CIRA Student: Milestone 2 Report

Applicant:
Gayatri Aniruddha
Student ID: 20875110

Supervisor:
Dr. Marcin Sokolowski

Curtin Institute for Radio Astronomy
Masters of Philosophy (MPhil)

Thesis: High-Time Resolution GPU Imager for Low-Frequency Radio Telescopes

May, 2023

1 Research overview

Fast Radio Bursts (FRBs) are very bright (even tens of Jansky) milli-second radio pulses originating even from a very distant Universe. The search for FRBs is similar to that of single pulse search from pulsar observations through beamforming. This method has a high associated computational cost and hence, in my research project, I am exploring alternate image-based approaches, specifically for low-frequency FRB searches. Furthermore, the reduced signal to noise ratio at low frequencies due to long dispersive delays and sky background temperature makes FRB detections at low frequencies even more demanding. Existing imagers such as CASA, MIRIAD and WSCLEAN have substantial I/O heavy operations, while high-time resolution images are required for FRB searches. Furthermore, there is no imaging software, operating entirely or predominantly on GPUs to look for FRBs. Thus, the main aim of my Masters by Research is to develop an alternative GPU imager which will be a part of the processing pipeline searching for FRBs. I will continue working on the imaging software to test and deploy it on SKA-Low stations and the Murchison Widefield Array (MWA) and further optimise its processing efficiency by implementing it on GPUs to capitalise on parallel programming. Finally, this imager will be used to image(in 10 or 100 ms time resolution) small amount (atleast 10 min, up to 60min) of SKA-Low station or MWA data to demonstrate the potential of the imager for high-time resolution science.

2 Work to date

Since Milestone 1, I have worked and completed the following tasks:

1. Understanding of interferometric imaging and test python code
   - Understanding of interferometric imaging and test python code: In order to understand what happens at every stage of interferometric imaging, I implemented a stand-alone version of the imager from scratch on python for a single time and frequency channel to translate equations in textbooks into code.
   - I also validated if the python imager produces the images as the current version of the C++ imager using test EDA2 data.
2. Development of C++ version of the imager for GPUs:
   - I developed a separate standalone test GPU C++ version of the imager, using the existing single time-step, single channel CPU and Python imager generating all-sky images from EDA2 data as starting points.
   - I developed the following two test versions for GPUs:
     - Test imager for a single time and frequency channel
     - Test imager for multi-channel, multi time-step

- The main difference with regards to CPU version was that the GPU code has gridding implemented as a CUDA kernel and uses the cuFFT library instead of the fftw library.
- I tested and verified the GPU imager by comparing the resulting sky image with those produced by the CPU imager. (The images produced by the CPU imager were already validated by my supervisor with those produced by the standard radio astronomy software such as CASA, MIRIAD or WSCLEAN on the same data and using compatible options).
- I benchmarked and compared performance of GPU and CPU versions of the imager on Topaz and Setonix Supercomputers at PAWSEY.
- I also benchmarked and compared the performance of different versions of parallel gridding implementations on Topaz and Setonix supercomputers.
- I also worked on a feasibility study question: "We would like to image 32 channels in 10ms time resolution. If you use 32 blocks how long will it take to image 1 second of data (let's count only gridding and FFT) on Topaz vs. Setonix for the following image sizes: 180x180, 1024x1024 and 4096x4096?

3. Written work:

- I started planning and writing sections of my proposed paper and completed writing a total of 4200+ words. (Paper draft along with turnitin report has been attached to this report).
- I also started planning the sections of my thesis, to be submitted in December 2023. (Link: Thesis plan)

3 Future work and dissemination plan

I need to complete the following tasks towards my project after my Milestone 2:

1. Along with my supervisor, we plan on testing and validating the the multi-channel, multi time-step imager to image in 10 ms or 100 ms time resolution, 10 - 60 minutes of both EDA2 and MWA data.
2. The remaining sections of the paper corresponding to imager validation and demonstration on real, simulated data need to be drafted and updated. The expected completion time of the paper is June and we plan to submit it to Publications of the Astronomical Society of Australia (PASA) journal by the end of June, at the latest.
3. After my Milestone 2, I plan to start writing my thesis, for a timely submission in December 2023.
4. Finally, I intend to attend the International High Performance Computing Summer School and Conference (https://ss23.ihpcss.org/) happening at Atlanta from 9-14

July, 2023 where I will be required to present an electronic poster describing my research project. All associated costs including flights, accommodation and meals will be covered by PAWSEY. I have completed and submitted an online travel request for the travel to this conference to be approved.

4 Completion plan

The duration of my proposed MPhil project is two (2) years. See Table 1, where the updated project time line is outlined. The green squares denote the months and work that has been completed and the grey squares denote the work to be done until the completion of MPhil. I acknowledge that there has been a delay due to change in my project circumstances and re-scope as a result of my conditional candidacy, lasting from June 2022 to February 2022. However, I believe that this delay will be compensated for in the coming months.

		Months since 10 December 2021							
Activity		3	6	9	12	15	18	21	24
Literature review									
Learning software packages									
Papers	I - High Time Resolution GPU Imager for SKA-Low stations								
Thesis	Chapter 1 - Background								
	Chapter 2 - Methods								
	Chapter 3 - Paper 1								
	Chapter 4 - Discussions and Conclusion								

Table 1: Upated timeline