Imaging Pipeline Software

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Math705 Research Project

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Abstract

Keywords: [Click here to add keywords.]

Acknowledgements

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1. Introduction

## 1.1 Aperture Synthesis

The resolution of radio telescopes can be increased by using pairs of telescopes (baselines) and taking the product of the received signals. This resolution can be changed by increases the separation of the baseline, rather then increasing the size of the individual telescopes. This method popularized by the work of (Ryle & Hewish, 1960) states that using these baselines it produces “exactly the same result as that obtained by using the complete large aperture”. This technique allowed for cheaper production of much larger apertures and the eventual development of the techniques used now.

These techniques gather Fourier domain data in the form of a visibility, however the way in which they are sampled is non-uniform, so we must place it on a rectangular grid. This process is known as gridding and the methods used now are based on the work by (Brouw, 1975). These visibilities V(u,v) fall upon the plane in which the baselines are setup, for a wider coverage of this place more baselines can be added and could also be moved around.

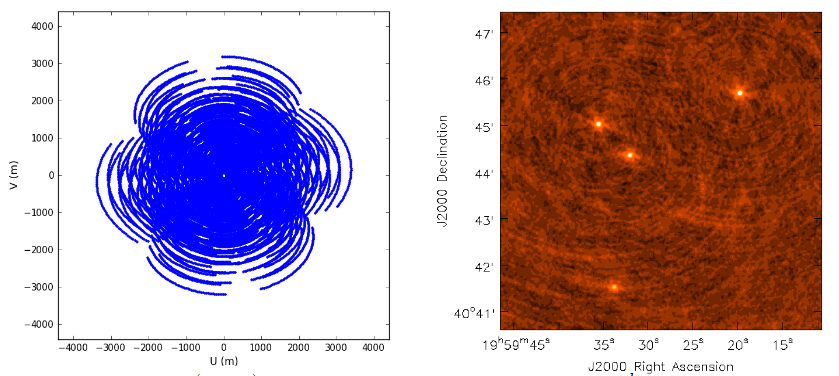
With more modern telescopes being developed, moving them around became a substantial task and instead the rotation of the earth can be used to move these points around the plane. An image of these points on the V(u,v) plane can be seen on the left of Figure 1.

Figure 1. V(u,v) plane showing data points. (Rau, 2012) Retrieved from Australian Telescope National Facility, from https://www.atnf.csiro.au/research/radio- school/2012/lectures/tue/RVU\_ImagingDeconvolution.pdf

## 1.2 Fast Fourier Transform (FFT)

A Fourier Transform is a process for signal-processing and analysis. (Brigham, 1988) states that the extent of the use the process is as follows “biomedical engineering, imaging, analysis of stock market data, spectroscopy, metallurgical analysis, nonlinear systems analysis, mechanical analysis, geophysical analysis, simulation, music synthesis”. It is widely regarded as one of the most important algorithms based on its impact in so many areas. Simply put a Fourier Transform is used to show different parts of a continuous signal, however for Interferometry an Inverse FFT (iFFT) is used as we are combining the amplitude and phase of the signal to form an image. For the performance of the pipeline an inverse Fast Fourier Transform will be used. Using such a method is based upon the work of (Hogg, MacDonald, Conway, & Wade, 1969). The algorithm used was first discovered by Gauss and later rediscovered by (Cooley & Tukey, 1965) which also notes that “Wherever possible the use of N = r^m with r = 2 or 4 offers important advantages” which impacts the design of the pipeline.

## 1.3 Gridding

Early techniques for places the visibility data on a grid involved placing the visibilities upon the closest grid point that aligns with the plane on which they were gathered and either adding then all together or averaging them out. Early methods where used by (Hogg, MacDonald, Conway, & Wade, 1969). However, this led to artifacts forming and therefore a limited application for the process. An alternative method was first used by (Brouw, 1975) and would take a weighted value based the distance between local grid point and the point of the visibility. This technique was improved upon by (O'Sullivan, 1985) with his gridding algorithm that was “computationally efficient” and resulted in “arbitrarily small artifact levels”.

Add more

## 1.4 Deconvolution

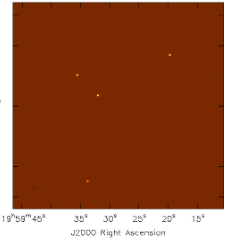
Once an image is formed from the Fourier Transform is it called a ‘dirty image’, as seen in Figure 1, this is due to the effects of having limited sampling of the V(u,v) plane. The process of Deconvolution can be used to ‘CLEAN’ the image. One example of this from (Cornwell & Bridle, 1996) is an iterative process that assumes that the real image can be made up of “small number of point sources in an otherwise empty field of view”. This ends up with the real sky image. An example of this can be seen in Figure 2, where the ‘dirty image’ from Figure 1 has been ‘CLEAN’ed.

Figure 2. Real image after it has been iteratively ‘CLEAN’ed. (Rau, 2012) Retrieved from Australian Telescope National Facility, from https://www.atnf.csiro.au/research/radio- school/2012/lectures/tue/RVU\_ImagingDeconvolution.pdf

## 1.5 Design Science

The methodolody to be followed for creating the pipeline is based on the work by (Henver, March, Park, & Ram, 2004). The

2. Methods

3. Results

4. Discussion of Results

5. Conclusion

**References**

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Appendix

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