Covariance matrix based elastic multi-channel image registration

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SYNOPSIS:

With the advent of new MR imaging modalities such as DT-MRI, MRA, and CSI, demand for image registration procedures capable of dealing with multi-channel image data has increased. A novel method based on multivariate linear correlation is proposed to align two multi-channel images each containing an arbitrary number of channels. Results obtained using diffusion tensor MRI data of the human brain show that image registration based on different channels generates different alignment results. In addition, we show that multi-channel image registration is more accurate to registration based on a single channel.

INTRODUCTION:

Whenever available, the inclusion of multi-channel image data can be beneficial in registering two images for it may help determine with more certainty whether or not two voxel locations in the different images are associated. Existing registration techniques for scalar images [1] do not generalize well to the multi-channel case because of excessive memory and computation requirements. Here we investigate the use of a novel similarity measure for multi-channel image registration and show that inclusion of all available channels is indeed beneficial to the registration process.

METHODS:

The image registration problem is approached with an optimization framework where the goal is to find spatial transformation $f:\mathbf{x}\rightarrow\Re^3$ that maximizes some similarity measure between M-channel image $\mathbf{S}(\mathbf{x})=\{S_1(\mathbf{x}),S_2(\mathbf{x}),\ldots,S_M(\mathbf{x})\}$ and N-channel image $\mathbf{T}(\mathbf{x})=\{T_1(\mathbf{x}),T_2(\mathbf{x}),\ldots,T_N(\mathbf{x})\}$. We use eq. (1) as similarity measure between images **T** and **S**, where $\sum_{\mathbf{T}}$ and $\sum_{\mathbf{S}}$ represent the covariance matrix of the images and $\sum$ represents their joint covariance matrix. Eq. (1) is the mutual information for the case of two multivariate normally distributed random variables [2]. Under weak assumptions it can be shown that (1) is a monotonic function of $|\mathbf{P}|$, where **P** is the matrix of linear correlation coefficients between the individual channels of images **T** and **S**. Eq. (1) can be used as a similarity measure whenever a linear relationship between the intensity values of individual channels of **T** and **S** can be expected. In our implementation we perform the nonrigid registration using the adaptive bases algorithm [3] to search for the elastic transformation *f* that maximizes (1).

$$I(\mathbf{S},\mathbf{T})=\frac{1}{2}\log\left(\frac{|\Sigma_{\mathbf{S}}||\Sigma_{\mathbf{T}}|}{|\Sigma|}\right) \quad (1)$$

RESULTS:

We computed the elastic registration of 7 multi-channel DT-MRI images of different subjects, each containing three distinct scalar channels (trace, relative anisotropy, and skewnes [4]), to an 8^{th} image of the same kind using both single and multi-channel approaches. The intensity variance across all subjects was computed for each voxel and averaged over all voxels for each channel. The relative improvement (ratio of average variance before and after registration) after each registration is reported in table 1. When considering improvement in intensity variance across all image channels, the multi-channel approach outperforms the traditional scalar registration approach using any of the three channels. Experiments using simulated deformation fields also indicate that the multi-channel scheme is more accurate. Figure 1 displays the average image of each channel after elastic registration with our multi-channel approach. The high resolution of the average images after registration indicates good overall image alignment.

	Trace	Anis.	Skew.	Avg.
Trace reg.	0.287	0.404	0.474	0.388
Anis. reg.	0.441	0.354	0.392	0.396
Skew. reg.	0.630	0.401	0.396	0.476
Multi-chan.	0.300	0.350	0.395	0.348

Table 1: relative improvement of intensity variance in each image channel after several registrations.

DISCUSSION & CONCLUSIONS:

The use of different image channels during registration cause different registration results. Experiments with DT-MRI data show that our multi-channel registration method produces results more accurate than scalar registration based on any single channel. These results should be important for studies that try to establish trends in populations of multi-channel data such as DT-MRI after spatial normalization.

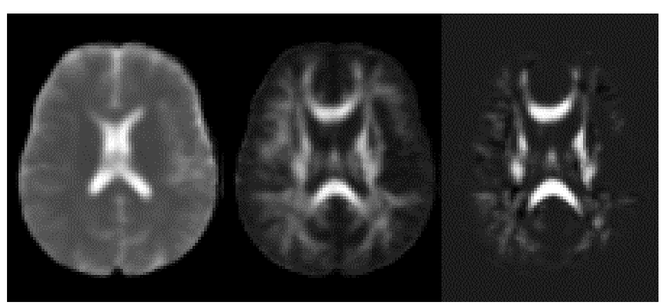

Figure 1: average of 7 multi-channel images after registration to a common template. From left to right: trace, relative anisotropy, and skewness channels.

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