Chapter 7
Image Fusion Method and the Efficacy of Multimodal Cardiac Images

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ABSTRACT

Currently, there is no single type of medical image that provides an indispensable tool for clinical diagnosis and treatment: Rather, different imaging devices are used for different diseases. Each imaging device has both advantages and disadvantages. To provide a more complete picture and to improve accuracy in diagnosis, techniques that combine images taken by different imaging modalities have recently used more in clinical practice. In addition, researchers continue to develop these techniques. Previously, images taken by different devices at different times were integrated using image processing techniques. After the development of hybrid imaging devices that can connect two kinds of devices, complicated processing by software was reduced. In this chapter, the authors review some representative imaging modalities that are commonly used as diagnostic tools and discuss the use and efficacy of image fusion techniques for clinical use.

INTRODUCTION

In recent years, imaging systems with various capabilities have become widely used in clinical practice. Images constructed from multiple imaging sources have both advantages and disadvantages. Combining images with different characteristics enables a deeper understanding of the objects under observation. It also provides useful information for diagnosis and treatment. Although image fusion can be applied to any part the body, here we focus on images of the heart and describe how image fusion can be used to evaluate cardiac function. We select four representative modalities that are widely-used in clinical practice, and we explain how multiple modalities may be combined.

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The first modality is Magnetic resonance imaging (MRI), which leverages nuclear magnetic resonance (NMR) to illustrate the nuclei of atoms in the human body. MRI enables high-quality delineation of soft tissue, including the heart. The second modality is X-ray Computed tomography (CT), which illustrates the absorption ratio of the X-ray in the body. CT scans generate excellent spatial resolution and can acquire many images in a short amount of time, making it possible to take full-motion heart scans. Thus, both MRI and CT provide high-resolution structural and anatomical information, but lack functional information. In contrast, single photon emission computed tomography (SPECT) and positron emission tomography (PET) lack high-quality spatial resolution but provide substantial functional information. SPECT is a nuclear medicine tomographic imaging technique that uses gamma rays. Patients are injected with a gamma-emitting radioisotope called a tracer. Gamma rays are radially emitted from this radioisotope as it travels through the bloodstream and are detected by a gamma camera outside the body. The concentration of the tracer at the point of interest in the body is calculated using an algorithm similar to that used in the CT technique. SPECT is mainly used in myocardial perfusion imagining. Finally, PET creates images from pairs of gamma rays emitted indirectly by a positron-emitting radionuclide. As in SPECT, the radionuclide is injected into the vein, but PET uses a different type of nucleus. In cardiac function, fluorine-18 (F-18) fluorodeoxyglucose (FDG) and nitrogen-13(N-13) ammonia are generally used as tracers detect myocardial glucose metabolism and myocardial blood flow, respectively. In SPECT and PET images, signal attenuation can occur due to absorption of the gamma rays by the various tissues they pass through before they can be detected by the camera outside the body. To correct the problem of signal attenuation, CT images have recently been used. Another modality, Ultrasonography (US), has been widely used because of its portability and its ability to measure heart motion in real time and to measure blood flow using Doppler. However, it is difficult to integrate these reports with other modalities because of its low image quality relative to MRI and CT; accordingly, we will not consider US further here. Cardiac images are generally taken together with an electrocardiogram (ECG) to account for the heart's movement as it pulses and its corresponding change in shape.

Combining multiple modalities leads to improved accuracy in evaluating cardiac function because the different modalities compensate for the disadvantages and enhance the advantages that any one modality has on its own. There are two methods for combining images across modalities. One involves integration of images taken at different times, an image processing technique known as image registration. The other involves the superposition of images using a hybrid device that sequentially connects two pieces of imaging equipment as shown in Figure 1; the images are not obtained at precisely the same time but are obtained through continuous measurement. Image registration can be used to fuse any two images – in principle, it could even fuse more than two kinds of images. Consequently, various combinations have been investigated. Hybrid devices, on the other hand, are commercially-produced. Representative hybrid devices include PET/CT, SPECT/CT, PET/MRI and SPECT/MRI. MRI and CT are superior for depicting the structure of an organ or tissue with high spatial resolution, while PET and SPECT provide functional information (such as metabolism and blood flow), but with poorer spatial resolution. Thus, combining the types of images makes it possible to evaluate the function of organs or tissue at very specific positions.

In this paper we evaluate cardiac function using image fusion and discuss image processing techniques and their application in clinical practice.