GPU ACCELERATION OF ACOUSTIC FIELD PROPAGATOR

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1 Motivation

Ultrasound simulation is needed to prevent accidental damage when used for transcranial ultrasound therapy.
Focus of this project is the speed-up of the original MATLAB implementation of Acoustic field propagator using GPU . Specifically, by using the CUDA toolkit.

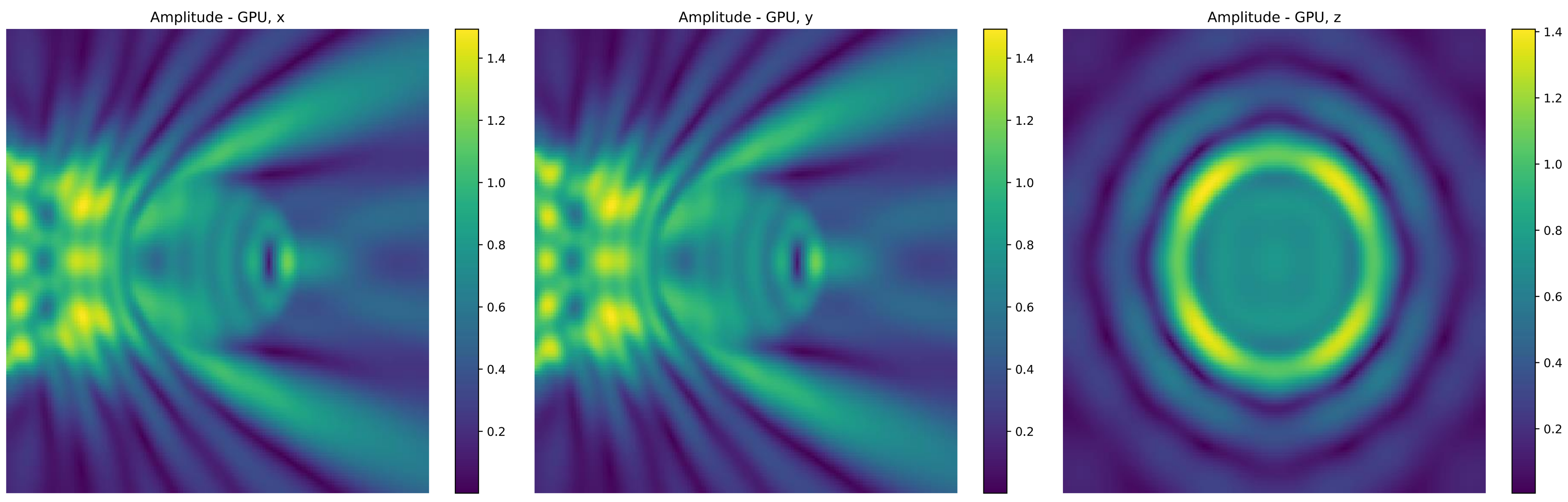

Figure 1

2 Acoustic field propagator

AFP computes the steady-state field pattern (complex pressure or amplitude and phase) from any phased array or acoustic source.

The method uses the Green's function for the homogeneous wave equation in k-space (spatial frequency domain)

The time convolution is solved analytically, and the remaining integrals are handled through a spatial Fourier transform. [Figure 2].

This approach allows calculating the acoustic pressure across space for any time **t > 0** in a single step without numerical integration.

$$p(\mathbf{x},t) = \mathcal{F}^{-1}\left\{\mathcal{F}\left\{A(\mathbf{x})e^{i\phi(\mathbf{x})}\right\} I(\mathbf{k},t)\right\}$$

Figure 2

$$I(\mathbf{k},t) = \left(\frac{e^{-\alpha c_0 t}}{c_0\tilde{k}}\right) \frac{c_0\tilde{k}(e^{(i\omega_0+\alpha c_0)t} - \cos(c_0\tilde{k}t)) - (i\omega_0 + \alpha c_0)\sin(c_0\tilde{k}t)}{(c_0 k)^2 + 2i\alpha c_0\omega_0 - \omega_0^2}$$

Figure 3

3 GPU acceleration

Project uses CUDA toolkit for the acceleration of the original MATLAB code on GPU.

- **Precomputed parts and variables** – constant memory
- **Templated class with precision parameters**
- **Use of CUDA graph for quicker kernel launching**
- **Reduction of memory transfers between GPU and system memory**
- **Multiple versions of AFP with different mem. requirements**

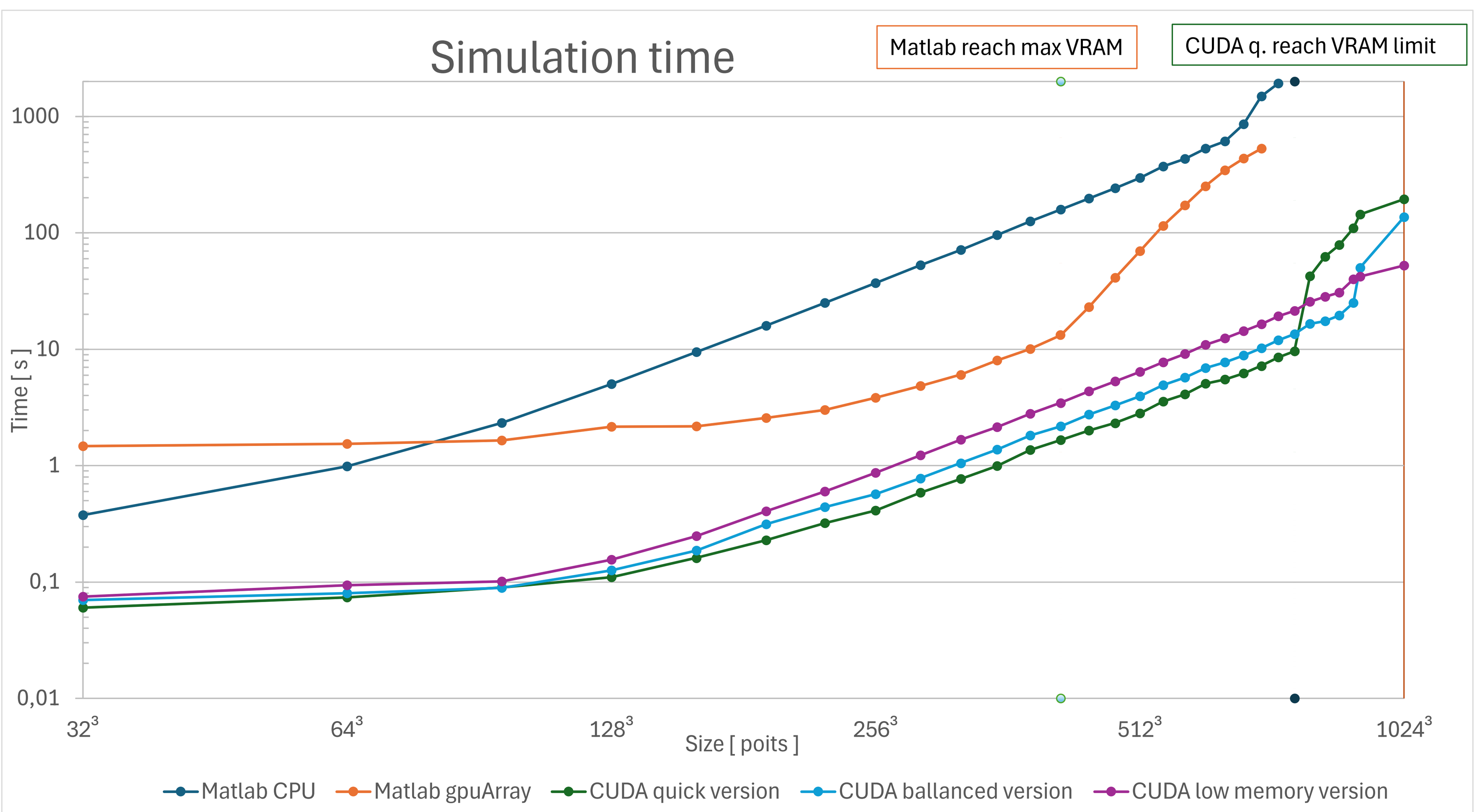

Chart 01

4 Result

In some cases, my version is up to 90 times quicker compared to the original version.

In comparison with gpuArray Matlab version my implementation is approximately 8 times quicker and uses 1/6 device memory.

User can fit even large acoustic grid with the use of low memory version that uses 1/3 of device memory, compared to quick version.

Tested on: CPU - Intel Core i7 13700k,
RAM - DDR5 64 GB 5600 MHz
GPU – Nvidia RTX 3080 Ti 12GB

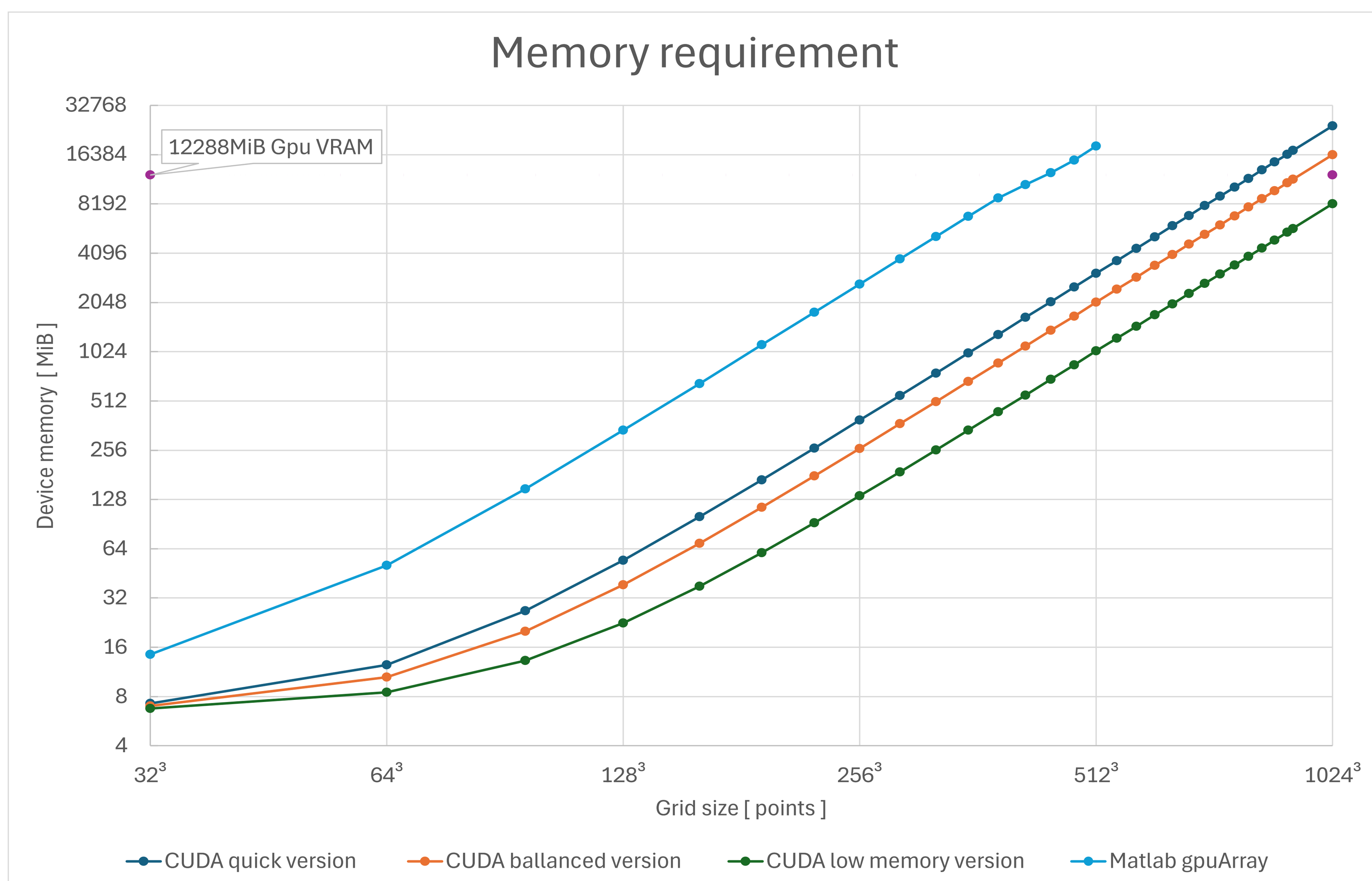

Chart 02

VSB TUO | IT4I
k-Wave
A MATLAB toolbox for the time-domain simulation of acoustic wave fields
European Innovation Council
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