Recent Trends in Medical Image Registration Methods

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Abstract

Medical imaging plays a vital role in current clinical practice and biomedical research. Medical imaging has gone through a revolution since the advent of X-ray computed tomography imaging in early seventies and the introduction of other imaging modalities such as magnetic resonance imaging, positron emission tomography, etc in the later years. In many image analysis tasks, frequently a problem arises when images taken at different times or from different viewing points need to be compared. Image registration is a fundamental task in many modern image processing and computer vision tasks. The combination of more advanced and user friendly image acquisition, 3D image displays, medical image databases have contributed to the recent developments of medical image registration techniques in the areas of nuclear medicine, along with the early applications of CT-MRI registration and PET-MRI registration. This paper attempts to summarize the importance of medical image registration with primary focus on present capabilities and possible future advances.

Introduction

Over the last decade image registration has become an important technique in medical image processing and analysis. A trend began in the early 1990's as new image database, mapping, registration, and segmentation issues arose in the context of neuroimaging with the Human Brain Project [1] and whole body imaging with the Visible Human Project [2]. In the biomedical domain, there is a frequent need for comparing images for analysis and diagnostic purposes. Since information gained from two images acquired in the clinical track of events is usually of a complementary nature, proper integration of useful data obtained from the other images of the same patient is often desired. Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different sensors [3]. It aligns geometrically two images; the reference image and the sensed image. An example of the use of registering different modalities can be found in radiotherapy treatment planning, where currently computed tomography (CT) is used almost exclusively. However, the use of magnetic resonance imaging (MRI) and CT combined would be beneficial, as the MRI is better suited for delineation of tumor tissues, while the CT is needed for accurate computation of the radiation dose. Medical imaging modalities widely used can be divided into two major categories: anatomical and functional modalities. Anatomical modalities, depicting primarily morphology include X-ray, CT, MRI, etc. Where as functional modalities, depicting primarily information on the metabolism of the underlying anatomy include single photon emission computed tomography (SPECT), positron emission tomography (PET), etc. Hence registration of the images from practically any combination of different modalities will benefit the doctors.

The need to register images has arisen in many practical problems in diverse fields such as remote sensing, medical imaging and computer vision. Various image registration applications include multispectral classification, environmental monitoring, change detection, target localization, tumor growth detection and lung cancer screening [4]. One of the most important applications of medical image registration are in image guided surgery, nuerosurgery, treatment verification of pre and post intervention images, treatment monitoring and in functional brain mapping. Because of its importance in various application areas and its complicated nature, image registration has been the topic of much recent research [3,5,6,7].

CT and MRI Registration

CT and MRI are essential tools for the diagnosis and follow-up of illness. These two image modalities are based on different physical principles and have different properties. For example,MRI has high tissue contrast and CT is good in displaying bones. The complementary nature of CT and MR images and the regular use of both modalities in clinical settings has made combination of MR and CT images as one of the first applications of medical image registration [8,9]. The early applications of MRI-CT registration were within the head, and this remains the widely used application till today. Most of the MR and CT image registration techniques are mainly concentrated on finding a rigid body transformation. In many clinical applications such as cardiac image registration, it is necessary to find a non-rigid transformation because of the mixed motions of heart and the thorax structures. The development of robust and efficient non-rigid registration algorithms are likely to make MRI-CT registration applicable to newer applications in surgery and radiotherapy planning in near future.

PET and MRI Registration

PET is an imaging modality that provides information about physiological and biochemical processes. Combining MRI

morphological data with functional PET data now offers unique capabilities for the medical imaging community and biomedical researchers. PET is able to provide information about a specific function like the cerebral blood flow and glucose consumption. In general it lacks spatial resolution and anatomical evidence which often are needed to localize the disease, or for planning therapy in cancers. MRI has excellent spatial resolution and signal to noise ratio characteristics, but it may offer relatively low specificity for differentiating disease from normal structures. Both imaging modalities are useful for clinical studies as well as for basic scientific investigations. The fused PET-MRI data was used extensively in a wide variety of clinical applications including brain trauma, stroke, epilepsy, Parkinson's disease, etc. The development of dual-modality imaging systems such as combination of PET and CT in one hardware device is already being used on a routine basis in oncology, but the combination of PET with MRI still exhibits several technical challenges [10]. Recent developments in PET-MRI image registration methods have made many clinical practices to support special surgical interventions, cancer detection and determination of functionally significant brain sections and delineation of tumor localization before surgery and radiotherapy.

Nuclear medicine

Nuclear medicine has a history of one hundred years. It started in early twentieth century, when Alexander Graham Bell suggested placing radioactive sources near tumors to treat them [11]. In the past few years, discoveries in the nuclear medicine field have been among medicine's most exciting advances, giving doctors the ability to detect conditions at their earliest stages and to monitor the spread of cancer. Nuclear medicine imaging techniques such as SPECT, PET, cardiovascular imaging give doctors another way to look inside the human body. The techniques combine the use of computers, detectors, and radioactive substances. Nuclear medicine is a medical specialty that helps in treatment planning and monitoring by using radiopharmaceutical, which contains a minute amount of a radioactive material. After injecting radiopharmaceutical, the diagnostic images show rapid changes in activity in particular area of the body of interest. Nuclear medicine images demonstrate function, rather than anatomy. Some of the limitations of nuclear medicine imaging studies include limited spatial resolution and poor signal to noise ratio. Medical image registration with complementary anatomical modalities such as MRI or CT and SPECT or PET can be useful in solving number of issues related to nuclear medicine in future as mentioned in [12]. Some of the promising applications of nuclear medicine include detection of aneurysms, irregular or inadequate blood flow to various tissues, blood cell disorders and inadequate functioning of organs, such as thyroid and pulmonary function deficiencies.

Conclusion

Medical imaging is now established as a scientific discipline with many technological advances. A better usage of the available medical imaging modalities would require more and more advanced medical image processing tools in future to assess the diagnosis, to control and evaluate the therapy. Important ongoing needs in biomedical imaging include efficient and robust multimodal non-rigid image registration, real-time volume rendering and visualization techniques. Nuclear medicine and other imaging specialties can only be benefited from these evolving advances, in which image registration plays a significant role. Progress in medical image registration methods will have a positive impact on biomedical imaging research and healthcare domain in near future.

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