South African Radio Astronomy Observatory
Research Project Proposals for Masters and Doctoral Research in 2020

Section A: Overview of the Research Project Proposal

1. Academic level of research project: Masters

2. Broad field of research: Astronomy

3. Title of the research project: Gradient Descent based Optimization for Radio Interferometer Field of View Shaping

4.Full names of supervisor and co-supervisor: Dr Marcellin Atemkeng and Prof Oleg Smirnov

5. University where postgraduate student would be registered: Rhodes University

Section B: Research Project Proposal

1. Scientific merit:

During the supervisor's prior research, well-known window functions (WFs) from the digital signal processing domain were examined to establish their feasibility for interferometric visibility averaging. These WFs were further turned into Baseline-dependent windowing functions (BDWFs) to reduce smearing over the field of view (FoV) of an interferometer and suppress unwanted signal from regions outside the FoV while the data are compressed to an acceptable level (see Atemkeng et al. 2016). Simulations using MeerKAT telescope and the European Very Long Baseline Interferometry Network show that both data compression, FoV shaping, and outer FoV suppression is achieved with BDWFs. Designing optimally matched filters for BDWFs is an interesting avenue of further research. In practical situations, the image-plane response of a discretized and band-limited low-pass WF is far from ideal. Filter design theory for low-pass filters and supervised learning could, therefore, be used to explore an optimal image plane response. The main mathematical concept behind supervised learning is to solve robust optimization problems. There are many methods to address this problem, most of them being derivative of stochastic gradient optimization. The project will aim to explore these methods, analyze their convergence behavior, and apply the resulting optimal WFs to MeerKAT data. Analysing these WFs convergence behavior to the optimal WFs will be an important part of the project, in which rigorous error analysis in the context of gradient flow will be performed.

2. Feasibility:

The RATT group already has access to large amounts of MeerKAT data, due to its active participation in open time projects. This data is sufficient to validate the developed algorithms. RATT's compute cluster provides sufficient resources for this work.

Time frames towards attaining the overall objectives of the project

Year 1

1) Background study of filter theory and optimization methods used in machine learning
2) Literature review in radio interferometry and aperture synthesis
3) Explore the different imaging and simulation tools used at RATT for data reduction, etc.
4) Implement a naive optimization algorithm that uses BDWFs
5) Analyze its computational cost and compare the compressions factor with existing compression algorithms
6) Attend conferences and present the ongoing work as a conference paper

Year 2

7) Derive, apply and discuss the mathematics for stochastic gradient optimization for an ideal BDWF with optimal FOV shaping
8) Improve section 7) by proposing or implementing a fast algorithm for stochastic gradient descent
9) Prepare a paper while writing up the MSc thesis

3. Link the proposed project to one or more of the SARAO research priority areas for 2020

MeerKAT is already producing extremely large volumes of data, while the future SKA will up this by several orders of magnitude – and SKA surveys that adopt multiple phase tracking (such as SKA-VLBI) will push volumes even higher. BDWFs offer the potential to substantially compress interferometric data. This work will explore filter optimization strategies for MeerKAT data compression and FoV shaping.