Registration of Pre and Post Intensity Modulated Radiation Therapy Prostate MRI for Quantification of MR Imaging Marker Changes and Precise Local Prostate Deformations

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Introduction: Intensity Modulated Radiation Treatment (IMRT) for prostate cancer involves irradiating the gland with ionizing radiation, and MRI is becoming the modality of choice for detecting the resulting changes to the prostate tissue. When a patient has an MRI pre- and post-IMRT, the changes to the gland can be quantified on a pixel-by-pixel basis from the MR images. However, the MR images must be first spatially aligned ("registered"), only after which can changes to the MR markers be quantified. In addition, the process of registering the MR images can allow one to quantify the precise local deformations to the prostate which have occurred as a result of radiation treatment. Traditional linear registration techniques, such as rotation, scaling, translation, and shear, are unable to account for the non-linear deformations and gland shrinkage which occur as a result of IMRT. A Finite Element Model (FEM) is a model describing tissue properties such as compressibility and elasticity and can be used to model the deformations following radiation therapy. FEM's have been used to model prostate deformations in the past [1-5], and in this work we utilize a FEM to register pre-, post- IMRT MR images for determining pixel-by-pixel changes to the MRI markers, and to quantify the specific local deformations which have occurred as a result of radiation treatment.

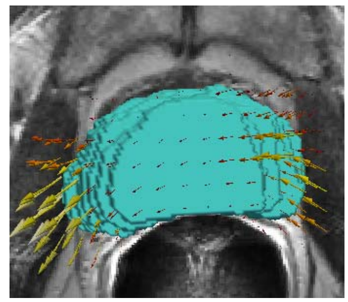

Figure 1. Forces (orange) on the surface of the prostate (blue) can deform the prostate MR images.

Methods: The registration algorithm aims to transform the pre-IMRT MRI by applying external forces at the surface of the prostate (Figure 1). A "particle swarm" optimizer aims to determine which forces on the prostate best model the radiation induced deformation in the prostate by maximizing the similarity between the pre- and post-IMRT MRI. A series of random forces are applied, and the optimizer will converge on the set of forces which best model the deformation.

Results: MR imaging was acquired for 7 prostate cancer patients undergoing IMRT, and the FEM framework was used to register the MRI in 3D. Each MRI had between 3 and 16 fiducials selected (mean of 8), corresponding to structures visible on both pre- and post-IMRT MRI, such as calcifications. To evaluate the error, the root-mean-square (RMS) distances between fiducials were calculated, as well as the center of mass (CoM) of the prostates. The mean RMS distance between the manual fiducials was 2.73 mm and the mean CoM distance was 1.84 mm.

Concluding Remarks: This work aims to use a FEM to register IMRT MRI, in which the physical properties (such as elasticity and mass) are modeled. Qualitative and quantitative results demonstrate the efficacy of this registration algorithm for IMRT evaluation, in which the RMS error between manually selected fiducials visible on both pre- and post-IMRT MRI was 2.73 mm.

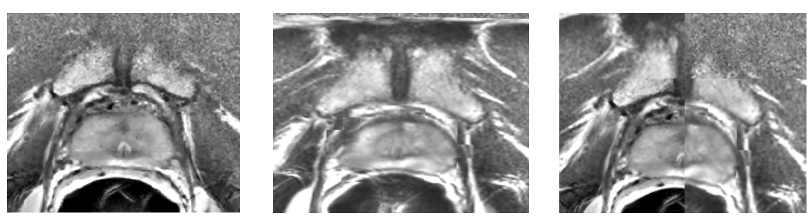

Figure 2. Qualitative results of a post-IMRT MRI (left), registered pre-IMRT MRI (center), and overlay of the two side by side (right).

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