ROBUST MULTIBAND DETECTION OF THERMAL ANOMALIES USING THE MINIMUM COVARIANCE DETERMINANT ESTIMATOR

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1. ABSTRACT

The observation of active fires and thermal anomalies on the land surface has gained a considerable benefit from satellite remote sensing in the last decades. Nonetheless it is not straightforward to make full use of fire detection from satellite data, mainly because the requirements of good resolution in the spectral, spatial and temporal domains are not fulfilled by a single sensor. Multisensor systems should therefore be considered and a special care about product accuracy is required, through the design of precise detection algorithms [1, 2] and through appropriate validation processes [3]. As regards accuracy, in this work we discuss the problem of robustness of detection algorithms when the system operates in a contaminated background, i.e. when atypical radiance values may get involved in the threshold estimation.

Fire detection from the Moderate Resolution Imaging Spectroradiometer (MODIS) is among the most popular and widely investigated in both the aspects of the algorithm design and its validation; it is based on the NASA-DAAC MOD14 algorithm [4] where contextual detection thresholds are set according to the mean value and the absolute displacement of background data. Despite the choice of adaptive thresholds, the algorithm is unable to control the false alarm probability, a property that is nevertheless highly desirable under changeable conditions of the surrounding environment. This is the rationale behind our previous work [2] where a Constant False Alarm Rate (CFAR) algorithm was presented and applied to brightness temperatures in the 4 μm and 11 μm MODIS channels (bands 21 and 31), after re–projection of data on a decorrelating basis, obtained from the eigendecomposition of the sample covariance matrix (Principal Component Analysis (PCA)) [5]. The design of CFAR systems always requires the knowledge of the statistical distributions: in [2] a Location-Scale model has been chosen and, in particular, the Weibull distribution has been found compatible with data. An important property of Location-Scale distributions is that the detection threshold can be evaluated from ordered and censored background samples, maintaining the CFAR property, that is to say, the desired probability of false alarm is guaranteed without any dependence on the true parameters of the distribution. This characteristic is the basis for a fundamental step of the proposed detection scheme where a censoring operation is introduced to make the system robust with respect to self-masking effects. This happens when the presence of large radiance values in the observation window affects the estimation of the background parameters, the value of the threshold and, finally, the detection result. To mitigate this problem, a given number of high rank samples from the order statistics is discarded. However, the censoring is applied to the two components after the PCA stage and the presence of anomalies actually has an impact on this operation. Again, self-masking may affect the final detection. To reduce the influence of atypical observations we introduce in this work the Minimum Covariance Determinant method (MCD) [6, 7] for a robust estimation of the covariance matrix. The Principal Component Analysis based on the MCD estimator provides an analysis that is little influenced by the presence of anomalies while provides results similar to the usual PCA for uncontaminated data. Experimental results have shown that some detection can be missed if the MCD estimator is not used in the presence of anomalies, even if their number is not so high but the values are able to alter significantly the sample covariance matrix.

Minimum Covariance Determinant estimator

The Minimum Covariance Determinant is a technique introduced by Rousseeuw [6], that provides a highly robust estimate of multivariate location and scatter, i.e. covariance matrix. Very shortly, in a sample of n observations, the MCD finds $h \geq n/2$ values whose covariance matrix has the minimum determinant: the sample mean of these h values is the estimator of the multivariate location, while the sample covariance matrix is the estimator of the multivariate scatter. For its good breakdown value (essentially $(n-h)/n$) and its statistical characteristics, the MCD estimator is better than other robust estimators, it is more precise in evaluating robust distances and then in detecting outliers. Also the problem of a high computational cost, especially when the data dimension is large, has been solved by means of a fast algorithm [8].

First results

The MCD method has been applied to a MODIS data set, acquired by a TERRA pass over Mediterranean area on August 20th 2004, for estimating the covariance matrix in the Principal Component Analysis of brightness temperatures T21 and T31, in a 16×16 observation window. A comparison between PCA with and without the MCD estimator is reported in Figure 1. The first scatter plot shows the original temperature values, while the second (PCA) and the third (robust PCA) show the two principal components without MCD and with MCD, respectively. The results clearly confirm that the usual PCA is strongly influenced

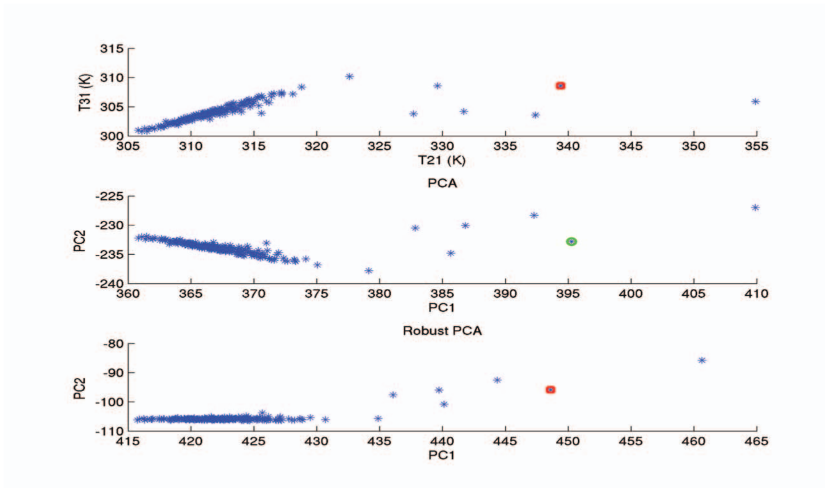

Fig. 1. PCA and robust PCA of brightness temperatures T21 and T31

by the presence of some anomalies, while the robust PCA gives the two components aligned with the major clustering of data, discarding the outliers. These different behaviors have then an effect on the detection: in the second plot the point marked in green color has been missed by the detection stage, but the same point, marked in red in the third plot, has been detected as a thermal anomaly when the robust PCA is used. This result seems reasonable if we look at the temperature values marked in red color in the first plot.

2. REFERENCES

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