Beyond respiratory models: a physics-enhanced synthetic data generation method for 2D-3D deformable registration

Supplementary Material

4. Supplementary results

4.1. Qualitative results

The Fig. 7 shows the prediction of the best performing network, trained on physically regularized data for 24 epochs on the sample 8 from IHUDeLiver10 dataset. In most cases, the predicted vessel tree branches superpose well with the ground truth branches. Note that due to the experimental data acquisition process, the length of the branch is not the same between the baseline vessel tree and deformed vessel tree, making the numerical comparison between the predicted and ground truth vessel trees harder to evaluate.

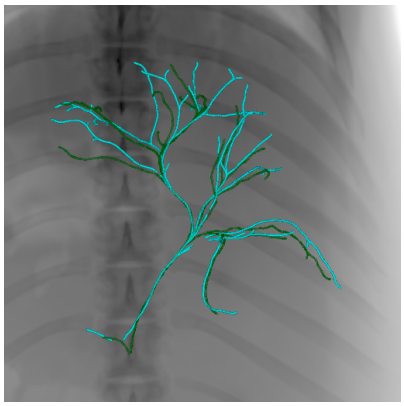

Figure 7. The vessel tree centerlines extracted from the deformed CT(in green) are overlaid on the DRR image generated from the deformed CT of the sample number 8 of the IHUDeLiver10 dataset. In blue, the vessel tree centerlines extracted from the baseline CT and deformed by the network prediction.

The Fig. 8 shows the prediction of the best performing network, trained on physically regularized data for 9 epochs on the synthetic cube dataset. Displacements of $+20$ and -20 mm are well recovered, but larger displacements of -40 and 40 mm show that the network may be biased against large displacements. This may be due to the fact that larger displacements are less represented in the training dataset than smaller displacements.

4.2. Quantitative results

Even though the proposed application of the method is interventional augmented 2D visualization, we also measured 3D errors for both datasets. Additionally, we also reported the Chamfer Distance (CD) on the experimental, IHUDeLiver10 case. The Tab 3 and 4 show that the accuracy, while still better than before registration, is degraded in 3D compared to the 2D accuracy. This is due to the motion in the out-of-plane motion not being visible in the image and thus not being taken into account in the loss function, making the training indifferent to it.

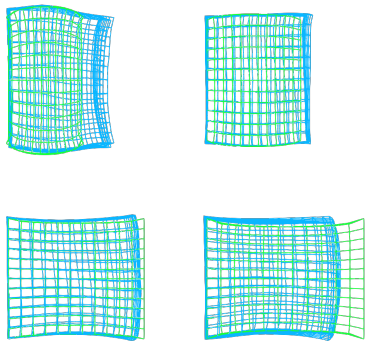

Figure 8. Top row: stretching of the cube of -40 mm (left) and -20 mm (right), with the ground truth mesh in green and the predicted mesh in blue. Bottom row: : stretching of the cube of +40 mm (left) and +20 mm (right), with the ground truth mesh in green and the predicted mesh in blue.

	EMD 2D	CD 2D	EMD 3D	CD 3D
Before reg.	6.2	4.7	6.9	6.1
After reg.	2.8	2.0	4.7	4.1

Table 3. Earth Mover's distance (EMD) and Chamfer distance (CD) before and after registration on the sample 8 of the IHUDeLiver10 dataset, in mm.

Stretching amount (mm)	mean TRE	mean RPD
-40	11.35 (21.96)	14.13 (30.19)
-20	3.49 (10.77)	3.50 (14.91)
20	3.49 (10.53)	3.82 (14.70)
40	12.90 (20.91)	17.49 (29.28)

Table 4. Target Registration Error (TRE), in 3D, and Mean Reprojection distance (RPD), in 2D, on the synthetic cube dataset, in mm, with the error before registration in parentheses.