

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 (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 is available here: http://elastix.isi.uu.nl/download/elastix_manual_v4.5.pdf.
- vv (<http://vv.creatis.insa-lyon.fr/>), [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`.

To run a command window in Windows, click on **Executer** in the Windows menu and type `cmd`. In this window, you can:

- Change drive by typing, e.g., `D:` to go to drive D.
- Change folder by typing, e.g., `cd tmp` to go to subfolder `tmp`.
- Create a directory by typing, e.g., `mkdir toto` to create a `toto` subfolder.

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. You will write a report to answer the instructions with a bold font which will contain concise comments supported with screenshots whenever possible.

1 Manual rigid registration

- Download the images `ct.mha` and `cbct.mha`: <http://www.creatis.insa-lyon.fr/~srit/tete>.
- 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 angles with YXZ, explain how the resulting matrix is computed from the parameters.**
- The software is not robust to the gimbal lock. **Explain for which parameter(s) the gimbal lock is reached and observe the consequence in vv.**

2 Automated rigid registration

- Download the elastix parameter file *Par0005.MI.rigid.txt* which has been taken from the elastix database on their website.
- Create a *rigid* directory with `mkdir rigid` 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 3 similarity measures and plot their evolution during optimization.

3 Non-rigid registration

- Download the pre-registered image *ct.mhd* and check that only deformations are left with
`vv ct.mhd --overlay cbct.mha`.
- Download the elastix parameter file *Par0005.MI.1.txt*. The latter has been modified to account for the embedded rigid registration with the parameter (UseDirectionCosines "true").
- Create a *dir* directory with `mkdir dir` and run
`elastix -f cbct.mha -m ct.mhd -p Par0005.MI.1.txt -out dir`
- Create a *dirres* directory with `mkdir dirres` and run
`transformix -in ct.mhd -out dirres -tp dir/TransformParameters.0.R1.txt -def all`
- **Discuss the results using the two commands:**
`vv cbct.mha --vf dirres/deformationField.mhd`
`vv --linkall cbct.mha --overlay ct.mhd cbct.mha --overlay dirres/result.mhd`

References

- [1] 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.