

PhD Thesis title: 'Evaluation of speed of sound aberration and correction for ultrasound guided radiation therapy'

Author: Davide Fontanarosa

Email: davide.fontanarosa@maastro.nl

Institution: MAASTRO Clinic, Maastricht, The Netherlands

Supervisors: Prof. Frank Verhaegen

Graduation Date: March 26th 2014

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ABSTRACT:

Correct positioning of the patient prior to each treatment fraction, in radiation therapy (RT), is of utmost importance. Ultrasound imaging (US) is one of the techniques which can be used to this end. Its introduction for RT applications is relatively recent. US imaging has certain benefits over other image guidance RT (IGRT) modalities but there is also a flaw: image aberrations. In RT, aberrations which deteriorate the quantitative reliability of the imaging system can be a major cause of under- or over-dosage of the patient. Among these, speed of sound (SOS) aberration is one of the most important ones. The SOS aberration is the result of the commonly used SOS value of 1540 m/s to convert echo times into distances in clinical US devices, whereas the real SOS value of tissues can deviate from this by up to 6%.

In this thesis, a SOS aberration correction strategy based on the physical density provided by a co-registered CT scan, taken prior to treatment commencement as in standard clinical practice, was introduced. Validation on phantoms and some applications on a prostate and a breast case were performed. Then SOS aberration correction effects on different clinical scenarios were systematically studied: five prostate, five breast and five liver cancer cases were examined. On each one of them, the correction was applied and the magnitudes of the shifts produced by the algorithm were considered indications of the impact of the aberration. The results show that for liver aberration is unpredictable for the effects on both structures' depth and shape, with errors up to 7 mm. Also for the prostate, an average error of about 3 mm in the position of the centers of mass was sufficient to suggest a correction for SOS aberration. The magnitude and direction of these shifts were in good agreement with the discrepancies between US and other imaging forms reported in literature, which made us hypothesize that SOS aberration might be an explanation for a large fraction of them. For breasts, small shifts were measured, typically around 1 mm. We did not exclude that the limited dataset with possibly small breasts might have biased these results. But from our experience, it does not seem that for these organs a correction is strictly required. The sensitivity of the procedure to workflow and changes in the patients was then examined. Possible combinations of the clinical workflows and changes that can occur in the patient or to the scanning protocol were addressed. In the absence of major changes, which would require CT rescanning and replanning, the algorithm works adequately. Then

the range of applications of the algorithm was extended from the initial parallelepipedal volumes produced by linear probes to a more general case of a generic 3D US volume produced by a curvilinear probe. Finally, an automated segmentation algorithm was described which makes for the first time a simultaneous use of the information from both CT and US modalities. The algorithm was able to reproduce independently the contours drawn by a physician expert to a good degree.

References to author publications that relate specifically to the dissertation:

D. Fontanarosa, S. van der Meer, E. Harris, F. Verhaegen "A CT based correction method for speed of sound aberration for ultrasound based image guided radiotherapy." *Medical Physics* 38(5):2665-73 (2011).

D. Fontanarosa, S. van der Meer, E. Bloemen-van Gorp, G. Stroian, F. Verhaegen "Magnitude of speed of sound aberration corrections for ultrasound image guided radiotherapy for prostate and other anatomical sites." *Medical Physics* 39(8):5286-92 (2012).

D. Fontanarosa, S. van der Meer, F. Verhaegen "On the significance of density-induced speed of sound variations on US-guided radiotherapy." *Medical Physics* 39(10):6316-23 (2012).

D. Fontanarosa, S. Pesente, F. Pascoli, D. Ermacora, I.A. Rumeileh, F. Verhaegen "A speed of sound aberration correction algorithm for curvilinear ultrasound transducers in ultrasound-based image-guided radiotherapy." *Physics in Medicine and Biology* 58(5):1341-60 (2013).