A tool for intraoperative visualization of registration results

Franklin King, Andras Lasso, Csaba Pinter, and Gabor Fichtinger

Queen's University, Kingston ON, Canada

ABSTRACT

PURPOSE: Validation of image registration algorithms is frequently accomplished by the visual inspection of the resulting linear or deformable transformation due to the lack of ground truth information. Visualization of transformations produced by image registration algorithms during image-guided interventions allows for a clinician to evaluate the accuracy of the result transformation. Software packages that perform the visualization of transformations exist, but are not part of a comprehensive and extensible application framework or otherwise have other shortcomings. We present a tool that visualizes both linear and deformable transformations and is integrated in an open-source software application framework suited for intraoperative use. **METHODS**: Visualization of transformations is accomplished by representing the transformation as a vector field with a choice of six different modes. Glyph visualization mode uses oriented and scaled glyphs, such as arrows, to represent the deformation field in 3D whereas glyph slice visualization mode creates arrows that can be seen as a 2D vector field. Grid visualization mode creates deformed grids shown in 3D whereas grid slice visualization mode creates a series of 2D grids. Block visualization mode creates a deformed rectangular model. Finally, contour visualization mode creates isosurfaces and isolines that visualize the magnitude of deformation across a volume. The transform visualizer was implemented as a plugin for the application 3D Slicer. 3D Slicer is a comprehensive open-source application framework developed for medical image computing. **RESULTS**: The transform visualizer tool fulfilled the requirements for quick evaluation of intraoperative image registrations. The plugin is freely available as an extension for 3D Slicer. **CONCLUSION**: A tool for the visualization of deformation fields was created and integrated into 3D Slicer, facilitating the validation of image registration algorithms within a comprehensive application framework suited for intraoperative use.

Keywords: 3D Slicer, open-source, deformation field, visualization, image registration

1. PURPOSE

Image registration is an essential part of ensuring the accuracy of image-guided medical interventions [4]. Researchers have developed numerous image registration algorithms capable of performing not only rigid body registrations but non-rigid registrations as well [4][5][6]. Validation of deformable transformations is difficult due to the lack of ground truth information, as is frequently the case during image-guided interventions where clinicians need to evaluate the accuracy of a transformation due to possible patient movement. Validation of deformable transformations is often performed through visual inspection with the aid of visualization software packages such as VV, CERR, or Paraview [1][2][3][9]. Such applications have shortcomings that result in them not being ideal for medical imaging and intraoperative purposes. Visual inspection in VV may be done using image fusion techniques, however, evaluation of a full region requires a clinician to inspect each image plane of a chosen orientation which is a time-consuming process. Visualization of individual image planes also increases the difficulty of evaluating motion in all directions besides those parallel (or near parallel) to the image plane. Other applications such as CERR are dependent on commercial closed-source software packages (MATLAB) or are distributed under restrictive licenses limiting availability. Applications that may overcome these shortcomings such as Paraview are ultimately unsuitable for medical images being outside of a medical imaging framework, lacking support for arbitrarily oriented images, and possessing default values not readily usable for medical imaging.

2. METHODS

The transform visualizer tool must satisfy several requirements for intraoperative validation of transformations. The visualization must allow for quick evaluation of the success of a registration and the nature of the motion that occurred. Maximum dislocation must be immediately visible. Options must exist for visualization of motion in any direction as opposed to motion within a chosen image plane as is the case with image fusion based visualization.

The transform visualizer takes as input linear transformations, non-linear transformations, or a vector volume describing a deformation field. Colors are assigned based on the magnitude of motion. A typical method of visualizing both 2D and 3D vector fields is the usage of oriented and scaled glyphs such as arrows [1]. Arrows are oriented in the direction of the motion and scaled according to the magnitude of the motion. Glyph visualization mode uses arrows, cones, or spheres as glyph shapes to visualize the 3D deformation field. Also available to the user is the choice of scaling the glyph either along the direction of the vector or in an isotropic manner. 3D glyph mode allows for the visualization of dislocation in all directions rather than being constrained to a chosen image plane. In addition to the module's ability to use glyphs to visualize 3D deformation fields, an option is also available for arrow glyphs to be viewed in 2D for each slice of a volume. Glyph slice visualization mode creates models that intersect with arbitrarily oriented slices.

Another method that is used to visualize deformation fields is a deformed grid [2]. The grid visualization mode creates a grid made up of cubic cells that is deformed allowing for a clear view of the deformation throughout the volume. The user is given the option of changing the spacing of the grid lines. Similar to the 3D glyph mode, the 3D grid mode allows for the visualization of dislocation in all directions. In addition to the module's ability to generate a 3D grid, an option is also available that is intended to create 2D deformed grids. The grid slice visualization mode creates a model specific to a chosen orientation. The result is a 2D deformed grid overlay for each slice of a volume.

The block visualization mode creates an opaque rectangular model that is deformed according to the deformation field. The contour visualization mode creates isosurfaces based on magnitude of deformation. The user inputs the number of contours to be generated and the range in which to generate the contours. The model may also be viewed on chosen image planes appearing as 2D isolines.

3D Slicer[1] is a free, comprehensive, and open-source software package widely used for a variety of medical applications including image-guided interventions [7]. Among its features are a number of state-of-the-art image registration algorithms, device tracking, support of numerous common data formats, ease of use, and comprehensive data visualization. The application features a modular organization, allowing for the easy addition of plugins known as modules. Integration of the transform visualizer tool into 3D Slicer allows a user to take advantage of the software's many other features, including modification of color assignments and overlays of the visualization with models or images. Accordingly, 3D Slicer was chosen as the platform for the transform visualizer tool.

[1] 3D Slicer website: http://www.slicer.org

3. RESULTS

The transform visualizer tool is capable of visualizing various kinds of motion including translations, rotations, and non-linear deformation.

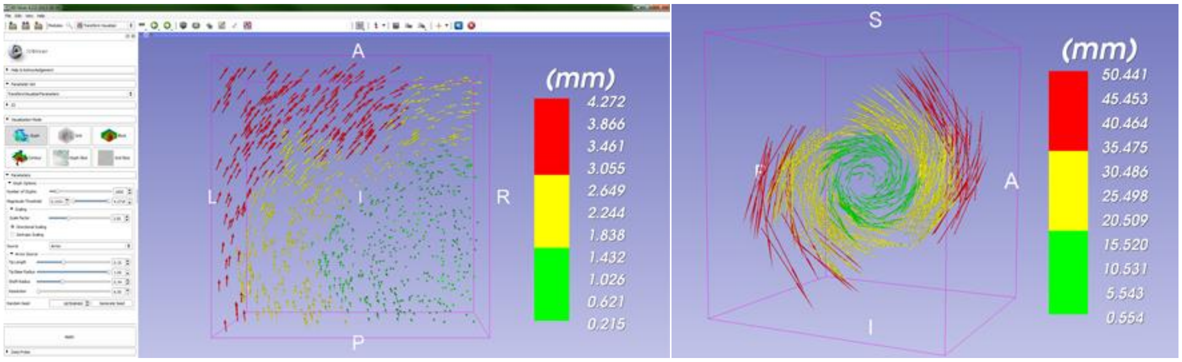

Figure 1. Non-linear deformation and rotation visualized using the transform visualizer's glyph mode

The tool's 3D visualization modes allow for visualizing motion that would otherwise be difficult to interpret from individual image slices. As shown in Figure 2, the nature of a rotation is clear when visualized using the 3D glyph mode as opposed to the same rotation visualized on an individual image slice where the direction of rotation is unclear.

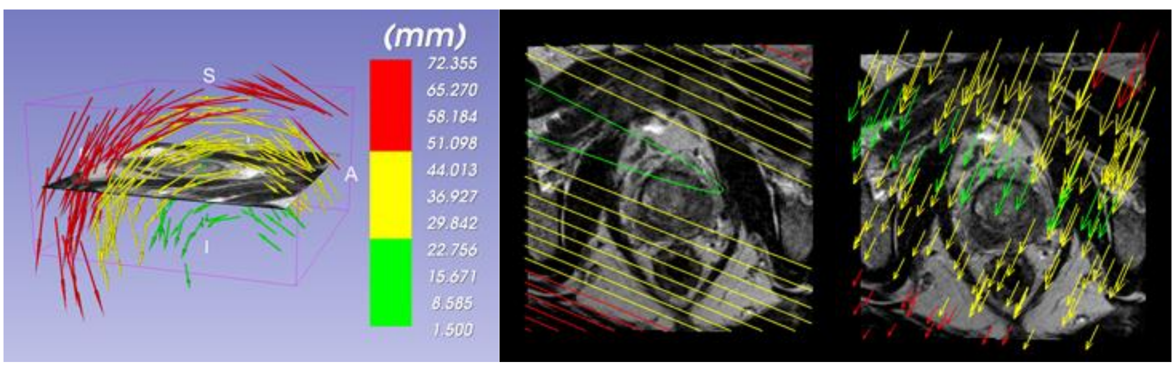

Figure 2. Rotation visualized using the 3D glyph mode, 2D glyph mode, and 2D contour mode

Quick evaluation of a registration is demonstrated in Figure 3 where a failed registration is contrasted with a successful registration using the grid visualization mode. Regions with large dislocation are made apparent by the color and warping.

The transform visualizer tool is implemented as an extension for 3D Slicer and can be downloaded from its extension manager under the name of Transform Visualizer. The source code is available on the SlicerRT support website[2]. It is encouraged for current and prospective users to visit the website and share feedback. 3D Slicer and the transform visualizer tool are distributed under a BSD-style, free, and open-source license with no restrictions on use of the software. A user guide for the transform visualizer module is available on the 3D Slicer Wiki pages[3].

---

[2] SlicerRT support website: https://www.assembla.com/spaces/slicerrt

[3] http://www.slicer.org/slicerWiki/index.php/Documentation/Nightly/Extensions/TransformVisualizer

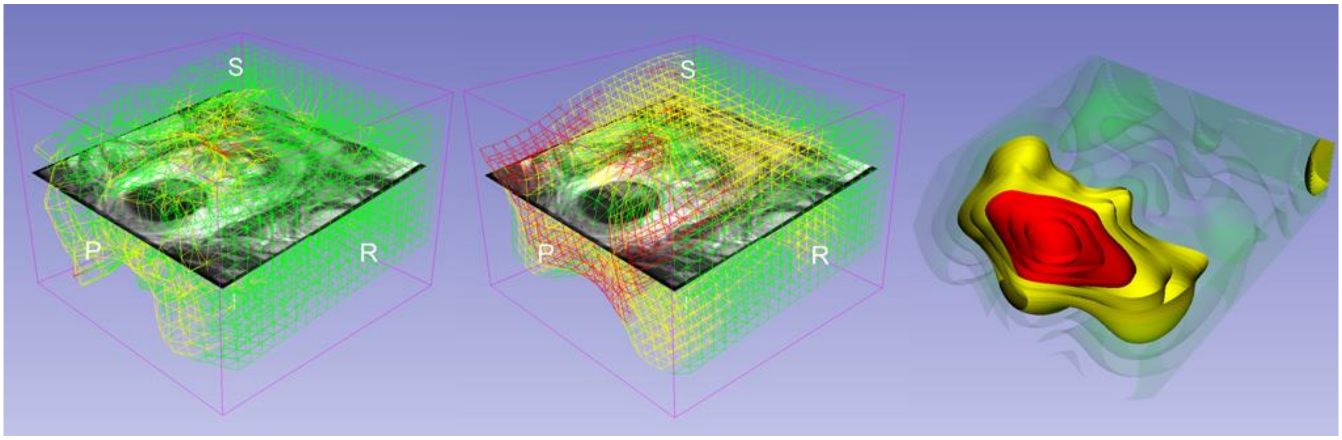

Figure 3. Failed registration shown using 3D grid mode and successful registration shown using the grid mode and 3D contour mode

4. CONCLUSION

A tool for visualizing transforms was created as a module for 3D Slicer allowing for easier validation of image registration algorithms. The module is freely available as an extension for 3D Slicer under the name of Transform Visualizer.

REFERENCES

1. Cheung MR, Krishnan K. Using manual prostate contours to enhance deformable registration of endorectal MRI. Comput Methods Programs Biomed. 2012;108:330-337.

2. Cheung MR, Krishnan K. Interactive deformation registration of endorectal prostate MRI using ITK thin plate splines. Acad Radiol. 2009;16:351-357.

3. Deasy JO, Blanco AI, Clark VH. CERR: A computational environment for radiotherapy research. Med Phys. 2003;30(5):979-985.

4. Hill DL, Batchelor PG, Holden M, and Hawkes DJ. Medical image registration. Phys Med Biol. 2001 March;46(3):R1–45.

5. Lester H, Arridge SR. A survey of hierarchical non-linear medical image registration. Pattern Recognition. 1999;32(1):129-149.

6. Maintz JB, Viergever MA. A survey of medical image registration. Med Image Anal. 1998;2(1):1-36.

7. Pieper, S., Halle, M., Kikinis, R. "3D SLICER," Proceedings of the 1st IEEE International Symposium on Biomedical Imaging: From Nano to Macro 1:632–635 (2004).

8. Seroul, P., Sarrut, D. "VV: a viewer for the evaluation of 4D image registration," MIDAS Journal (Medical Image Computing and Computer-Assisted Intervention MICCAI'2008, Workshop – Systems and Architectures for Computer Assisted Interventions), 1-8 (2008)