A development environment for medical image registration procedures

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Overview

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- Registration procedures
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Medical image registration

- Is the process of finding the optimal geometric transformation which maximizes the correspondences across images.
- Geometric transformation:
    - *Rigid*: rotations, translations;
    - *Nonrigid*: deformations.
- Images:
    - 3D Mono-modal;
    - 3D Multi-modal.
- Used for:
    - Detection and diagnosis of diseases;
    - Planning the therapy;
    - Followup and monitoring of patients;
    - Etc.

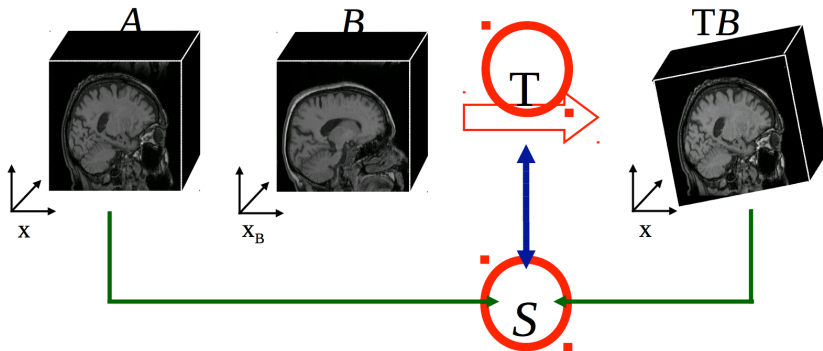Figure : Image registration basic components
(https://e.famnit.upr.si/course/view.php?id=1346)

Registration procedures
Development & testing

- Development of image registration procedures requires:
  - Work with 3D images;
  - Provide a slice by slice visualization;
  - Compare the geometric relations between images;
  - Apply and display registration results;
  - Etc.
- Available software tools & libraries:
  - 3DSlicer [4], ImageJ [1], ITK [2], VTK [9], Matlab [10], Python [8], etc.
- This tools may require exhaustive learning and adaptation.
- We implemented a new development environment that offers all this with only minimal influence on the user development strategies.

Development environment

- **Improve and speed-up the process of implementing new image registration procedures**.
- It is build on the top of Matlab.
- Requirements:
    - *Data structure*:
        - Store images and related registration properties;
        - Provide a common way to manipulate images.
    - *Graphical user interface*:
        - Load 3D images in different file formats;
        - Provide a slice by slice visualization;
        - Load/execute different image registration procedures;
        - Etc.
    - *Registration toolbox*:
        - Provide a set of lower level processing functions.

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Development environment
Data structure

- Stores images, image properties, registration results and other registration parameters.
- Is organized as an array of images.
- Properties:
    - **RefIdx**: index of the reference image;
    - **MovIdx**: index of the moving image;
    - **Img**: array of images;
    - **Img[i]**: structure defining a single medical image
    - **Img[i].name**: image name;
    - **Img[i].path**: absolute path to the image data;
    - **Img[i].voxelSize**: image voxel size in millimeters;
    - **Img[i].data**: image data used in registration procedures which is converted to uint8 format;
    - ...

Development environment
Graphical user interface (1/2)

- Simplifies work with medical images and registration techniques.
- It allows loading 3D image:
  - DICOM [6];
  - BrainWeb [3];
  - RIRE [11].
- Main features:
  - Display image histogram (reference/moving image);
  - Display joint intensity distribution histogram [7];
  - Display slice by slice absolute difference between images;
  - Display slice by slice checkerboard image;
  - Set region of interest;
  - **Select and execute image registration procedures**.

Development environment
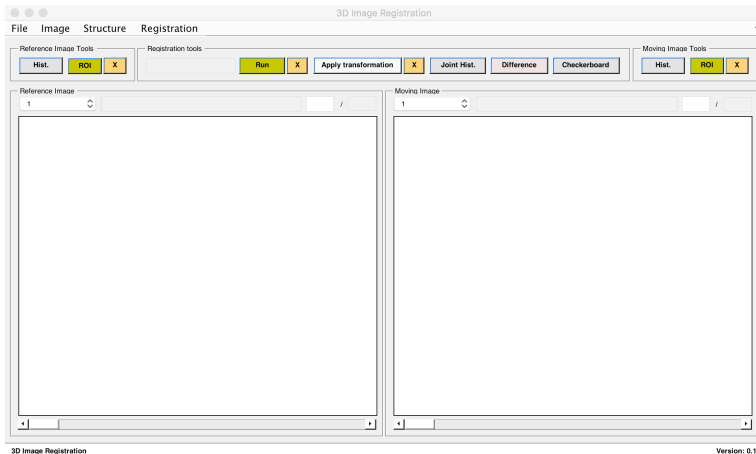## Graphical user interface (2/2)

Figure : Graphical user interface

Development environment
Registration toolbox

- Collection of **lower level processing functions** that were implemented in past research activities.
- Grouped into a toolbox that can be used through the graphical user interface or directly in the Matlab workspace.
- It will be constantly updated according to the needs of future image registration procedures.
- Examples: *im2uint8, loadDicomVolume, moveOrigin, resampleMov2Ref, resampleRef2Move, pvi* ...

Results (1/3)

- Image data:
    - *Reference image*: MRI image of brain with $181 \times 217 \times 181$ voxels, 1mm slice thickness and with 3% of noise from the BrainWeb database;
    - *Moving image*: applied a rigid rotation of 10 degrees over the reference image.
- Rigid registration procedure:
    - 1. component: controlls the overall registration workflow;
    - 2. component: computes the rigid geometric transformation;
    - 3. component: computes the similarity between the reference and the moving image (registration toolbox);
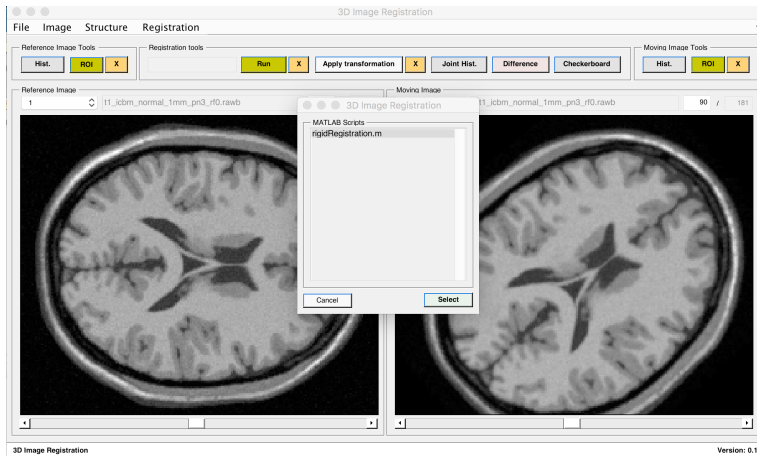   - 4. component: optimization process (NLopt [5]).
- Debugging & testing.

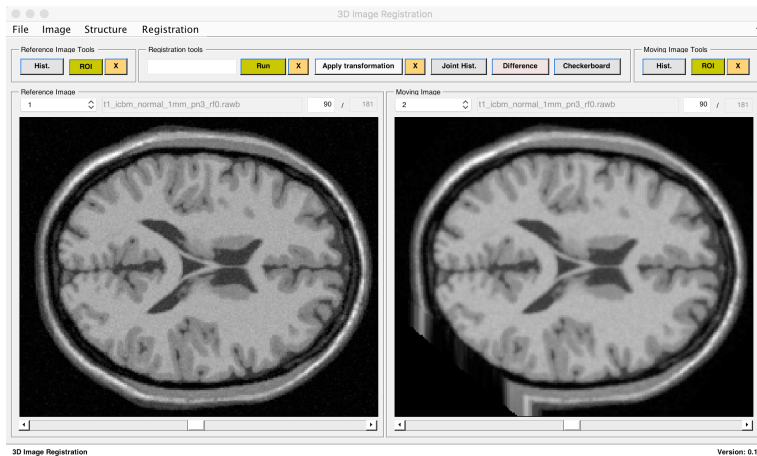Figure : File selector for selecting image registration procedures

Figure : Graphical user interface after image registration

Conclusion

- We have implemented a new image registration environment for Matlab.
- It includes a graphical user interface, a large set of lower level processing functions and a well defined data structure.
- It provides a comprehensive solution to simplify and to speed-up the development of image registration procedures.
- We used this environment in a new project in which we implemented a rigid registration procedure for medical images.

Questions?

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