An X-Ray and Computed Tomography based Registration Method for Patient to Beam Alignment designed for high Reliability despite of degraded X-Ray Image Quality

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Background

To benefit from particle beam cancer treatment accurate tumor to beam alignment is crucial. In image guided radiotherapy (IGRT) this is done by comparison of reconstructed radiographs (DRRs) from pre-treatment CTs and stereoscopic intra-treatment digital radiography (DR) images. Mutual Information (MI) based similarity measures (SM) have been found suitable for geometric registration of these images. But there are several factors influencing DR quality that can degrade registration performance, as vignetting, low contrast e.g. in pelvic images, noise and non-rigid transformations through movement of body parts (e.g. femurs). To overcome those obstacles, we present a novel method, improving alignment reliability and reducing computation time.

Material and Methods

With low quality DRs, automatic algorithms often fail to perform registration to DRRs, thus manual registration is often still possible. We therefore propose a full automatic method that in a first step omits dispensable information by extracting gradients of the DRs and the DRRs. Because DRs can contain a high amount of noise, we use large (≈ 80 pixels) filter masks to extract gradients from a large neighborhood. To decrease computation time we use filter operations without different weights for neighboring pixels and work on integral images to summarize over large portions of data with only a few operations. The image gradients are smoothed to remove noise and to increase their range of influence and the probability to find extrema in the SM during maximization. Information in the neighborhood of a gradient helps to decide which gradients to use and which to omit. Finally, the SM is computed by an MI based approach modified through weights from gradient intensity differences to improve stability. Iterative maximization of the SM for 2 pairs of images gives the rigid transformation of the patient body in 6 degrees of freedom (DOF).

Results

We compared common MI (AP1) with our new approach (AP2) using A) high quality DRs as well as B) low quality images and C) DRs, degraded, so that even manual registration was nearly impossible. For cases A, both approaches succeed, AP1 being slightly more accurate. For cases B, the advantages of the new approach became clear. AP1 failed for some datasets, but AP2 still was able to register the images correctly. For cases C, mostly pelvic images, AP1 failed for almost every dataset, but AP2 performed well.

Conclusion

We presented a new approach for 6 DOF alignment, able to overcome problems resulting from low quality DRs. For images e.g. of the head & neck, where bony structures become clear, our approach performs as well as a common MI based registration, but it becomes much more reliable for images of the pelvic or thorax region, where low contrast and irregular dose distribution degrade the DRs. Compared to common MI, our approach reduced the computation time by factor 2 as global maxima of the SM can be found within less iterations.