8DC00 Medical Image Analysis

Project 1 - Registration

Report

1-10-2021

Group 3

Aiik Biermans – 1241616

Brigitte van der Geest – 1464027

Pauline Haulez – 1462245

Willem Schellekens - 1636308

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# 1. Introduction

Image registration, the process of aligning two images, is a vital practice used throughout the field of medical imaging. It is used in the comparison of medical images of different moments in time, different modalities or different patients, necessary for clinical evaluation E.g., images from before and after treatment of a patient can be used to evaluate the effectiveness of the treatment, Computed tomography (CT) images can be aligned with Positron Emission Tomography (PET) images to further improve tumor detection and segmentation of structures in an image can be made easier when aligned with an atlas. For good and relevant comparisons between images, accurate alignment is needed (Kostelec & Periaswamy, 2003). The structures in the images must overlap in the area of interest, with as little error as possible to achieve this. Image registration can be done automatically to eliminate human the human factor and to make the registration objective. Various algorithms which optimize the alignment of the images can be used, each with its own characteristics and features.

In this report, different methods of registration are elaborated and applied on a provided dataset of MR brain scans. A transformation matrix is calculated either semi-automatically or automatically and then applied to the moving image to align it with a fixed image. The methods are evaluated with the use of different metrics to assess the quality of the registration. The goal of this project is to compare and evaluate the different inter-and intra-modal registration methods. Experiments will be performed to demonstrate the advantages and disadvantages of each.

# 2. Methods

## 2.1 Approach

[elaborate what we’ve done for the project]

- intra-modal rigid intensity-based registration, evaluated through the method of normalized cross-correlation.

- intra-modal affine intensity-based registration, evaluated through the method of normalized cross-correlation.

- inter-modal affine intensity-based registration, evaluated through the method of normalized cross-correlation.

- intra-modal affine intensity-based registration, evaluated through the method of mutual information

- inter-modal affine intensity-based registration, evaluated through the method of mutual information

## 2.2 Dataset

The dataset provided consists of transverse MR brain scan slices. For a total of three patients, three different slices are used, which are all scanned both T1-weighted and by T2-FLAIR (Mendrik, et al., 2015). For the T1-weighed scans, both the original and a randomly transformed image are used. Throughout this report, the following format is used: {Patient ID}\_{Slice ID}\_{Sequence}, where patient ID is one of the three patients, slice ID is one of the three slices and sequence is the modality used. For the randomly transformed image, a ‘d’ is appended after the sequence number.

For intra-modal registration the images 1\_1\_t1 versus 1\_1\_t1\_d and 3\_3\_t1 versus 3\_3\_t1\_d are used. For inter-modal registration the image 1\_1\_t1 versus 1\_1\_t2 and 3\_3\_t1 versus 3\_3\_t2 are used

## 2.3 Transformations

The geometrical transformations are the transformations applied to the moving image, . These include:

Translation: , with the original position vector and the translation.

Rotation: , with , with the rotation angle

Scaling: , with

Shearing: , with .

Rigid transformations consist of only translation and rotation, i.e., the dimensions of the moving image do not change. Affine transformations can be combinations of translation, rotation, scaling and shearing, which does change the dimensions of the moving image.

## 2.4 Point-based and intensity-based registration

Point-based registration is performed semi-automatically based on user input in the form of reference points picked by the user. These points that are selected in the fixed image that are considered reliable, based on distinguishable features, are the fiducials (Fitzpatrick, J.M., et al.). The same points are selected in the moving image, after which a transformation matrix is calculated, using the difference in and coordinates, giving and . These values are then used in an affine transformation on the moving image.

Intensity-based registration is performed automatically. The intensity values of the pixels in the images are used as the basis for the registration. The alignment of the fixed and moving images are iteratively improved. An optimal registration is reached when the values used to evaluate the alignment reach an optimum for normalized cross-correlation or mutual information, as explained in the following paragraph.

## 2.5 Methods of registration evaluation

The different intensity-based similarity measures used in the evaluation of the alignment are:

**Normalized cross-correlation (nCC)**

Normalized cross-correlation assumes there is a linear relationship between the pixel intensities in the two images. However, for inter-modality registration, there is a lack of linearity.

In which, and are the two images and is the pixel number. The nCC value is normalized, meaning it will have a value between . The higher the value returned, the better the registration. It is possible the value of is not reached when more transformations than translation are done because of inverse mapping.

**Mutual information (MI)**

The pixels of the images have a finite set of possible values; thus, the probability mass function (PMF) can be defined which maps each possible value to a probability. Mutual information uses this probability mass function (PMF) of the two discrete images, defined with normalized image histograms.

In which and are again the images, and . The logarithm has base 2, therefore, the MI is expressed in units of bits. Again, the higher the value returned, the better the registration.

**Target registration error (TRE)**

The evaluation of the quality of the alignment is determined by calculating the error. This is done by taking the -norm for every pixel in the fixed and moving image.

Then the mean error is calculated by dividing this error by the total amount of pixels.

**Gradient**

[]

# 3. Results

In the following table 1 the target registration error (TRE) are mentioned after affine transformation of the moved image.

#### Table 1. Point-based affine image registration

|  |  |
| --- | --- |
| **Intra-modal registration** | **TRE** |
| 1\_1\_t1 vs 1\_1\_t1\_d | 22.80 |
| 3\_3\_t1 vs 3\_3\_t1\_d | 12.27 |
| **Inter-modal registration** |  |
| 1\_1\_t1 vs 1\_1\_t2 | 10.65 |
| 3\_3\_t1 vs 3\_3\_t2 | 8.76 |

In table 2 the values of the normalized cross-correlation (NCC) or mutual information (MI) are mentioned of affine intensity-based registration. The values are mentioned based on the standard parameters of the rigid transformation ([0, 0, 0]) or affine transformation ([0, 1, 1, 0, 0, 0, 0]). Also, the values of NCC or MI based on the optimal transformation calculated after the gradient ascent are mentioned. The TRE is also metioned in table 2. A complete overview with the values of the learning rate and the resulting optimal transformation matrix is shown in appendix A.

#### Table 2. Intensity-based image registration (NCC = normalized cross-correlation, MI = mutual information)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Registration method** | **Used images** | **Result NCC or MI**  **Before optimalization** | **Result NCC or MI**  **After optimalization** | **TRE** |
| Rigid Intra-modal | 1\_1\_t1 vs 1\_1\_t1\_d | NCC = 1 | NCC = 1 | 5.10 |
| Affine Intra-modal | 1\_1\_t1 vs 1\_1\_t1\_d | NCC = 1 | NCC = 1 | 18.21 |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t2 | NCC = 0.53 | NCC = 0.54 | 213.02 |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t1\_d | MI = 3.02 | MI = 1.92 | 2.20 |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t2 | MI = 0.72 | MI = 0.85 | 157.95 |
|  |  |  |  |  |
| Rigid Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | NCC = 0.60 | NCC = 0.63 | 444.88 |
| Affine Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | NCC = 0.60 | NCC = 0.74 | 193.38 |
| Affine Inter-modal | 3\_3\_t1 vs 3\_3\_t2 | NCC = 0.56 | NCC = 0.60 | 118.94 |
| Affine Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | MI = 0.63 | MI = 0.83 | 122.35 |
| Affine Inter-modal | 3\_3\_t1 vs 3\_3\_t2 | MI = 0.71 | MI = 0.82 | 97.27 |

# Discussion

The discussion section should contain the analysis of the results

# Appendix

### Appendix A – A complete overview of the values used for the optimalization of the intensity-based registration

*Table 3 – The used learning rate (mu) and resulting initial parameter vector for the optimalization of the intensity-based registration*

|  |  |  |  |
| --- | --- | --- | --- |
| **Registration method** | **Used images** | **Learning rate (mu)** | **Best initial parameter vector** |
| Rigid Intra-modal | 1\_1\_t1 vs 1\_1\_t1\_d | 0.0001 | [1.55e-06, 2.24e-06, -2.19e-06] |
| Affine Intra-modal | 1\_1\_t1 vs 1\_1\_t1\_d | 0.0001 | [0, 1, 1, -9.31e-08, -8.34e-08, 3.19e-07, 5.03e-09] |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t2 | 0.00001 | [0, 1, 1, 0.0024, -0.0025, 0.0019, -0.0019] |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t1\_d | 0.00001 | [0, 1, 1, 2.32e-03, 8.89e-04, 1.16e-03, 1.22e-04] |
| Affine Inter-modal | 1\_1\_t1 vs 1\_1\_t2 | 0.001 | [0, 1, 1, 0.058, -0.050, -0.30, -0.078] |
|  |  |  |  |
| Rigid Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | 0.0015 | [-0.031, -0.088, -0.015] |
| Affine Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | 0.0015 | [0, 1, 1, 0.0033, -0.081, -0.021, -0.094] |
| Affine Inter-modal | 3\_3\_t1 vs 3\_3\_t2 | 0.001 | [0, 1, 1, 0.047, -0.044, -0.053, -0.079] |
| Affine Intra-modal | 3\_3\_t1 vs 3\_3\_t1\_d | 0.001 | [0, 1, 1, 0.0030, -0.080, -0.042, -0.10] |
| Affine Inter-modal | 3\_3\_t1 vs 3\_3\_t2 | 0.001 | [0, 1, 1, 0.051, -0.061, -0.069, -0.066] |

# References

<http://library.msri.org/books/Book46/files/07kostelec.pdf>

<https://link.springer.com/content/pdf/10.1007%2F978-1-4471-7320-5.pdf>

# Discussion

For the intensity-based error function, the error will be too big for inter-modal registration because of the difference in intensity values

# Appendix

# References

<http://library.msri.org/books/Book46/files/07kostelec.pdf>

<https://link.springer.com/content/pdf/10.1007%2F978-1-4471-7320-5.pdf>

[*A.M. Mendrik, K.L. Vincken, H.J. Kuijf, M. Breeuwer, W.H. Bouvy, J. de Bresser, A. Alansary, M. de Bruijne, A. Carass, A. El-Baz, A. Jogh, R. Katyal, A.R. Khan, F. van der Lijn, Q. Mahmood, R. Mukherjee, A. van Opbroek, S. Paneri, S. Pereira, M. Persson, M. Rajchl, D. Sarikayan, O. Smedby, C.A. Silva, H.A. Vrooman, S. Vyas, C. Wang, L. Zhaon, G.J. Biessels, M.A. Viergever. “MRBrainS Challenge: Online Evaluation Framework for Brain Image Segmentation in 3T MRI Scans.” Computational Intelligence and Neuroscience, special issue on Simulation and Validation in Brain Image Analysis 2015. Article ID 813696.*](http://www.hindawi.com/journals/cin/aa/813696/)

Voorbeeld registration points aanklikkenA picture containing graphical user interface

Description automatically generated

Point error

Graphical user interface

Description automatically generated with medium confidence

Ls\_affine t1 en t1\_d van patient 1

Chart

Description automatically generated

Ls\_affine t1 en t2 van patient 1

Chart

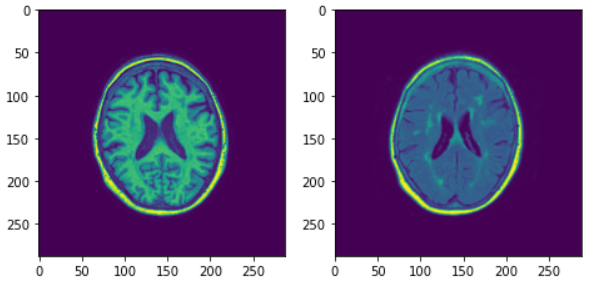
Description automatically generated

Ls\_affine t1 en t1\_d bij patient 3

Chart

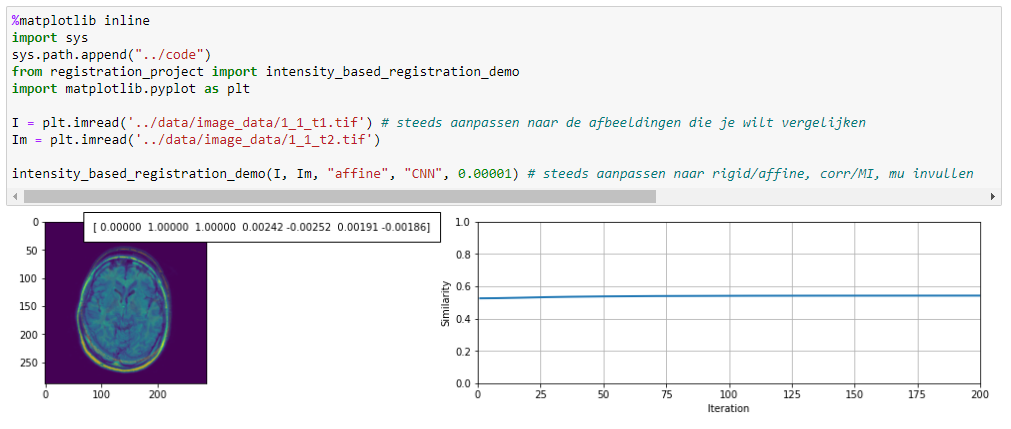
Description automatically generated with medium confidence

Ls\_affine t1 en t2 bij patient 3



Table

Description automatically generated with medium confidenceTable

Description automatically generatedTable

Description automatically generated with medium confidence

Graphical user interface

Description automatically generated

A picture containing chart

Description automatically generatedGraphical user interface

Description automatically generated with medium confidenceChart, line chart

Description automatically generatedA picture containing chart

Description automatically generatedGraphical user interface, table

Description automatically generated