Combining variational and model based techniques to register MR finger images and PET hand data

D. Magee[1], S. F. Tanner[2], M. Waller[3], A-L. Tan[4], D. McGonagle[4], and A. Jeavons[3]
[1]School of Computing, University of Leeds, Leeds, W-Yorkshire, United Kingdom, [2]Division of Medical Physics, University of Leeds, Leeds, W-Yorkshire, United Kingdom, [3]Medical Physics, St James University Hospital, Leeds, United Kingdom, [4]Academic Section of Musculoskelatal Disease, Chapel Allerton Hospital, Leeds, W-Yorkshire, United Kingdom

Introduction: Clinically focussed studies of human diseases increasingly combine information obtained using different imaging modalities. Here, we present a non-rigid registration method for combining Positron Emission Tomography (PET) and Magnetic Resonance (MR) data of the hand and fingers. Our study includes images obtained from patients with osteoarthritis. It involves very high resolution MR images and PET data acquired from a scanner based on High-Density Avalanche Chambers (HIDAC) [1].

Methods: MR images of a selected finger joint were acquired using a 1.5T Gyroscan ACS-NT scanner (Philips, Best, The Netherlands) equipped with 23mm diameter surface 'microscopy' coil. High-resolution images (voxel size ≈ 0.1×0.1×1.0 mm) were obtained from a 2D T1-weighted spin-echo imaging sequence that employed TR/TE values of 475/18 ms [2]. High-resolution PET data was acquired in list mode using a QuadHIDAC PET scanner forty minutes after intravenous injection of 100 MBq of ^{18}F-labelled Sodium Fluoride (NaF) in physiological saline.
A previously developed method for image co-registration was combined with a kinematic model in this study. A variational image registration approach [3] employed mutual information as a metric to generate a free-form transform field to transform the PET voxels and thereby register the images. The variational method, used in isolation, co-registered the images in ways that differed from what is physically reasonable. The method was therefore 'regularised' by using the estimated free-form transform to estimate the parameters of a piecewise rigid kinematic model based on finger bones segmented from the MR data, and incorporating this model in the variational registration process by means of periodic re-initialisation of the transform. This protocol was used to register PET and MR images acquired from 9 patients with osteoarthritis. The accuracy of the protocol was assessed using synthetic PET data generated from images obtained from a hand mimicking phantom. A finite element mesh was calculated from these images and synthetic MR data produced by moving the mesh points by known amounts. A series of measurements determined accuracy by comparing known initial relative displacements with those measured after registration. This synthetic data was also used in comparative studies involving established rigid- and non-rigid- (B-spline) methods from the Insight Toolkit (ITK) [4].

Results: Analysis of our registration technique applied to the synthetic images showed that the mean registration error was less than 1.5 mm and the maximum error was less than 4mm (occurring in areas away from the region of interest). Analogous studies using other previously established methods (i.e. ITK-rigid or -non-rigid techniques) resulted in relatively poor image co-registration. Mapping the spatial variation of the registration error indicated that our protocol gave uniformly accurate registration across the fingers. In contrast, the registration accuracy of the rigid body method was distinctly heterogeneous whilst the established non-rigid technique gave surprisingly large registration errors.
Fig 1 shows grey scale MR images with superimposed PET data (b-d) acquired from a patient with osteoarthritis. Examination of these images (and analogous data obtained from other patients) indicates that the registration errors are consistent with those determined in our study using synthetic data. For example, these images show high PET signals that are coincident with the osteophytes (arrowed). These structures are associated with bone metabolism and a strong PET signal originating in the osteophytes is therefore expected and indeed observed in the registered images.

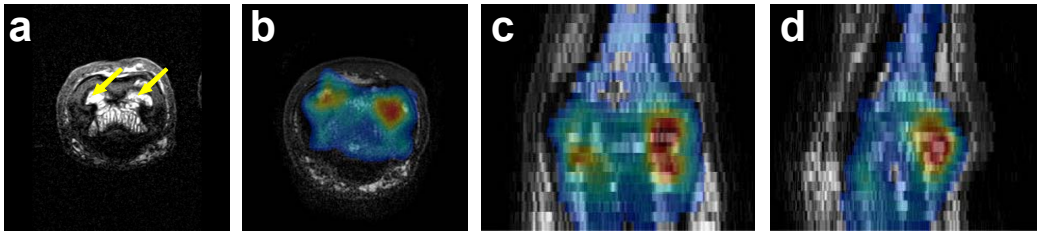

Fig.1: Axial (a and b), coronal (c) and sagittal (d) MR images in the region of the proximal interphalangeal joint in a patient with osteoarthritis. Images b-d also show registered PET data displayed as a colour overlay with 'warm' colours indicating relatively high ^{18}F uptake (see text).

Discussion: Much of the pathology in the fingers in arthritis patients occurs in close proximity to the joints. Accurate image registration is therefore required when combining results obtained using separate imaging equipment. Our protocol has outperformed some established methods generating registration errors of less than approximately 1.5mm in the vicinity of the finger joints and we are currently investigating the clinical utility of this technique in a study involving a larger number of patients.

[1] Jeavons A et al. IEEE Trans Nuc Sci 1999;46:468. [2] Tan A-L et al. Arthritis and Rheumatism 2005;52:2355.
[3] Hermosillo G et al Int. J. of Comp Vis 2002;50;329. [4] Ibabez L et al. The ITK Software Guide, Kitware Inc 2005.