Non-rigid lung registration using Edgeworth-based approximation of Mutual Information

M. Rubeaux, J.-C. Nunes, L. Albera, and M. Garreau

INSERM, UMR 642, Rennes, F-35000, France and
Université de Rennes 1, LTSI, F-35000, France.
{mathieu.rubeaux, jean-claude.nunes, laurent.albera,
mireille.garreau}@univ-rennes1.fr
Tel: +33 2 23 23 57 19

Abstract. The EMPIRE 10 challenge offers the opportunity to validate a non-rigid registration algorithm in the context of the difficult lung registration task. We propose a new similarity measure for this purpose, which is a Edgeworth-based third order approximation of Mutual Information (MI) and named 3-EMI. Athough this kind of expansion is well-known in independent component analysis, no result was available for potentially correlated random variables. In a conference paper [1], we briefly described the method used to get the MI approximation.

Keywords: image registration, mutual information, Edgeworth expansions, cumulants.

1 Introduction

Estimating a non-rigid deformation between two medical images is nowadays still challenging. Number of methods have been described in the litterature, and scientific improvements are still needed. In the context of non-rigid medical image registration, Mutual Information (MI) has demonstrate its ability as a similarity measure. In practice, MI cannot be computed exactly and has to be derived from an estimation of marginal and joint Probability Density Functions (PDF's). There are essentially three different techniques to estimate these PDF's: histogram-based estimators, kernel-based estimators and parametric methods. Parametric methods are clearly not appropriate to the context of medical image registration due to the statistical complexity of processed images. Histogram-based and kernel-based estimators are more attractive due to their simplicity. However, they suffer from variance, bias caused by i) the finite number of observations, ii) quantization and iii) the finite histogram.

In order to overcome this drawback, a new similarity measure is proposed to register lung volumes, which is an approximation of MI based on third order Edgeworth expansion of marginal and joint PDF's. This idea has been introduced two decades ago in the context of Independent Component Analysis (ICA)[2].

Nevertheless, the different approximations derived for ICA can't be used for our purpose, since they assume a deccorelation of involved random variables. For that reason, we developped novel approximations, leading to the 3-EMI metric [1]. To evaluate the performance of this metric in the context of monomodal non-rigid registration, we decided to use the data of the EMPIRE 10 challenge, because it offers four different ways to evaluate the accuracy of a registration method.

An extensive description of our method, and more precisely of the similarity measure used, will be submitted shortly in a journal paper. For that reason, we only give a brief description of the different components of our algorithm. When our work will have been published, we will update this document to give a full description of our similarity measure.

2 Method

The elastiX toolbox [3] is used to perform the registration tasks. We performed in two stages:

- first, an affine registration is performed as a prepocessing step, without using the lungs masks.
- then, non-rigid registration is performed using the initial transformations found in the first stage.

2.1 Transformation

In the first part of the process, we use an affine transformation to roughly align the fixed and moving images. Then, a non-rigid transformation using a B-Spline deformation model is used to match the images more precisely.

2.2 Hierarchical strategy

For the affine part of the registration, we choose a five levels image gaussian pyramid, with a downsampling of two between each level of the pyramid. For the non-rigid registration, the hierachical strategy is used for both images and B-Spline grid. We use a four level pyramid, with a downsampling of two for the images. The final resolution of the B-Spline grid is 20 mm in each direction, and is decrease by a factor 2 when we go to a lower level of the B-Spline pyramid.

We use 1000 iterations for each level of the pyramid during affine registration, and 150 during non-rigid registration.

2.3 Interpolation

We use linear interpolation.

2.4 Similarity Measure

We use our 3rd-order Edgeworth-based approximation of MI as a similarity measure. 2000 samples were used to estimate the metric during affine registration, and 1000 during the non-rigid task. The derivatives used during the optimization process are computed using central difference.

2.5 Optimizer

We choose the Adaptive Stochastic Gradient Descent optimizer described in [4] with automatic parameter estimation.

References

1. Rubeaux, M. and Nunes, JC. and Albera, L. and Garreau, M. : Edgeworth-based approximation of Mutual Information for medical image registration. Image Processing Tools and Applications (2010), 195-200.
2. Comon, P. : Independent Component Analysis, a new concept ? Signal Processing, Elsevier, 1994, 36, 287-314
3. S. Klein, M. Staring, K. Murphy, M.A. Viergever, J.P.W. Pluim : elastix: a toolbox for intensity based medical image registration. IEEE Transactions on Medical Imaging, vol. 29, no. 1, pp. 196 - 205, January 2010.
4. Klein, S. and Pluim, J. and Staring, M. and Viergever, M. : Adaptive stochastic gradient descent optimisation for image registration International. Journal of Computer Vision, (2009), 81, 227-239