Deformable Image Registration for Dose Accumulation: Principle and Evaluation

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Résumé

Most Treatment Planning Systems for adaptive radiotherapy today propose Deformable Image Registration (DIR) tools which enable contour propagation or dose accumulation between images acquired over the course of treatment. While the results of DIR for contour propagation can be easily assessed and eventually manually corrected, the evaluation of DIR for dose accumulation relies on a knowledge of anatomical point correspondences and is therefore much more challenging. This talk will review the methodological principle of DIR for dose accumulation and current evaluation methods. Accumulating dose in a tissue element contained in a voxel of the reference image requires to determine the location of that element in the considered longitudinal images. The role of DIR is to automatically establish those spatial correspondences usually in the form of displacement vector fields (DVF). The first natural way to evaluate DIR results is to deform the longitudinal image onto the reference image based on the DVF and to measure the resulting similarity between the images. However, as demonstrated in previous studies, popular DIR algorithms for contour propagation can lead to high similarity between the deformed and reference images and critically wrong anatomical point correspondences. For this reason, image similarity measures or visual assessment with image fusion tools should be considered in clinical practice only after the local accuracy (in millimeters) has been quantified for a significant number of cases. Among DIR validation methods for dose accumulation, the most reliable one consists of manually identifying pairs of landmarks in the images and to relate the misalignment of those landmark pairs after DIR to the spatial resolution of the dose distributions. This approach can be easily implemented for some anatomical localizations but identifying correspondences on the surface of smooth organs or in large homogeneous tissues is not always feasible. In that case, DIR validation will have to verify that the estimated DVF respect physical considerations such as a reasonable range of local volume variations measured with the Jacobian determinant of the DVF. DIR algorithms can also be tested with images derived from numerical or physical phantoms which provide a ground truth deformation. Phantoms have demonstrated that traditional DIR algorithms could fail to estimate complex deformations such as a sliding motion between organs and justified the need to develop anatomical site-specific models. Finally, a limited number of studies have addressed DIR of longitudinal images presenting inconsistent content (i.e. in case of tumor growth or erosion) and a special attention should be paid in those situations. In parallel of efforts to develop more accurate DIR methods, it is important today to define a commissioning strategy for available DIR solutions to be used in clinical trials involving dose accumulation. In that sense, a Task Group of the American Association of Medical Physicists recently reported its recommendations.

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