Abstract

Customized deformable image registration using open-source software SlicerRT

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Purpose: SlicerRT is a flexible platform that allows the user to incorporate the necessary images registration and processing tools to aid in improving clinical workflow. This work validates the accuracy and the versatility of the deformable image registration algorithm of the free open-source software SlicerRT using a deformable physical pelvic phantom versus available commercial image fusion algorithms.

Methods: Optical camera images of nonradiopaque markers implanted in a pelvic phantom were used to evaluate the theoretical deformations by x and y coordinates in the middle of the phantom (Kirby et al., 2013). To perform the registration, full and empty bladder computed tomography (CT) images of the phantom were obtained and used as fixed and moving images respectively. The DIR module, found in SlicerRT, used a non-rigid B-spline deformable image registration with multiple optimization parameters that allowed customization of the registration including a regularization term that controlled the amount of local voxel displacement (Pinter et al., 2012). The virtual deformation field at the centre of the phantom was obtained and compared to the experimental "gold standard" values. To quantify image similarity, the mean absolute difference (MAD) parameter using Hounsfield units (HU) was calculated. In addition, the Dice coefficient of the contoured rectum was evaluated to validate the strength of the algorithm to match physician contours.

Results: Overall, SlicerRT achieved one of the lowest MAD values across the algorithm spectrum, but slightly smaller mean spatial errors in comparison to MIM software (MIM). On the other hand, SlicerRT achieved higher mean spatial errors than Velocity Medical Solutions (VEL), although obtaining an improvement on the DICE to 0.91. The large spatial errors were attributed to the poor contrast in the prostate bladder interface of the phantom.

Conclusion: Based phantom validation, SlicerRT is capable of achieving comparable DIR accuracy to commercial programs such as MIM and VEL.

Innovation: This study is innovative because it shows that available open source software such as SlicerRT can be a customisable platform that allows advanced CT-CT deformable image of the pelvic region. In addition, the spatial errors can eventually be decreased by implementation of customizable tools such as image contrast functions to improve barely visible boundaries in the CT images.

Key Results: The results summarize the performance of 10 different algorithms. Two different modules of SlicerRT were used to achieve improved results, indicating that SlicerRT allows customization of the registration to anatomical site of interest. Figure 1 shows the percentage of markers with spatial errors of 3mm and 7mm as a function of MAD. The DIR of SlicerRT (Slicer_3) produces same MAD values (16.9 HU) in comparison to MIM but lower values than VEL(18.5 HU); this indicates that the algorithm focuses in image similarity but tries to fit noise producing large percentage of error at the 7 mm margin. However, the algorithm is capable of transferring the rectum contour given by achieving a relatively high Dice coefficient (0.91) through the transition between empty and full bladder. The algorithm resembles the results of the commercial software MIM (0.96) and VEL (0.90) while achieving smaller mean spatial errors. The accuracy of the deformable registration is analyzed using a cumulative histogram (Figure 2); this histogram illustrates that around 2.1% of pixels produced over 7 mm deformations using SlicerRT (Slicer_3) which is relatively smaller in comparison to MIM (3.7 %) and VEL (2.0 %).

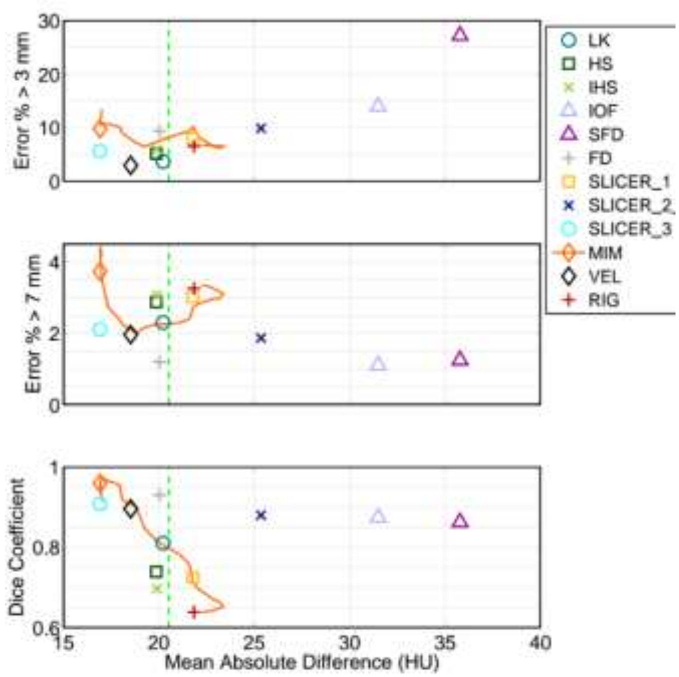

Figure 1. Percentage of markers with more than 3 mm and 7 mm error and rectum Dice coefficient as a function of MAD. Ground-truth represented as vertical dotted line and SLICER_3 as blue circle. SLICER_3 achieves a small value of MAD while getting a high Dice coefficient in comparison to other algorithms

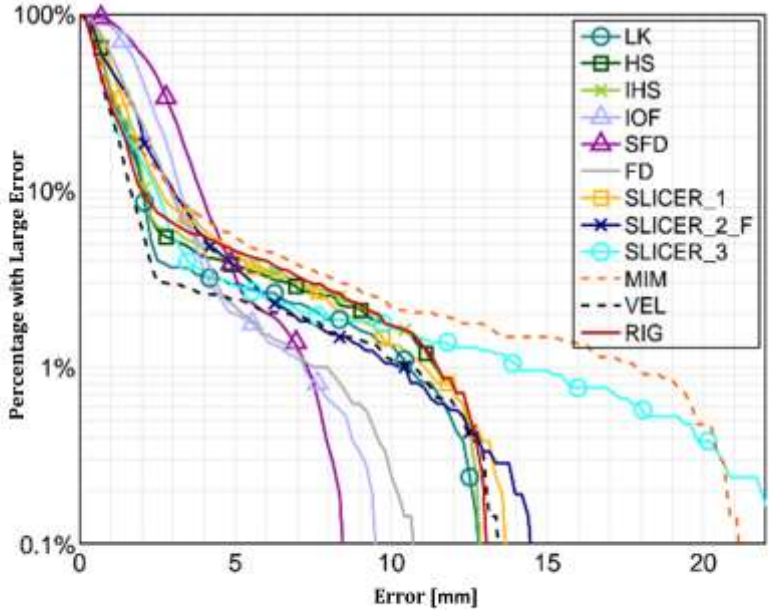

Figure 2. Cumulative error histogram evaluates the accuracy of the deformable registration achieved by SlicerRT in comparison to other commercial algorithms

References

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