Integration of SlicerRT into the clinical adaptive radiation therapy workflow: deformable image registration algorithm optimization and validation

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Adaptive radiation therapy (ART) integrates daily images into the radiotherapy process to evaluate and modify the plan in order to account for weight loss and geometric changes throughout treatment. SlicerRT (Pinter et al., 2012) is a powerful open-source software toolkit that includes the resources needed to evaluate various radiation therapy metrics (i.e. contour changes, dose volume histogram), that can potentially be incorporated as a module in a radiation therapy record and verify (RV) system to perform on-line adaptive RT. Such an application would integrate core components of: 1) pre-set input/output locations for DICOM-RT files 2) automatic implementation of optimized site-specific rigid and deformable registration routines and 3) dose accumulation and target/organ at risk violation reporting. Such a platform will likely allow clinicians to monitor and evaluate the necessity for adaptive re-planning.

In this work, we describe and validate an adaptive framework using SlicerRT to incorporate deformable image registration (DIR) routinely into the ART process. The DIR module, found in SlicerRT, uses non-rigid B-spline deformable image registration and gradient vector flow to generate deformation maps that can be utilized to 1) deform planning CT contours onto daily image guided radiation therapy (IGRT) images and 2) perform dose accumulation. In addition, the wide variety of adjustable DIR parameters in SlicerRT such as cost function routine, image subsampling rate, and maximum iterations allow for the development of class solutions optimized to the target site and imaging modality (i.e. KV-CBCT, MVCT) of interest.

Here, we describe our experience implementing rigid/deformable image registration routines for pancreatic and head and neck cancer cases. These deformed contours were evaluated against gold standard physician-drawn contours using dice similarity coefficient and Hausdorff distance metrics available in the SlicerRT's contour comparison module.

The overall accuracy and limitations of the SlicerRT DIR algorithm is part of an ongoing project that will perform site specific evaluation of the generated deformation maps with experimental phantom measurements. Overall, SlicerRT can be considered a flexible platform that allows the user to incorporate the necessary tools to aid clinical routines. In addition, our institution has tailored new modules, such as the overlap volume histogram (OVH) module, to describe the geometric relationship between targets and organs at risk, and eventually could be utilized for re-planning processes.

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References

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