

Chapter VI

Image Registration for Biomedical Information Integration

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ABSTRACT

The rapid advance and innovation in medical imaging techniques offer significant improvement in health-care 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.

INTRODUCTION

With the reduction of cost in imaging data acquisition, biomedical images captured from anatomical imaging modalities, such as Magnetic Resonance (MR) imaging, Computed Tomography (CT) and X-ray, or from functional imaging modalities, such as Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT), are widely used in modern clinical practice. 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 integrating the complementary and valuable information from diverse image datasets. By searching the optimal correspondence among the multiple datasets, biomedical image registration enables a more complete insight and full utilization of heterogeneous imaging resources (Wang and 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 extract common patterns of morphological or functional changes across a large specific population (Wang and Feng, 2005). Therefore, registration and fusion of diverse imaging resources is important component for clinical image data warehouse and clinical data mining.

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 for biomedical datasets with larger imaging ranges, higher resolutions, and more dimensionalities.

CONCEPTS AND FUNDAMENTALS OF BIOMEDICAL IMAGE REGISTRATION

Definition

Image registration is to compare or combine multiple imaging datasets captured from different devices, imaging sessions, or viewpoints for the purpose of change detection or information integration. The major task of registration is to search for an appropriate transformation to spatially relate and simultaneously represent the images in a common coordinate system for further analysis and visualization. Image registration can be mathematically expressed as (Brown, 1992):

$$I_R(X_R) = g(I_S(T(X_S))) \quad (1)$$

where I_R and I_S are the reference (fixed) image and study (moving) image respectively; $T : (X_S) \rightarrow (X_R)$ is the transformation which sets up spatial correspondence between the images so that the study image X_S can be mapped to and represented in the coordinate system of reference image X_R ; $g : (I_S) \rightarrow (I_R)$ is one-dimensional intensity calibration transformation.

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