Chapter IX

Biomedical Image Registration for Diagnostic Decision Making and Treatment Monitoring

Xiu Ying Wang, The University of Sydney, Australia and
Heilongjiang University, China

David Dagan Feng, The University of Sydney, Australia and
Hong Kong Polytechnic University, Hong Kong, China

Abstract

The chapter introduces biomedical image registration as a means of integrating and providing complementary and additional information from multiple medical images simultaneously to facilitate diagnostic decision-making and treatment monitoring. It focuses on the fundamental theories of biomedical image registration, major methodologies and contributions of this area, and the main applications of biomedical image registration in clinical contexts. Furthermore, discussions on the future challenges and possible research trends of this field are presented. The chapter aims to assist in a quick understanding of main methods and technologies, current issues, and major applications of biomedical image registration, to provide the connection between biomedical image registration and the related research areas, and finally to evoke novel and practical registration methods to improve the quality and safety of healthcare.

Introduction

Clinical knowledge management is a challenging and broad discipline related to the collection, processing, visualization, storage, preservation, and retrieval of health-related data and information to form useful knowledge for making critical clinical decisions. As an important part of clinical knowledge, medical images facilitate the understanding of anatomy and function, and are critical to research and healthcare. Medical imaging modalities can be divided into two major categories: anatomical modalities and functional modalities.

Anatomical modalities, mainly depicting morphology, include X-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US). Functional modalities, primarily describing information on the biochemistry of the underlying anatomy, include single photon emission computed tomography (SPECT) and positron emission tomography (PET). With the advances in medical imaging technologies, these imaging modalities are playing a more and more important role in improving the quality and efficiency of healthcare. For example, the functional imaging techniques can be used to image physiological and biochemical processes in different organs, such as brain, lung, liver, bone, thyroid, heart, and kidney (Figure 1). In such clinical settings, PET aids clinicians in choosing the most appropriate treatment and monitoring the patients' response to these therapies. Since information from multiple medical imaging modalities is usually of a complementary nature, proper extraction registration of the embedded information and knowledge is important in the healthcare decision making process and in clinical practice.

The combination of more advanced and user-friendly medical image databases is making medical imaging results more accessible to clinical professionals. Starting in the early 1990s, the Visible Human Project and Human Brain Project at the US National Library of Medicine have produced a widely available reference of multimodal images of the human body. These projects provide users with labeled data and the connection of structural-anatomical knowledge with functional-physiological knowledge (Ackerman, 2001; Riva, 2003), and assist in making image data more usable for clinical training and surgery simulation and planning. A significant step in these virtual reality projects is the collection and registration of medical images from multiple imaging modalities.

Clinical practice often involves collecting and integrating considerable amounts of multimodality medical imaging data over time intervals to improve the optimization and precision of clinical decision making and to achieve better, faster, and more cost-effective healthcare. For example, in neurosurgical planning, the proper registration of the functional information with the detailed anatomical background enables the surgeon to optimize the operation with minimal damage to the healthy organs. The accurate and efficient registration of the complementary information available from different imaging modalities provides a basis for diagnostic and medical decision-making, treatment monitoring, and healthcare support.

A key issue in clinical knowledge management is biomedical image registration, which provides an effective mechanism to integrate the relevant information and knowledge in clinical and medical decision-making, operation planning, and image guided surgery. Registration algorithms also offer new possibilities to analyze and visualize multimodal image datasets simultaneously.

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