THEORETICAL AND PRACTICAL PROBLEMS IN FEATURE-BASED REGISTRATION

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ABSTRACT

The first part of this thesis proposes a new registration algorithm, Covariance Driven Correspondences (CDC), that depends fundamentally on the estimation of uncertainty in point correspondences. This uncertainty is derived from the covariance matrices of the individual point locations and from the covariance matrix of the estimated transformation parameters. Based on this uncertainty, CDC uses a robust objective function and an EM-like algorithm to simultaneously estimate the transformation parameters, their covariance matrix, and the likely correspondences. Unlike the Robust Point Matching (RPM) algorithm, CDC requires neither an annealing schedule nor an explicit outlier process. Experiments on synthetic and real images using polynomial transformation models in 2D and in 3D show that CDC has a broader domain of convergence than the well-known Iterative Closest Point (ICP) algorithm and is more robust to missing or extraneous structures in the data than RPM.

The second part of the thesis presents an algorithm, Location Registration and Recognition (LRR), that is designed as an aid for longitudinal diagnosis and treatment monitoring, particularly for lung cancer. The algorithm takes (a) two temporally-separated CT scans, I_1 and I_2, and (b) a series of locations in I_1, and it produces, for each location, an affine transformation mapping the locations and their immediate neighborhood from I_1 to I_2. It does this without deformable registration by using a combination of feature extraction, indexing, refinement using ICP or CDC, and decision processes. Together these essentially "recognize" the neighborhoods. We will show that this is at least as accurate as the Diffeomorphic Demons algorithm while working at interactive speeds.

Motivated by the goals of improving detection of low-contrast and narrow vessels and eliminating false detections at non-vascular structures, the third algorithm we present is a new technique for extracting vessels in retinal images. The core of the technique

is a new likelihood ratio test that combines matched filters to extract vessels of widely varying widths, confidence measures to emphasize the vessel shape rather than its magnitude, and vessel boundary measures and the associated confidences. Combined, these responses form a 6-dimensional measurement vector that is mapped to a likelihood ratio at each pixel. Results comparing the new Likelihood Ratio Vesselness (LRV) measure to matched filters alone and to measures based on the Hessian of intensities show substantial improvements both qualitatively and quantitatively. The new vesselness likelihood ratio is embedded into a vessel tracing framework, resulting in an efficient and effective vessel centerline extraction algorithm.

The algorithms that we present are important for a longitudinal analysis of images. The new refinement algorithm, Covariance Driven Correspondences (CDC), is capable of aligning images with structural changes and noise. It can be used as a core refinement algorithm in more complicated systems. The Location Registration and Recognition (LRR) algorithm is a registration system for the analysis of regions in temporally-separated CT scans. Such system is an essential tool for the assessment of the pulmonary nodule growth. The Likelihood Ratio Vesselness (LRV) measure effectively detects thin and low-contrast vessels in retinal images that contain pathologies. Vessel centerlines can be used as features for registration or for vessel change detection after two time-separated images have been registered.