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Analysing Internal Motion of The Lung With Fluid-Based Image Registration and Finite Element Simulation in Radiation Therapy

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Modern technique of radiotherapy like intensity modulated radiation therapy (IMRT) makes it possible to deliver high dose distribution to the target volume of different irregular shapes, at the same time save surrounding healthy tissue as much as possible. However, the change of internal tumor position during treatment or between fractional treatment makes precisely calculated dose distribution ineffective. In order to conquer this problem, various devices with external signals or online images have been currently developed to detect the tumor motion and adapt it to the treatment plan. While the bad relationship between internal motions and external signals has been proven in previous works, methods based on online images are superior for detecting the tumor motion directly. During the treatment, real-time controlling images are taken and compared with planning images. The transformation which describes how one physical mass point moves from time to time can be estimated with certain numerical methods. One of the methods is deformable image registration. In the department of medical physics at German Cancer Research Center, a landmark based template-matching method was developed. The method runs fast but loses accuracy if the deformation is large. So it is not suitable to match respiratory motions of the lung. In order to describe large deformation of the lung, a novel intensity based method was developed in this project which applied the fluid-flow model to constrain the point displacement. The accuracy was high, but unrealistic motions were found in the result, due to some influencing factors (artefacts in CT images, image resolutions, and missing of geometric information) which are common to all intensity based methods. These drawbacks can be turned around by imposing geometry based strategies. To correct unrealistic deformations in the result, another method based on 3D simulation was implemented. In the simulation, a model of the lung were developed to simulate the respiratory movement. The 3D model compensates drawbacks of intensity based registration by imposing 3D geometric information and biological motion mechanism. Respiratory motion was simulated by adjusting the surface deformation, which corresponds to continuum motion mechanism of the lung. The surface deformation was calculated from a computationally cheap registration process. Experiments were carried out for 5 patient 4DCT lung datasets. Diaphragm motions were around -25 mm in cranial-caudal direction. The results of the novel image registration method of different sampling-scales and 3D simulation were compared. Image registration with high sampling scales increases computing time, but achieves the best accuracy (< 2.7mm). Image registration with low sampling scale performs better, finished within one minute, but the result was sub-optimal (> 5mm). The performance of 3D simulation was relatively similar to that of registration with low sampling scale. But the error of motion estimation was acceptable, around 3.5mm. If accuracy is the first criterion, image registration with high sampling scale is superior to other methods. In radiotherapy, treatment planning has high requirement to the time duration. So, 3D simulation becomes a strong candidate of alternative choice.