D5.42 – Early Detection Module 2

Due date of deliverable: 31/03/2017
Actual submission date: 31/05/2017

Organisation name of lead contractor for this deliverable: UoR

Revision: 1.0

Grant Agreement N°: 607567
Project Acronym: IPATCH
Project Title: Intelligent Piracy Avoidance using Threat detection and Countermeasure Heuristics
Funding Scheme: SEC-2013.2.4-2
Start date of project: 01/04/2014
Duration: 36M

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**Revision History**

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<td>13/01/2017</td>
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<td>TST contribution, UoR contribution on EDS interaction with other modules.</td>
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<td>15/02/2017</td>
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<td>31/05/2017</td>
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**Quality Control**

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**Security Scrutiny Committee Review**

**Comments**

Distribution should be controlled, as the document contains information on the potential weaknesses and vulnerabilities of the detection and tracking module.

**Recommended Distribution**

Consortium and Commission services.

**Date**

31/05/2017
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List of Abbreviations

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<th>Term</th>
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<td>ABCD tracking</td>
<td>Adaptive object region + Background weighted scaled Channel coded Distribution field tracking</td>
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<td>BMS</td>
<td>Boolean Map Saliency</td>
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<td>EDM</td>
<td>Early Detection Module</td>
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<tr>
<td>GNN</td>
<td>Global Nearest Neighbour</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>HMI</td>
<td>Human-Machine Interface</td>
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<td>IMU</td>
<td>Inertial Measurement Unit</td>
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<td>MST</td>
<td>Multi-Sensor multi-target Tracker</td>
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<tr>
<td>RANSAC</td>
<td>RANdom Sampling And Consensus</td>
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<td>RGB</td>
<td>Red, Green and Blue</td>
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<td>Thermal Camera Module</td>
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Executive Summary

This document presents the follow-on work to deliverable D5.41 regarding the development of the Early Detection Module (EDM) of the on-board system in IPATCH. The role of the EDM is to utilise sensor fusion algorithms to combine the outputs of sensors and detection/tracking algorithms and provide input to the higher-level situational awareness modules of the on-board system.

This document updates on how the prototype of the Early Detection Module has evolved compared to the version presented in D5.41. The progress made in the individual detection and tracking algorithms which operate on data from single sensors (visible cameras, thermal cameras, and data from the ship’s bridge systems) is described and updates to the multi-sensor multi-target tracking component are reported. The updated architecture of the Early Detection Module and its constituent parts is presented and the current performance and remaining issues to be addressed are discussed.
1 Introduction

1.1 The IPATCH Project

Funded by the European 7th Framework Programme, the IPATCH project addresses Security Topic SEC-2013.2.4-2: Non-military protection measures for merchant shipping against piracy. The goal of the IPATCH project is three-fold:

1. To perform an in-depth analysis of the legal, ethical, economic and societal implications of existing counter piracy measures.
2. To produce well-founded recommendations to the industry in the form of a manual, extending and complementing the Best Management Practices document and to support the use and further development of countermeasures.
3. To develop an on-board automated surveillance and decision support system providing early detection and classification of piracy threats and supporting the captain and crew in selecting the most appropriate countermeasures against a given piracy threat.

The analysis performed under (1) will lead to recommendations for the use of countermeasures in a range of scenarios, structured as a manual (2), and development and implementation of a proactive surveillance system forming part of the system developed in (3). The situational awareness system will robustly monitor the area around maritime vessels, providing early warning to crew members if piracy threats are detected. A low false alarm rate due to environmental or other innocuous events, combined with high threat detection sensitivity are central ambitions of the project.

To achieve these goals, a multispectral sensor suite comprising both passive and active sensors is envisaged, i.e., a system based on radar, visual and thermal sensors. The sensor suite will be complemented with advanced algorithms for information fusion, object detection and classification, and high level modelling of intent and behaviour analysis. The IPATCH project is strongly user-driven and demonstration of the developed surveillance system will be conducted in two different maritime environments.

1.2 Task 5.4 Objectives

In the context of the global system specification from D2.3, the objective of T5.4 is to develop the architecture and algorithms for fusing/combining the output of sensors and information sources to provide a more complete picture of targets and their tracks in maritime environments. Algorithms developed for detection and tracking (see D5.3) produce track histories, as well as point target detections. The outputs can be exploited through multi-level fusion that can take advantage of the complementarities of the different sensor modalities and detection approaches. Similarly, the detection/learning algorithms could take advantage of the fused output.

The output of this task will be a sub-system of the overall on-board system which detects and tracks objects using all available sensors. The results are output in a suitable format for use in WP6 and other modules of the system, as well as for displaying to the users via the HMI.
1.3 Deliverable Overview

While deliverables D5.1 to D5.3 reported on the development of individual algorithmic methods, a first prototype of an Early Detection Module (EDM) was presented in D5.41. The role of the EDM is to utilise sensor fusion algorithms to combine the outputs of the individual algorithmic introduced in D5.1 to D5.3 to provide an unified tracking output to the higher-level situational awareness modules of the on-board system.

This document updates how the prototype of the Early Detection Module, presented in D5.41, has evolved. Section 2 describes the progress made in the individual detection and tracking algorithms which operate on data from single sensors (visible cameras, thermal cameras, and data from the ship’s bridge systems). Section 3 reports on the updates to the multi-sensor multi-target tracking component, which plays the key role of merging the outputs of the individual sensors and algorithms into a single track per target. Section 4 describes the updated architecture of the Early Detection Module and its constituent parts, and Section 5 discusses the current performance and remaining issues to be addressed.
2 Detection and Tracking in Individual Sensors

2.1 Bridge Sensors

Vessel bridge systems are already equipped with several sensors which can be exploited by the IPATCH system for detection and tracking. Under maritime regulations, ships must be equipped with radar, AIS, GPS and an inertial measurement unit (IMU) which measures the 3 degree of freedom (DOF) pose of the vessel, namely roll, pitch and heading (yaw).

In the IPATCH system, the AIS is used to discover the positions of large vessels (all vessels over a certain size must broadcast their position over AIS), the radar can be used to detect objects around the vessel (although it does not detect pirate skiffs well), and the GPS and IMU data is used to localise and orient the targets in relation to the vessel.

BMT has developed a Bridge Sensor Manager whose role is to act as a connector and adapter to allow data from existing bridge systems to be used in the IPATCH system. In a real operational scenario, and during the sea trials, the Bridge Sensor Manager will interface with the bridge hardware. In the first sea trials, this was achieved through the AUTOPROTECTION network. In the second trials, this will be achieved with a direct serial connection to the bridge.

The radar, AIS and IMU navigational data is received in the form of standardised NMEA messages. The Bridge Sensor Manager parses the incoming messages to extract the relevant information and converts the data into the IPATCH format. The messages are then relayed to the other modules of the system directly (via Protobuf) and via the Integration Platform.

The second version of the Bridge Sensor Manager is able to handle the following NMEA messages:

<table>
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<th>Use in IPATCH</th>
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<td>!AIVDM</td>
<td>AIS</td>
<td>AIS messages from other vessels</td>
</tr>
<tr>
<td>$GPGNS</td>
<td>GNSS fix data</td>
<td>Latitude and longitude position data</td>
</tr>
<tr>
<td>$GPVTG</td>
<td>Course over ground and ground speed</td>
<td>Speed and course of vessel</td>
</tr>
<tr>
<td>$GPZDA</td>
<td>Time and date</td>
<td>Time and date synchronisation</td>
</tr>
<tr>
<td>$HEHDT</td>
<td>Heading, true</td>
<td>Heading of vessel</td>
</tr>
<tr>
<td>$RATTM</td>
<td>Tracked target message</td>
<td>Radar detections</td>
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For land-based testing, we are simulating the presence of a real bridge by reading in data which was recorded during the data collection exercise (see D5.2 for full details).

A sample sequence of NMEA messages is given in Figure 1:
2.2 Visible Cameras

This section explains updates to the detection and tracking components which operate on the visible camera data.

2.2.1 Horizon detection

In the second version of the EDM, horizon detection is performed in every camera. Detecting the horizon in the images is important for two reasons:

1. It allows incorrect detections above the horizon to be discarded by each camera algorithm, thereby reducing the number of false positives sent to the MST.
2. It allows the pose of the cameras (rotation and orientation) to be estimated frame by frame.

Horizon estimation is performed through detection of horizontal edge segments across the columns of the image and then finding the best candidate line using a RANSAC optimisation. This method is fast and has reasonable performance. Performance drops if the contrast between sea and sky is poor, or if only a small amount of the horizon is visible in the image. It also sometimes incorrectly detects other strong horizontal lines (such as a trail of wake created by a skiff) instead of the true horizon. Other methods were trialled which had slightly better performance, but had longer processing times so were not suitable for a real-time system. Figure 2 shows horizon detection and tracking in a visible camera.
Figure 2: Horizon detection and saliency-based tracking in visible camera

2.2.2 Updates to the TSFC tracker

The UoR detection and tracking component – the Temporally Stable Feature Cluster (TSFC) tracker – is described fully in deliverable D5.3. To summarise, the algorithm locates features in the image (regions in the image that exhibit relatively large changes in intensity over small distances; typically these occur on corners and edges) and attempts to re-locate the same features in subsequent frames. If it can do so, then the assumption is that the features are describing a persistent structure in the image, rather than a transient feature such as a wave. The algorithm looks at groupings of these stable features, and compares their relative motions. Features moving together (similar direction and similar speed) are clustered together, under the assumption that objects-of-interest (skiffs and other vessels) are rigid (and hence all constituent parts move together). Stable clusters generate potential target detections that are located on a vessel.

In the updated version of the EDM, optimisations to the TSFC have been made, the main one being the parallelisation of the algorithm to achieve real-time performance. The horizon detection was also incorporated into the pipeline so that the algorithm ignores any features which are detection above the horizon. This has the effect of reducing the number of false detections, as well as a slight speed increase (due to the reduced number of features required to process). Additionally, various alternative parameter configurations of the algorithm have been trialled to address some of the more challenging aspects of the data collected so far. The algorithm now operates faster, as well as achieving slightly better detection accuracy and fewer false positives.

2.2.3 New saliency-based tracker

In D5.3, the Temporally Stable Feature Cluster (TSFC) tracking algorithm was described. Since then, a new tracking method has been developed which has been integrated into the Early Detection Module to complement the other algorithms and provide additional input to the multi-sensor multi-target tracker.
2.2.3.1 Overview

The new saliency-based tracker (Figure 3) creates a saliency map for each frame and performs adaptive hysteresis thresholding to locate the salient regions corresponding to potential objects. The list of candidate objects is filtered using some basic constraints and surviving object detections are matched from frame to frame using the Hungarian algorithm. Finally, the tracks are smoothed using a Kalman filter.

![Block diagram of the new saliency-based tracker for visible camera sensors](image)

**Figure 3: Block diagram of the new saliency-based tracker for visible camera sensors**

2.2.3.2 Modified Boolean Map Saliency (BMS)

The Boolean Map Saliency (BMS) method [1] exploits the visual property of surroundedness whereby objects in an image are more salient, the more surrounded they are by background regions. It starts by converting the RGB input image to the CIELAB colourspace. The colourspace is rectified using a whitening step. Each of the channels, L, A and B, is then normalised to the range [0; 255] and binary thresholded at regular intervals. This yields a set of N binary images (Boolean maps).

An activation map is then created for each Boolean map by identifying the surrounded regions. A black region is surrounded if it is enclosed by a white region and vice versa. The activation map is created by setting pixels to 1 if the corresponding pixel is in a surrounded region, and setting 0 elsewhere. The set of activation maps is then normalised in order to emphasise maps with small activated regions. This serves to emphasise clumps of small activated regions whilst reducing the importance of small, scattered regions. The final saliency map, S, is found by taking the average of all the normalised activation maps and performing a dilation operation followed by Gaussian smoothing. The whole process is illustrated in Figure 4.
One of the weaknesses of the BMS method when applied specifically to maritime scenes is a tendency to highlight the wakes of the boats and whitepeaks in the water. To counter this, we have implemented a modification which is designed to suppress these features of the background. Instead of using the CIELAB colourspace, we use broadly-tuned, intensity-decoupled red, blue and green colour channels used in earlier, biologically-inspired salient object detection approaches.

A broadly-tuned colour channel is one that gives maximum response for the pure, fully-saturated hue for which it is tuned, and yields a zero response for black and white. Hue is decoupled from intensity by dividing the red, green and blue channels of the image (r, g, and b) by the intensity channel (I). The channels are set to zero for pixels where I is less than 1/10 of its maximum value to represent the fact that hue variations are not perceivable at low luminance.

In the IPATCH algorithm, the broadly-tuned, intensity-decoupled red, blue and green colour channels are used instead of the L, A and B channels of the CIELAB colourspace, as indicated in Figure 4. The colour whitening step is also omitted.

By comparing the saliency maps in Figure 5 (bottom row), it can be observed that the broadly-tuned, intensity-decoupled RGB channels used in the maritime-specific IPATCH algorithm help suppress unwanted wake that is apparent in the original BMS method.
2.2.3.3 Hysteresis thresholding

Once the saliency map has been generated, it is binary thresholded to extract candidate object regions. Setting a fixed value for the threshold would not generalise well for different scenarios, so the threshold is set to the 99th percentile of the saliency map. This captures the most salient points in the image but may only partially detect the full object region. However, a lower threshold is likely to introduce more false detections. Hysteresis thresholding is a common way to address this and is used here for this purpose. Two thresholds are set: an upper and a lower. The saliency map is binary thresholded at the upper value and the flood-fill algorithm is then used to grow regions to add connected pixels which are above the lower threshold. In the proposed approach, the upper and lower thresholds are set to the 99th and 98th percentiles, respectively.

2.2.3.4 Object Extraction and Filtering

Candidate objects are extracted from the binary mask by labelling connected components and computing bounding boxes. The set of candidate objects is likely to contain some false detections from the background, so filtering is carried out by applying some simple constraints. False detections from glint tend to have very small bounding boxes. However, objects on the horizon also have small bounding boxes, so setting a global minimum allowable size would not be suitable. Instead, the minimum allowable size is calculated as a function of the distance from the base of the image to the horizon. Bounding boxes with a height less than this value \((T_h)\) are removed. Figure 6 illustrates the filtering calculation.
Figure 6: Filtering of false detections based on distance from horizon line

\[ T_h = h_{\text{max}} - (h_{\text{max}} - h_{\text{min}}) \left( \frac{H - y_c}{\alpha H} \right)^\lambda \]

2.2.3.5 Tracking

In each frame, new detections are assigned to detections and tracks from the previous frame using the Hungarian algorithm. The cost matrix is completed by calculating the Euclidean distance between the centroids of each pair of bounding boxes. Gating is implemented by introducing a maximum distance threshold for assignment.

Matches between new detections in two consecutive frames triggers the creation of a new track which is managed by a standard constant velocity Kalman filter based on the position and velocity of the bounding box centroid, and the bounding box width and height and their respective rates of change.

When new detections are assigned to existing tracks, the track is updated by estimating the state using the new observation. If a track is not assigned a new detection in the frame, the new bounding box is predicted by the Kalman filter. The filter is allowed to predict up to 5 frames without a new matched detection before the track is terminated.

Figure 7 shows the saliency-based tracker in operation on a sequence from the IPATCH dataset. Green boxes represent the current estimated location of the objects (skiffs) and the pink lines indicate the history of tracked positions over the sequence.
2.3 Thermal Cameras

This section explains updates to the detection and tracking components which operate on the thermal camera data.

2.3.1 Horizon detection

The problems of detection and low-level (image-based) tracking in thermal imagery are treated in the previous deliverable D5.3 (Section 5). In addition, we also need horizon detection in order to establish the camera rotation and to remove detections above the horizon (such as birds).

Horizon estimation is performed by detection of horizontal edge segments followed by RANSAC to remove outliers and a simple temporal filter to avoid jumps. This works surprisingly well, and no failures have been observed in test data. However, the method is predicted to fail when a too small part of the horizon is visible, such as when near the coast or a large vessel. Results are shown in Figure 8, and, in fact, better results are probably not achievable since they are limited by the pixel resolution of the camera.

2.3.2 Updates to the tracker

For target detection, we use a simple linear background model for anomaly (foreground) detection, detecting targets that are warmer than the sea surface. This is then followed by morphological operations to clean up the results as well as removing detections out of scope (above horizon, on the own ship). Low-level tracking, that is, connecting detections in consecutive image frames, is performed using the ABCD algorithm described in detail in D5.3. The current performance is illustrated in Figure 8; a stable detection of the approaching skiff is achieved when the skiff is well below the horizon.
Figure 8: Thermal detection and horizon estimation

The small yellow rectangle marks a stable detection of an approaching skiff. The camera pan angle, that is, the compass direction relative to the ship in which the camera is pointing, is given as a manual input. The value in the image indicate that the camera is pointing aft. The tilt and roll angles are calculated from the estimated horizon line (red). The yellow line indicates “out of scope”, that is, targets should not be detected below this line since they are likely to belong the own ship.
3 Multi-Sensor Multi-Target Tracking

The multi-sensor multi-target tracker (MST) receives detections from the various sensors / detection algorithms in the system, converts them to ship-centred coordinates, merges detections from different sensors, and outputs tracks to the IPATCH integration platform.

The MST is essentially a single-hypothesis multi-target tracker found in the literature [2, 3], with certain adaptations specific to IPATCH. For example, the MST should be able to receive individual detections (that should be associated to form tracks) as well as detections that are already a part of a track created by the low-level sensor tracking algorithms (“informed detections”) described in the previous sections. The major components of the multi-sensor multi-target tracker are Sorting, Track mapping, Prediction, Gating, Association, Update, and Track management, as briefly described below:

- **Sorting**: Detections from the sensors need to be processed by the MST in chronological order. However, the EDM is an asynchronous system, and, moreover, the various sensors will have different processing times. Thus, the incoming detections are sorted and the oldest one processed first. Detections newer than a certain time (for example, a few seconds in the past) are left to give detections from other sensors the possibility to arrive late. Then, the detections are processed in batches so that each batch contain the detections from only one sensor.

- **Track mapping**: Since the different low-level trackers might have their own track identification numbers there must be a mapping from low-level tracks to high-level tracks (the ones created by the MST). Thus, when the first detection with a low-level track ID arrives from a sensor, a mapping table is created for that specific sensor. Then, when the Track management (see below) is done, the associated high-level tracks are filled into the table; see Figure 9.

- **Prediction**: The position of each track is predicted in sensor coordinates. The prediction is done in ship-centred coordinates using an Extended Kalman Filter and projected into sensor coordinates (such as image pixel coordinates).

- **Gating**: Detections and predictions are compared; only if they are close enough (i.e., within the gate), they can be associated.

- **Association**: A global nearest neighbour (GNN) algorithm is used to find the most likely combinations of detections and tracks. Mostly, this is not complicated, but can be so when there are several overlapping gates and detections.

- **Update**: Each track is updated, either with an associated detection or the prediction. Note that this update is highly sensitive to a correct mapping from world coordinates to sensor coordinates. For example, assume that a skiff is observed by a camera that is positioned 10 metres above the sea. If the skiff is believed to be one degree below the horizon, the estimated distance will be 573 metres. If the skiff is believed to be two degrees below the horizon, the estimated distance will be 286 metres. Thus, the horizon estimates described previously are crucial for accurate tracking.

- **Track management**: Each track has a status; Possible, Active or Lost. Only active tracks are published to the Integration Platform, and there is a set of configurable criteria to be fulfilled for transition between the three states. Examples of such criteria are that a track must have been observed a certain number of times during a certain time span to go from Possible to Active, and when it has not been observed for a certain amount of time, it will go from Active (or Possible) to Lost.
Figure 9 below illustrates how tracks are managed within the MST – Top: The Track contains two tables, one for the radar (mapping radar tracks 3, 5, 6, 7 to MST tracks 2, 3, 9, 11) and one empty table for a thermal camera. Middle: Three detections from a thermal image arrives. The first two are already associated with previous detections (not reported to the MST) while the third is not. Bottom: The first thermal detection have been associated with MST track 9 (radar track 6), for the second and third, new tracks are created (with the numbers 12 and 13). There is yet no mapping to MST track 13.

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**Figure 9: Track management within the MST**

Figure 10 shows the visual interface that was created for testing and development of the MST. The tracks for the two skiffs approaching the vessel can clearly be seen. These tracks have been created by merging the detections and tracks from the different sensors to create a single trajectory per object (called MergedTracks). The MergedTracks are sent to the other modules via the Integration Platform for further processing.
Figure 10: The multi-sensor multi-target tracker visual interface
4 Early Detection Module Architecture

The Early Detection Module is composed of several components which provide services to other components within the module as well as to other modules via the IPATCH Integration Platform. Since D5.41, the architecture has been updated slightly: Figure 11 shows how the sub-modules interact and Figure 12 shows the individual software and hardware components of the module and how they are connected. The components are described in more detail in the following sections.

Figure 11: Logical architecture of the Early Detection Module
4.1 Ship bridge interface

The output of the bridge system (either ethernet or serial) is connected to a laptop. The bridge interface module reads NMEA messages from the bridge data stream and directs them to one of three sub-modules; one for AIS, radar and IMU data. These sub-modules handle the messages and extract the relevant data. The data is then forwarded to the MST over a ZeroMQ-Protobuf network in order to avoid overloading the Integration Platform.
4.2 Visible cameras detection and tracking

Each visual camera connects to a computer. Each computer can handle the data from multiple cameras. Recent testing indicates that network bandwidth is the limiting factor for the number of cameras supported by a single machine - the 2016 Brest Sea Trials successfully connected to 3 cameras with a small loss of framerate (but still within real-time).

The camera input is read by the Visual Detection and Tracking subsystem running on the same machine. Multiple detectors and trackers can be run in parallel. In addition, different algorithms can access the data from a single camera in parallel, meaning that the saliency-based tracker, horizon detectors, and the TSFC tracker can be run on the same data independently. Algorithms can process at different framerates, and may not consume every frame of video available.

Bounding boxes are sent to the Multi-Target Tracking subsystem using Protobuf messages (specifically IPATCHCameraDetections messages), where each message contains one or more detections from a particular algorithm. Different detectors (either different algorithms from the same camera, or the same algorithm on different cameras) transmit independently via different network ports. Horizon data is buffered, and the most recent information about the horizon is sent with bounding boxes as the object detectors generate output.

4.3 Thermal cameras detection and tracking

Each thermal camera is connected to a computer. One computer can handle several cameras, if processing power and available bandwidth allows. The software connecting to the camera reads the images and published them within the EDM (not to the IPATCH Integration Platform), that is, sending Protobuf messages (of type IPATCHCameraSensorData) over ZeroMQ. Each such Thermal Camera Module (TCM) is thus run as a separate process.

One Thermal Detector/Tracker Module (see Sec. 2.3) per TCM is started, subscribing on image messages and publishing camera detection messages to the EDM (Protobuf message IPATCHCameraDetections), where each message contains one or more detections.

4.4 Multi-sensor multi-target tracking

The MST Module subscribes to messages from various sources; the visual and thermal cameras, the radar, the AIS, and the ship’s navigation system. All these messages are received as Protobuf messages over ZeroMQ.

The output is published to the IPATCH Integration Platform in the form of MergedTrack objects, where track number 0 is always the own ship in world (GPS) coordinates. All other tracks are in ship-centred coordinates. Tracks are not published as often as they are updated, since this is completely unnecessary for the rest of the system – the tracks are updated each time there is a detection in any of the above-mentioned sensors, that is, typically multiple times per second. Instead, a threshold of once per second or less is set. Moreover, the tracks’ temporal resolution is reduced before published, so that one (not many) position per second is reported, and the tracks’ length limited.
4.5 Integration with other modules

The EDM provides imagery from the cameras via Protobuf messages (IPATCHCameraSensorData messages) to the HMI. The EDM provides two services to the HMI in this regard: compressed MPEG streams are decompressed into individual frames, and Thermal images (where each pixel is a 16-bit value representing a temperature) is similarly converted to a 24-bit RGB image (though practically, the image is greyscale). The EDM must necessarily be able to decode images of different modalities into raw pixel values in order to generate detections. The HMI subsequently receives all images in a common and unified format, without needing to support decoding imagery from a range of potential camera devices.

MergedTracks produced by the EDM are direct input to other higher-level modules in the IPATCH system. Specifically, MergedTracks are consumed by a situation assessment module and an event recognition module. Both modules will consider data from the tracking algorithms (MergedTracks from the EDM). On the basis of these, two subtypes of micro-events, which are described in the data model, are provided i.e. Relations (how two or more detected objects behave as a group) and Behaviours (information about one object). The situation assessment module further provides a macro-event, which is calculated using GIS extensions and the geographical data which could describe the types of waters, lands, landmarks, etc. Those events consider mainly information about entering, leaving and being nearby the own vessel, e.g. vessel is entering Exclusive Economic Zone of country X and nearest port is 300 miles far on direction 70º. This type of information is stored in a general data structure associated with the own vessel (CommonOperationalPicture). Micro-events and Macro-events will be the basis of threat recognition in IPATCH. Communication between the EDM and situation assessment and event recognition modules is made through the IPATCH integration platform.

The EDM provides detection and tracking data (MergedTracks) as well as image data to the HMI. The Integration Platform is not designed to handle image and video data streaming. As such, modules wishing to receive image data must use the same protocol as the Early Detection Module to communicate directly with the Sensor Manager components; that is Protobuf.
5 Conclusions and Future Work

The results from the visible and thermal tracking algorithms are reported in D5.3 and have not changed significantly. Some incremental improvements have been made, in particular in detecting targets sooner and with fewer false detections, and more robust, long-term tracking has been achieved. Improvements to the processing speed of the algorithms have also been made, which has improved the overall real-time performance of the system. An additional algorithm for detecting objects using a saliency-based approach has been added to the visible sensors detection and tracking subsystem. This provides additional detections for the MST to analyse.

The MST is currently under final testing and evaluation for the IPATCH Final Demonstration in May 2017. While the general functionality described is working, each testing and evaluation session reveals issues that may or may not be necessary to resolve before the Final Demonstration. The current issues to be addressed are:

- Fusion of all combinations of sensor data is not yet fully tested.
- The ship’s own position is not predicted, instead the latest reported position is used. This might lead to “jumps” in the estimated position of radar / AIS targets relative the ship (to be resolved).
- As mentioned above, the MST is sensitive to errors in the mapping from sensor (camera) coordinates to world coordinates. The process of obtaining these mappings precisely was identified as a challenge from the previous sea trials, and a solution needs to be worked out before the Final Demonstration.
- A relevant IPATCH scenario is when a ship launches one or more skiffs that approach the ship. In camera images, the skiff may not separate from the mothership until it is several pixels below the mothership. This means that when a new track is created for the skiff, the new track may start several hundred metres from the track of the mother ship, making it difficult for the IPATCH decision support system to associate these two.
References

