DEFORMABLE REGISTRATION OF ABDOMINAL IMAGES

Thesis submitted in partial fulfillment

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by

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Part - IV

CLOSURE

CHAPTER 7

SUMMARY AND CONCLUSION

Highlights of the Chapter

- *Summary of the research works*
- *Highlights of the methods*
- *Discuss the conclusion*

The thesis has extensively reviewed the existing conventional methods for deformable image registration subjected to medical image analysis in Chapter 2. In Chapter 3, the learning-based supervised and unsupervised approaches for deformable registration are explored which are applied on medical images. A gradient based similarity measure has been employed in Chapter 4. Chapter 5 shows the performance of two deformable registration algorithms along with registration refinement, while precision is compared for the three optimization techniques separately. Chapter 6 contains the implementation of an unsupervised learning-based approach for constructing a generalized deformation field, pertaining to faster deformable registration.

Using the conventional method, deformable registration of multimodal abdominal images (Ultrasound and Computed Tomography) is performed in Chapter 4 and Chapter 5. As the liver and its surface shows prominent intensity features, a surface segmentation operation is executed followed by the selection of best matching CT slice from a set of CT images in Chapter 4. Also a gradient based similarity metric is incorporated in the cost function and utilized for registration.

This metric is further used in Chapter 5 for registration refinement along with an algorithm and compared with another refinement algorithm consisting of multilevel B-splines. Performance evaluation with a distance based measurement indicates better accuracy of the former one, while Levenberg-Marquardt method is found to be more precise than the rest two optimizations utilized. It is also concluded precisely that distance measure is fairly independent of the optimization technique.

Using the learning-based method, deformable registration of monomodal abdominal CT images is performed in Chapter 6. Convolutional Neural Network based U-Net architecture (including skip connections) is combined with the Spatial Transformer Network and employed as an unsupervised learning framework for the computation of a registration function. The learning (for 2D and 3D images separately) is done using the images from LiTS dataset after necessary preprocessing. Three different experiments are performed: 2D atlas-based, 2D pairwise, and 3D pairwise registration and validation is done using the test images from LiTS and 3D-IRCADb-01 dataset. For each of the experiments, performance evaluation using Dice Score and Hausdorff Distance metric shows competitive outcomes with a significant improvement in terms of computation time (120 times faster for 2D test image registration, 50 times faster for 3D test image registration) when compared to a conventional registration method (ANTs - SyN).

Thus the thesis utilizes the distinguishable intensity and gradient measures of the liver for the deformation modeling in order to develop non-rigid registration algorithm for abdominal images. The thesis also provides the insight of using unsupervised learning-based approaches, as the employed model is able to perform deformable registration with state-of-the-art accuracy on abdominal images, while reducing the computation time.

CHAPTER 8

FUTURE SCOPE OF WORK

Highlights of the Chapter

- *Background of the work*
- *Identification of the problem*
- *Probable solutions and future scope*

In this thesis, a part of research work is done using unsupervised learning-based deformable registration technique which proved to be efficient with reduced runtime for testing. The implementation is done with monomodal abdominal CT images. But different modalities, such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Positron Emission Tomography (PET), show unique tissue features. Multiple image modalities often need to be registered to get the combination of complementary information for diagnostic or interventional purposes. Now, learning-based Multi-modal image registration is a challenging problem, due to the unknown and complex relationship between the intensity distributions of the images to be aligned. Also, there remains the possibility of the presence of features in one modality but missing in another, as well as some intra-patient anatomical changes.

In [1], unsupervised learning is utilized to reduce the multimodal registration problem to a monomodal by using an image-to-image translation approach where images of both modalities change appearance through latent spaces, employing latent similarity metric and adversarial loss. In [2] Cycle-GAN model is used with mutual information to generate synthesized CT image

from the corresponding pre-procedural MR (pMR) to finally register the pMR with iCT (inpainted CT). These articles generated their own dataset and are not available in public domain.

CHAOS dataset [3] is available for annotated multimodal abdominal images, but it consists of the data of 40 individuals only. This much data is not sufficient enough for Generative Adversarial Network models. Developing complicated models and using complex similarity measures can be proved fatal sometimes and the model can behave unpredictable. Also, image preprocessing is a concern in this matter. While it is not always possible to have pre-procedural data, this notion should be avoided. Till now, all these above mentioned points sum up the probable problems when starting the work on unsupervised learning-based deformable registration of multimodal abdominal images.

So, the future work will probably include the following:

- To create an annotated multimodal abdominal image dataset for learning-based registration.
- To develop an image-to-image translation model; with adversarial and cycle consistency loss.
- To regulate the parameters and hyperparameters of the model correctly, including image preprocessing, for avoiding mode collapse or unpredictable behaviour of GAN.

References

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2. Wei, D., Ahmad, S., Huo, J., Peng, W., Ge, Y., Xue, Z., ... & Wang, Q. (2019, October). Synthesis and inpainting-based MR-CT registration for image-guided thermal ablation of liver tumors. In International Conference on Medical Image Computing and Computer-Assisted Intervention (pp. 512-520). Springer, Cham.
3. CHAOS - Abdominal CT and MRI (T1 and T2 weighted) Dataset. Link: https://chaos.grand-challenge.org/Data/