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Ultrasound Signal Processing with GPUs — Introduction to Parallel Programming

ALL the LATEST short-course materials are available on-line:

- **https://github.com/Lab4US/gpu-short-course**
- **YouTube playlist | Vimeo playlist**

Abstract

This is our 4th edition of the Ultrasound-GPU short-course!
We are going to modify the course to focus more on practical ultrasound use-cases. Thus, the participants will need to familiarize themselves with the on-line lecture materials before attending the short-course!

Nowadays, GPUs (Graphics Processing Units) serve as workhorses for processing massive amount of data and to accelerate general-purpose scientific and engineering computing.

The main goal of the training is to get familiar with the GPU/parallel programming and apply it to ultrasound signal processing. The short-course is going to be practically oriented with a 25/75 split between the lectures and exercises. We are planning to leverage a common knowledge of the basic ultrasound processing methods and show how to translate them into working parallel algorithms.
The workshop will target both low-level Nvidia CUDA GPU programming and high-level Python tools. This blend of development tools enables fast prototyping of new processing methods and later migration to a high-performance native GPU implementation.
During the exercises, the Participants will implement and test their algorithms on ready to use RF datasets, as well as have an opportunity to run them on an ultrasound research system equipped with GPU.

Target

Students, PhD students, researchers, and R&D staff interested in extending their skills to apply parallel and GPU programming for ultrasound signal processing in their daily work.

Prerequisites

- Basic programming skills (Python and C language).
- Basic knowledge of ultrasound imaging and reconstruction algorithms.
- A PC/laptop:
  - min 8 GB of RAM memory,
  - Nvidia GPU with at least 2GB of GPU memory, compatible with CUDA Toolkit 12,
  - Windows or Linux OS,
  - Installed software:
    - Nvidia CUDA Toolkit 11.0;
    - Python 3.10, including pip package manager.

Topics

- Intro to parallel programming: GPU architecture and NVIDIA CUDA, Python tools for GPU programming.
- Examples — implementation of practical ultrasound signal processing:
  - ultrasound image reconstruction — linear array and RCA 3D probe,
  - Color Doppler and SWE,
  - image enhancement algorithms,
  - speed-of-sound estimation,
  - data streaming and processing for real-time operation.

Course materials

- Course slides (partly based on the Nvidia training).
- Example GPU kernels (on Github).
- Example RF datasets.

References

1. CUDA Toolkit Documentation, https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html
2. David Kirk, Wen-mei Hwu, Programming Massively Parallel Processors: A Hands-on Approach, 3rd ed., Morgan Kaufmann, 2017.
3. Jason Sanders, Edward Kandrot, CUDA by Example: An Introduction to General-Purpose GPU Programming, Addison-Wesley, 2010.

Supporters

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SPEAKERS

Dr Marcin Lewandowski <marcin@us4us.eu>
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Since receiving a Masters degree in Physics followed by a PhD in Electronic Engineering, Marcin Lewandowski has headed many projects in R&D, commercial product design and medical devices development and certification. He has also authored numerous publications in scientific journals on the medical and industrial applications of ultrasound. Over the course of 30+ years working in ultrasound, electronics and software development, Marcin has strived to apply his research expertise in projects with a strong potential for innovation and commercialization. Today, he balances his continued work in science with his role as CEO at us4us Ltd., who produce original ultrasound platforms for research, biomedical and industrial applications.

Novel ultrasound imaging solutions and GPU implementation have formed a key part of Marcin's work for several years. us4us products all employ software processing on GPUs for real-time access to raw ultrasound data, and garner interest from universities, research institutes and commercial clients looking for powerful, versatile and fully programmable imaging solutions.

Piotr Jarosik <piotr.jarosik@us4us.eu>
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Piotr Jarosik received his Bachelor's and Masters Degree in Computer Science at Faculty of Electronics and Information Technology, Warsaw University of Technology. Currently, he is a software architect at us4us and a PhD student at IPPT PAN. His research interests include machine learning and ultrasound data processing.

Dr Billy Y. S. Yiu <yshyi@dtu.dk>
Affiliation: Technical University of Denmark.

Billy Y. S. Yiu received his B.Eng. degree (Hons.) in medical engineering and the M.Phil degree in electrical and electronic engineering from The University of Hong Kong in 2007 and 2010, respectively. He was awarded his Ph.D. degree in electrical and computer engineering from the University of Waterloo, Waterloo, ON, Canada, in 2019. He was a research staff member with the Biomedical Ultrasound Laboratory in The University of Hong Kong from 2010 to 2016, and served as an associate scientist with the Laboratory on Innovative Technology in Medical Ultrasound (LITMUS), University of Waterloo. Recently, he joined DTU Center for Fast Ultrasound Imaging as an associate professor.

Billy's research interests are in advanced ultrasound imaging techniques and systems innovations; GPU implementation of these novel imaging techniques on research platforms for real-time performance has been of his long-standing interest dating back to 2010. Some of his contributions include high-frame-rate DAS beamforming, adaptive beamforming, eigen-based clutter filtering and speckle imaging in which he has published several journal articles based on these works.

SUPPORT TEAM

Mateusz Walczak, Piotr Karwat, Ziemowit Klimonda, Damian Cacko, and Julia Lewandowska.

THANK YOU!