Fusion of Kalman Filter and anomaly detection for multispectral and hyperspectral target tracking

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Abstract

This paper proposes a novel tracking methodology for multispectral and hyperspectral sequences. Our approach (HS-KF) combines techniques used in multispectral and hyperspectral anomaly detection with Kalman-Filter(KF) for tracking. The algorithm takes advantage of the additional information provided by the spectra in multispectral and hyperspectral sequences together with KF to track a target in the presence of occlusion.

In [1], we proposed the use of Self Organizing Maps (SOM) for anomaly detection. The SOM was fed with a uniformly picked subset of image pixels as representatives of the classes in the image. The SOM units were considered as cluster centres, each of which had accumulated a number of input pixels with similar spectra. Classification was carried out by assigning individual pixels to classes (clusters). To assess how well a pixel was associated with a cluster, the spectral angular distance (SAD) of the pixel from its cluster centre was computed. A threshold was applied to the distance values to detect potentially anomalous pixels. Pixels with distances higher than the chosen threshold were marked as potential targets. Here we use the above approach to model the target's local background. Pixels within a window of the target are evaluated by the SOM by computing the distances of the pixel spectra from the SOM nodes. The position of the target, and thus the window, is recalculated for each frame. For this, we define a Centre of Gravity Map (CoGM). The CoGM is computed for each new frame and the new position of the target is computed taking into consideration the CoGM statistics. The CoGM is calculated as a function of the Euclidean distance between the pixel positions and the similarity of the target spectra with the background model. Moreover, a Kalman Filter in prediction mode is employed in order to perform robust tracking during occlusion. For each frame, we compute the CoGM that is considered as the observation for the KF. Occlusion prediction is computed based on the anomaly detector values, and thus the confidence in the current observations. Finally, the estimated position of the target is updated using the trajectory prediction given by the KF assuming locally linear motion.

Experimental results with simulated and real sequences with 4 bands (RGB, Infrared) where both ego-motion and occlusion intervals were present, are presented next. Figures 1 and 2 show examples of the tracker working under occlusion for the simulated and real date sets, respectively. The evaluation was performed using the Mean-Square-Error (MSE) between the target's predicted positions and the actual ones. For comparison purposes, a block-matching based tracker (BM) was implemented, the output of which was used as the observations to be fed to the Kalman Filter instead of using the CoGM. We also provide results of just using the SOM anomaly detector where the position of the

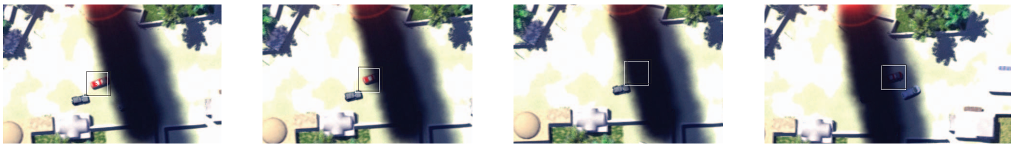

Figure 1: Tracking with the HS-KF algorithm (white squares) using the simulated data sequence. The ground truth positions are shown in black squares

Figure 2: Tracking with the HS-KF algorithm (white squares) using the real data sequence. The ground truth positions are shown in black squares

target is given by the CoGM.

The first set of data we tried was a simulated data sequence where a car is to be tracked (figure 1). The MSE was equal to 7.26, 14.56 and 11.39 for the HS-KF, BM-KF and CoGM, respectively. Here, during the occlusion interval, the measurements obtained by the HS procedure are fairly accurate because of the IR channel. Therefore, the KF prediction has only a stabilizing and enhancing effect.

A real sequence is shown in Figure 2. The HS-KF algorithm provided considerably better tracking performance than the BM-KF or the CoGM on its own. As it may be observed in figure 3, the measurements provided by the three algorithms during the occlusion interval were imprecise, however the HS-KF managed to track the target while the BM-KF and CoGM trackers lost the target after the occlusion interval. The MSE was equal to 4.8, 20 and 11.84 for the HS-KF, BM-KF and CoGM, respectively. The mean time of processing for one frame was 850ms using MATLAB on a 3.20GHz processor with 1GB of RAM. This is certainly inside the acceptable real-time specifications.

References

[1] O. Duran and M. Petrou, "A time-efficient method for anomaly detection in hyperspectral images," *Geoscience and Remote Sensing, IEEE Transactions on*, vol. 45, no. 12, pp. 3894–3904, Dec. 2007.

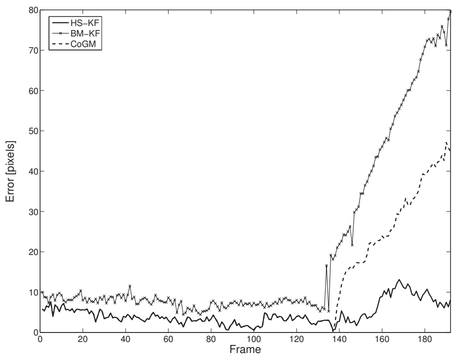

Figure 3: Error in the estimated positions given by the HS-KF, BM-KF and CoGM algorithms, respectively.