Program name: 3dwarper

Purpose: This program is a part of the *automatic registration toolbox* (ART) package. It is designed to perform non-linear inter-subject registration of high-resolution ($\approx$ 1 mm) T_1-weighted 3D MRI brain scans.

The program takes two NIFTI images of type *short* as inputs: a target image and a subject image. The target image, sometimes referred to as the reference or the template image, is the image to which the subject image is to be matched. The subject image undergoes a deformation to match the target image.

It is assumed that the NIFTI files are of type "n+1" and contain the correct subject orientation information. The program uses this information to determine an initial rigid-body registration before commencing non-linear deformation.

The program outputs a deformation vector field in NIFTI format of type *short*. To obtain that actual deformation vectors in units of mm, the numbers stored in this NIFTI file have to be multipled by the *scl_slope* variable in the NIFTI header.

Usage: 3dwarper [-v or -verbose] [-h or -help] [-iter N] [-I -acpc -A] [-T filename] [-trgorient orientation code] [-suborient orientation code] [-u filename] [-o filename] [-cubicspline] [-sd *sd*] [-w N] [-s N] -sub subject image.nii -trg target image.nii

Required arguments

-sub subject image.nii: Subject image in NIFTI format of type *short* (*data type* 4). This is the image that will be deformed to match the target image.

-trg target image.nii: Target (template or reference) image in NIFTI format of type *short* (*data type* 4). This is the image to which the subject image is matched.

Optional arguments

-v or -verbose: Enables verbose mode

-h or -help: Prints help message

-iter N: Specifies the number of iterations used in finding the initial affine transformation when the -A option is specified (default: $N = 4$).

-I: Uses the identity matrix as the initial subject to target transformation.

-acpc: Uses AC-PC alignment to find a initial subject to target rigid-body transformation.

-A: Automatically finds an initial subject to target affine transformation.

-T filename: Uses the (4x4) matrix specified in filename as the initial subject to target linear transformation.

-trgorient orientation code: Overrides the orientation information in the target image NIFTI header with the given orientation code (PIL, LPS, etc.). There are 48 distinct possible orientation codes consisting of combinations of letters A, P, L, R, S, and I denoting, anterior, posterior, left, right, superior, and inferior directions, respectively. Examples:

PIL for Posterior-Inferior-Left

RAS for Right-Anterior-Superior

This option is useful in cases where the orientation information is missing or it has not been properly recorded in the NIFTI header. See "acpcdetect.pdf" for more information on how the

orientation code is defined.

-suborient orientation code: Overrides the orientation information in the subject image NIFTI header with the given orientation code.

-u filename: Stores the displacement vector field in the specified filename) in NIFTI vector field format (default: filename=subject filename_wrp.nii).

-o filename: Stores the transformed (registered) subject image.nii in the specified filename (default: filename=Csubject image.nii).

-cubicspline: The output transformed (registered) subject image.nii is generated using the cubic spline interpolation (default is trilinear interpolation).

-sd *sd*: Specifies the degree of smoothing applied to the displacement vector field. sd typically ranges from 5.0 to 12.0 mm (default = search window size minus 1 mm).

-w N: Correlation window size in voxels (default=5; minimum=3).

-s N: Search window size in voxels (default=5; minimum=3).

Example: 3dwarper -v -trg targetimage.nii -sub subjectimage.nii -acpc -A -sd 7.0

Major changes relative to earlier versions:

1. This version reads and write in NIFTI format only as opposed to ANALYZE format.

2. The deformation field is stored as a vector field in NIFTI format as opposed to the ẇrp format used before.

3. ACPC detection and automatic affine transformation is used to initial alignment of subject and target images. These features can be utilized using -acpc and -A options together.

References:

1. Klein A, Andersson J, Ardekani BA, Ashburner J, Avants B, Chiang MC, Christensen GE, Collins LD, Gee J, Hellier P, Song JH, Jenkinson M, Lepage C, Rueckert D, Thompson P, Vercauteren T, Woods RP, Mann JJ, Parsey RV. Evaluation of 14 nonlinear deformation algorithms applied to human brain MRI registration. Neuroimage. 2009.

2. Ardekani BA, Bachman AH. Model-based Automatic Detection of the Anterior and Posterior Commissures on MRI Scans. Neuroimage. 2009.

3. Ardekani BA, Guckemus S, Bachman A, Hoptman MJ, Wojtaszek M, Nierenberg J. Quantitative comparison of algorithms for inter-subject registration of 3D volumetric brain MRI scans. J Neurosci Methods. 2005 Mar 15;142(1):67-76.

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June 10, 2011.