Chapter 72
Anomaly Detection in Hyperspectral Imagery: An Overview

Karim Saheb Ettabaa
Ensi University, Tunisia

Manel Ben Salem
IsitCom, Tunisia

ABSTRACT

In this chapter we are presenting the literature and proposed approaches for anomaly detection in hyperspectral images. These approaches are grouped into four categories based on the underlying techniques used to achieve the detection: 1) the statistical based methods, 2) the kernel based methods, 3) the feature selection based methods and 4) the segmentation based methods. Since the first approaches are mostly based on statistics, the recent works tend to be more geometrical or topological especially with high resolution images where the high resolution implies the presence of many materials in the same geographic area that cannot be easily distinguished by usual statistical methods.

INTRODUCTION

Anomaly detection is an important research topic for diverse domains. For the Cyber-Intrusion detection (Yu & Wu, 2012) and Fraud detection (Eberle & Holder, 2013; Lee, Yeh & Wang, 2013), the aim of anomaly detection is to avoid malicious attacks in critical systems. In the medical field, anomaly detection can be of a great importance for preventing attacks (Zhang, Raghunathan & Jha, 2013) or detecting patient anomalies (SALEM, Guerassimov, Mehaoua, Marcus & Furht, 2013) in personal healthcare systems or for diagnosing tumor in medical images (Goswami & Bhaiya, 2013). In sensor networks (OReilly, Gluhak, Imran, & Rajasegarar, 2014), anomaly detection can provide an idea about sensors data quality and integrity. In the industrial word, the damage detection aims to detect different faults and failures in complex industrial systems (Hu, Subbu, Bonissone, Qiu, & Iyer, 2008). Another anomaly detection field concerns the detection of anomalies in documents such as texts (Srivastava &

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Zane-Ulman, 2005) and images (Kim, 2013). More details about these anomaly detection applications are addressed in this survey (Chandola, Banerjee & Kumar, 2009).

In remote sensing, the anomaly detection aims to detect anomalous pixels in multispectral and hyperspectral images. Anomalies are pixels that deviate from the expected behavior and can hold interesting information. For instance, anomaly can be rare vegetation species, anomaly in vegetation growth, illegal plants associated to drug commerce, polluted area in coastal waters, adventurers lost in the dessert, buried archaeological structures, illegal border crossing or military vehicle under vegetative cover.

The remainder of this chapter is organized as follows; the second section gives a survey of anomaly detection, including problems faced and proposed statistical based, kernel based, feature selection based and segmentation based approaches. The third section enumerates the different criterion used for the evaluation of anomaly detectors. The fourth section discusses the advantages and inconvenient of these presented solutions and gives an idea about the future direction in anomaly detection. And the last section will conclude this overview.

ANOMALY DETECTION IN HYPERSPECTRAL IMAGERY

Problems

The magnitude of anomalies motivated researches in anomaly detection and interpretation for hyperspectral images. Since the beginning, researchers had to cope with the problem of the absence of any prior knowledge about the treated data. Therefore, they try to use statistical methods to compare between the Pixel Under Test (PUT) and the background. For statistical methods the background is modeled with a linear distribution of the Probability Density Function (PDF) that supposes its homogeneity. This supposition accentuates the False Alarm Rate (FAR) especially for high resolution images where the supposition of homogeneity seems to be inappropriate since the big diversity of existing materials. To decrease this fact, non linear models of the background have been proposed with the kernel based anomaly detectors. Other researches try to solve the anomaly detection problem with different techniques as feature selection and the segmentation.

Whatsoever the underlying techniques are, there are three principal challenges to overcome. The first challenge concerns increasing the detection rate while decreasing the false alarm rate which is related to the fact that the presence of noise, the contamination of the background statistics with the signature of the anomaly and the supposition of background homogeneity increase considerably the false alarm rate. The second challenge is related to the detection of anomaly with different shapes and sizes. In fact the size of anomalies can range from sub-pixel level to few pixels and the detection of these different sizes anomalies with the same detector steels a big challenge. The third challenge aims to achieve the nearest computational cost to real-time processing to perform anomaly detection on board as pixels are received.

Solutions

To achieve anomaly detection, researchers adopt several techniques relevant to diverse disciplines such as statistic, information theory, graph theory, and so on. Figure 1 shows that these approaches can be grouped into four families based on the underling techniques.