ANOMALY DETECTION IN NOISY MULTI AND HYPER SPECTRAL IMAGES OF URBAN ENVIRONMENTS

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ABSTRACT:

The recent surge in remotely sensed imagery with multi to hyper spectral cubes has made it very difficult to detect features because of the sheer volume of data. In a sense it is locating the needle in the haystack which in urban areas is extremely difficult unless we have specific knowledge of the anomaly spectrum. Adding noise and atmospheric masking makes it even more complex a problem. In this paper we will present an approach by which we base our study on a novel spectral-segmentation algorithm for multi-or hyper spectral images and consider how to detect multi-pixel environmental anomalous objects in the urban space. In particular, we have developed several filters to compensate for noise which may be present in the initial cube. We also assume no a priori knowledge on the objects other than the fact that they are different from the background and are regularly shaped. We show that for speckle noise, a modification of our morphology technique allows us to detect features without correcting for atmospheric influences nor producing an enhanced false alarm result. We will show several results from urban environs in Israel and the USA using a variety of sensors.

1. INTRODUCTION

Urban mapping, segmentation into semantically meaningful objects, and classification is of importance and interest both to planners and urban social scientists. Furthermore, the ability to capture a bird’s eye views of the urban matrix and from that automatically retrieve anomalous features is of interest to local governments, search and rescue operations, and urban planners. In recent years a wealth of satellites captures images of urban environments at growingly higher spatial and spectral resolutions. While this wealth of data is considered positive, the analysis has become very time consuming and almost impossible. The traditional methods of aerial photography analysis with human interpreters is obviously too time consuming and misleading when there are large spectral cubes associated with each image. Furthermore, the common method for classifying and analyzing hyper-spectral cubes requires knowledge of potential end-members and is very sensitive to noise. In this paper we will present the use of an anomaly detection scheme that is sensitive to shape an insensitive to noise. This scheme was developed for target detection but we suggest using it for anomaly detection in the urban environment.

The ability to do so from ground surveying is expensive and extremely time consuming. However, images for which spectral vectors are available contain a wealth of information which can be used for anomalous feature detection. Moreover, because of the spectral richness of the data, objects which would naturally blend into the background can be made to stand out with the addition of the spectral data**.** Such data comes with a price: a major increase in the volume of the data taken. Every image is now a large cube; if such cubes need to be saved in real time, any realistic system would be overwhelmed. Thus, a method to concisely save such data is needed. One possible approach that has been used is by deriving the principal components present in the data. This reduces the dimensionality of the data and allows the noise to be discarded.

Recent papers (Silverman et al., 2002; Silverman et al., 2003; Silverman et al., 2004) showed how principal components can be used to segment cubes into their component parts; the resulting segmented images were then analyzed to find anomalous objects of particular dimensions. Good results were obtained and successful anomaly detection was performed.

Classic methods of urban mapping from hyper-spectral data (Spectral Angle Mapping, Spectral Correlation Mapping and Orthogonal Subspace Projection) assume that we have a reference signature for the potential endmembers composing the pixels (for example a library of signatures). For Anomaly Detection we use other models, for example the Local Normal Model, the Gaussian Mixture Model and the Linear Mixture Model (Stein et al., 2002). In this paper, the algorithm is based on anomalous object detection and we apply it to images of urban structures. As test data we use AISA hyperspectral data of part of Tel-Aviv and Netanya in Israel and an AVIRIS and Hyperion images of New York city following the 9/11 attacks and of San Francisco.

2. ANOMALOUS OBJECT DETECTION ALGORITHM

Our algorithm for the detection of anomalous objects is as follows (Silverman et al., 2004):

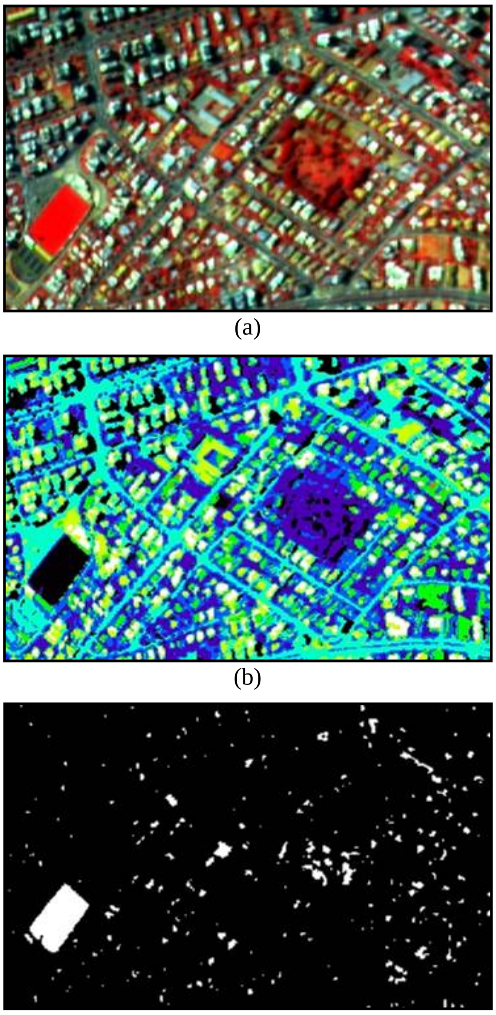
I. We first produce a two-dimensional histogram where the values of each axis are determined by each of the first two principal components images.
II. We find the peaks in this image and then associate each of the possible combinations of principal component values to one of these peaks. At this point, the original cube is segmented.
III. We next define the largest segments to be background; we choose enough segments so that roughly 90% of the area is covered (minimum value).
IV. Each cluster that contributed is averaged separately over its constituent pixel members; the resulting endmembers are defined to be the endmembers of the background.

V. Every pixel is now revaluated by its minimum distance (either Angular or Euclidean) to one of these endmembers.
VI. An analog morphological operation is next performed to eliminate objects which are either too small or two large to fit a size criteria (Rivest et al., 1996; Vincent et al., 2000).
VII. The results are analyzed by producing ROC (Receiver Operating Characteristics) curves relating the number of false alarms to the number of targets detected.

3. CASE STUDIES

3.1. Israel

Hyper-spectral images of part of Tel-Aviv and Netanya were acquired using an AISA airborne sensor (with 30 bands from 422nm to 890nm).



(a)

(b)

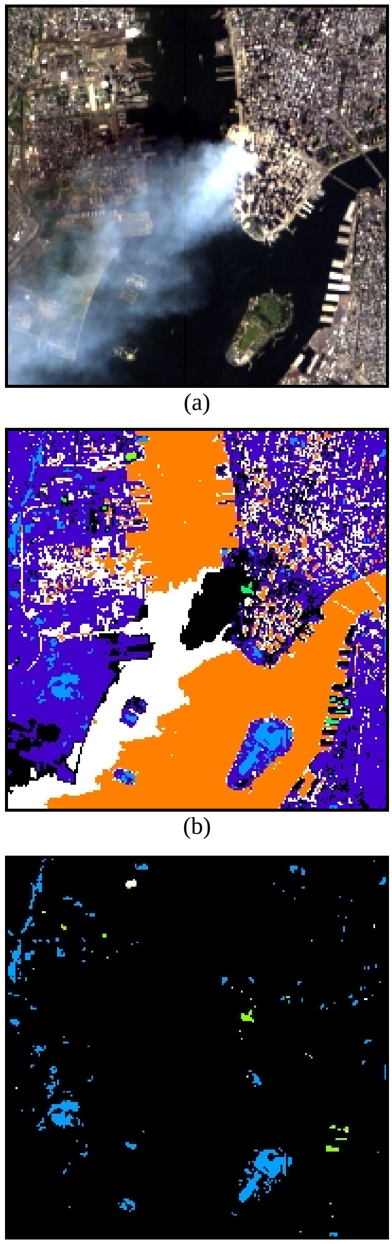
(c)

Figure 1. The image of Netanya: (a) includes three layers in the visible and NIR spectrum. (b) shows the image after it was classified into its main peaks, and (c) is after defining 95% of the image as background pointing to anomalous features.

Both cities are Mediterranean lying cities consisting of a blend of modern and old buildings with more vegetation in Tel-Aviv and less in Netanya. Tel-Aviv is a larger city of over 1 million inhabitants in the metro region and thus is more complex and Netanya is a smaller city of less than 100,000. Figure 1 shows the image of Netanya, the classification and the anomaly image with 95% defined as background. In this city the features that were detected as anomalous included a football field and some large vegetation patches.

3.2. United-States

Available to us were two sets of images covering the cities of New-York and San-Francisco. The image of NY was acquired 09/12/2001, only one day after the WTC attack. Obviously this image is overcastted by a thick layer of smoke (Fig 2).



(a)

(b)

(c)

Figure 2. Hyperion image of NYC on 9/12/2001. (a) is the visible layers, (b) is the classification and (c) is the image showing the anomalous features based on a 80% defined as background.

We ran our algorithm on this image and would like to point to two anomalies that are notable after defining 80% as background. The two anomalies include the heat sources for the main fires burning at the site of “ground zero” and include the two towers but also building 7. The second is the linear feature in the upper left part of the left image which is a line of vegetation in the New Jersey side of the Hudson River and is anomalous to this image.

4. CONCLUSIONS

In this paper, we have reviewed a method to automatically segment hyperspectral cubes and detect anomalous features in urban environments. We have applied this to images of New York, San Francisco, Tel-Aviv and Netanya. Unfortunately we have yet to acquire images of the same cities at different times so that the changes in anomalous features can be studied.

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