DTU Informatics
Department of Informatics and Mathematical Modelling

SPATIALLY VARYING RIEMANNIAN ELASTICITY REGULARIZATION

Application to thoracic CT registration in image-guided radiotherapy

T. Bjerre[1,2], M.O. Fogtmann[1], M. Aznar[2], P. Munck af Rosenschöld[2], L. Specht[3], R. Larsen[1]

1: Technical University of Denmark (DTU Informatics, Image Analysis & Computer Graphics), Kgs. Lyngby, Denmark.
2: Rigshospitalet, University of Copenhagen (Department of Radiation Oncology), Copenhagen, Denmark.
3: Rigshospitalet, University of Copenhagen (Department of Oncology), Copenhagen, Denmark.

Contact: trbj@imm.dtu.dk

Purpose:

We apply Riemannian elasticity regularization in deformable image registration (DIR) of CT scans in image guided radiation therapy (IGRT). We explore the use of spatially varying elasticity parameters to encourage bone rigidity and local tissue volume change only in the gross tumor volume (GTV) and the lungs.

Methods:

We applied a sum-of-squared-differences free-form deformation, B-spline model to register the staging and planning CT scans allowing for a subsequent mapping of the GTV contour to the planning CT.

We applied an isotropic Riemannian elasticity prior, with spatially varying elasticity parameters as a trade-off between modelling capability and simplicity. The Riemannian elasticity prior is a simple weighted quadratic penalty on the Hencky strain tensor which inherits local rotational invariance and is given as

$$\mathcal{R}_{rie}(\mu,\lambda;\phi) = \frac{\mu}{4}\sum_{i=1}^{N}\log^2\varepsilon_i + \frac{\lambda}{8}\left(\sum_{i=1}^{N}\log\varepsilon_i\right)^2$$

, where the Lamé coefficients μ controls the amount of elastic potential due to shearing, and λ controls the amount of elastic potential due to local compression or expansion. ε_i are the principal stretches. φ are the B-spline transformation parameters.

Results:

We demonstrated its use and properties by registration of pre- and post-chemo CT scans for contour propagation in a Hodgkin lymphoma case (HL) showing significant tumor shrinkage.

Using spatially varying regularization for the HL case, deformation was limited to the GTV and lungs, as seen in Fig. 2.

Conclusions:

Automatic deformable registration and propagation of the PET-positive contour to the RT planning CT would be a valuable aid to the physician, when defining the radiation target volume. For the HL case we demonstrated that local volume change can be encouraged in volumes where it is expected (GTV, lungs, etc.). By visual inspection it is apparent that qualitatively, the registration result using spatially varying regularization is superior.

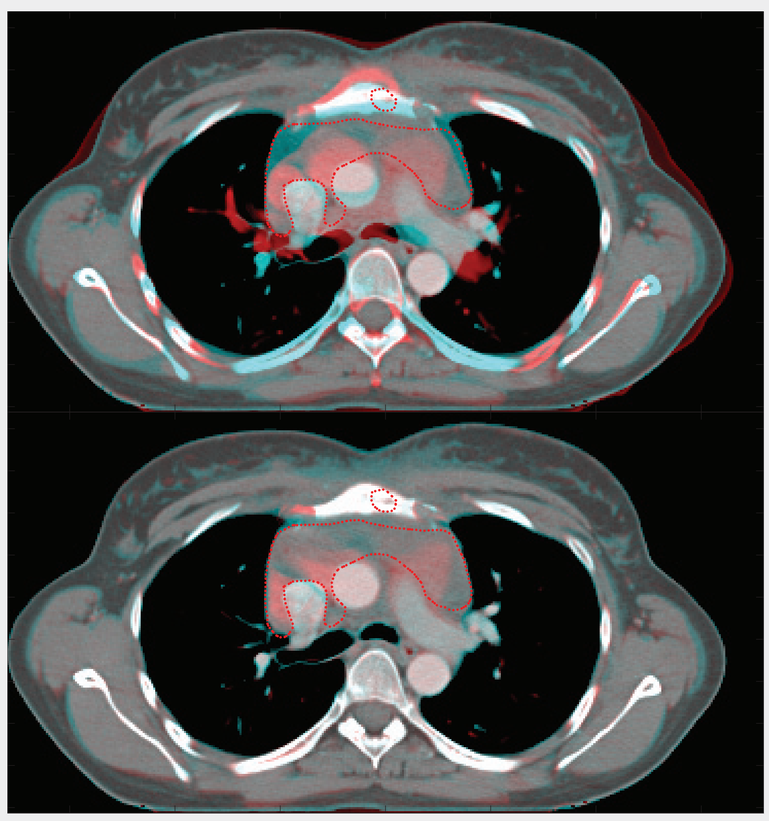

Fig. 1. Overlay of transverse slice of pre-chemo CT and deformed post-chemo CT in a Hodgkin lymphoma case. The red, dotted line is the PET- positive contour. **Top:** Spatially constant elasticity parameters. **Bottom:** Spatially varying elasticity parameters.

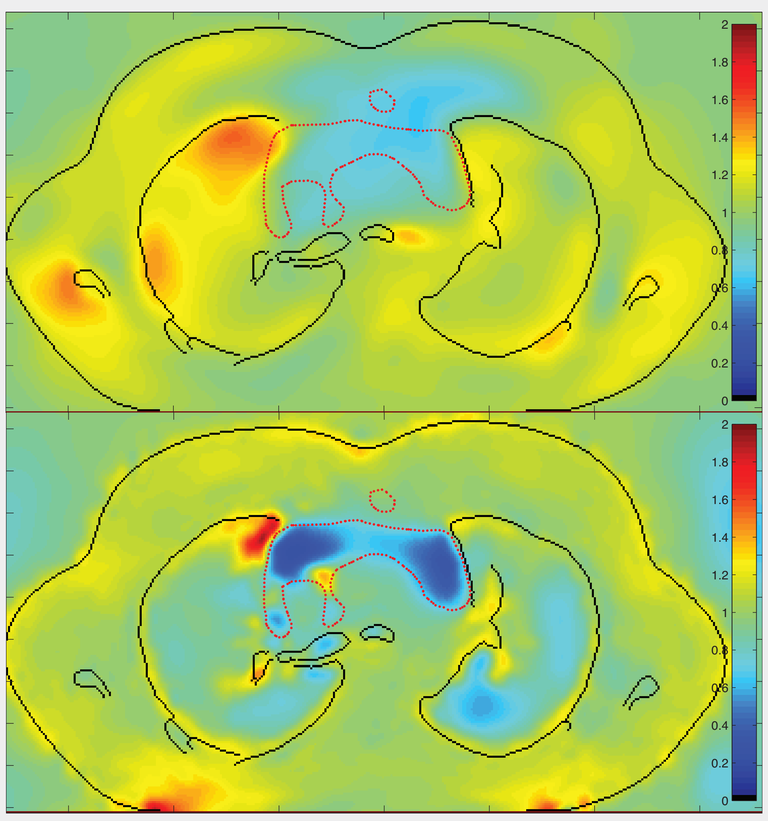

Fig. 2. Volume change in the transverse slice in Fig. 1. Values of 1 indicate no local volume change. The black contour is gradients extracted from the CT. **Top:** Spatially constant elasticity parameters. **Bottom:** Spatially varying elasticity parameters.

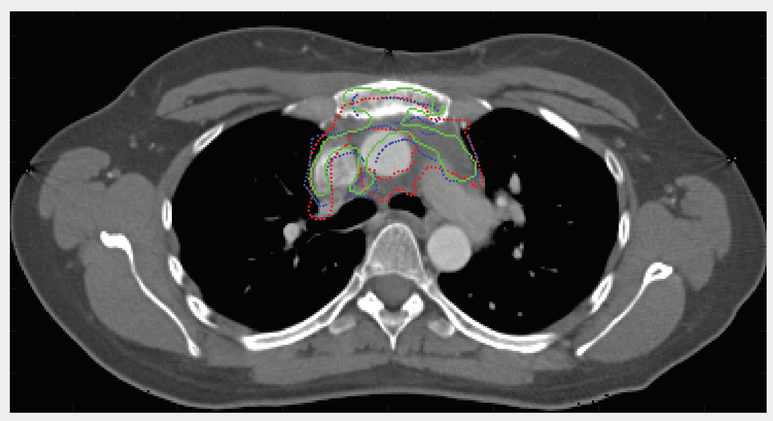

Fig. 3. Post-chemo CT with manually propagated and adapted contour (red) and contours propagated automatically using spatially constant (blue) and varying (green) regulariza- tion.