HAMMER: Hierarchical Attribute Matching Mechanism for Elastic Registration

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Motivations

Develop a fully automatic registration method by robust anatomical correspondence detection.

Individuals:

Model:

Average brain

Affine  HAMMER
Innovations

1. Use attribute vector to detect the correspondence
   (image intensity, edge types, geometric moment invariants)

Distinctive attribute vectors

Reduce the ambiguity in feature matching

Select most distinctive voxels in the image

Driving voxels

Similarity map
Innovations

2. A hierarchical approximation of the energy function, initially by *lower* dimensional energy functions with significantly *fewer* local minima.

**Few driving voxels**
Smooth approximation of the energy function

**Many driving voxels**
Complete energy function

Voxels with distinct attribute vectors.

Roots of sulci
Crowns of gyri

All boundary voxels
Methods

1. Remove the global different by linear registration

2. Hierarchically select driving voxels

3. Establish the correspondence on driving voxels

4. Interpolate the dense deformation field

5. Relax the criterion of driving voxel

Results

18 elderly brain used to construct the average brain
Results

Linear registration

Model

Average brain by HAMMER
Results

Model brain

Average brain

A subject before warping and after warping
Results

HAMMER in labeling brain structures
Results

Cross-sectional views

Model

Subject
Results

Label cortical surface

Inner cortical surface

Outer cortical surface

Model

Subject

HAMMER
Successful Applications of HAMMER

10+ large clinical research studies and clinical trials involving >10,000 MR brain images:
(5000+ downloads for software)

• One of the largest longitudinal studies of aging in the world to date,
  (an 18-year annual follow-up of 150 elderly individuals)
• A relatively large schizophrenia imaging study (148 participants)
• A morphometric study of XXY children
• The largest imaging study of the effects of diabetes on the brain to date
  (650 patients imaged twice in a 8-year period)
• A large study of the effects of organolead-exposure on the brain
• A study of effect of sustained, heavy drinking on the brain
HAMMER in Slicer

✓ Successfully implemented HAMMER in ITK. (Over 2,000 lines of code)
✓ Integrated HAMMER into Slicer3
✓ Verified and tested its performance in Slicer3

Tutorial on using HAMMER in Slicer 3 can be found at http://wiki.namic.org/Wiki/index.php/AHM_2010_Tutorial_Contest_-_Hammer_Registration


Hammer And VML Modules for 3D Slicer


We will also develop a 3D Slicer module for white matter lesion (VML) segmentation. (Chijiang Liao, Chianggeng Shen, Chixia Li, Cici Wang). This project is supported by the NITRC project. For more information, please visit http://wiki.namic.org/Wiki/index.php/AHM_2010_Tutorial_Contest_-_Hammer_Registration.
HAMMER in Slicer

Data Processing Pipeline

AC/PC

Segmentation

Affine Registration

Template

HAMMER

Registration Result
Preprocessing step in Slicer

Skull strip module in Slicer, developed by Xiaodong Tao

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HAMMER in Slicer

Preprocessing step in Slicer

Fuzzy tissue segmentation module in Slicer, developed by Xiaodong Tao

This module computes voxel by voxel tissue classification of an MR brain image using a fuzzy c-means algorithm. Bias field is modeled as a lower order polynomial. Bias field and tissue classification are estimated iteratively in an EM fashion. Internally, each voxel is assigned tissue membership function values, which range from 0 to 1. At any voxel, the sum of membership function of all classes is either 0 (outside of brain), or 1. The membership functions are converted in tissue labels to generate hard segmentation.

HAMMER in Slicer

Average of 18 aligned images
HAMMER in Slicer

Image Parcellation Result
HAMMER in Slicer

NIREP Dataset
16 subjects with manually labeled 32 ROIs

http://www.nirep.org
Overall Dice ratios on 32 ROIs by HAMMER on 16 NIREP dataset
HAMMER in Slicer

LONI LPBA40 Dataset
40 subjects with 54 manually labeled ROIs

HAMMER in Slicer

Overall Dice ratios on 54 ROIs by HAMMER on 40 LONI dataset
HAMMER in Slicer

Left hippocampus
Warped result of left hippocampus
Right hippocampus
Warped result of right hippocampus
Further Improvements on HAMMER

RABBIT: To speed up our HAMMER registration algorithm (1.5 hours)

12~15 minutes

Further Improvements on HAMMER

Further Improvements on HAMMER

**TPS-HAMMER:**

- Use soft correspondence detection to robustly establish correspondences for the driving voxels
- Use Thin Plate Splines (TPS) to effectively interpolate deformation fields, based on those estimated at the driving voxels

Groupwise Registration

Hierarchical Groupwise registration:


6.0% increase for Dice ratio

- 40 subjects with 54 manual ROIs
Groupwise Registration

Tree-based Groupwise registration:

Groupwise Registration

**ABSORB:**

- Initial inputs
- Global center (1st iteration)
- Pair-wise deformation between subject and its qualified neighbors in 1\(^{st}\) iteration
- Moving direction in 1\(^{st}\) iteration
- Outputs in 1\(^{st}\) iteration
- Global center (2nd iteration)
- Pair-wise deformation between subject and its qualified neighbors in 2\(^{nd}\) iteration
- Moving direction in 2\(^{nd}\) iteration
- Outputs in 2\(^{nd}\) iteration

Groupwise Registration

Groupwise Registration

Groupwise Registration

Our new registration methods in this MICCAI:

- Pahal Dalal, Dinggang Shen, Feng Shi, Song Wang, "Multiple Cortical Surface Correspondence using Pairwise Shape Similarity", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010. **Oral**


Acknowledgement