Information Fusion: Protection of Military Forces and Homeland Security

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Abstract: Information fusion is a key factor to enable Homeland security and military protection systems. Applications have to detect, track, classify and identify objects in real time. Sensor resources must be allocated to these objects of interest and the whole situation has to be analyzed concerning threats. Whenever necessary counter measures have to be initialized.

1 Introduction

1.1 Homeland Security

Homeland security refers to civil application domains, like the surveillance of borders, infrastructures or critical facilities or events.

E.g. border security handles the surveillance of several thousand kilometres of borderline within different terrains and climate conditions. The task is to prohibit illegal immigration, illegal fishing, smuggling, piracy or terroristic infiltration.

1.2 Protection

Protection is related to the military domain, and addresses the protection of own forces in peacekeeping or peace enforcement out of area missions. Typical applications address the protection of military camps, convoys, naval platforms in critical situations, or military airports and sites.

Also interoperability issues for combined and joined forces have to be ensured. Therefore, external C2-components as well as surveillance systems, like site surveillance, air defence systems or civil air traffic management have to be integrated. Finally the different data links (Link11, Link 16, Link22) are used to distribute the recognized picture and additional real-time or non real-time information.

1.3 Information Fusion Topics

The main issue of information fusion is to keep sea or land areas, and the lower air space under surveillance. Therefore, objects within these areas have to be detected, tracked, classified and whenever possible identified.

To get the necessary information items and to ensure a good coverage of the surveillance area the information fusion has to deal with a distributed sensor suite. The sensors are mounted on top of surveillance towers, land vehicles and naval platforms and are linked together via fibre optical and radio networks.

For spectral diversity different types of sensors are commonly used. Ground surveillance radars are used because of their good detection and tracking capabilities for large surveillance areas und different climate conditions. Electro optical systems contribute to classification and identification. These systems consist of long range day light cameras, infra red systems and laser rangers which are mounted on top of a pan tilt head. This pan tilt head allows directing the electro optical systems onto the different objects.

Video processing software involves the detection of moving objects within image sequences (change detection), the steering of a camera to follow a designated object (template matching), or to recognize targets by comparison with predefined patterns (automatic target detection), e.g. by neuronal networks. Hence, also the video processing software addresses information fusion items mentioned above.

2 Radar Processing

2.1 Radar: Sensors

For ground surveillance tasks pulse and FMCW radars are used. Pulse radars are normally realized as multi mode radars to support the ground surveillance task in an optimal manner. The modes can be switched by the user and therefore allow an active interaction. Often they possess modes for

- Acquisition,
- Single target tracking,
- (Single or multi) sector surveillance (TWS),
- Panorama surveillance (TWS) and
- Jammer detection

The acquisition mode is used to direct the radar beam manually into a small sector.

Within the single target tracking mode the radar catches a designated target and controls the antenna in such a way that the target is kept. STT results in a very high update rate for the track which also helps to improve course and speed estimations.

The most important modes are the track while scan modes of ground surveillance radars. These allow the scanning of one or multiple predefined sectors. In these scanning modes the update rate is lower as within single target tracking. This is a real challenge for the filter and association algorithms because of the spectrum of ground target types (e.g. pedestrians, vehicles) and the corresponding bandwidth in dynamic variations. Mechanically scanning radars allow also to scan several sectors in a sequential manner. Electronically scanning antennas offers higher performances because, they allow quasi simultaneous scanning of several sectors and offer a constant update rate for the objects. Further they allow a parallel tracking of dedicated objects with a higher update rate or the intensive observation of special point of interests.

Finally, a 360° (panorama) surveillance is possible with ground surveillance radars.

2.2 Radar: Detection – Tracking - Classification

The detection of targets is most times based on Doppler processing and so called CFAR algorithms. Special attention must be given to the plot extraction with respect to resolution phenomena. Tracking uses non linear filter algorithms to take the measured Doppler value into account. Further the filters must be adapted to the different radar modes. For plot track association a gating algorithm is used, which depends on the false alarm density. Complex multi dimensional data association techniques [BP99] are used to overcome the uncertainty in state prediction and the possible long update intervals.

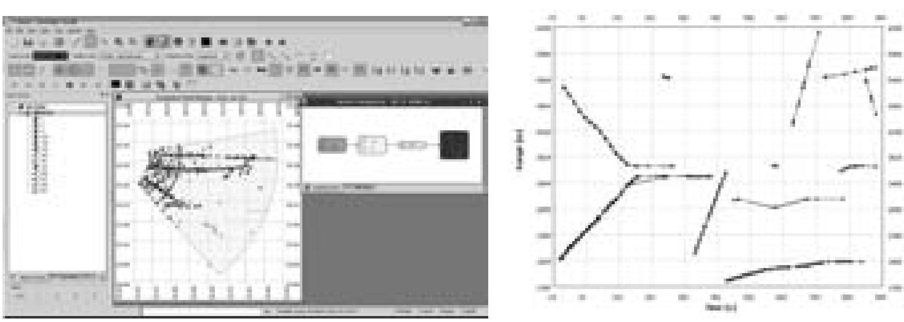

Figure 1: Sector Scan: Fusion++ Radar Tracks vs. Time

Because of the object spectrum track initialisation is done very carefully. The object spectrum contains pedestrians as well as vehicles, which depends on very different dynamic models. Therefore a score based initialisation mechanism was selected. This offers fast initialisation for fast vehicles and a very stable initialisation for slow moving objects simultaneously [BP99].

The tracking performance can be improved by taking into account digital terrain elevation data (DTED) or road map information (VMAP).

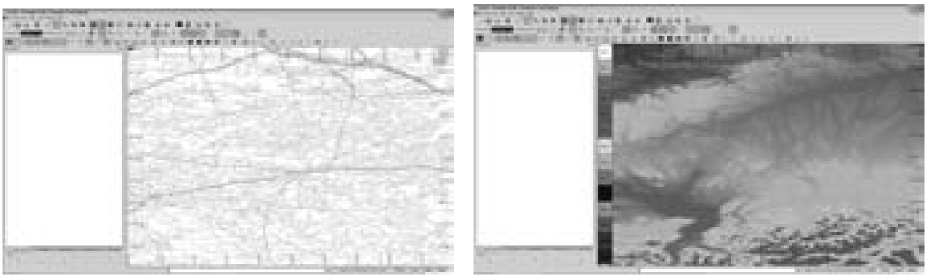

Figure 2: Fusion++ with VMAP and DTED

Performance tests were executed within the European and Arabian environment. Especially in the challenging environment of heavy sandstorms a good performance was important.

3 Video Processing

3.1Video: Sensors

The sensors consists of IR and long range day light TV cameras which are mounted on a pan tilt head. Often a laser ranger is also available. The sensor delivers a video for each camera. Further a data stream is provided, which contains the commands to steer the pan tilt head and the cameras. Status messages offer the actual direction and camera settings.

3.2 Video: Detection – Tracking - Classification

Four main software components are used to create a georeferenced view of the camera image.:

- Alignment
- Video processing, change detection and correlation
- Georeferencing with DTED
- Sensor tracking
- Visualisation with a display area.

A real challenge for georeferenced tracking with camera systems is the alignment of the camera system. The Alignment of the camera has to be very accurate since small uncertainties of the elevation can cause great uncertainties in the range estimation [DKO09].

Different aspects have to be taken into account when a camera system has to be aligned. On one hand the pan-tilt-head has to be adjusted in north orientation and horizontal direction. Otherwise the calculated target direction does not direct to the correct DTED position.

Further the optical axis within the camera system can be misaligned with respect to the pan/tilt system or misalignment effects occur through zooming operations with respect to the calculated field of view (bore sight alignment).

On the other hand two cameras (IR and TV) mounted on one pan-tilt-head may be misaligned to each other. Than the tracked targets are misaligned in range and bearing and fusion of these tracks becomes difficult.

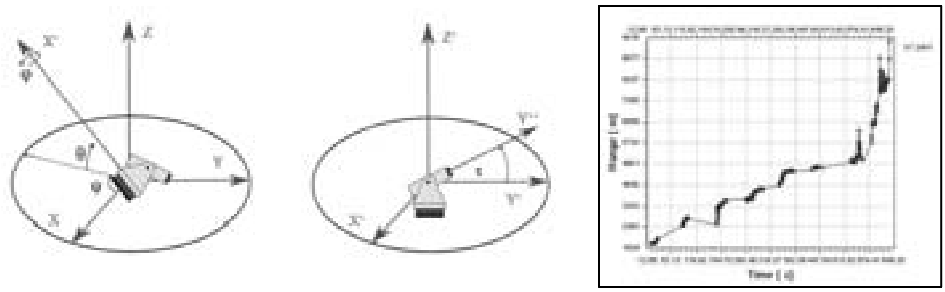

Figure 3: Alignment and coordinate systems: Earth vs. pan-tilt system (left), pan-tilt vs. camera (optical axis, centre); Video tracking: Stop and Go scenario (right)

After the alignment a video based detection and tracking software is used to identify moving objects in a scene, e.g. a landscape with moving vehicles and pedestrians. The software detects these objects automatically and delivers their pixel coordinates in the video picture.

If an object is detected within one video frame it is described in image coordinates. With respect to the current platform parameter, given by azimuth and elevation the direction of the target can be calculated. [DKK09]

Digital Terrain Elevation Data allows the range estimation of an object that is moving on the ground. By calculating the intersection between the direction and a DTED layer the range can be found [Ba09].

Once the extracted image is georeferenced the object can be tracked with a special Filter to handle different motion models of targets.

Additionally an automatic target recognition (ATR) is available, which distinguishes between different object classes.

4 Conclusion

Potential applications of information fusion for homeland security and protection are shown and various techniques of information fusion which are involved in the sensor integration and processing are described. These handle the detection, tracking and classification process for the radar and video based processing. These are key factors for effective and user friendly surveillance systems.

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