Chapter XXVII
Anomaly Detection in Medical Image Analysis

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ABSTRACT

Various approaches have been taken to detect anomalies, with certain particularities in the medical image scenario, linked to other terms: content-based image retrieval, pattern recognition, classification, segmentation, outlier detection, image mining, as well as computer-assisted diagnosis, and computer-aided surgery. This chapter presents, a review of anomaly detection (AD) techniques and assessment methodologies, which have been applied to medical images, emphasizing their peculiarities, limitations and future perspectives. Moreover, a contribution to the field of AD in brain computed tomography images is also given, illustrated and assessed.
INTRODUCTION

In general terms, anomaly detection (AD) can be considered as the process of detecting a small fraction of the data that differs, in some sense, from the global trend or pattern defined by the data set. The goal of an anomaly detector can be thought as the identification of the most unusual samples in a data set, without having any a priori information about their properties, other than they are rare and have a low probability of occurrence.

By their nature, anomalies do not permit a positive definition of their properties, making difficult a general formulation of the AD problem. Most of the approaches to detect anomalies use, instead, a negative definition: anomalies are data samples that do not conform to the rule or model of normalcy. This led to a broad group of anomaly detectors that are based on some type of a mathematical model, or description, characterizing the data under interest. Data fitting this description is considered as normal; those not fitting the model are considered anomalous. The general taxonomy for AD in image analysis can be thought to be composed of: (1) Observation field definition, (2) Background model estimation and (3) Detection.

This chapter discusses the particularities of the AD techniques in the context of medical images, their current status and perspectives. The Chapter is organized as follows: the next section presents the AD problem in pathology, gives an overview of the state-of-art in AD, and discusses AD algorithms assessment, where we propose a new evaluation measure. Then, we propose an AD algorithm for brain computed tomography (CT) images. In the last sections we analyze future trends in the domain and give some conclusions.

BACKGROUND

Most AD algorithms for medical image analysis are profoundly influenced by the specific image datasets used and by the medical or biological task. Figure 1 shows this diversity at a glance. Most reported studies have dealt with detection of tumors in digital mammography (Huang, 2004; Selvi, 2005; Wei, 2005; Peng, 2006; Chiracharit, 2007; Ikedo, 2007; Karnan, 2007), lung CT images (Minhas, 2005; Sluimer, 2006), and brain magnetic resonance (MR) images (Gering, 2003; Prastawa, 2004; Lee, 2005; Benamrane, 2006; Menze, 2006; Shinkareva, 2006; Bouix, 2007; Ekin, 2007), but many others can be mentioned.

Since the foundational work of Sklansky and Ballard (1973) on automatic location of tumors in radiographs using pattern-recognition-related methods, there have been several approaches focused in the detection of anomalies represented in medical images. Among others, one can cite the detection of different kind of tumors (Krivacic, 2004; Iyatomi, 2006; Strzelecki, 2006; Xu, 2006; Kelm, 2007; Montgomery, 2007), hemorrhages, multiple sclerosis, malformations and more (Bertelli, 2006; Shinkareva, 2006; Stoitsis, 2006). Any lesion (characterizing a disease, as Alzheimer’s (Ashton, 2006), or due to an accident) that is structurally and compositionally distinct from surrounding healthy tissue could be highlighted by an appropriate imaging modality and therefore could be detected by an AD approach.

Most AD works in the medical scenario are focused on studying organs more prone to develop certain types of cancers: breast, lungs, and brain. Variety of studies comprises AD techniques applied to images of cells (Krivacic, 2004; Spinosa, 2005), as well as to whole body scans (Ashton, 2006; Huang, 2007). In addition, image analysis of some other organs have benefited from AD procedures, e.g. the prostate (Kelm, 2007), the carotid artery (Stoitsis, 2006), the heart (Bertelli, 2006;