BM 4301 – MEDICAL IMAGE PROCESSING

ASSIGNMENT 3 – BRAIN VOLUME REGISTRATION

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GITHUB LINK:-

1. INTRODUCTION

- The goal of registration is to estimate the transformation which maps points from one image to the corresponding points in another image. The transformation estimated via registration is said to map points from the **fixed image** coordinate system to the **moving image** coordinate system.
- In this assessment, I have registered T2-Weighted MRI volume to a T1-Weighted MRI volumes of the same subject acquired as a part of Female data set of Visible Human Project.
- To create a specific registration instance, we need to select major components which together define the registration instance:

    1. Transformation.
    2. Similarity metric.
    3. Optimizer.
    4. Interpolator.

2. JUSTIFICATION OF SELECTING EACH MAJOR COMPONENT OF REGISTRATION FRAMEWORK

2.1 TRANSFORMATION

IMPORTANT OBSERVATIONS

- Given data is 3D
- Moving image has to be translated to register with the fixed image.
- Moving image has to be rotated to register with the fixed image.
- Deformable registration is not needed, Rigid registration is sufficient for this application

SUITABLE CANDIDATES

- Euler3DTransform
- Versor3DRigidTransform
- Similarity3DTransform

COMPARISION

Euler3D	Versor3DRigid	Similarity3D
Represents a 3*D* rotation and a 3*D* translation. Users can specify the coordinates of the center of rotation.	Represents a rigid 3*D* rotation and a 3*D* translation. Users can specify the coordinates of the center of rotation.	Represents a 3*D* rotation, a 3*D* translation and a homogeneous scaling. Users can specify the coordinates of the center of rotation.
No.of Parameters - 6	No.of Parameters - 6	No.of Parameters - 7

- Similarity 3D transform was eliminated because scaling wasn't needed for our application
- Trial And error procedure was performed to select the optimum transform out of the remining two.

SELECTED TRANSFORMATION :- **EULER 3D TRANFORMATION**

2.2 SIMILARITY METRIC

IMPORTANE OBSERVATION

- This is a multi-modality registration

SELECTED SIMILARITY METRIC :- **MATTES MUTUTAL INFORMATION METRIC (MMIM)**

REASONS

- Mutual information (MI) measures how much information one random variable (image intensity in one image) tells about another random variable (image intensity in the other image).
- The major advantage of using MI is that the actual form of the dependency does not have to be specified.
- Therefore, complex mapping between two images can be modelled. This flexibility makes MI well suited as a criterion of multi-modality registration [47]

2.3 OPTIMISER

SELECTED OPTIMISER :- **GRADIENT DESCENT LINE SEARCH (GDLS)**

REASONS

- TRIAL AND ERROR METHOD

2.4 INTERPOLATOR

SELECTED INTERPOLATOR :- **GAUSSIAN INTERPOLATOR**

REASONS

- TRIAL AND ERROR METHOD

3. METHODOLOGY

1. Import necessary libraries (ex:- ITK , SimpleITK , matplotlib.pyplot, ipywidgets)
2. Visualise the input volumes

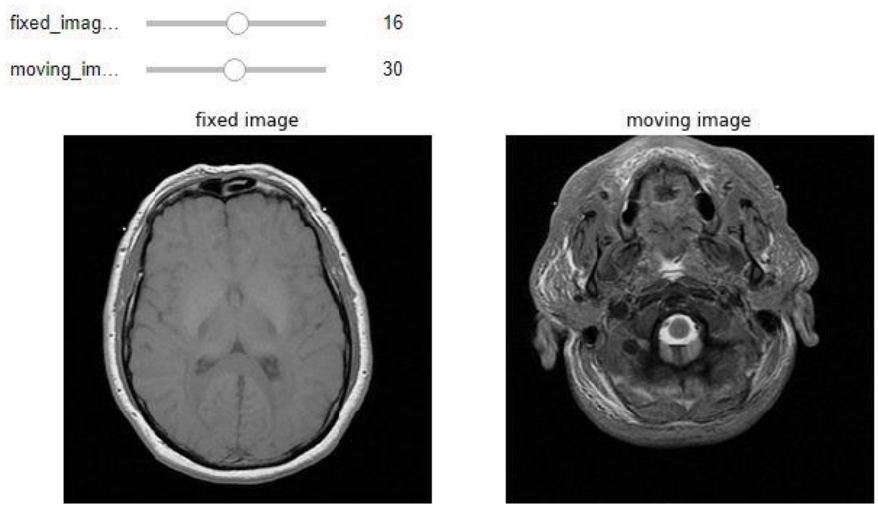

Figure 1 – Visualization of Inputs

3. Used the **CenteredTransformInitializer** to align the centres of the two volumes and set the center of rotation to the center of the fixed image.
    a. Defined Euler3D / Versor3DRigid / Similairty3D transforms
    b. Selected 'MOMENTS' as mode of operation
4. Define the Registration Procedure

    The specific registration task at hand estimates a 3D rigid transformation between images of different modalities. There are multiple components from each group (optimizers, similarity metrics, interpolators) that are appropriate for the task. Note that each component selection requires setting some parameter values. I have made the following choices:

    - Similarity metric :- mutual information (Mattes MI)
        - Number of histogram bins, 50.
        - Sampling strategy, random.
        - Sampling percentage, 1%.
    - Interpolator :- sitk.Gaussian.
    - Optimizer :- GradientDescentLineSearch
        - Learning rate - 1.0 .
        - Number of iterations, maximal number of iterations, 100.
        - Convergence minimum value - 1e-6.
        - Convergence window size, number of values of the similarity metric - 10.
5. Performed Multi Resolution Registration based on the above-mentioned settings.

    - Performing image registration using a multi-resolution approach is widely used to improve speed, accuracy and robustness.
    - The basic idea is that registration is first performed at a coarse scale where the images have fewer pixels. The spatial mapping determined at the coarse level is then used to initialize registration at the next finer scale. This process is repeated until it reaches the finest possible scale.
    - For this purpose, we must define three factors

- Number of levels
- Smoothness
- Resolution

6. Queried the registration method to obtain the metric value
7. Visually inspected the output
8. Saved the output for further analysis
9. Steps 1 to 8 was done iteratively to find the optimum interpolator and optimiser.

4.RESULTS WITH JUSTIFICATION

Table 1 – Combinations vs Metric score

Combination ID	TRANSFORM	SIMILARIY METRIC	INTERPOLATOR	OPTMISER	METRIC SCORE
1	Euler 3D	MMIM	Gaussian	GDLS	-0.842
2	Versor3D rigid	MMIM	Gaussian	GDLS	-0.836
3	Similarity3D	MMIM	Gaussian	GDLS	-0.831

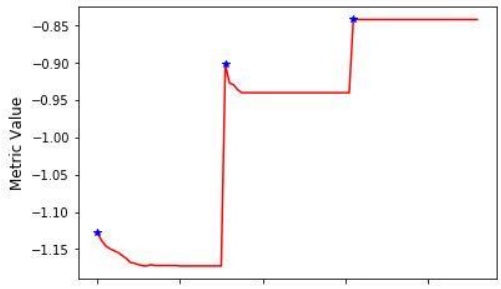

Figure 2 – Metric vs Iteration for Combination ID 1

```
itk::simple::Transform
 CompositeTransform (000000CB870289E0)
   RTTI typeinfo:   class itk::CompositeTransform<double,3>
   Reference Count: 1
   Modified Time: 71120
   Debug: Off
   Object Name:
   Observers:
     none
   Transforms in queue, from begin to end:
   >>>>>>>>>
   Euler3DTransform (000000CB8672C7D0)
     RTTI typeinfo:   class itk::Euler3DTransform<double>
     Reference Count: 1
     Modified Time: 71112
     Debug: Off
     Object Name:
     Observers:
       none
     Matrix:
       0.999996 -0.00216746 0.00175189
       0.00218584 0.999942 -0.0105589
       -0.0017289 0.0105627 0.999943
     Offset: [0.116877, -7.69316, -1.80574]
     Center: [101.654, 111.555, 87.4898]
     Translation: [0.0279629, -8.40124, -0.808181]
     Inverse:
       0.999996 0.00218584 -0.0017289
       -0.00216746 0.999942 0.0105627
       0.00175189 -0.0105589 0.999943
     Singular: 0
     Euler's angles: AngleX=0.0105629 AngleY=0.001729 AngleZ=0.00216759
```

Figure 3 – Final transform for Combination ID 1

REFLECTIONS ON RESULTS

1. Combination **ID 1** has given the best result of all
   a. This combination has yielded the lowest metric score (refer table 1)
   b. Visual comparison between the transformed volume and the fixed volume has confirmed that the registration procedure has been successful.(refer figure 4)
2. Our initial observations have been reconfirmed again through the final transform resulted from combination ID 1. (Refer figure 3)
   a. Translational components = [0.0279629, -8.40124, -0.808181]
   b. Rotational components = [AngleX=0.0105629 AngleY=0.001729 AngleZ=0.00216759]

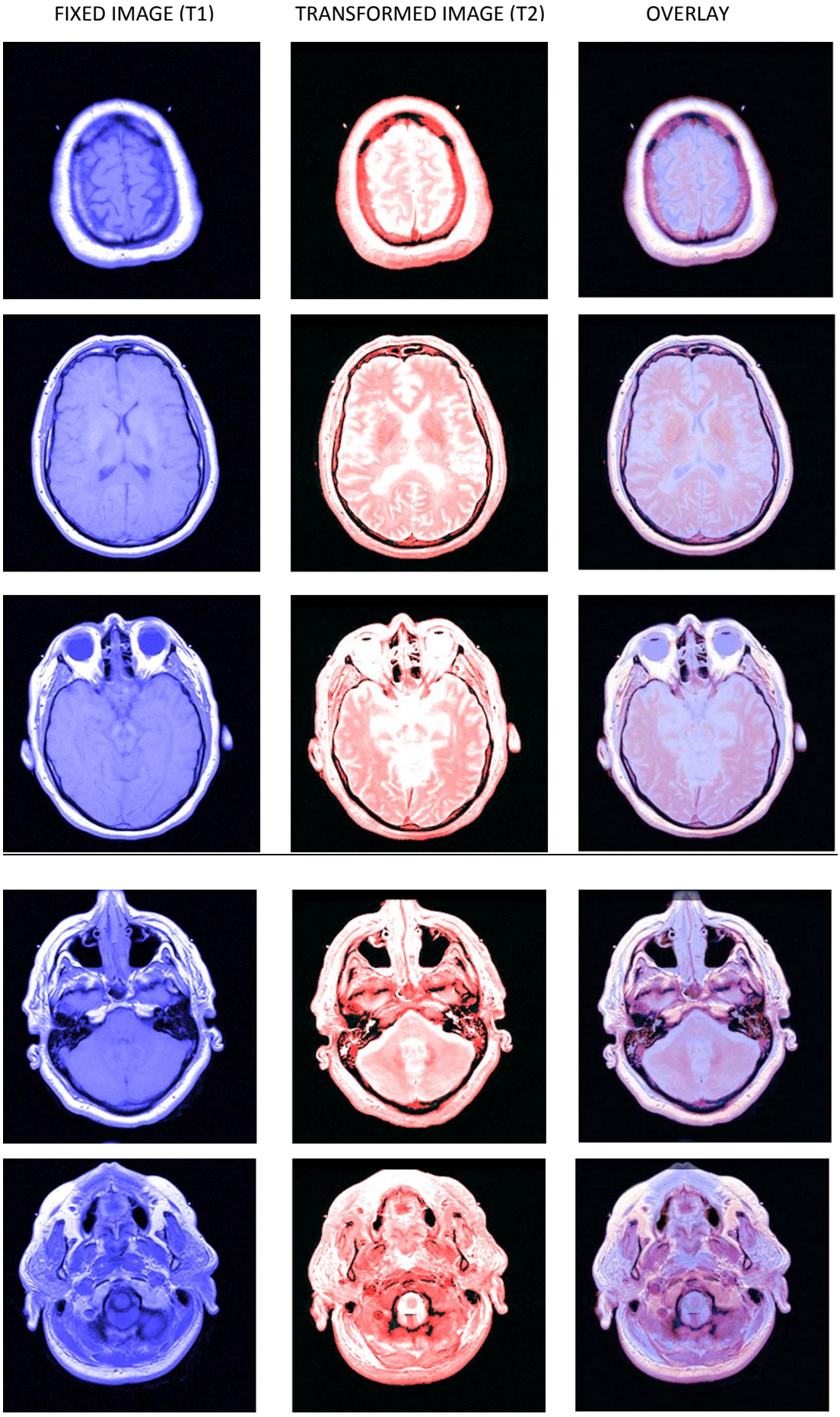

Figure 4 – Comparison between fixed image , transformed image and overlay image consisted of fixed image and transformed image.