Medical Image Processing: An Anatomical Template for Adult Human Hands

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Abstract

During medical image analysis, it is often useful to align, or ‘normalize’, a given image of a given body part to a representative standard, or ‘template’ of that body part. Normalizing images in this fashion allows one to draw statistically reliable conclusions regarding the given individual image or patient, as well as across multiple patients, across multiple images, and across multiple imaging modalities.

It is no surprise, therefore, that templates of the human brain have revolutionized not only brain research [1]. Templates also find clinical application in multimodal registration, neurosurgery, and volumetric analysis of pathology [2]. More recently, anatomical templates of other body organs, such as lungs, have had similar salutary effects [3]. However, templates for the human hand do not exist, even though hand imaging is one of the most commonly performed imaging procedures [4].

Normalization is especially important for hand images, because unlike brains, hands readily change shape during various tasks, by design. Here we report the construction of an anatomical template for healthy adult human hands.

We carried out T1 magnetic resonance imaging (MRI) of either hand in 34 healthy adult patients. Subjects who had hand-related complaints or clinical diagnoses were excluded. Each hand, including the wrist and the distal ≥5 cm of the forearm, was imaged in its natural resting position from the standard anteroposterior viewpoint using a 64-channel radiofrequency coil in a Siemens Magnetom Vida 3T scanner (voxel volume: 0.5x0.5x0.5mm3).

Of the resulting 68 images of 68 different hands, 27 images (14 and 13 images of left and right hands, respectively; 8 men and 13 women; mean age, 35.9 years±17.9 [standard deviation]; age range, 19.4–66.9 years; African American, 2; Asian 3; Caucasian, 14; Latino, 2) with excellent image quality were selected by visual inspection for further processing.

We used the open-source, cross-platform ANTs (Advanced Normalization Tools) medical image analysis software framework to carry out the preprocessing and to
construct the template. The 14 left-hand images were mirror-reflected about the vertical axis so that they had same orientation as the right hands.

The resulting 27 images were used as input to the ANTs’ standard multivariate template construction script [5], which constructed the template in stepwise manner. Briefly, images were first registered rigidly to remove differences in the orientation and positions of hands from one image to the next. Global orientation and positional variations, followed by affine registration to remove further translational, rotational, scaling, and shearing differences, and ending with symmetric normalization (SyN) deformable registration.

The resulting template image preserves all the essential anatomical features of the hand, including but not limited to, all the individual bones, muscles, tendons, ligaments, as well as the main branches of the median nerve and radial, ulnar, and palmar metacarpal arteries (Figure 1).

Future work in this ongoing project will incorporate even greater anatomical detail into the template.

References
Figure 1. Representative transverse sections of the hand template. Section numbers are shown at the bottom left corner of each panel.