VTK CISG Registration Toolkit

An open source software package for affine and non-rigid registration of single- and multimodal 3D images

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Zusammenfassung. Voxel-based image registration using Normalised Mutual Information (NMI) has been shown to register single- and multi-modal 3D images accurately without any user interaction [1, 5, 4]. Our group has proposed both an affine and a non-rigid registration algorithm based on NMI, and has validated these algorithms on a range of medical applications like brain, breast, and cardiac data [7, 8, 6, 2, 3]. We present a publicly available software package that incorporates these algorithms in a user-friendly command-line and graphical interface including a visualisation tool for 3D image pairs in order to analyse registration results. Beside the pure usage of registration algorithms, the software can be easily adjusted to specific environments (e.g. including other image file formats) and can be modified for specific applications.

1 Method

We present a software package that provides an affine and a non-rigid voxel-based image registration algorithm. The affine registration algorithm optimises an affine transformation iteratively by maximising the normalised mutual information (NMI) [9] of the joint probability distribution of two images using a multi-resolution approach [8] (Fig.1). The optimisation process can either be restricted to a selected number of degrees of freedoms (e.g. only rigid parameters) or be initiated to optimise up to 12 degrees of freedom. While the affine registration captures only the global motion between an images pair, the non-rigid registration models local motion using a free-form deformation (FFD) model based on B-splines (Fig.2). The non-rigid registration algorithm defines a regular grid of B-spline control points and deforms the underlying image by moving these control points [6]. Again, NMI is used as a measure of the similarity of the image pair.

Both algorithms are implemented using the free and widely-used visualisation software VTK by Kitware (http://www.kitware.com/vtk) a powerful visualisation pipeline for interactive image display.

2 Result

Our software package provides command-line programs for off-line affine and non-rigid registration of 3D single- or multi-modal images. The resulting transformations are

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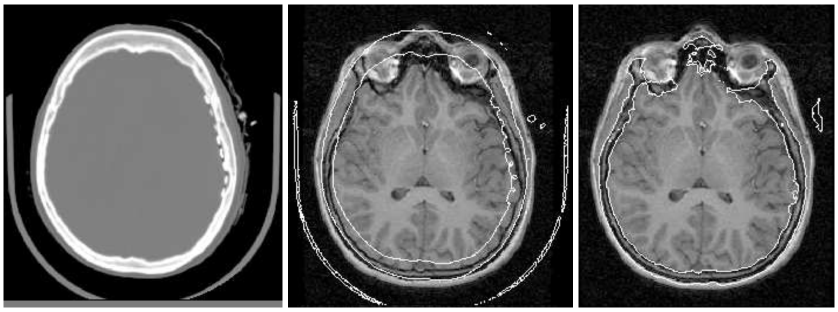


Abb. 1. Rigid registration of 3D CT and 3D MR image
The subfigure in the middle shows the contour of the unregistered CT image (left) overlaid on the reference MR image. The contour of the registered CT image is overlaid in the right subfigure.

stored in a file for use of an image transformation tool for interpolating the registration result.

The function used in the command-line programs are also incorporated in a graphical interface (see Fig. 3) which displays orthogonal views of 3D image pairs and offers an interactive interface to initialise and animate the registration process. The result of the registration can be assessed by comparing, interacting, and combining images, for instance by subtracting two images or using contour overlay, colour overlay, or side by side visualisation. For resulting non-rigid transformations the deformation field can be visualised by vectors representing the displacement for each point in the image.

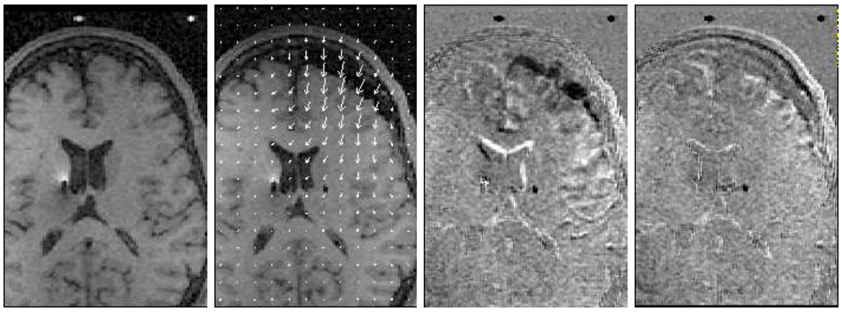
Our software package is able to read and write images in the Analyze7.5, Interfile, and our in-house GIPL file format. Other file formats can be easily added to the package by adjusting a template image reader and writer provided with the software. Additional functions can be easily incorporated into the graphical interface without changing the original code by binding Tcl scripts into the interface.

The package has been tested on Solaris 8.x, Linux 7.x, and MS Windows NT.

3 Conclusion

We have implemented an open source software package which provides an automatic affine as well as an automatic non-rigid registration algorithm. Beside command-line programs, a user-friendly and extendible graphical interface is provided which incorporates the registration algorithms and enables the user to visualise and interact with 3D image pairs and registration results. The package is designed as an open project which offers other groups both an easy-to-use registration algorithm and a platform to contribute additional functionalities. This software is available under the terms of GNU General Public License and can be downloaded for free from
http://www.image-registration.com.

An overview about alternative publicly available registration packages can be found on the web page http://www.cc.nih.gov/cip/registration/registration.html .



(a) pre (b) post (c) affine (d) non-rigid

Abb. 2. Non-rigid registration of two 3D MR images which were acquired immediately before and after an intervention

The pre-procedure image (a) is registered non-rigidly to the post-procedure image (b) and the resulting deformation field is displayed. Subfigure (c) shows the subtraction of the pre- and post-procedure image after rigid registration and subfigure (d) after additional non-rigid registration. The comparison of the subtraction images shows that the non-rigid registration algorithm captures well the deformation in the post-procedure image.

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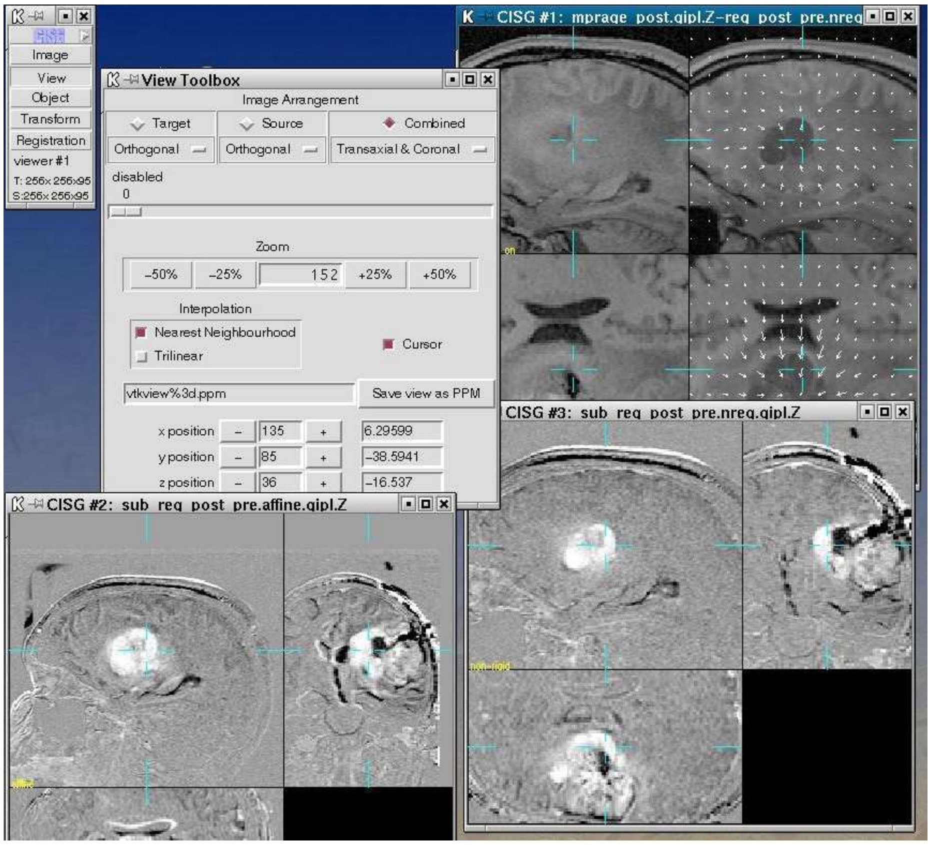

Abb. 3. Example screenshot of the graphical user interface

The graphical user interface consists of the "Toolbox Window" (shown on the upper left corner) and at least one "Viewer Window" (in this screenshot three "Viewer Windows" are displayed). Clicking on the buttons in the "Toolbox Window" opens graphical interfaces, called "Toolboxes", to manipulate the "Viewer Windows". Beside the "View Toolbox" which is opened in this screenshot, a "Registration Toolbox" to start a registration, a "Transformation Toolbox" to apply and organise image transformations, an "Object Toolbox" to display additional information like displacement vectors or text in the viewer, and an "Image Toolbox" to change the image lookup table are provided.

The "Viewer Windows" show an image pair either side-by-side (upper right window), combined (both bottom windows), or each image separately. The displayed slices of a window can be interactively changed by clicking into the images. In this screenshot the upper right "Viewer Window" shows an MR image pair side-by-side while the right image was non-rigidly registered to the left image and displacement vectors visualising the non-rigid transformation are overlaid. To assess the registration result an image pair can be combined in different ways, e.g. the images can be colour overlaid, the contour of the transformed image can be displayed in the reference image (see Fig.1), or they can be subtracted as it can be seen at the bottom of the screenshot. These "Viewer Windows" show the subtraction of the MR image pair after affine (left) and non-rigid (right) registration, respectively.