Application of heterogeneous multiple camera system with panoramic capabilities in a Harbor Environment

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ABSTRACT

In a harbor environment threats like explosives-packed rubber boats, mine-carrying swimmers and divers must be detected in an early stage. This paper describes the integration and use of a heterogeneous multiple camera system with panoramic observation capabilities for detecting these small vessels in the Den Helder New Harbor in the Netherlands. Results of a series of experiments with different targets are presented. An outlook to a future sensor package containing panoramic vision is discussed.

Keywords: Panoramic Vision, IRST segment, Detection, Image Enhancement, Image Fusion, Image Stitching.

1. INTRODUCTION

1.1 Background

History has proven that commercial and military vessels are vulnerable to asymmetric and volatile threats posed by terrorists and pirates. This threat is not only present at sea, as shown by the numerous attacks on commercial vessels in recent years [7], but also in harbors as was demonstrated by the attack on the USS Cole in 2000. The USS Cole was bombed in the harbor of Aden (Yemen) by a small craft approaching the ship from the port side killing 17 crewmen and damaging the ship's hull (Fig. 1)[3, 4].

Fig. 1 Damaged hull of USS Cole [4]

Observation of these asymmetric threats at an early stage is indispensable to give the vessels sufficient time to react with appropriate measures. New techniques and approaches are required to support the crew to detect, classify and identify these threats, clock round against complex backgrounds and during adverse weather conditions.

1.2 Objectives

A trial was defined to collect data in order to demonstrate the feasibility of new techniques and approaches to detect, track, recognize and identify small surface targets in and near a harbor environment.

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For the purpose of the trial a sensor network had been set up consisting of a heterogeneous set of cameras with panoramic observation capabilities, radar and an automated identification system (AIS). The sensor network was used to collect data of small surface targets in and near the New Harbor of Den Helder, in the Netherlands, in October 2008.

The collected data will be used in several studies involving the target detection, clutter reduction, classification, fusion and cueing based on infrared images and radar measurements. The first approach uses the wide field-of-view infrared images and radar to produce plots (detections, contacts) that will be sent to their individual trackers (MT3, MT2) to build target tracks. The second approach uses the plots to send to another tracker (M6T, [12]) that first builds infrared and radar tracks and secondly fuses them. The final approach uses both infrared and radar plots first to fuse within the M6T tracker (i.e. plot fusion) and secondly to build the fused tracks (Fig. 2).

After building the infrared, radar or fused tracks, they can be used for further action, e.g. to cue narrow field-of-view cameras on the plots of interest (Fig. 2). Images of different narrow field-of-view cameras can be fused (image fusion), and merged into the wide field-of-view images (image stitching) to enhance target recognition and identification by the human operator. Moreover, automated systems will be able to determine more and more accurate object attributes, which on the one hand will contribute to automated management of cameras and radar, and on the other hand will contribute in the compilation of an improved common operational picture. The latter forms the basis for decision making processes and subsequent actions [9].

Studies involving target detection, tracking and classification based on infrared images and radar are carried out among others within the TNO [10, 13]. Studies involving plot and track fusion are carried out among others within the current project [see acknowledgements]. The results of these studies, however, will be presented in future papers. In SPIE paper [8] results of new classification algorithms will be discussed which will use the collected data described in this paper.

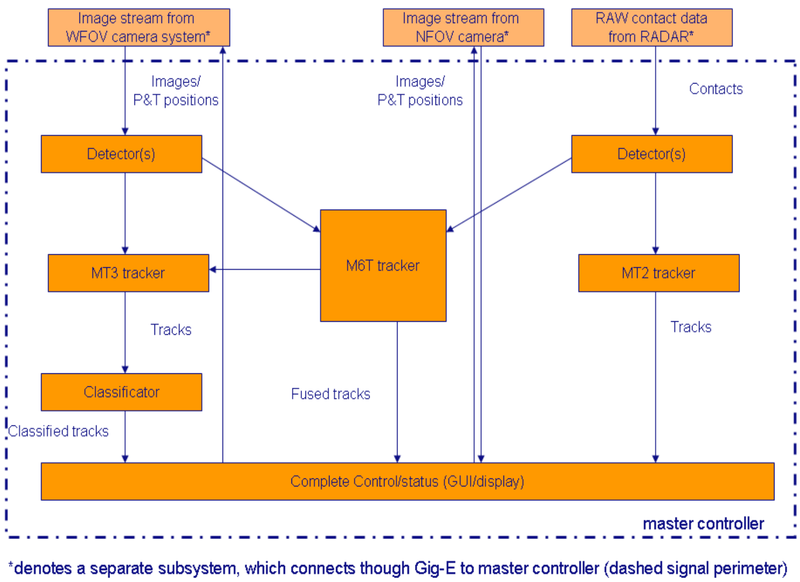

Fig. 2 Cueing, contact and track fusion scheme: Cueing of narrow field-of-view camera based on fused radar and wide field-of-view camera plots (or tracks).

1.3 Results

This paper describes the trial setup including the attack scenarios of the targets, the sensors used, the data collection network and the sensor data acquired. In addition some examples are given of new approaches to present target image data in order to enhance situation awareness. In Section 2 the trial setup, attack scenarios, sensors and data collection network are described. An overview of the acquired data including additional data like weather station and radiosonde data is given in Section 3. Examples of image stitching, image fusion, and a new approach are described in Section 4. Some conclusions are drawn in Section 5.

2. TRIAL SETUP

A trial was defined to collect data in order to demonstrate the feasibility of new techniques and approaches to detect, track, classify and identify small surface targets in and near a harbor environment. For the purpose of the trial a littoral (offshore) and a harbor scenario were defined. Both scenarios were adapted from a generic scenario in which a docked frigate was attacked by small surface targets. The targets approached the frigate from the sea side or from inside the harbor.

2.1 Scenario

2.2 General attack scenario

A target appears from behind an island and moves through a group of fishing vessels towards the frigate at slow speed. As soon as the target has left the group of fishing vessels, it accelerates and maintains a straight trajectory towards the frigate. The frigate detects and engages the target with gunfire as soon as it is within range of the surface gun. The target reacts with a weaving trajectory but maintains its general course towards the frigate. At first it carries out a weaving trajectory with a period of 20 s and as it comes closer the period increases (40 s). The speed of the target during the trajectories is constant.

2.3 Trial scenarios

In these scenarios the targets were sailing between the jetty of the isle of Texel and the harbor of Den Helder (littoral scenario) or within the confines of the harbor of Den Helder (harbor scenario). Target data like signature, position and velocity were collected using a heterogeneous set of cameras, radar and global positioning system (GPS). Where applicable AIS was used to gather information on other sailing objects. The cameras, radar and AIS were all located at the eastern pier of the harbor of Den Helder, near the collimation tower (Fig. 3). The GPS data loggers were fixed to the targets.

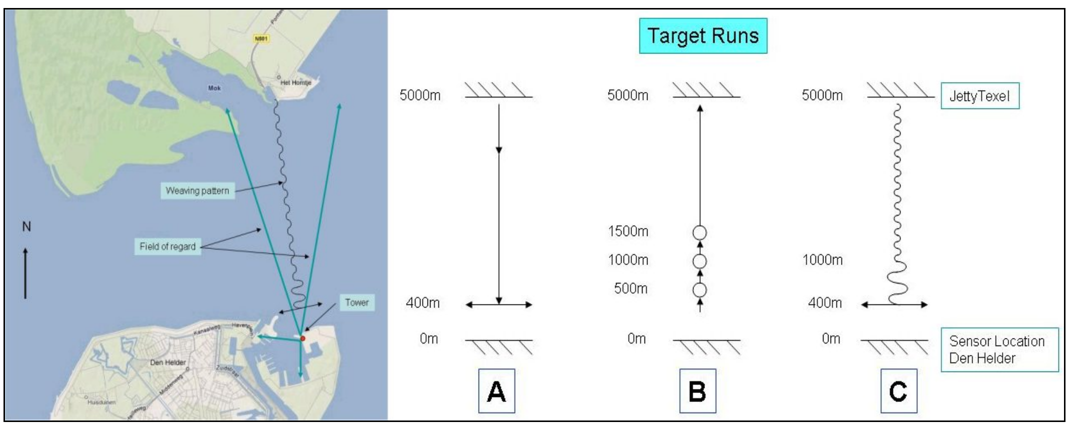

Fig. 3 Trial map of Den Helder and Texel (North). Measuring location is near the tower (left image, red dot). Right image shows for each target run three tracks: inbound straight line (A); outbound (B); inbound weaving (C).

<u>Littoral scenario</u>

Each target run consisted out of three tracks: an inbound straight line (Fig. 3, A), an outbound (Fig. 3, B) and an inbound weaving pattern track (Fig. 3, C). For track (A) the targets started at the jetty of Texel (approximately 5 km north of the measurement location). The targets came inbound at high speed in a straight line towards the sensors to about 400 m before the pier, and then turned to the East to make a final beam-on passage from East to West. For track (B) the targets went outbound towards the Texel jetty starting in front of the sensors. During this track the targets had to make circles: at 500 m, 1000 m and 1500 m. For track (C) the targets came inbound making a weaving pattern to abound 400 m before the measurement location, then turned to the East to make a final beam-on passage from East to West (second time). During this scenario the direction of the sensors is approximately north.

<u>Harbor scenario</u>

In this scenario no predefined tracks were used. One or two targets appeared from behind obstacles (other vessels) or near the quay and moved slowly towards the measurement location. At some moment the targets increased their speed towards the sensors simulating an attack.

2.4 Targets

Several small surface targets were arranged to sail the different attack scenarios. The targets arranged included two twin kayaks, a Landing Craft Rubber Motorized (LCRM), two rigid hull inflatable boats (RHIBs), two small patrol vessels and a jetski (Fig. 4, Fig. 5, Fig. 6). Furthermore several targets of opportunity passed the sensors' field-of-regard, among others the ferry (TESO) between Den Helder and Texel (Fig. 6).

Fig. 4 Kayak (left) and LCRM (right)

Fig. 5 RHIB (left) and small patrol vessel (right)

Fig. 6 Patrol boat and jetski in harbor (left image); RHIB and ferry between Den Helder and Texel (right image).

2.5 Cameras

In order to be able to develop algorithmic techniques to detect, track, classify and identify small surface targets in real-time a data collection trial was organized. Target data were collected with set of electro-optical cameras, radar and GPS. The cameras were mounted on a tripod on the roof of a building at 9m above sea level.

The set of cameras consisted of two long-wave infrared (LWIR) cameras with a wide field-of-view (WFOV) and 5 cameras with a narrow field-of-view (NFOV). Details of the cameras are tabulated in Table 1.

Table 1 Details of the cameras.

System	Type	Lens [mm]	Array	FOV	IFOV [mrad]	Output
WFOV LWIR	Vosskühler IRC 320	18	320 x 240	35 x 26º	1.9 x 1.9	Digital
NFOV MWIR	Radiance HS	75 mm	256 x 256	6.0 x 6.0º	0.4 x 0.4º	Digital
NFOV LWIR	AIM QWIP	250	640 x 512	3.9 x 3.0º	0.11 x 0.11	Digital
NFOV VIS (hot)	Marlin F-033B	75	640 x 480	4.9 x 3.7º	0.13 x 0.13	Fire wire
NFOV NIR	Merlin EM-247	Zoom	320 x 240	7.9 x 5.9º	0.4 x 0.4	USB
NFOV color	Hitachi HV-C20	Zoom	752 x 582	3.0 x 2.2º	0.07 x 0.07	Analog

Note: The Marlin F-033B camera was fitted with a Andover 775FW82 (∅=24mm) HOT filter, cutting off the near infrared wavelengths. The Raptor Photonics Merlin EM-247 EMCCD camera was fitted with a infrared transmitting Black Glass filter (Melles Griot 03FCG509), cutting of the visible wavelengths.

In order to track targets with the narrow field-of-view cameras they were mounted on a (Quickset) pan-tilt unit, which was fitted on to a second pan-tilt unit (see Fig. 7 and Fig. 8). The wide field-of-view long-wave infrared cameras were mounted on the second pan-tilt, allowing turning the camera set as a whole. This was useful as in one scenario the targets were sailing north of the harbor from and back to Texel, and in the other scenario the targets were sailing inside the harbor of Den Helder.

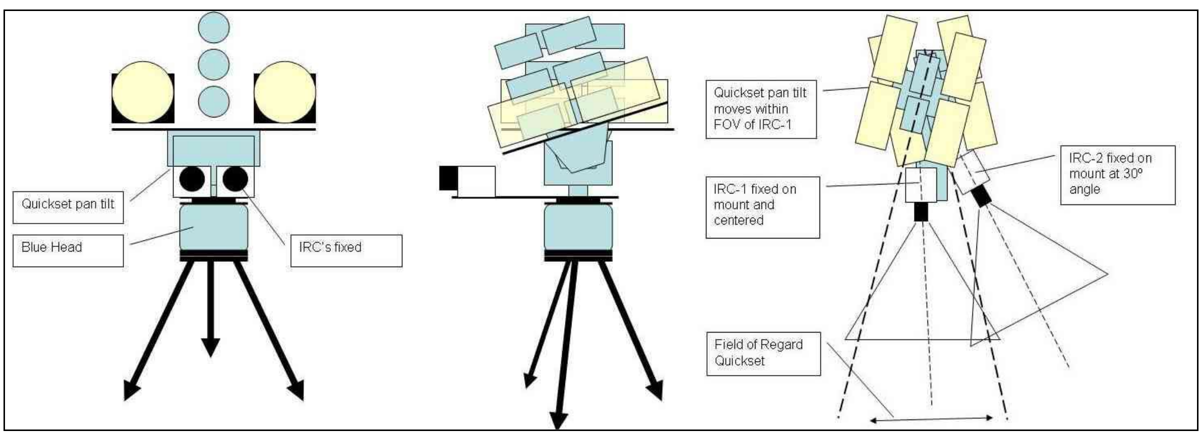

Fig. 7 Schematic view of cameras on two pan-tilt units and tripod; front view (left image), side view (middle) and top view (right).

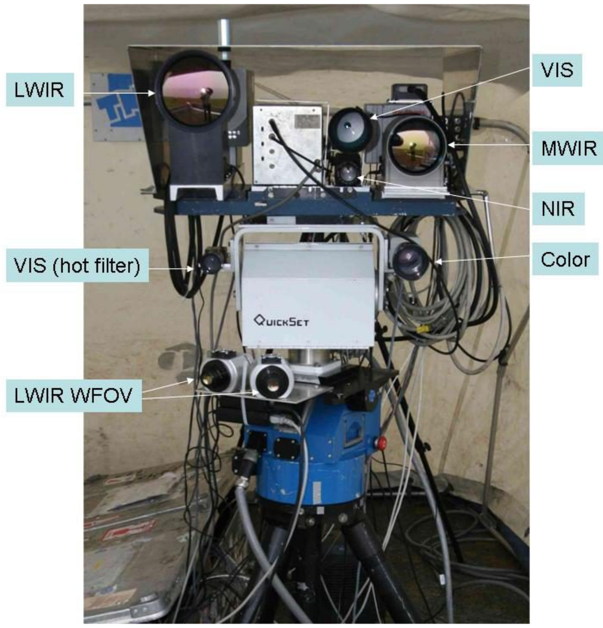

Fig. 8 Cameras on tripod.

2.6 Radar

The radar was mounted on a trailer that was located on the eastern jetty of the Den Helder New harbor. The antenna altitude was about 7m above sea level (see Fig. 9). The SHIRA radar is an X-band (9.6 GHz) navigation radar of which the main components are the radar antenna and the antenna drive.

The radar has a radar pulse length of 50 ns and horizontal pulse transmit and receive polarization (HH). The measurements have a maximum range of about 4.5 km, with a sampling in the range direction of 2.5 m. The 50 ns pulse length corresponds to a spatial (range) resolution of 3.75 m. The antenna beam width is 0.9 degrees. The rotation rate of the antenna is 1.5 s, corresponding to a maximum temporal frequency of 0.33 Hz [5].

Fig. 9 SHIRA radar located on the eastern jetty of the New Harbor in Den Helder.

2.7 Sensor network

Fig. 10 depicts the network of the camera data collection systems and hardware interfaces. The cameras were connected with the acquisition PCs via Gigabit Ethernet switches. In this way camera data could in principle be acquired, stored and accessed for processing purposes by each PC in the network. Automatic time synchronization of the data was obtained by connecting a time server via the network to each acquisition PC.

The radar data were acquired by a dedicated PC, which was not connected to the network. Time synchronization was done by hand frequently. The time for the time server was obtained from the GPS. Obviously, the target GPS did not require any further synchronization.

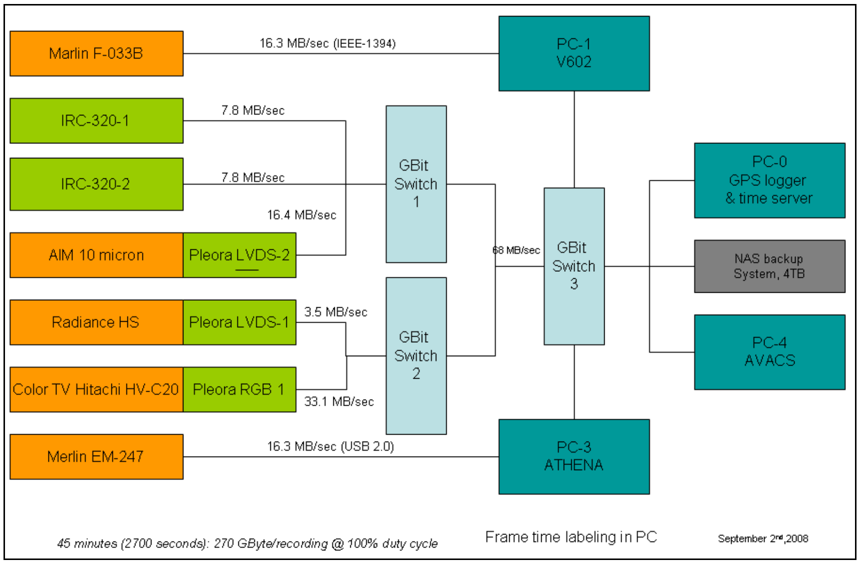

Fig. 10 Camera interconnection diagram with maximum expected data rates.

2.8 Additional equipment

During the experiment meteorological data was gathered by a mobile weather station (Fig. 11). This station measured the hemispherical short wave and long wave radiation, ambient temperature, air pressure, relative humidity, wind speed and direction and precipitation. In addition to these synoptic measurements radiosonde data were collected twice a day by the Navy meteorological office in the nearby airfield of De Kooy (Fig. 11).

Fig. 11 Mobile weather station located on the jetty near the observation station (left) and weather balloon with radiosonde launched at the Navy meteorological office on the airfield of De Kooy.

3. DATA

This section gives an overview of the data collected during the trial. Examples are given of the images obtained with the various cameras, the actual data and frame rates obtained during acquisition of the images, target position plot, weather and radiosonde data. Table 2 shows the resulting time table for each run. The 'LCRM sonar buoy' run was an additional run to test the acquisition equipment and to place a sonar to one of the buoys near the 'littoral' scenario area. The runs jetski 3, patrol 4 and RHIB 4 took place in the confine of the Den Helder harbor. The other listed runs took place between Den Helder and Texel.

Table 2 Realized target runs, dates and local time.

Date	7-10-2008	**Date**	8-10-2008	**Date**	9-10-2008
Run	**Local Time**	**Run**	**Local Time**	**Run**	**Local Time**
LCRM sonar buoy	08.30-09.45	LCRM 2	09.30-10.40	Patrol 3	10.00-10.45
Kayak 1	09.45-10.45	Kayak 3	10.45-12.00	RHIB 3	10.00-10.45
Kayak 2	09.45-10.45	Kayak 4	10.45-12.00	Jetski 2	10.00-10.45
LCRM 1	10.50-11.50	Jetski 1	13.40-15.00	Jetski 3	11.10-12.00
RHIB 1	12.00-13.30			Patrol 4	11.10-12.00
Patrol 1	12.45-15.00			RHIB 4	11.10-12.00
RHIB 2	14.30-15.40				

Fig. 12 and Fig. 13 show images of the patrol boat, jetski and RHIB in the harbor of Den Helder taken on the October, 9th 2008. The left image of Fig. 12 was acquired by the long-wave infrared wide field-of-view 'panoramic' camera. The targets are located within the projected circle. The right image shows images of the targets acquired by the mid-wave narrow field-of-view camera. Fig. 13 also shows images of the same targets, however, acquired with different cameras. Fig. 14 shows long-wave infrared narrow field-of-view images of the LCRM (left) and two twin kayaks taken outside the harbor (i.e. littoral scenario) on October, 8th 2008.

For each run the images were taken at almost the same time with partly overlapping fields-of-view. This allows for (new) techniques and approaches such as image stitching and image fusion (see Section 4). However, due to differences in sensor frame rates (Table 3), latencies, fields-of-view and parallax errors in target pixel positions between the different images can occur. The lowest frame rate realized was 9 frames per second for the Merlin EM-247 camera (Table 3). Given a maximum (lateral) speed of 70 km/h for the RHIB or jetski in the harbor resulted in a target displacement of 2 m per frame or 5 pixels at 1 km.

Fig. 12 Long-wave wide-field-of-view (left) and mid-wave infrared narrow field-of-view (right) images of patrol boat, RHIB and jetski in harbor of Den Helder.

Fig. 13 Visual (left), near infrared (middle) and long-wave infrared (right) images of patrol boat, RHIB and jetski in harbor of Den Helder.

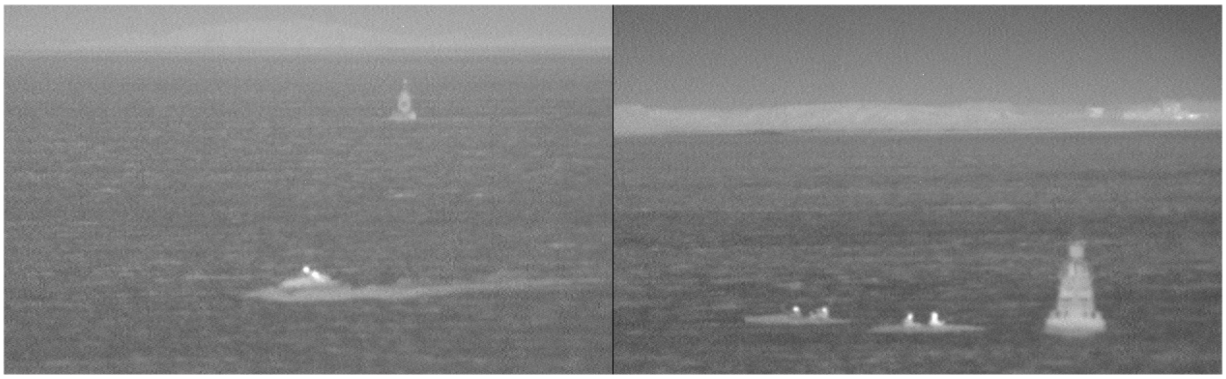

Fig. 14 Long-wave infrared narrow-field-of-view image of LCRM (left) and two twin kayaks (right) in littoral scenario North of Den Helder New Harbor.

Table 3 Data rates, frame rates and lateral displacement of target (v=70 km/h) per frame.

Camera	Data rate [Mbyte / s]	Frequency [frames / s]	Lateral displacement [pixel]
Vosskühler IRC 320	5.7	38	0.27
Radiance HS	3.2	25	1.9
AIM QWIP	6.5	11	16.1
Marlin F-033B	7.5	12	12.5
Merlin EM-247	6.0	9	5.4
Hitachi HV-C20	6.7	11	25.3

Fig. 15 shows AIS and GPS-data of trial targets and targets of opportunity recorded between 1-2 pm (Local Time) on October 7th, 2008. From this figure it can be seen that the RHIB (red cross) was in the middle of run 1 (Table 2) sailing a weaving trajectory between Den Helder New Harbor and the Texel jetty. Further, the ferry between Den Helder and Texel was identified as 'Schulpengat'. In Fig. 16 radar data are added. The figure shows data measured between 2:07 pm and 2:14 pm. Details around the patrol ship are given by Fig. 17 (cross-marker, right side of image). This figure shows a good match between the radar plots and the GPS-track of the patrol ship.

In addition to the camera, radar, AIS and GPS-data weather data were measured. This included radiosonde and synoptic data. The radiosonde data were measured using a weather balloon which was launched every trial day at 4 and 10 am (UTC) at the navy airbase 'De Kooy'. This launch area was located 4.5 km southwest of the trial site. Fig. 18 shows the radiosonde data relative humidity and temperature up to 8 km altitude.

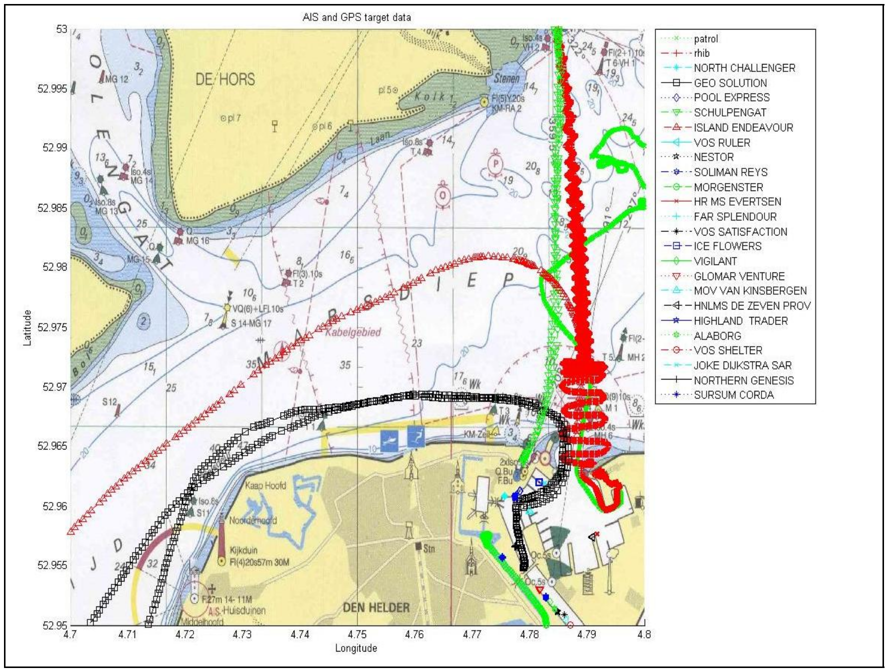

Fig. 15 AIS and GPS-data between 1-2 pm (LT), October 7th, 2008.

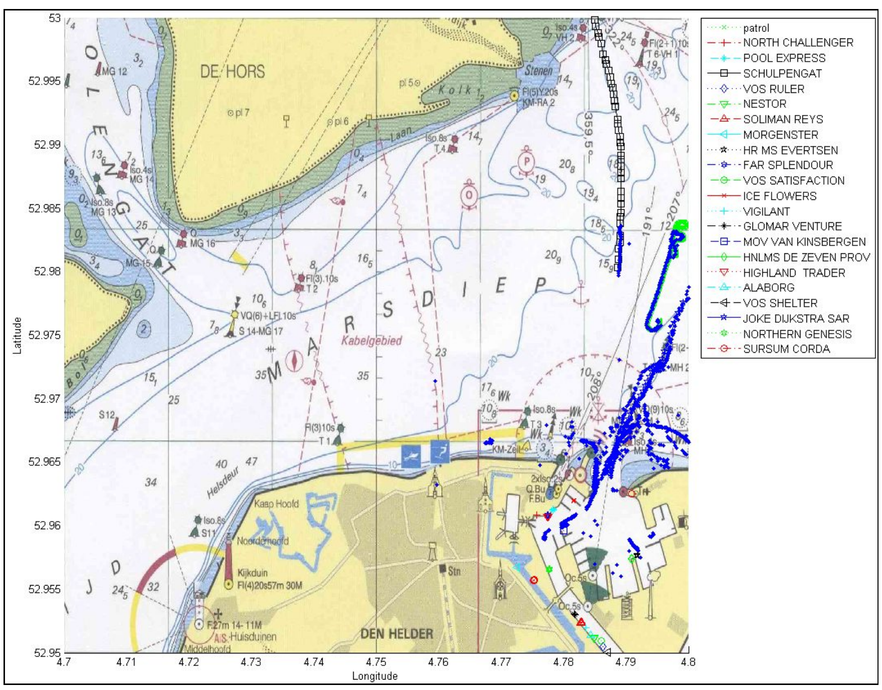

Fig. 16 Radar, AIS and GPS-data between 2:07-2:14 pm (LT), October 7th, 2008.

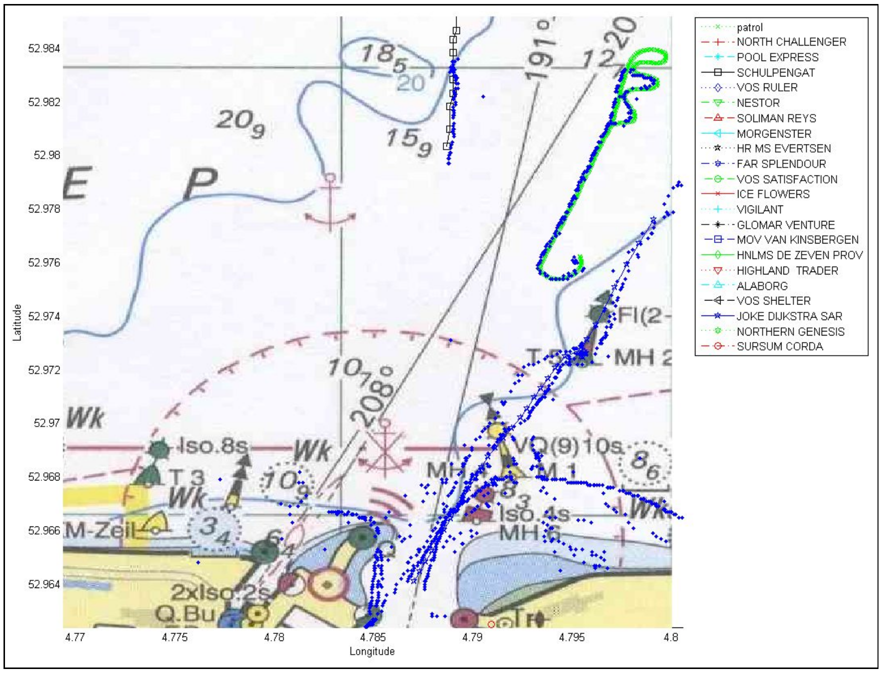

Fig. 17 Radar, AIS and GPS-data between 2:07-2:14 pm (LT), October 7th, 2008 (details).

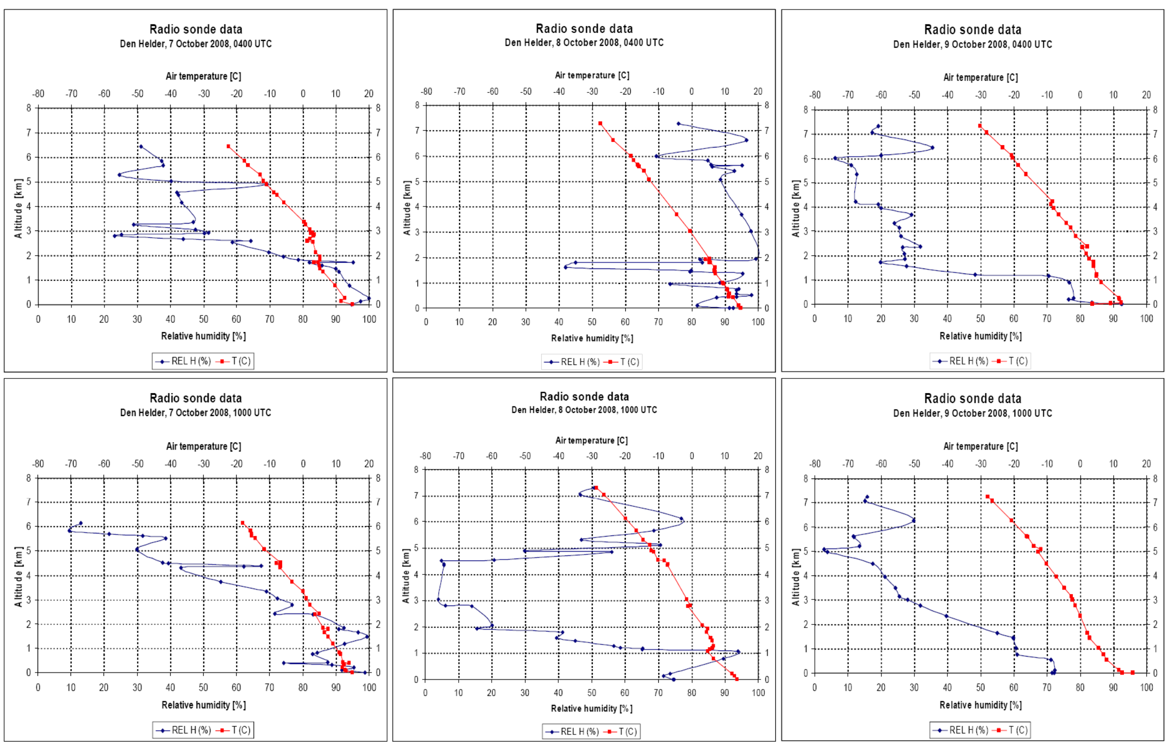

Fig. 18 Radio sonde data measured at the Navy Airbase (De Kooy), at 0400 h and 1000 h (UTC) on the 7th, 8th and 9th of October 2008.

The synoptic weather data were gathered by a mobile weather station located at the trial site. The data are shown in Fig. 19. The data is plotted against local time.

Both types of weather data can be used to feed models to predict the performance of e.g. the electro-optical sensors or radar to detect, track, recognize or classify small (surface or air) threats. This can be useful during the sensor selection or management process.

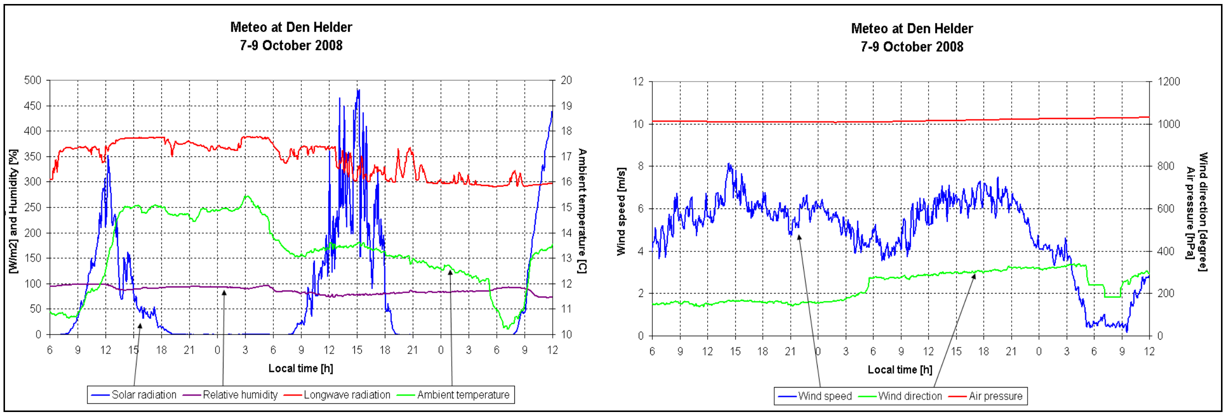

Fig. 19 Weather data measured at the Den Helder trial site on the 7th, 8th and 9th of October 2008.

4. NEW APPROACHES

Existing approaches for enhancing situational awareness are mainly focused on enlarging the observable field-of-view by stitching captured images or different camera views together. In this section we will propose two alternative techniques that go beyond creating a single overview image. The first technique is warping image data to absolute coordinates and the second is combining multi-resolution images. Further we will show two color representations of a multiband fused image that can enhance situational awareness.

4.1 Warping to absolute coordinates

Systems designed for situational awareness that use image stitching build a panorama image from several camera inputs. However, other sensor systems that are employed for situational awareness, such as radar, use a map-view of the world. In order to obtain a map view of the camera information it is necessary to transform the camera images to the ground plane. This requires an affine transform function for relating the camera image pixels to pixels projected onto the ground plane. The advantage is that when image pixels are transformed to the ground plane they can be shown in the same reference frame as radar. Alternatively, the radar data could be re-projected from a virtual ground plane into the panoramic image. Fig. 20 shows a normal camera image on the left. The right side shows a part of this image that has been projected to a map view.

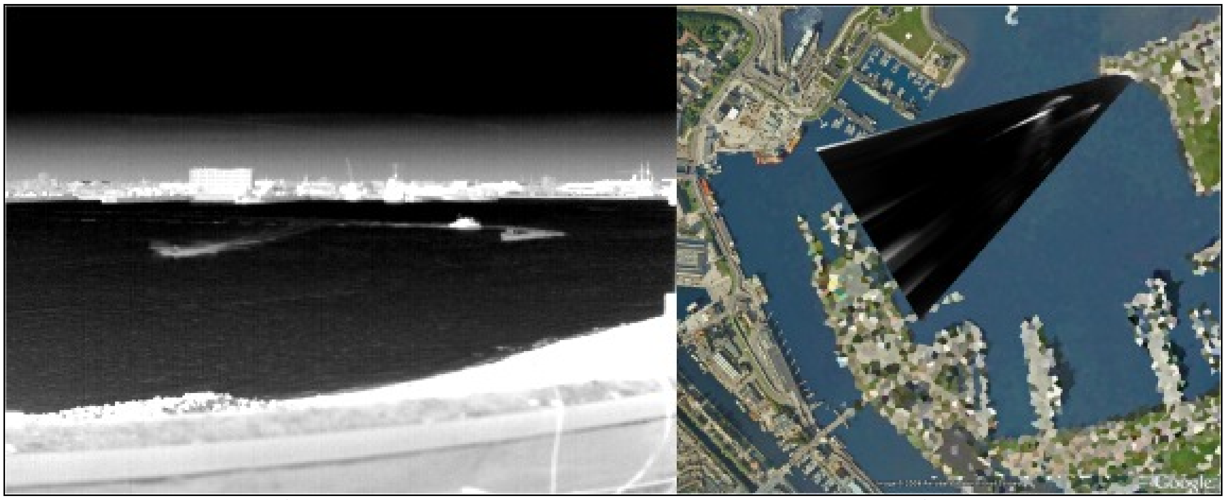

Fig. 20 Example of projecting a camera view to a map type view. Normal view (image left); map view (image right).

If it can be assumed that the local area near the camera is planar, the transformation between the camera and the ground plane can be described by a single homography matrix H. This matrix is based on both the camera intrinsic projection parameters and the 3D transformation between the ground plane reference frame and that of the camera.

Suppose that vector s indicates a point in the ground plane reference frame and that the same point in the image plane is indicated by vector P. Vector s can be transformed to the camera's reference by applying the correct 3D rotation matrix R and translation vector t:

$$\boldsymbol{s}' = \boldsymbol{R}\boldsymbol{s} + \boldsymbol{t}$$

Subsequently, the transformed vector s' can be projected, up to a scale λ, to the image vector P using the camera's projection matrix ***P***:

$$\lambda \boldsymbol{p} = \boldsymbol{P}\boldsymbol{s}' \quad \text{with} \quad \boldsymbol{P} = \begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix}.$$

Here, f_x, f_y and C_x C_y are intrinsic parameters, which are related to the cameras focal length and principal point. It can be shown that both the Euclidean transformation, defined by ***R*** and ***t***, and the image projection can be combined into the homography matrix ***H*** if 3D points indicated by vector ***s*** are coplanar:

$$\lambda \boldsymbol{p} = \boldsymbol{H}\boldsymbol{s}$$

This matrix can therefore be used to relate 2D points on the ground plane directly to 2D image points. In Zhang [6] it is shown how to estimate ***H*** and how to retrieve ***R***, ***t*** and ***P*** from this homography. The values of ***R*** and ***t*** have to be updated when the camera changes its orientation and position. When the camera is mounted on a ship, updates can be retrieved from the ships navigation sensors such as GPS and Inertial Navigation System (INS) .

4.2 Combining wide and narrow field-of-view cameras in panoramic imaging

Building a 360º panoramic image requires wide field-of-view cameras. Even if high-resolution image sensors are used, the distance at which targets can be detected or recognized will be limited due to the required large field-of-view. Naval vessels often utilize other cameras systems with a narrow field-of-view to observe targets at larger distances. These cameras are mounted on pan-and-tilt units in order to be able move the cameras field-of-view around and track targets. However, it is often difficult for an operator to keep track of the camera's azimuth and elevation based only on visual references.

A better solution would be to add the narrow field-of-view image to the panorama image obtained from the wide field-of-view cameras. In this case, the panoramic image formed by the wide field-of-view cameras can also be used to direct the narrow field-of-view (zoom) camera to targets. This idea is illustrated in Fig. 21. The top of the diagram shows an example panoramic image. A ship (target) is visible in this image. However, due to the wide field-of-view, there is a limit to the resolution in which the target can be observed. This limit can obscure important details required for recognition proposes.

In order to get a higher resolution image of the target, the panoramic image can be used to define a region of interest around the target. Based on the position of this region, a pan-tilt and zoom camera system can be queued to move its line of sight towards the target. This camera system then captures a narrow field-of-view image of the target. The resulting high resolution image is merged with the panoramic image in order to enhance the target details. Because all image data is merged into a singe display, the operator can zoom seamlessly between the panorama image for an overview of the situation and the high resolution image of the target for identification purposes.

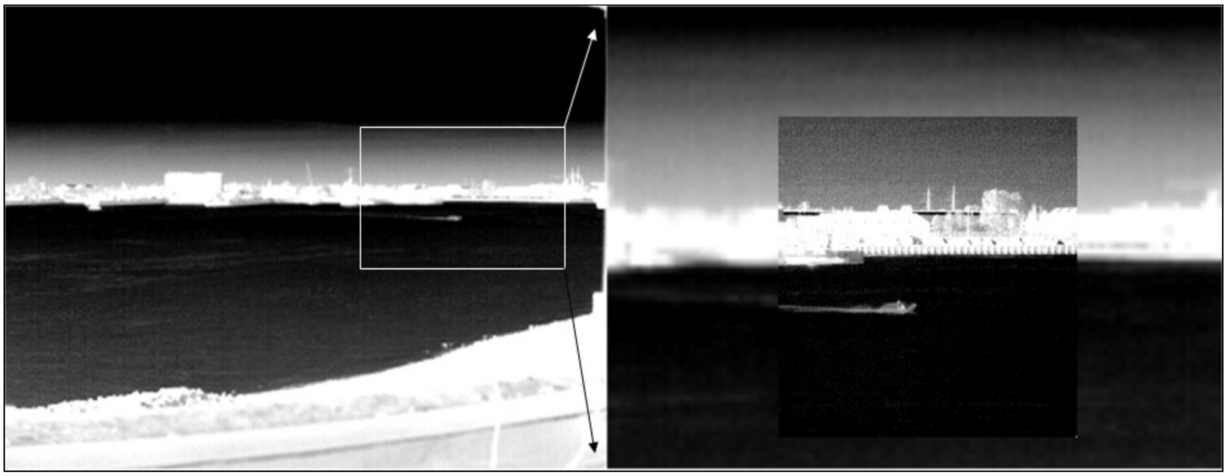

Fig. 21 Diagram of the novel situational awareness system. The mid-wave infrared panoramic image (left) is used to steer the pan-tilt and zoom camera to a target. The resulting (in this case long-wave infrared) narrow field-of-view image is combined with the panorama image in order to obtain a single situational picture (right).

4.3 Multiband image fusion

Currently, multi-band and hyper spectral imaging sensors in the thermal infrared are under development. These systems promise significant improvements in military task performance. With these new systems, targets may be distinguished not only on the basis of differences in radiation magnitude, but also on differences in spectral properties. A problem with presenting multi or hyper spectral imagery to a human observer is the (huge) amount of information. The question is how the data should be made available to the human visual system, i.e. which presentation offers the best information transfer. This also depends on the task at hand (e.g. detection, situational awareness, identification) and the prior information available [11].

In this paper we used two color representations to visualize a multiband image of a scene that occurred during the trial. The multiband consisted of four images of a frigate docked in the harbor with a group of people standing on the bow (Fig. 22). The four images were acquired by a near infrared camera (image left), a mid-wave infrared camera (second image left), a long-wave infrared camera (third image left) and a color camera (image right). In order to get the color representations first a principal component transformation was carried out. Next, the first three principal components were assigned with hue, saturation and value signals. The result image is depicted in Fig. 23 (left image). In this image there is a clear distinction between the people on the bow (dark dots on the left), the frigate, building, parking lot and the sky. Also sun reflections such as arriving from the parked cars are clearly visible (dark blobs on the lower right). In the right image of Fig. 23 the hue and saturation were taken from the color image. This color representation appears more natural. Now, the trees and grass are better visible. Both representations can enhance the situation awareness.

At night, when no daytime image is available, a recently developed technique for adding natural daytime colors to nighttime imagery can be used to enhance situational awareness and create a more intuitive image [14, 15]

Fig. 22 Images of a frigate docked in the harbor with a group of people standing on the bow. The images are acquired by a near infrared camera (first image left), mid-wave infrared camera (second image left), long-wave infrared camera (third image left) and a color camera (image right).

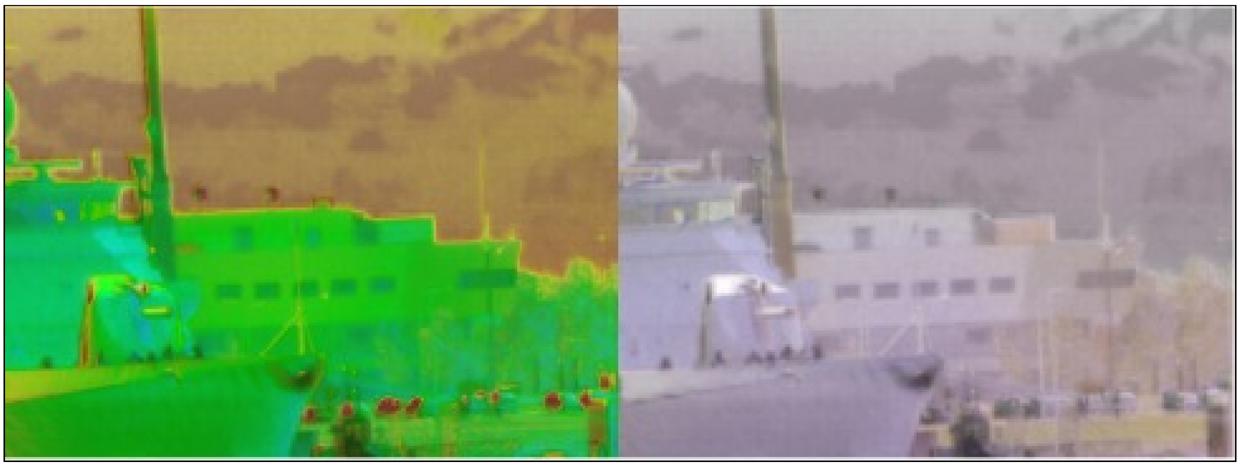

Fig. 23 Color representation of a multiband image using the first three principal components as hue, saturation and value signals (left). The multiband image combines a near infrared, mid-wave infrared, long-wave infrared and color image. In the image right the hue and saturation is obtained from the color image.

5. CONCLUSIONS

In this paper a trial was described to collect data with the purpose to demonstrate the feasibility of new techniques and approaches to detect, track, recognize and identify small surface targets in and near a harbor environment. It was demonstrated that a sensor network could be realized consisting of a heterogeneous set of cameras with panoramic observation and zoom capabilities. The data collected using this network was completed by radar, GPS, AIS, synoptic and radiosonde weather data. During the trial data had been collected of small surface targets in and near the New Harbor of Den Helder, in the Netherlands, in October 2008.

In this paper the application of a heterogeneous panoramic sensor and it's application in a harbour environment have been discussed. The combination of such a sensor combined with a high-resolution narrow field-of-view sensor has been demonstrated. Acquiring and fusing detailed imagery for classification whilst keeping an eye on the complete situation around your platform provides a major advantage. Combining the strength of overview and detail simultaneously brings constant situational awareness to future observation systems. A sensor package consisting of a static panoramic camera, combined with a fast narrow field-of-view heterogeneous camera set seems feasible.

In addition to the trial description some examples are given of new approaches to present target image data. These new approaches included warping of image data to absolute coordinates and combining multi-resolution and multiband images. The first approach is to project images to a ground coordinate system. It involves extrinsic camera calibration as well as using navigation sensors such as GPS and INS. This concept can be used to demonstrate how camera data can be combined with maps or detections from other sensors. The second approach combines detailed narrow field-of-view images obtained from a pan-tilt and zoom camera with those from a wide field-of-view panoramic camera system. All image data is merged into a single display, which allows for seamless panning, tilting and zooming between the panoramic view and the detailed narrow field-of-view of the zoom camera. This concept will demonstrate how to simultaneously keep an panoramic overview of the situation with the ability to zoom in on details for classification purposes. The third approach combines six multiband images into one fused image with two different color representations. These representations can enhance the situation awareness.

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REFERENCES

[1] "Dutch Frigate to Somalia against piracy", http://www.netherlandsembassy.ca, October 23, 2008.
[2] Eger, C., "US Aircraft Carrier Sunk", http://modern-war.suite101.com, March 31, 2008.
[3] "USS Cole (DDG 67), Command History", http://www.cole.navy.mil, October 12, 2000.
[4] "USS Cole bombing", http://en.wikipedia.org/wiki/USS_Cole_bombing.
[5] Kleijweg, J. C. M., Bree, R. J. P. van, Maarseveen, R. A. van & Smith, A. J. E., “Use of a navigation radar for detection of small surface targets and rapid environmental assessment”, TNO-DV 2007 A354, 2007.
[6] Zhang, Z., “Flexible Camera Calibration by Viewing a Plane from Unknown Orientations”, Seventh IEEE International Conference on Computer Vision, pp. 666—673, Corfu, Greece, 20-27 September, 1999.
[7] ICC Commercial Crime Services (CCS), http://www.icc-ccs.org
[8] Broek, S. P. van den, Bouma, H., Degache, M. A. C. & Burghouts, G., “Discrimination of classes of ships for aided recognition in a coastal environment”, SPIE Paper No. 7335-32, in press, 2009.
[9] Valkenburg-van Haarst, T., Norden, W. van & Bolderheij, F., “Automatic sensor management: challenges and solutions”, in ‘Optics and Photonics in Global Homeland Security IV’, eds. Halvorson, C.S., Lehrfeld, D., Saito, T.T., SPIE Vol. 6945, Published 17 April 2008.
[10] Schwering P.B.W., Broek S.P. van den & Iersel M. van, "EO System Concepts in the Littoral”, in 'Infrared Technology and Applications XXXIII', eds. Andresen, B.F., SPIE Vol. 6542-100, 654230, Orlando Florida (USA), April 9-13, 2007.
[11] Hogervorst, M.A., Bijl, P. & Toet, A., “Visualization of hyperspectral imagery”, in ‘Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XIII’, eds. Shen, S. S. & Lewis, P. E., SPIE-6565-16, 2007.
[12] Theije, P., de, Kester, K., & Bergmans, J., “Application of the M6T Tracker to Simulated and Experimental Multistatic Sonar Data”, Fusion 2006, Florence, Italy, July 2006.
[13] Ditzel, M., Lageweg, C., Janssen, J., & Theil, A., “Multi-target Data Aggregation and Tracking in Wireless Sensor Networks”, Journal of networks, 2008.
[14] Hogervorst, M.A., & Toet, A., “Method for applying daytime colors to nighttimeimagery in realtime”, in ‘Multisensor, Multisource InformationFusion: Architectures, Algorithms, and Applications 2008’, eds. Dasarathy, B.V., SPIE-6974, 2008.
[15] Hogervorst, M.A., & Toet, A., “Fast natural color mapping for night-time imagery”, Information Fusion, (in press) 2008.