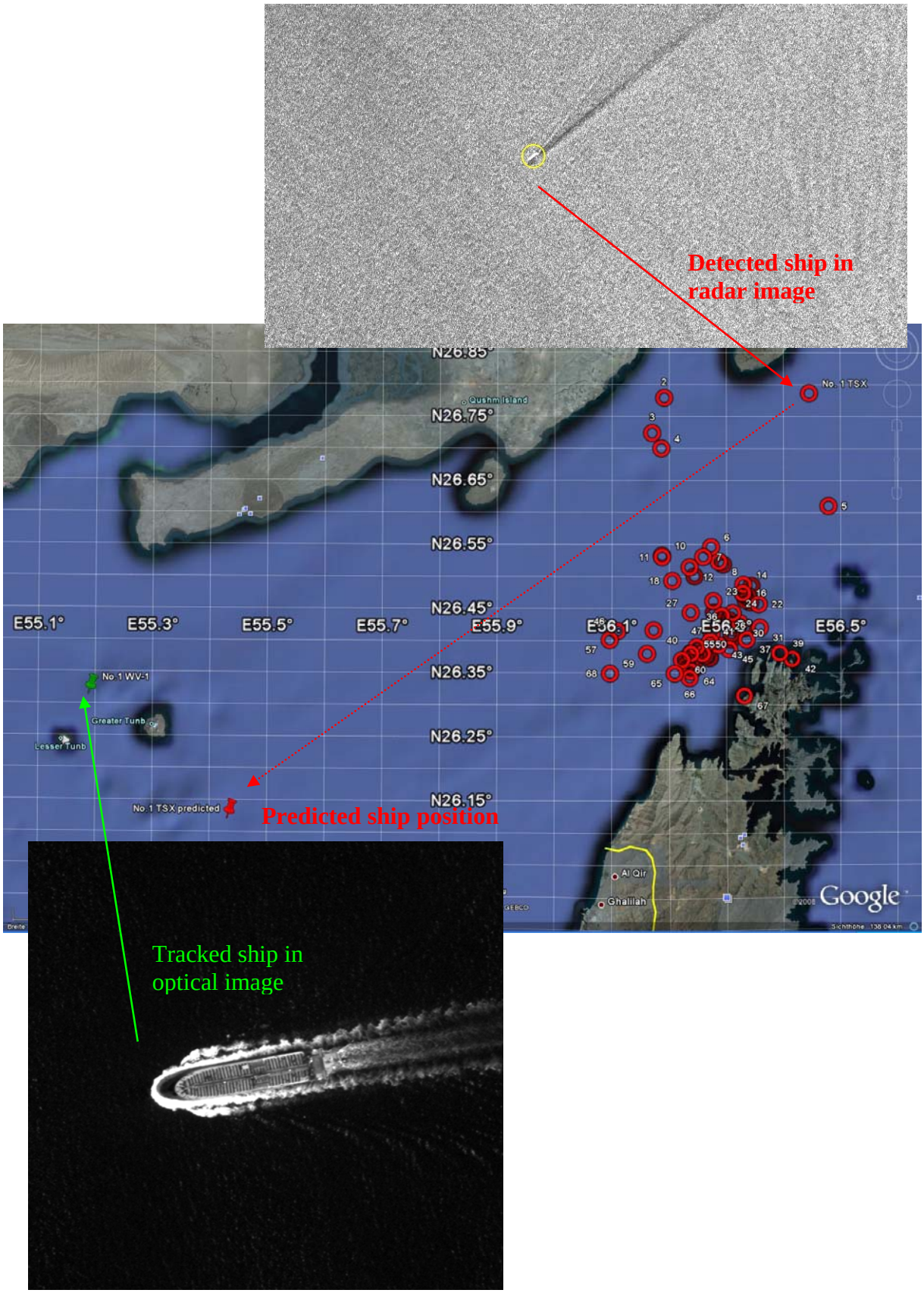

Fig 3 Illustration shows how detected ship in radar image is tracked into optical image. Red dashed line presents the predicted ship track.