# Rigid, affine and non-rigid registrations Practical exercises

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The goal of these practical exercises is to introduce you to the problem of image registration. Because software development is time consuming, you will not develop your own software but use existing open-source programs:

- elastix (http://elastix.isi.uu.nl/, [1]) is an open-source platform for automated image registration based on the Insight Segmentation and Registration Toolkit (http://www.itk.org/). The development was initiated by the Image Sciences Institute of the University Medical Center of Utrecht (The Netherlands). It is command line driven with configuration settings defined in a parameter file.
- The user manual (version 5.0.1) is available here: https://elastix.lumc.nl/download/elastix-5.0. 1-manual.pdf. Command line options are accessible with elastix --help.
- vv (https://github.com/open-vv/vv), [2]) is an open-source and cross platform image viewer, designed for fast and simple visualization, based on ITK and the Visualization Toolkit (www.vtk.org). The development was initiated by the CREATIS laboratory of Lyon (France). It can also be command line driven. Command line options are accessible with vv --help, key shortcuts with F1.

Stand-alone binaries can be downloaded from elastix' and vv's website. For elastix, download page is https://github.com/SuperElastix/elastix/releases/tag/5.0.1. For VV, on windows, you can download it from https://www.creatis.insa-lyon.fr/~baudier/vv/vv-1.4Qt4-win64.zip. On Linux : https://www.creatis.insa-lyon.fr/~baudier/vv/vv-1.4Qt4-linux64.tar.gz. Warning: there is no Mac version.

At the end of the exercises, you should be able to do rigid (manual and automated) as well as non-rigid registrations and to visualize the results. The report should answer the instructions with a bold font which will contain concise comments supported with screenshots whenever possible.

#### 1 Data

Download all the data for this exercice from the following URL, unzip the archive. You will obtain images (in mha file format) and parameters files.

https://www.creatis.insa-lyon.fr/~dsarrut/master/tp-master-data.zip

### 2 Manual rigid registration

- Consider the images *ct.mha* and *cbct.mha*
- Open them in vv with the command line vv ct.mha cbct.mha. Observe them, change image on each slicer and analyze the effect of each shortcut and mouse option in the help menu (F1).
- Open them in vv with the command line vv --linkall ct.mha cbct.mha and observe the difference.
- Open them in vv with the command line vv ct.mha --overlay cbct.mha and observe the difference.
- In the menu Tools, open the manual registration tool and play with the sliders. Check that the behavior of vv manual registration is consistent with that described in the elastix manual, section 2.6.
- Manually register the two images.
- Knowing that the convention is Euler / Tait-Bryan angles with YXZ, explain how the resulting matrix is computed from the parameters.

## 3 Automated rigid registration

- Consider the elastix parameter file Par0005.MI.rigid.txt which has been taken from the elastix database on their website.
- Create a *rigid* directory and run elastix with the command line elastix -f cbct.mha -m ct.mha -p Par0005.MI.rigid.txt -out rigid Observe the result with vv by typing the result parameters in the manual registration window (in the file *rigid/TransformParameters.0.txt*).
- Detect a not so well aligned region and elaborate on the cause.
- Compare 2 similarity measures, AdvancedNormalizedCorrelation and NormalizedMutual-Information, and plot their evolution during optimization.

### 4 Non-rigid registration

- For this exercice, you will use images from a 4D CT described here: http://www.creatis.insa-lyon. fr/rio/popi-model\_original\_page. Consider the following pair of images and observe them in vv: 00-P.mha and 50-P.mha
- Consider the elastix parameter file Par0005.MI.1.txt.
- Create a *nonrigid* directory and run elastix -f 00-P.mha -m 50-P.mha -p Par0005.MI.1.txt -out nonrigid
- Create a *nonrigidout* directory and run transformix -in 50-P.mha -out nonrigidout -tp nonrigid/TransformParameters.0.R1.txt -def all
- Discuss the results using the two commands: vv 00-P.mha --vf nonrigidout/deformationField.mhd vv --linkall 00-P.mha --overlay 50-P.mha 00-P.mha --overlay nonrigidout/result.mhd

Alternative configuration files for other types of registration can be found here: https://elastix.lumc.nl/modelzoo

### 5 Non-rigid registration with mask

- The data also contains the segmentation of the lungs. The lungs have been extracted separately in *00-lungs.mha*.
- Consider this lungs segmentation, superimpose it on the corresponding 00-P.mha image and try to use this mask during non-rigid registration. You might need to change the sampler to (ImageSampler "RandomSparseMask") (see elastix online FAQ for more information). Discuss the results with a special emphasis on the sliding at the pleura.

### References

- S. Klein, M. Staring, K. Murphy, M.A. Viergever, and J.P.W. Pluim. elastix: a toolbox for intensity-based medical image registration. *IEEE Trans Med Imaging*, 29(1):196–205, Jan 2010.
- [2] S. Rit, R. Pinho, V. Delmon, M. Pech, G. Bouilhol, J. Schaerer, B. Navalpakkam, J. Vandemeulebroucke, P. Seroul, and D. Sarrut. VV, a 4D slicer. In *Proceedings of the Fourth International Workshop on Pulmonary Image Analysis*, pages 171–175, Toronto, Canada, September 2011.