GPU Accelerated Lesion Prediction Software Tool for the Radiofrequency Ablation of Tumours

Panchatcharam Mariappan, Phil Weir, Ronan Flanagan
NUMA Engineering Services Ltd, Dundalk, Ireland
panchatcharam.mariappan@numa.ie, phil.weir@numa.ie, ronan.flanagan@numa.ie

Marina Kolesnik, et al.
ClinicIMPPACT Project (http://www.clinicimppact.eu)
marina.kolesnik@fit.fraunhofer.de

Abstract

Radiofrequency ablation (RFA) is a well known minimally invasive medical treatment to ablate tumour tissue in the liver [1]. To facilitate the planning of RFA, a software tool is required to simulate and potentially optimise the cancer treatment procedure. Most of the existing lesion prediction software for RFA has been developed based on the finite element (FE) approximation of the Pennes' bioheat equation or similar variations. The entire lesion prediction computation involves (1) obtaining the liver, tumour and vessel data set from pre-operative images, (2) generating a finite element mesh of the influence domain, (3) solving the Pennes' bioheat equation for temperature using FE approximation and (4) updating the living cell state depending on the temperature. Approximately one hour is required to do the first two steps, whereas depending on the mesh and tumour size 2-10 hours is needed for the last two steps on a multicore CPU. Our main objective in this research work is to minimize the computation time involved in steps (3) and (4). Combining CPUs and Graphics Processing Units (GPUs) to accelerate computing has gained attention in both academia and industry over the last number of years. In this research work, a GPU accelerated finite element software tool is developed to compute the lesion prediction based on the patient-specific parameters and geometry, such as perfusion data, tumour and liver from pre-interventional images and the needle tip locations obtained from interventional images. As the patient-specific perfusion data is known a priori, blood flow computation is not required and hence the problem domain is fixed. The GPU is used to solve bioheat and cell death model, while the CPU extracts and stores the lesion for visualization. Promising results were obtained when comparing the predicted lesion and the real lesion segmented from post-interventional images obtained one month after treatment. Our fast simulation software tool is useful at the time of treatment as it simulates a 26 minute ablation protocol in less than 3 minutes on a high end computer, Intel Core i7-5930K CPU @ 3.5 GHz with NVIDIA GeForce Titan Black GPU @ 3.5 GHZ (2880 cores), with a sufficient mesh resolution of one million 4-noded tetrahedral elements.

References

1. Stephen Payne and Ronan Flanagan and et al. Image-based multi-scale modelling and validation of radio-frequency ablation in liver tumours. Philos. Trans. R. Soc. A. 369:1954(2011) 4233–4254..