Chapter 3.9
Image Registration for Biomedical Information Integration

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ABSTRACT

The rapid advance and innovation in medical imaging techniques offer significant improvement in healthcare services, as well as provide new challenges in medical knowledge discovery from multi-imaging modalities and management. In this chapter, biomedical image registration and fusion, which is an effective mechanism to assist medical knowledge discovery by integrating and simultaneously representing relevant information from diverse imaging resources, is introduced. This chapter covers fundamental knowledge and major methodologies of biomedical image registration, and major applications of image registration in biomedicine. Further, discussions on research perspectives are presented to inspire novel registration ideas for general clinical practice to improve the quality and efficiency of healthcare.

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INTRODUCTION

With the rapid advance in digital imaging techniques and reduction of cost in data acquisition, widely available biomedical datasets acquired from diverse medical imaging modalities and collected over different imaging sessions are becoming essential information resources for high-quality healthcare services. Anatomical imaging modalities such as Magnetic Resonance (MR) imaging, Computed Tomography (CT) and X-ray mainly provide detailed morphological structures. Functional imaging modalities such as Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) primarily reveal information about the underlying biochemical and physiological changes. More recently, the combination of functional and anatomical imaging technologies into a single device, PET/CT and SPECT/CT scanners, has widened the array of biomedical imaging approaches and offered new challenges in efficient and intelligent use of imaging data. Since each of these imaging technologies can have their own inherent value for patient management, and ideally all such imaging data would be accessible for the one individual when they are required, huge volumes of biomedical imaging datasets are generated daily in the clinical practice (Wang et al, 2007). However, these ever-increasing huge amounts of datasets unavoidably cause information repositories to overload and pose substantial challenges in effective and efficient medical knowledge management, imaging data retrieval, and patient management.

Biomedical image registration is an effective mechanism for maximizing the complementary and relevant information embedded in various image datasets. By establishing spatial correspondence among the multiple datasets, biomedical image registration enables seamless integration and full utilization of heterogeneous image information, thereby providing a more complete insight into medical data (Wang, Feng, 2005) to facilitate knowledge discovery and management of patients with a variety of diseases.

Biomedical image registration has important applications in medical database management, for instance, patient record management, medical image retrieval and compression. Image registration is essential in constructing statistical atlases and templates to capture and encode morphological or functional patterns across a large specific population (Wang and Feng, 2005). The automatic registration between patient datasets and these available templates can be used in the automatic segmentation and interpolation of structures and tissues, and the detection of pathologies. Registration and fusion of information from multiple, diverse imaging resources is critical for accurate clinical decision making, treatment planning and assessment, detecting and monitoring dynamic changes in structures and functions, and is important to minimally invasive treatment (Wang, Feng, 2005).

Due to its research significance and crucial role in clinical applications, biomedical image registration has been extensively studied during last three decades (Brown, 1992; Maintz et al., 1998; Fitzpatrick et al. 2000). The existing registration methodologies can be catalogued into different categories according to criteria such as image dimensionality, registration feature space, image modality, and subjects involved (Brown, 1992). Different Region-of-Interests (ROIs) and various application requirements and scenarios are key reasons for continuously introducing new registration algorithms. In addition to a large number of software-based registration algorithms, more advanced imaging devices such as combined PET/CT and SPECT/CT scanners provide hardware-based solutions for the registration and fusion by performing the functional and anatomical imaging in the one imaging session with the one device. However, it remains challenging to generate clinically applicable registration with improved performance and accelerated computation