Multisensor based generation of templates for object tracking in complex scenarios

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Abstract: Protection and surveillance of persons and facilities is frequently associated with automatic tracking of striking objects like vehicles or persons in an image sequence. It is well known that common methods based on template matching imply problems concerning the automatic generation of realistic templates to be used in correlation based tracking systems. We propose a concept for generating templates of IR target signatures based on the fusion of IR images and classification results in laser range data. To optimize the tracking process different methods for a situation-constrained choice of the template were developed and evaluated. Results are shown by the analysis of an exemplary data set representing automatic tracking of vehicles from an airborne platform.

1 Introduction

The increasing demand for the protection of persons and facilities requires the application of sophisticated technologies and sensors for surveillance and object tracking. For this purpose typically a set of several sensors is used which have complimentary characteristics to optimize the system performance. In particular improving the performance of tracking systems is of great importance in military and civilian operations. Main objective is the reduction of the observer's workload using suitable sensor systems and intelligent algorithms for automatic data analysis. Appropriate sensors are for example imaging IR sensors suitable for day/night operation and laser radar supplying 3D information of the scenario.

Existing tracking systems are mainly based on template matching by correlation. An obvious problem of template matching with rectangle templates is that background pixels contribute to the correlation calculation and could create high correlation values at any position. Thus great efforts are made in designing automatic segmentation methods, so that the object is strictly separated from the background.

Furthermore considering an image sequence there need to be adequate techniques to define the moment of updating the template. Confusing objects could be in the scene and yielding high correlation values and false alarms. In this case the tracking could continue with one of these false alarms instead of the target.

This paper describes the automatic generation of IR templates based on the classification results of laser range data. Different approaches for the optimal usage of the templates are analyzed. Our work is part of a research project initiated by the German Ministry of Defence. The main focus is the development and validation of concepts for the fusion of multisensor data taken by airborne systems. For this purpose test scenarios are prepared and acquired by a helicopter equipped with a multisensor suite (infrared imager, scanning laser radar).

2 Sensor data and template generation

2.1 Testbed and sensor data

One of the main research activities at FGAN-FOM is the development and evaluation of algorithms concerning target detection and classification by applying a multisensor suite mounted on an airborne platform like a helicopter. The multisensor suite consists of a two-dimensional laser scanning device[1] for range measurements, an infrared sensor[2] to record long wave thermal imagery data and a navigational system[3] for recording the sensor pose (Figure 1). The navigational system consists of a GPS receiver, an inertial measurement unit (IMU) and a position and orientation computing system (PCS) using a Kalman filter to fuse all channels.

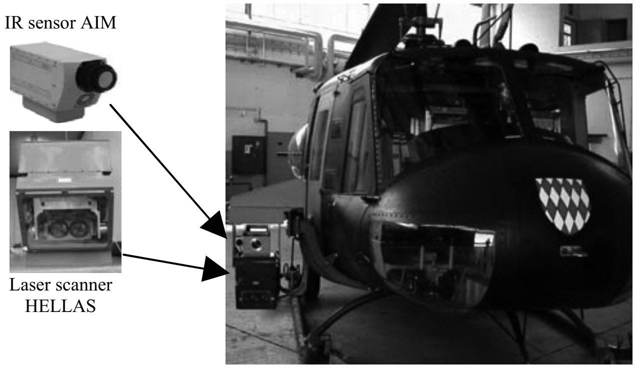

Figure 1: Helicopter, type Bell UH-1D, used as airborne platform of a multisensor suite.

[1] EADS HELLAS = HELicopter LASer radar (http://www.eads.com)
[2] FPA detector AIM 640 QWIP LW thermal imager (http://www.aim-ir.com)
[3] (http://www.applanix.com)

The test scenario consists of a group of different vehicles (tanks, trucks, pick-ups) situated in natural environment near a landing place for helicopters. The data of the laser scanner and IR sensor are gathered simultaneously by approaching the scenario (Figure 2).

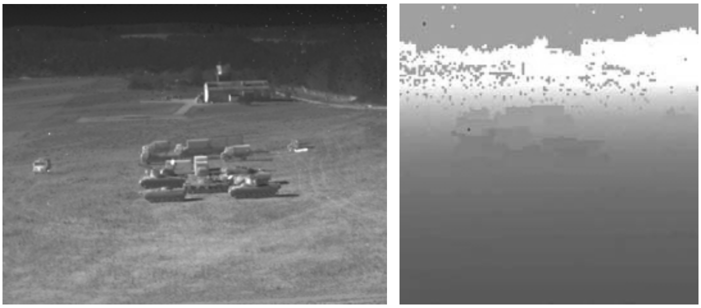

Figure 2: Test scenario. IR image (left), gray-value coded laser range image (right).

2.2 Template generation

Due to the fact that the time synchronization of the IR, laser and position channel is known as well as all spatial relations, corresponding data sets can be transferred directly into a global reference space. This can be a world reference frame as well as the reference frame of one of the sensors.

The sensor co-registration can be done in two different ways: on the one hand the 3D laser points can be projected into the IR image plane, on the other hand the 2D IR image rays can be intersected with the 3D laser point cloud [Wi07]. Details of the registration process as well as a description of our approach for image based optimization of time synchronization can be found in [HBJ06].

Separation of objects and background can be done robustly by 3D laser data analysis, starting with the segmentation of ground level. Subsequently the point clouds above ground level are clustered to be matched with 3D models of vehicles ([Ar05], [NA05]).

For the generation of the templates for vehicle tracking the segmented laser points belonging to the target vehicle are projected into the IR image plane defining the shape and IR signature of the target object. Finally the template consists of the bounding rectangle enclosing the target (Figure 3).

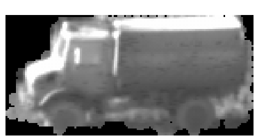

Figure 3: Target classification in laser data (left) and exemplary template (right).

For distributed sensor systems we use the 3D representation of the target consisting of the corresponding laser points textured with IR grey values. In this way we get a collection of views from different aspects.

3 Target tracking and system control

The laser sensor provides us with the segmentation of the target by robust classification algorithms. So we can omit those parts of the rectangular template belonging to the background or to objects in the foreground (Figure 3).

For the tracking process we use the normalized two-dimensional correlation coefficient (cc) of two matrices A, B representing the grey-value images of the template (B) and a section (A) of the scanned image. For every image reference point (i,j) we obtain a section $A^{(i,j)}$ of the same size as the template and calculate the correlation coefficient $cc(A^{(i,j)}, B)$. Thus a Matrix M of correlation values can be achieved. This matrix is analyzed for maximum values.

Robust tracking during target approach demands to update the template in suitable time steps. Different approaches were evaluated: first a static update every 10 images was performed corresponding to the frequency of the laser sensor. Second a dynamic update according to a lower limit of the maximum correlation value. The update is performed every time when the maximum value is smaller than a threshold.

	First peak		Second peak	
	mean	std dev	mean	std dev
Static	0.927	0.047	0.707	0.042
Dynamic limit 0.9	0.933	0.026	0.704	0.029
limit 0.85	0.909	0.040	0.703	0.043
limit 0.80	0.877	0.051	0.716	0.044
limit 0.75	0.858	0.065	0.712	0.034
2 Constraints	0.908	0.043	0.703	0.040

Table 1: Statistics

According to the mean values of the first peak of the static method (Table 1, line 1) 0.9 is a good limit for the dynamic update method. It leads to a robust target tracking, characterized by an increasing update frequency during target approach. For both methods there is a significant gap between first and second peak so that no confusions with false alarms can happen. The second method is more reliable for target approach because the update process enforces high correlation values.

Smaller limits were tested to evaluate system performance. In these cases confusions may occur because the maximum values are very close to each other (first and second peak). To solve this problem a distance between first and second peak is defined, enforcing the second peak to be at most 85% of the first peak, for example. This is a second constraint for updating the template in addition to the specified limit (Figure 4 right).

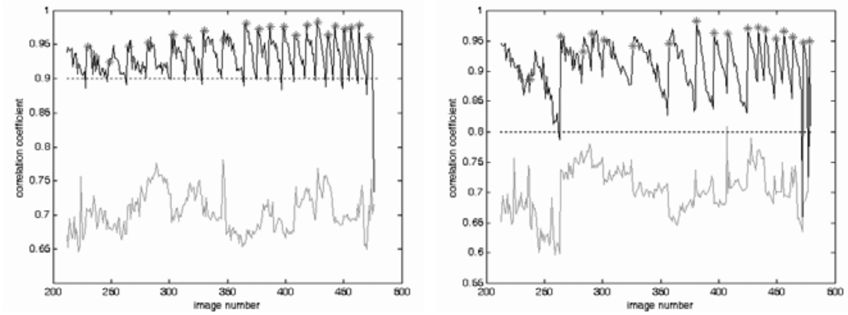

Figure 4: Correlation in an image sequence with lower limit 0.90 (left) and 0.80 (right).
On the right side the additional constraint was applied.

This is a good method to enforce the incidence of a unique maximum resulting in a successful tracking. At the end of the tracking process the target leaves the FOV of the IR sensor causing high fluctuations of the correlation values.

4 Summary

The presented work describes a tracking system combining information of two sensors: The IR tracking has the additional advantage of good visualization for human observers at a high image frequency. The laser scanner is a kind of verification sensor used to update the tracking system if the tracking in the IR imagery data seem to fail. With this system typical problems of correlation based template matching are eliminated. The target is the only object which yields high correlation values and there is low risk of loosing the target.

References

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