Sensor Integration in the Security Domain

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Abstract: The Sensor Integration Package is a reusable subsystem, combining the complementary capabilities of radar, infra red and long range day light camera, laser, image processing software and geographic information. It covers applications within the domains security, protection and defence.

1 Introduction

The Sensor Integration Package addresses data fusion and sensor management. A complete sensor suite consisting of ground surveillance radar and electro-optical sensor is encapsulated as a generic higher level sensor which simplifies and optimises integration tasks. The Sensor Integration Package fuses measurements of ground surveillance radar, long range infra red camera, long range daylight camera and laser rangefinder with terrain data and results of a video processor software. The results of the fusion process are fused tracks which are provided on an external interface to a command and control system (C2). The Sensor Integration Package also provides an interface for monitoring and controlling the sensors involved. This allows a project specific modification of the sensor equipment with only minor effects on the interface to the C2 system and ensures a high level of reusability. The Sensor Integration Package can be used in systems that cover

- Security: Border security, security for critical facilities
- Protection: Camp protection, convoy protection, anti asymmetric warfare
- Defence: Battlefield surveillance, reconnaissance, BMC4I systems, naval combat management systems

The interface is transparent, i.e. all sensor data remain available and are referenced to processed data. It has the following interfaces

- EO Video streams including overlays [DKO09]
- Audio streams (Doppler tone)

- Sensor Management & Maintenance
- Fused tracks
- All sensor data (plots) remain available and are referenced to processed data (i.e. no information is lost)

2 Architecture and Functionalities

Fig. 1 shows the different components and functional flows within the sensor integration package. The main components are the ground surveillance radar and an electro-optical sensor consisting of an IR and TV camera which allow a visual observation during day and night.

Each sensor has its own processing software for data improvement and tracking while a fusion software finally combines the results. The output of the fusion process are then assigned to the C2 system. Furthermore a sensor management process controls the sensor specific modes automatically or by execution of operator commands.

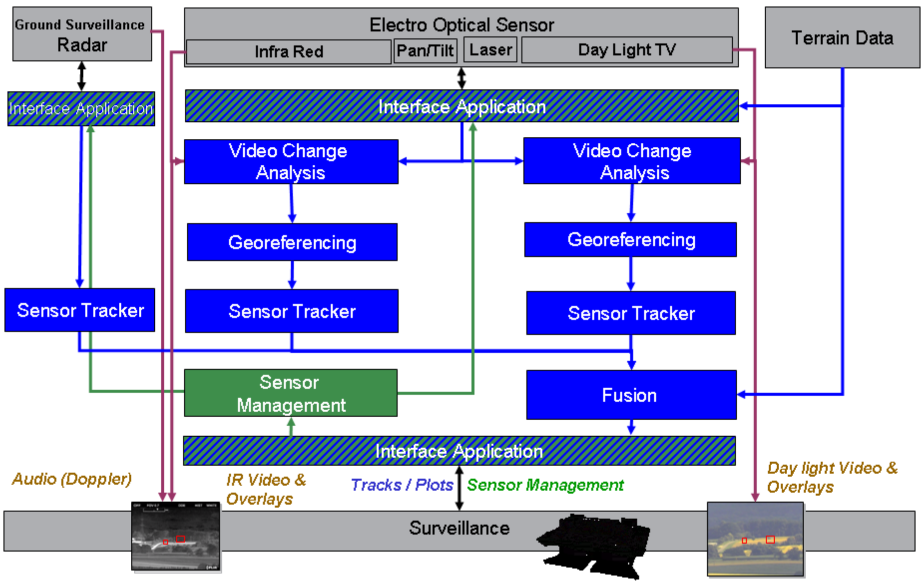

Figure 1: Architecture and functional flow

2.1 Track generation with radar

For ground surveillance tasks often especially suited multi mode radars are used which support two modes. One mode offers the surveillance (scanning) of a predefined area. All plots which were detected by the radar during a radar scan are associated to tracks with a view to improve the estimation of the target position and velocity.

A sensor tracker associates raw measurements (plots) to tracks. If the sensor tracker detects a loss of the track because of missing detections the track will be deleted. The track loss can be caused by a stopping target, a new and different observation area etc. So a sensor tracker can be described as a filter that ignores unassociated clutter plots and correlates position and velocity correlated plots to the same track.

Normally scan oriented algorithms are used for ground surveillance radars. This means that for each radar scan all plots are collected and the association is calculated afterwards [BP99]. To decide whether a track is lost or not the tracker waits a configurable number of scans for which a track has not been updated. Then it will be deleted. A fixed lost time will raise the probability for false correlations.

The other mode is dedicated to following a single target, which was selected before. In this mode one is able to classify a target by analysing the Doppler sound. A well trained operator can interpret the audio signal very accurate and therefore classify a target exactly. But to unload the operator the classification also can be done automatically.

Fig. 2 shows the visual presentation of the audio signal of a tracked vehicle. By combining the information of Doppler speed, signal power and number of detections this target can be classified [KO07].

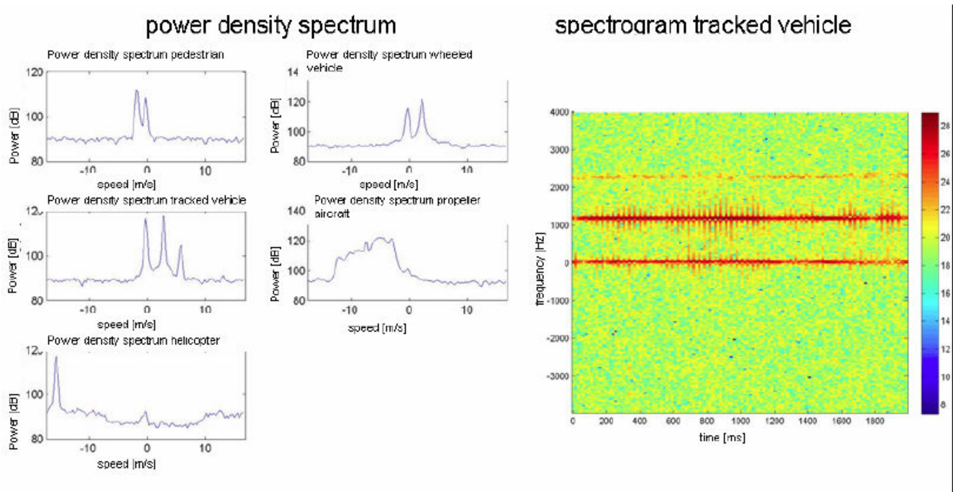

Figure 2: Ground surveillance radar

2.2 Track generation with electro-optical systems

The electro-optical systems for security applications contains IR, day light TV and laser components. The IR and TV component delivers two video streams. These video streams have to be analysed by a video processing software to extract the objects within the image coordinate system. To do this the software detects changes in the video and combines similar changes to objects [DKO09].

Another functionality is template matching which is important for the sensor management. The operator selects an object in the image which will be used as template. The video processing software tries to find this template in each new video frame and calculates the difference of the template positions. Template matching is used to direct the camera following a designated object so that the operators task is facilitated and the track continuity is ensured (Single Target Tracking).

Finally the Sensor Integration Package generates overlays to enrich the videos. These overlays contain markings of the detected object in the video by the use of a coloured rectangle and a track id.

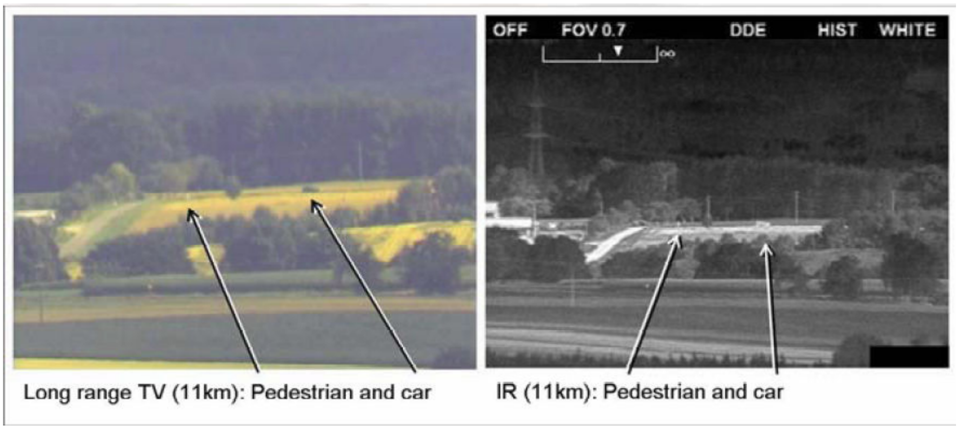

Figure 3: TV and IR video image

2.3 Georeferencing

The video processing software delivers target reports within the image coordinate system. This has to be transformed into a sensor centric coordinate system to describe the objects direction in azimuth and elevation.

Therefore the angular camera position information, the current field of view and the relative position of the object within the image is used to calculate an exact object direction. By using digital terrain elevation data (DTED) the direction measurements can be completed to a three dimensional WGS84 position [BA09], [DKO09].

2.5 Two-Tier Fusion

To fuse the sensor data of radar, electro optical systems, the evaluation of the video processing software and terrain information a fusion process is employed. Its kernel 'Fusion++' was created to be highly configurable for different heterogeneous sensor suites and operational environments. It works on the plot, associated plot and/or track level [DKO07a], [DKO07b], [DKO07c].

Fig. 4 shows a configuration for a two-tier Fusion approach. The first Fusion level is the Sensor Tracking level based on incoming raw data either from Change Detection or Template Matching. Moreover a Radar Sensor Tracker can also be added, processing raw radar plots.

The second Fusion level is realised with a Multi Sensor Tracker. The Multi Sensor Tracker ensures a system track continuity: if a sensor track is lost it will be kept a configurable time. If a new sensor track occurs that matches with the lost track during this time, these two tracks will be fused. So it is ensured that the track id and classification attributes stay the same. This feature is also utilised with integrated sensors that use different physical methods to detect their targets. By exploiting the specific sensor advantages, the weakness of one sensor can be balanced out by the strength of the other sensor: e.g. radars are good in detecting radial moving targets but have problems with tangential moving targets because of the missing Doppler. However the video processing software can detect targets that move tangentially very well. So the multi sensor tracker can continue the track although the radar lost the target. This example works the other way round also.

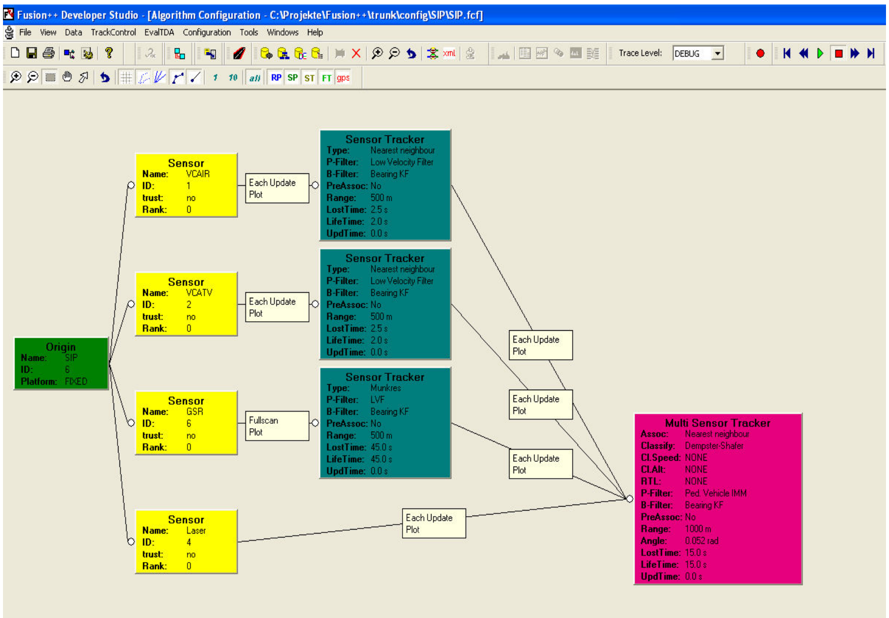

Figure 4: Configuration for a two-Tier Fusion approach

By the usage of two tracking instances, i.e. sensor tracking and MST one is able to allow the MST a longer lifetime. Therefore one can increase the lost time of an MST track over the lost time of a sensor track (which is affected by false plots). This is not only important for the fusion of different sources. It is also important to fuse tracks established in several radar modes (switching radar modes).

In order to configure and evaluate different Fusion approaches the Fusion++ Sensor Suite is used [Op08].

2.6 Sensor management

The sensor management of the Sensor Integration Package encapsulates sensor specifics and allows a generic sensor management by the operator and by the C2 system. It manages the sensor resources and controls the interaction between the sensor systems and the video processing software. Three different modes are available which are described in the following.

i.) Manual control of sensors

The manual acquisition mode operates without an automatic radar scan. Directions of radar beam and camera are controlled by the operator.

ii.) Automatic surveillance

In the automatic surveillance mode the radar automatically scans within predefined sectors. Targets are automatically detected and tracked (track while scan, TWS) by the radar. Therefore, several sub modes are available:

- Sector Scan
- Multiple Sector Scan
- Full Scan (360°)

The optical system is able to scan a set of way points with pre-defined camera settings (step and stare), e.g. the field of view. This mode includes the "Micro-Scan" mode, which is used to automatically acquire a target cued by the radar or the other EO-Sensor (in search mode).

iii.) Single Target Tracking

In this mode a target detected by the radar is automatically tracked. It may be used for the classification of moving targets via Doppler tone processing.

The optical sensor single target tracking uses two sub modes:

- Cueing Sensor controlled (Designate EO system)

- Image guided (Template matching)

In the cueing sensor controlled mode the camera follows the position of a track which has been established and is updated by another sensor e.g. Radar. The Image Extraction of video processing is used to extract targets directions. These directions can be used for an improvement of the object position measurement by the cueing sensor.

In the image guided mode the automatic target track is initiated by the operator by "marking" an object (template) on the displayed video stream that he is analysing. The video processor task analyses the video stream and searches the template which has been selected by the operator before. If the template is found the camera direction is adapted automatically in order to keep the template centered in the cameras field of view. Using this approach, Single Target Tracking is performed based on a video stream while objects are automatically observed and followed with the camera. The actual WGS84 position of the tracked object will be calculated using the Georeferencing functionality.

An additional range measurement by the laser range finder initiated by the operator delivers a precise object position in both sub modes.

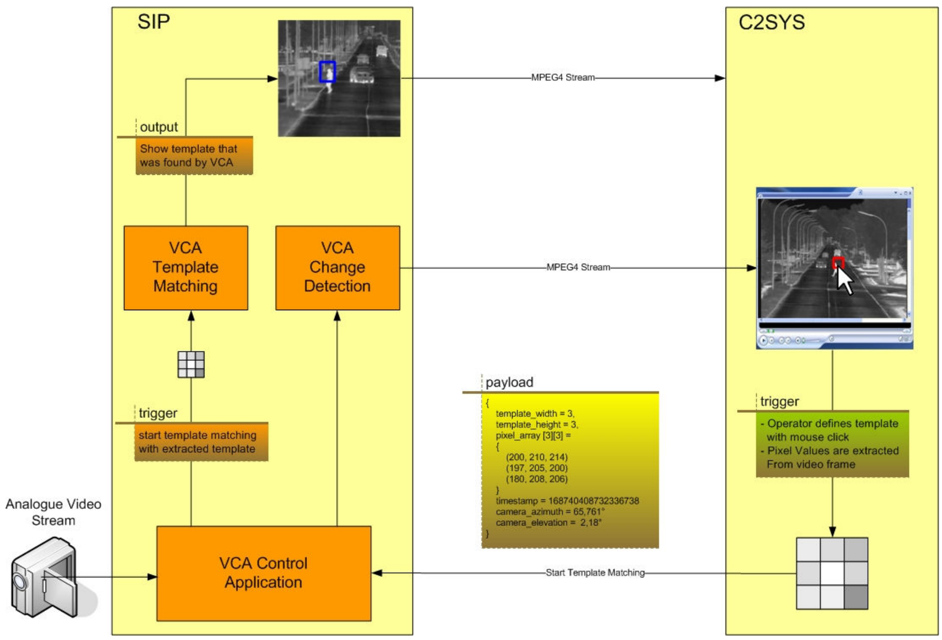

Figure 5: Principle of Template Matching

2.7 Maintenance

In order to perform maintenance activities, the system provides a maintenance HMI which is accessible via standard Web browser thus enabling an operator to get maintenance access to the system remotely.

Among others the following "views" are provided for each integrated sensor:

- List or change current sensor settings / sensor status
- List tracks
- Sensor management
- Execute built in self test (BIT)

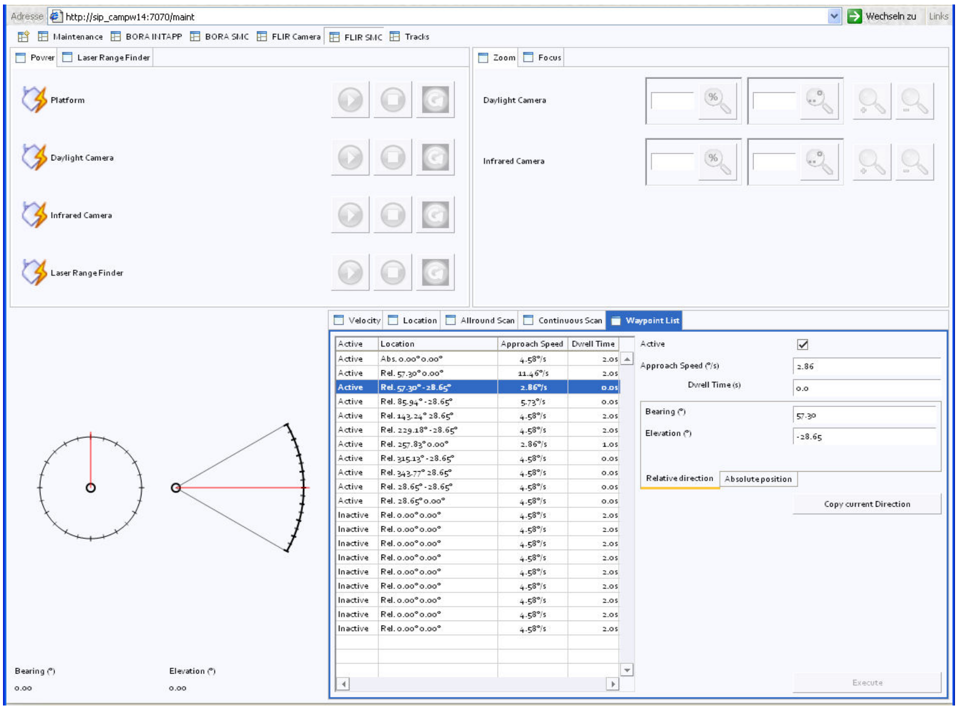

Figure 6: Screenshot of the Camera maintenance HMI

3 Conclusion

The combined usage of sensors like Radar and EO systems provides a way to verify and classify targets while the surveillance task can still be accomplished. Furthermore automatic sensor modes (like image guided Single Target Tracking) offer the possibility to ease the operators daily work by automating tasks (e.g. keep camera centered on a dedicated target) in order to avoid fast distraction or inattention.

Due to its architecture as encapsulated generic higher level sensor, the Sensor Integration Package serves as an abstraction layer between sensors and C2 system. This allows a project specific modification of the sensor equipment with only minor effects on the interface to the C2 system and ensures a high level of reusability.

Moreover it integrates automated sensor management while exploiting each sensors advantages which leads to an improved situational awareness. Joining these benefits with the tow-tier Fusion approach using the 'Fusion++' kernel a better track continuity and quality is ensured.

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