Chapter 10
Content-Based Image Retrieval for Medical Image Analysis

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ABSTRACT

The growing repositories of clinical imaging data generate a need for effective image management and access that demands more than simple text-based queries. Content-Based Image Retrieval (CBIR) is an active research field and has drawn attention in recent years. It is a technique to organize and search image archives by their visual content. It is a multi-discipline field that integrates technologies from computer vision, machine learning, information retrieval, human-machine interaction, database systems, and data mining. CBIR consists of four main components: database and indexing, feature extraction, query formation and interface, and similarity measures. The applications of CBIR to the medical field include PACS integration, image annotation/codification, computer-aided diagnosis, case-based reasoning, and teaching tools. This chapter intends to disseminate the CBIR techniques to their applications to medical image management and analysis and to attract greater interest from various research communities to advance research in this field.

INTRODUCTION

With the development of multi-detector CT scanners and other advanced medical imaging equipment, the number of clinical images produced in medical institutions is rising rapidly in recent years. One typical cardiac CT study can have up to 15000 slices. For instance, the radiology department at the National Institutes of Health in USA generated about 1TB data every month in 2010. Medical image collections are high-throughput, high-resolution, and high-dimensional, which makes the searching highly challenging and also highly important. An efficient way to organize and retrieve such large amount of data becomes an imminent research topic.

Content-Based Image Retrieval (CBIR) is a multi-disciplinary research field which combines interests among different fields, including Machine Learning (ML), Information Retrieval (IR),

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Computer Vision (CV), Multimedia (MM), and Human-Computer Interaction (HCI) (Smeulders, Worring, Santini, Gupta, & Jain, 2000). CBIR provides three levels of retrieving an imaging database that range from highly concrete to the very abstract (Datta, Joshi, Li, & Wang, 2008). Level-1 comprises retrieval by primitive features such as texture, color, and shape. Level-2 comprises retrieval by derived features involving some degree of logical inference about the identity of the objects depicted in the image. Level-3 comprises retrieval by abstract attributes and possibly subjective reasoning about the images depicted. Most existing systems support level 1 and partially level 2 retrieval. IBM's Query By Image Content (QBIC) (Flickner, et al., 1995) is regarded as the first CBIR system, which was originally developed in the 1990s. Other systems such as Virage (Bach, et al., 1996), Photobook (Pentland, Picard, & Sclaroff, 1996) and Blobworld (Carson, Thomas, Belongie, Hellerstein, & Malik, 1999) were also well known in the research community. GNU Image Find Tool (GIFT) (Squire, Müller, Müller, Marchand-Maillet, & Pun, 2001) is freeware which provides some building blocks for users to build their own system.

In general, medical images arise from one of three mechanisms: (1) photography, including endoscopy, histology, cytology, pathology and dermatology; (2) radiographic projection, including x-rays and mammography; and (3) tomography, including CT, MRI, PET and ultrasound. Photography images usually contain color properties. Projection images are often in 2D and tomographic images are often in 3D. The application of CBIR in medical images has gained interest in the past decade and is regarded as one of the principal application domains of CBIR in terms of potential impact. There are a few major areas that CBIR techniques can improve the use of medical images and the quality and efficiency of health care. One of the main goals of a medical information system is to deliver the right image to the right person at the right time (Müller, Michoux, Bandon, & Geissbuhler, 2004). CBIR can certainly help achieve this goal by integrating into the medical image system such as Picture Archiving and Communication Systems (PACS) (Choplin, 1992). CBIR can also support imaging diagnosis through case-based reasoning or evidence-based medicine (Bui, et al., 2002) by supplying the clinicians with similar cases. Furthermore, CBIR can enhance Computer Aided Diagnosis/Detection (CAD) systems by characterizing lesions and reducing false positives using prior information stored in the database. Medical teaching tools can be augmented by the intuitive way provided by CBIR to browse large image repositories.

The chapter is organized as follows. We first introduce the architecture of a typical CBIR system, and then describe in detail each component of the system. After that, we present several applications of CBIR in the medical imaging field. At the end, we discuss the limitations and future directions of this research topic.

CBIR TECHNIQUES

The techniques in CBIR evolve from many other disciplines such as computer vision, computer graphics, artificial intelligence and information retrieval. This section will describe the architecture and its main components. Most descriptions are high level with references for further reading.

General Architecture

The architecture of a typical CBIR system is shown in Figure 1. It has four basic components: database and indexing, feature extraction, query formation and interface, and similarity measures. The workflow proceeds as follows. At the time a new study is stored into the image database (e.g. a PACS system), the visual or semantic features of this study are extracted from the content of the image and stored into a logical database. To perform the retrieval, a query is formed through