Chapter 3

Multi-Modal Content Based Image Retrieval in Healthcare: Current Applications and Future Challenges

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ABSTRACT

Modern healthcare environments have become increasingly reliant on medical imaging, and this has resulted in an explosive growth in the number of imaging acquisitions obtained as part of patient management. The recent introduction of multi-modal imaging scanners has enabled unprecedented capabilities for patient diagnosis. With multi-modal imaging, two or more complementary imaging modalities are acquired either sequentially or simultaneously e.g. combined functional positron emission tomography (PET) and anatomical computed tomography (CT) imaging.

The efficient and accurate retrieval of relevant information from these ever-expanding patient data is one of the major challenges faced by applications that need to derive accumulated knowledge and information from these images, such as image-based diagnosis, image-guided surgery and patient progress monitoring (patient’s response to treatment), physician training or education, and biomedical research. The retrieval of patient imaging data based on image features is a novel complement to text-based retrieval, and allows accumulated knowledge to be made available through searching. There has been significant growth in content-based image retrieval (CBIR) research and its clinical applications.

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However, current retrieval technologies are primarily designed for single-modal images and are limited when applied to multi-modal images, as they do not fully exploit the complementary information inherent in these data, e.g. spatial localization of functional abnormalities from PET in relation to anatomical structures from CT.

Multi-modal imaging requires innovations in algorithms and methodologies in all areas of CBIR, including feature extraction and representation, indexing, similarity measurement, grouping of similar retrieval results, as well as user interaction. In this chapter, we will discuss the rise of multi-modal imaging in clinical practice. We will summarize some of our pioneering CBIR achievements working with these data, exemplified by a specific application domain of PET-CT. We will also discuss the future challenges in this significantly important emerging area.

INTRODUCTION

Content-based image retrieval (CBIR) refers to the use of the visual attributes of images for searching an image database. In recent years, we have witnessed a rapid rise in CBIR research and the development of CBIR based clinical applications for medical image databases (Müller, 2004; Cai, 2007; Deserno, 2007; Long, 2009; Kim, 2009). Some well-known CBIR investigations include the retrieval of high-resolution lung computed tomography (CT) introduced by Shyu (1999); a study by El-Naqa (2004) for the retrieval of microcalcification types from mammography images; the retrieval of dynamic positron emission tomography (PET) images based on temporal attributes (Cai, 2000; Kim, 2006); and more recently, a retrieval system for spine X-ray images using a partial shape matching approach (Xu, 2008).

The aforementioned CBIR systems were designed for a single type of imaging modality, and were thus able to utilize domain specific knowledge and image processing optimizations. Such approaches, however, may be limited in their application when applied to different imaging modalities. There are several CBIR studies that are not bound to a single modality and that aim at supporting a diverse range of medical images. For example, in Lehmann (2005), an automatic categorization for a wide variety of medical images was presented that allowed for a robust classification of medical images. Their results demonstrated that their categorization technique, which based on global image textural features and scaling, was successful in classifying images according to their anatomical regions, imaging modality and specific orientation. The introduction of ImageCLEFmed, a medical section of the Cross Language Evaluation Forum (CLEF), has led to increasing interest in benchmarking the automatic classification and information retrieval from diverse medical image modalities (Deselaers, 2009; Rahman, 2007). ImageCLEFmed has created a standard environment for the evaluation and improvement of medical CBIR from heterogeneous collections containing images as well as text information.

However, regardless of their ability to retrieve from multiple modality databases, current retrieval technologies are inherently designed for single-modal images. Thus, these algorithms and systems are limited when applied to multi-modal images, as they do not fully utilize the additional complementary information that may be derived from these images. In this chapter, we refer to multi-modal images as two or more medical image modalities that are co-aligned to each other. These separate modalities may be co-aligned through sequential or simultaneous acquisition by a hybrid scanner or via image processing (see “Multi-modal Biomedical Imaging” for more details). Significant clinical benefits have arisen from the use of these multi-modality images and this has
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