Towards Real-Time Deformable Image Registration in Radiotherapy

Inverse Problems

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Abstract

This project shows the performance of a deformable registration algorithm implemented on GPU. The algorithm is going to be used for real-time tracking of liver tumors during radiotherapy.

Introduction

An MR-Linac is the combination of an MRI scanner with a linear accelerator used for radiotherapy. This device allows to visualize the patient's anatomy in real-time during treatment [1]. Liver radiotherapy is one of the challenging applications that benefits of an MR-Linac.

Due to breathing liver tumors deform and move during treatment. The MR-Linac requires to track the liver when is on target to apply the radiation dose. The system uses a 3D pre-treatment image where the tumor has been delineated by an oncologist. During treatment, the scanner acquires 2D sagittal images at 4 frames per second. We propose a tracking system based on real-time deformable registration. The system is depicted in Figure 2.

Materials and Methods

This work is in collaboration with Department of Oncology, Rigshospitalet. The data of already treated patients are used for this study. The images are acquired with the MR-Linac (MR @ 0.35T, T2-Trufi-Sagittal). The pre-treatment image is 3D with resolution [300x300x150 pixels] and spacing [1.5x1.5x3.0 mm]. The input images are 2D with resolution [150x150 pixels] and spacing [1.5x1.5 mm].

This study aims to achieve a deformable registration within 250 ms. We chose to implement the diffeomorphic demons as a fast solution [2]. The computational bottleneck of registration is not the optimizer but the computation of the transformation and the similarity metric [3]. We primary focus on this stage to improve performance. Our algorithm is parallelized for GPU with OpenCL 1.2.

Results

All the tests are run on CPU and GPU. The CPU is an Intel(R) Xeon(R) Silver 4110 @ 2.10GHz, 8 cores, 16 threads. The GPU is an NVIDIA GeForce GTX 980 @ 1278MHz, 2048 cores, 64 bits and 4 GB of memory. Tests are computed for transformation plus interpolation and iteration of the algorithm. Our algorithm is compared to ITK implementation. Figure 1 summarize the performance of the algorithm in 2D.

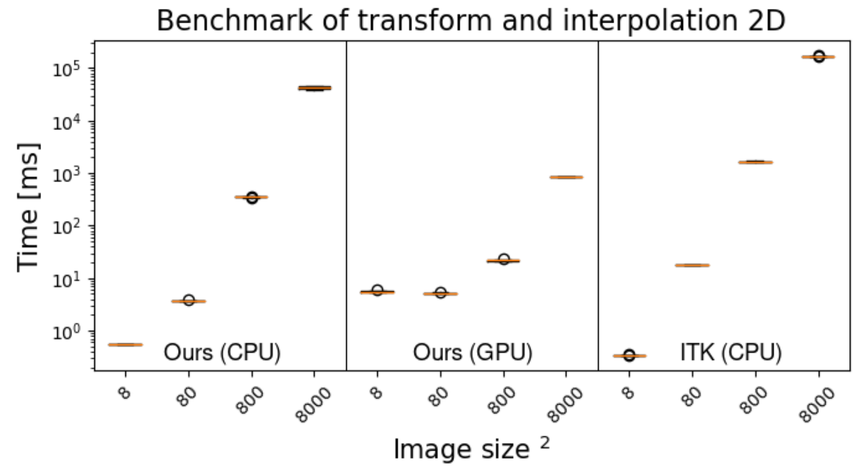

Figure 1: Benchmark of transformation and interpolation of 2D image. Image size correspond to horizontal values squared (e.g. 800x800)

An iteration in the optimization using the 2D input images takes in average 12.2 ms on GPU. This makes possible to achieve the deformable registration in real time.

Further Research

Accuracy is the next step to improve for our algorithm. We are going to evaluate other registration methods as well as other optimizer alternatives in order to select the best trade-off between performance and accuracy.

References

[1] C. Kontaxis, G. Bol, B. Stemkens, M. Glitzner, F. Prins, L. Kerkmeijer, J. Lagendijk, and B. Raaymakers, "Towards fast online intrafraction replanning for free-breathing stereotactic body radiation therapy with the mr-linac," *Physics in Medicine & Biology*, vol. 62, no. 18, p. 7233, 2017.

[2] T. Vercauteren, X. Pennec, A. Perchant, and N. Ayache, "Diffeomorphic demons: Efficient non-parametric image registration," *NeuroImage*, vol. 45, no. 1, pp. S61–S72, 2009.

[3] R. Shams, P. Sadeghi, R. A. Kennedy, and R. I. Hartley, "A survey of medical image registration on multicore and the gpu," *IEEE signal processing magazine*, vol. 27, no. 2, pp. 50–60, 2010.

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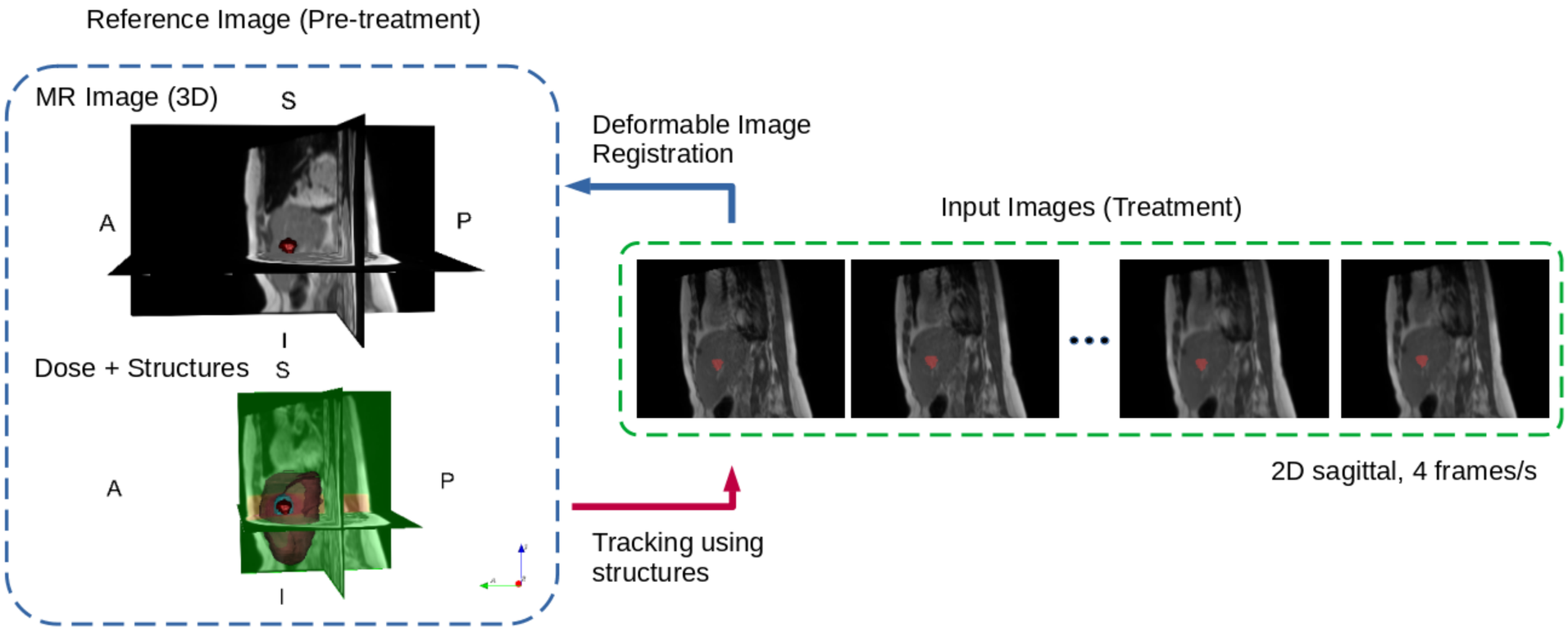

Figure 2: Proposed pipeline of a real-time deformable registration algorithm used for tumor tracking in liver radiotherapy