Preface

Our goal is to develop automated methods for the segmentation of three-dimensional biomedical images. Here, we describe the segmentation of confocal microscopy images of bee brains (20 individuals) by registration to one or several atlas images. Registration is performed by a highly parallel implementation of an entropy-based nonrigid registration algorithm using B-spline transformations. We present and evaluate different methods to solve the correspondence problem in atlas based registration. An image can be segmented by registering it to an individual atlas, an average atlas, or multiple atlases. When registering to multiple atlases, combining the individual segmentations into a final segmentation can be achieved by atlas selection, or multiclassifier decision fusion. We describe all these methods and evaluate the segmentation accuracies that they achieve by performing experiments with electronic phantoms as well as by comparing their outputs to a manual gold standard.

The present work is focused on the mathematical and computational theory behind a technique for deformable image registration termed Hyperelastic Warping, and demonstration of the technique via applications in image registration and strain measurement. The approach combines well-established principles of nonlinear continuum mechanics with forces derived directly from three-dimensional image data to achieve registration. The general approach does not require the definition of landmarks, fiducials, or surfaces, although it can accommodate these if available. Representative problems demonstrate the robust and flexible nature of the approach.

Three-dimensional registration methods are introduced for registering MRI volumes of the pelvis and prostate. The chapter first reviews the applications, challenges, and previous methods of image registration in the prostate. Then the chapter describes a three-dimensional mutual information rigid body registration algorithm with special features. The chapter also discusses the three-dimensional nonrigid registration algorithm. Many interactively placed control points are independently optimized using mutual information and a thin plate spline transformation is established for the warping of image volumes. Nonrigid method works better than rigid body registration whenever the subject position or condition is greatly changed between acquisitions.

This chapter will cover 1D, 2D, and 3D registration approaches both rigid and elastic. Mathematical foundation for surface and volume registration approaches will be presented. Applications will include plastic surgery, lung cancer, and multiple sclerosis.

Flow-mediated dilation (FMD) offers a mechanism to characterize endothelial function and therefore may play a role in the diagnosis of cardiovascular diseases. Computerized analysis techniques are very desirable to give accuracy and objectivity to the measurements. Virtually all methods proposed up to now to measure FMD rely on accurate edge detection of the arterial wall, and they are not always robust in the presence of poor image quality or image artifacts. A novel method for automatic dilation assessment based on a global image analysis strategy is presented. We model interframe arterial dilation as a superposition of a rigid motion model and a scaling factor perpendicular to the artery. Rigid motion can be interpreted as a global compensation for patient and probe movements, an aspect that has not been sufficiently studied before. The scaling factor explains arterial dilation. The ultrasound (US) sequence is analyzed in two phases using image registration to recover both transformation models. Temporal continuity in the registration parameters along the sequence is enforced with a Kalman filter since the dilation process is known to be a gradual physiological phenomenon. Comparing automated and gold standard measurements we found a negligible bias (0.04%) and a small standard deviation of the differences (1.14%). These values are better than those obtained from manual measurements (bias = 0.47%, SD = 1.28%). The proposed method offers also a better reproducibility (CV = 0.46%) than the manual measurements (CV = 1.40%).

This chapter will focus on nonrigid registration techniques. Nonrigid registration is needed to correct for deformations that occur in various contexts: respiration or organ motion, disease progression over time, tissue deformation due to surgical procedure, intersubject comparison to build anatomical atlases, etc. Numerous registration techniques have been developed and can be broadly decomposed into intensity-based (photometric) and landmark-based (geometrical) techniques. This chapter will present up-to-date methods.

This chapter will then present how segmentation and registration methods can cooperate: accurate and fast segmentation can be obtained using nonrigid registration; nonrigid registration methods can be constrained by segmentation methods. Results of these cooperation schemes will be given.

This chapter will finally be concerned with validation of nonrigid registration methods. More specifically, an objective evaluation framework will be presented in the particular context of intersubject registration.

This chapter concerns elastic image registration for biomedical applications. We start with an overview and classification of existing registration techniques. We revisit the landmark interpolation and add some generalisations. We develop a general elastic image registration algorithm. It uses a grid of uniform B-splines to describe the deformation. It also uses B-splines for image interpolation. Multiresolution in both image and deformation model spaces yields robustness and speed. We show various applications of the algorithm on MRI, CT, SPECT and ultrasound data. A semiautomatic version of the registration algorithm is capable of accepting expert hints in the form of soft landmark constraints.

The chapter will include algorithms based on landmark and intensity-based image registration. It will compare traditional unidirectional registration algorithms to those that are bidirectional and minimize the inverse consistency error. It will discuss how small deformation models can nonrigidly be used for medical image registration in the brain, skull, and inner ear. It will also discuss how to extend the small deformation model to the large deformation model to accommodate locally large deformation image registration problems. We will provide examples using phantom images and brain images to demonstrate the large deformation case.