Abstract ID: 16928 Title: Optimized knot placement for B-splines in Deformable Image Registration

Purpose: The current trend of incorporating multi-modality and multi-instance imaging in treatment planning for external beam radiotherapy has highlighted the need for fast and accurate deformable image registration techniques. One current implementation of non-rigid registration uses uniform B-splines to parametrically represent the displacement vector field (DVF). The piecewise B-spline segments are joined at “knots” that define the local region of support and influence for each segment. This approach has limited flexibility and can require a fairly large number of control points to describe local complexity in the DVF. By preferentially placing knots in regions of high complexity, we can more efficiently utilize the control points. The authors present the implementation of an automatic knot optimization scheme.

Methods: We developed a two-step approach to fit a known one-dimensional DVF. An initial fit was made with uniform knot spacing. The error generated by this fit was then assigned as an attractive force pulling on the knots, acting against a resistive spring force in an iterative equilibration scheme. To demonstrate the accuracy gain of knot optimization over uniform knot placement, we compared the sum of the squared errors and the frequency of large errors.

Results: Fits were made to artificial surface DVFs as well as real-world datasets. For each dataset, the optimized B-spline fit reduced both the sum of the squared error and the frequency of errors larger than one standard deviation of the mean.

Conclusion: Non-uniform B-splines offer an attractive alternative to uniform B-splines in modeling the DVF. They carry forward the mathematical compactness of B-splines while simultaneously introducing new degrees of freedom. The increased adaptability of knot placement gained from the generalization to NURBS offers increased local control as well as the ability to explicitly represent topological discontinuities.