# IMAGE REGISTRATION
# GUEST EDITORS' INTRODUCTION

In this issue, a collection of papers covering different aspects of image registration is presented. Image registration is the process of determining correspondence between all points in two images of the same scene. By registering two images, information from different sources can be combined, the geometry of the scene can be recovered, and changes occurred in the scene between the times the images were obtained can be determined. Image registration is often needed in medical image analysis, processing of remotely sensed data, robot vision, automated monitoring, and industrial inspection. To register two images, generally, a number of features are selected from the images, correspondence is established between them, and from feature correspondences a transformation function is determined to map points in one image to points in the other image. Feature selection, feature correspondence, and image mapping all depend on geometric differences between images. The papers presented in this issue are, therefore, classified into two groups: those that discuss registration of images with linear geometric differences, and those that discuss registration of images with nonlinear geometric differences. The first five papers cover registration of images with linear geometric differences, while the last four papers cover registration of images with nonlinear geometric differences.

Linear methods use either the affine transformation or the transformation of Cartesian coordinate systems to register images. The transformation parameters are determined using a number of corresponding features in the images. Point landmarks are the most suitable features because their positions can be determined with subpixel accuracy. Rohr introduces differential operators that can be used to select point landmarks in images. Once a number of landmarks are selected from each image, the next step is to establish correspondence between them and use the coordinates of corresponding landmarks to determine the transformation parameters. Mount *et al.* describe a point correspondence algorithm using the Hausdroff distance.

In addition to point landmarks, line segments, contour segments, and surface patches can be used as features to register images. Shekhar *et al.* describe a method that uses line segments, while Fischer *et al.* describe a method that uses surface patches to register images. A technique described by Studholme *et al.* does not use image features but rather uses the image intensities directly, and by minimizing the normalized joint entropy of overlapping areas in images, determines the registration parameters.

Since the landmark detection process collapses in images with nonlinear geometric differences, nonlinear techniques typically try to gradually deform one image in such a way that image structures, such as contours or surface patches, deform to locally match similar structures in the other image. Gabrani and Tretiak describe a method for registering images with nonlinear geometric differences using an energy minimizing elastic transformation function, while Gee describes an elastic matching algorithm based on a probabilistic approach. A hierarchical algorithm described by Chen *et al.* initially register images using a composite of transformation functions, each in the form of a trilinear function. Then by a fine-tuning mechanism deform one image to overlay with the other. Lester and Arridge survey different nonlinear image registration techniques and categorize them according to the complexity of the data, complexity of the transformation functions, and complexity of the algorithms.

The papers by Mount *et al.* and Shekhar *et al.* discuss registration of 2-D images, while the papers by Chen *et al.*, Fischer et al., Gee, Rohr, and Studholme *et al.* discuss registration of 3-D images. The paper by Gabrani and Tretiak discusses registration of both 2-D and 3-D images. Except for the paper by Fischer *et al.*, which registers range images, all other 3-D techniques register volumetric images. The paper by Lester and Arridge reviews both 2-D and 3-D registration techniques.

Five of the papers presented in this issue were selected from among seventeen papers submitted as a result of a call for papers for this special issue. Each paper was reviewed by at least one of the editors and at least two other experts in the field. The remaining four papers were selected from forty-two papers presented at a workshop on Image Registration held at NASA Goddard Space Flight Center, Geenbelt, MD, in November 1997. Papers selected at the workshop went through a review process similar to that of the regular papers.

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In spite of significant progress in image registration during the past two decades, considerable work remains to be done. Most difficulties are in registration of multimodal images. Techniques using structural features rather than signal-based features seem most promising. Techniques that can detect structural features, especially point landmarks, and establish correspondence between them when the images have nonlinear geometric differences are in great demand. Transformation functions that can locally deform one image to overlay with another using local image information also need further research. Quantitative evaluation criteria and adequate test data also need to be defined. Algorithms need to be evaluated for their accuracy; robustness to noise, nonlinearity, and anisotropic sampling densities; computational requirements; and level of user interaction. We hope papers included in this issue special provide necessary pointers to past work and set the ground work for future work to appear in image registration.

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