DEFORMABLE IMAGE REGISTRATION FOR IMAGE GUIDED PROSTATE RADIOTHERAPY

Roberto Cassetta[1], Kleber Leandro[2], Marco Riboldi[1], Vinicius Gonçalves[3], Paulo Eduardo Novaes[2], Roberto Sakuraba[3], Giovanni Fattori[4], Guido Baroni[1]

1. *DEIB, Politecnico di Milano, Milano, Italy*
2. *Hospital Vitoria, Santos, Brazil*
3. *Hospital Israelita Albert Einstein, Sao Paulo, Brazil*
4. *Paul Scherrer Institute, Center for Proton Therapy, Villigen, Switzerland*

Resumo: Neste estudo, nós apresentamos um método de fusao deformável entre CT e CBCT baseado na biblioteca ITK. Um algoritmo foi desenvolvido a fim de explorar as informações dos tecidos moles das imagens CT-CBCT para realizaçao de fusao deformavel, fazendo esforços para superar a baixa relação sinal-ruído que limita o uso da CBCT para fins de planejamento do tratamento. Imagens e contornos deformados da CT de planejamentos foram gerados e seu impacto na radioterapia adaptativa foi avaliada por análise DVH para tratamentos com fotons e protons. Discrepâncias consideráveis relacionados a distribuição da dose planejada podem ser encontradas devido a alterações na anatomia dos pacientes.
Palavras-chave: radioterapia, protonterapia, prostata, IGRT, IGPT.

Abstract: In this study, we present a CT to CBCT deformable registration method based on the ITK library. An algorithm was developed in order to explore the soft tissue information of the CT-CBCT images to perform deformable image registration (DIR), making efforts to overcome the poor signal-to-noise ratio and HU calibration issues that limits CBCT use for treatment planning purposes. Warped CT images and contours were generated and their impact in adaptive radiotherapy was evaluated by DVH analysis for photon and proton treatments. Considerable discrepancies, related to the treatment planning dose distribution, might be found due to changes in patient's anatomy.
Keywords: radiotherapy, proton therapy, prostate, IGRT, IGPT.

Introduction: Head and neck (H&N) cases have been studied and considered for the implementation of deformable image registration (DIR) using Cone beam Computed Tomography. A previous work with H&N phantom shows that deformable registration relying on CBCT-CT information is useful for daily proton dose recalculation[1]. This present study investigates the above-mentioned methods for prostate patients, due to the evidence of positives outcomes from the treatment with protons[2, 3]. As the prostate moves or deforms independently of adjacent bone structures, taking into account soft tissue information could lead to a more precise treatment, since pelvic bone-based alignments may underdose the prostate in one-third of the fractions[4].

Methods:

1. Patient Data

The planning CT of 4 patients and 4 CBCT images for each patient were selected from Hospital Albert Einstein (SP-Brazil). The CT images were obtained with GE light speed multi slice and the CBCTs images with Varian 23EX.

2. Deformable Registration

A C++ code based on the ITK Library was developed for DIR between CT-CBCT images of the same patient. Its efficiency was shown in a previous work[5]. The first steps of the algorithm were to rescale the intensity of the CBCT image, then apply a histogram-matching filter between images, which contributes for correspondent points identification between them. These initial operations were carried out envisioning a better performance of the optimizer. The metric chosen was Mattes Mutual Information [6], largely used for multi-modality images, with the advantage of rescaling them internally when it builds up the discrete density function[7]. As optimizer we used the limited-memory Broyden–Fletcher–Goldfarb–Shanno (L-BFGSBO). In order to handle the deformable transformation of the images, we set the B-Spline interpolator in our algorithm.

3. Planning CT Warping

The Vector field obtained from the deformed registration was applied to the planning CT and contours with the function warp of PLASTIMATCH (http://plastimatch.org/). This procedure allowed the creation of a virtual CT with new contours representing an updated anatomy of the patient.

4. Dose Recalculation and DVH measurements

The same plan was applied to the warped CTs in order to verify the new dose distribution within the patient. For photons, the Eclipse (Varian Medical Systems – Palo Alto,CA) treatment planning software was used for IMRT recalculation and optimization. For protons, we applied the Slicer's Proton Dose module[8] using active beam scanning mode.

Results: Daily anatomical changes were taken into account for automatic planning adaptation, resulting in updated treatment plan, thus reducing errors in dose distribution within the patient. As seen in figure 1, the developed deformed registration framework was able to deform the bladder contour due to a variation on its volume, likewise for the rectum. For photons, at 50% of the posterior rectal wall volume, the dose could raise from 9% to 97% of the total dose. For protons, the same calculation showed an increase from 0% to 93%. For the bladder, the most significant difference was found for proton therapy, where the dose at 30% of the total organ volume raised from 0% to 61% of PTV's dose.

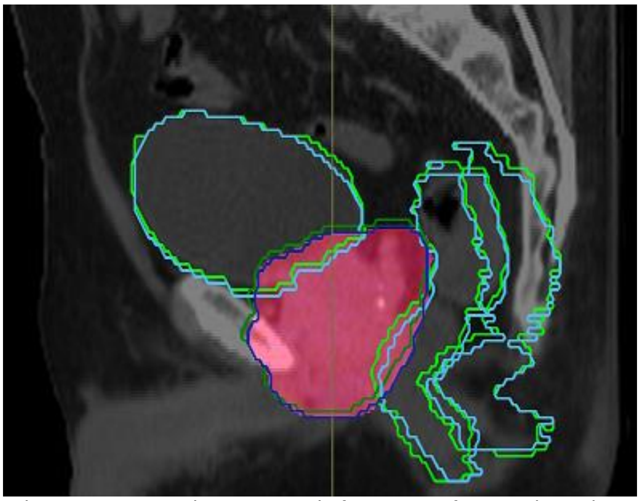

Figure 1 – Automatic propagated of contours after DIR (green) compared with original contours (blue). The red area is derived from a threshold on 95% of the planned dose.

Discussion: Previous studies for H&N results shows promising results for using CBCT as a support for dose recalculation and re-planning decisions. Our results point out the potential of using CBCT and deformable registration for radiotherapy and particle therapy prostate patients, since it is a tool for adaptive radiotherapy, aiming prescribed dose administration while avoiding unwanted dose to organs at risk, and might serve as a trigger for treatment replanning as well.

Acknowledgement: For the radiotherapy department staff of Hospital Albert Einstein (Sao Paulo -SP) and Hospital Vitoria (Santos-SP). This study was partially funded by CAPES (grant 9374/13-2).

Bibliography:

1 G. Landry et al., "Phantom based evaluation of CT to CBCT image registration for proton therapy dose recalculation," Phys. Med. Biol. 60(2), 595–613 (2015).
2 T.J. Pugh et al., "Quality of life and toxicity from passively scattered and spot-scanning proton beam therapy for localized prostate cancer," Int. J. Radiat. Oncol. Biol. Phys. 87(5), 946–953 (2013).
3 N.P. Mendenhall et al., "Five-year outcomes from 3 prospective trials of image-guided proton therapy for prostate cancer," Int. J. Radiat. Oncol. Biol. Phys. 88(3), 596–602 (2014).
4 S. Ferjani et al., "Alignment focus of daily image guidance for concurrent treatment of prostate and pelvic lymph nodes," Int. J. Radiat. Oncol. Biol. Phys. 87(2), 383–389 (2013).
5 F.R. Cassetta Jr., D. Ciardo, M. Fattori, Giovanni Riboldi, R. Orecchia, and G. Jereczek-Fossa, Barbara Baroni, "Virtual CT for adaptive prostate radiotherapy based on CT-CBCT deformable image registration," in ESTRO 35 Proc.(2016).
6 D. Mattes and D. Haynor, "Nonrigid multimodality image registration," in SPIE(2001), pp. 1609–1620.
7 H.J. Johnson, M. Mccormick, L. Ibanez, and I.S. Consortium, The ITK Software Guide Third Edition - Updated for ITK version 4.5, (2013).
8 M. Desplanques, An open source software for proton treatment planning (Politecnico di Milano, 2015).