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2D/3D-Registrierung auf Volumengradienten

2D/3D Registration Based on Volume Gradients

Wolfgang Wein[1], Nassir Navab[2]

[1]Fakultät für Informatik, Lehrstuhl I16 (CAMP)
TU München
[2]Lehrstuhl I16 (CAMP)

Intensity-based 2D-3D registration allows to automatically align a preoperative CT scan of a patient with any X-Ray based modality. It does not require any segmentation or other user interaction, and has numerous applications in computer-aided diagnosis and therapy. The general workflow is to simulate X-Ray images by computing a digitally reconstructed radiograph (DRR) from the CT volume at a pose estimate of the real X-Ray image. This DRR is iteratively compared to the real X-Ray image and the best pose is obtained using a non-linear optimization method. Both improving the speed of DRR computation and the robustness of the similarity measure comparing the simulated and real image are still challenges the CAS community is facing.

We address both these issues by directly performing the computations on the gradient vector volume of the CT data. This has several advantages. It can increase the precision of the registration as it assesses mainly the alignment of intensity edges in both CT and X-Ray images. At the same time, by using only significant areas of the gradient vector volume, the amount of information needed in each registration step can be reduced up to a factor of 10 and more. These both speed up the registration process and allow for using the CT data with full size, e.g. 512^3 voxels.
From this approach, we derived two novel algorithms: I) „Volume Gradient Rendering" computes the horizontal and vertical 2D gradient images of a DRR directly from the CT volume, in order to compare it to the respective X-Ray gradient images. An efficient ray-casting technique with empty-space skipping was used for the computation from the sparse gradient volume. II) „Volume Gradient Correlation" uses a forward-projection of the significant gradient voxels for direct comparison with the X-Ray gradients, and therefore skips the step of rendering a simulated X-Ray image, i.e. generation of DRRs.

We evaluated the new method with a software-based implementation on body phantom data with marker-based ground truth information, containing a CT scan and a set of 6 MV

portal images done by a linear accelerator. The improvement in terms of speed, compared to a regular DRR rendering method, is more than ten times, while the robustness of the new method is comparable to a regular rendering method for this data set.

As the volume rendering involved in DRR computation can be done very efficiently by means of 2D and 3D Texturing on modern graphics hardware, there is an increasing trend in using GPUs for registration. We are currently porting the described methods to be GPU-accelerated. Volume Gradient Rendering can be done in a quite straight-forward manner by using the RGB color channels for the components of the gradient vectors. Volume Gradient Correlation is similar to a volume rendering technique named „Splatting", and basically consists in drawing all used volume gradient voxels as single vertices.

The objectives of our new algorithms are two-folded. On one hand, intensity-based registration for realtime applications becomes feasible. On the other hand, the robustness for applications without real-time demand can be increased by allowing more pose evaluations in the same time frame.