Image Synthesis Software

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Aim

Research the techniques used in image synthesis pipelines. Gather knowledge about producing a useful image from visibility data produced by interferometry techniques.

Successfully implement the software and produce accurate results.

Methodology

- Perform a literature review on relevant topics. Then applying the knowledge gathered to implement the three main steps of a pipeline namely gridding, (inverse) Fourier transform, and deconvolution.
- Use visibility input data from the High Performance Computing Research Laboratory. Render the images using a python script which maps black through red to white based on the values.

Gridding

Visibilities must be organised onto a regular grid.

Gridding is the process of taking the raw data and placing it onto a 2D grid. Each visibility consists of 4 values, the first two values are the data points location on a u,v plane, the next two make up a complex number. This plane is mapped onto the grid.

For each point, the values are spread onto the grid using a prolate spheroidal. This shape can be seen in Figure 1.

The algorithm initially added each point iteratively, then later revised to have 4 threads gridding points at a time. Concurrency issues are solved by each thread having independent grids to map onto.

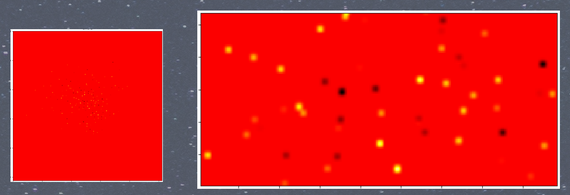


Figure 1. The whole image showing gridded points (Left), A zoomed in view showing the spread for each point (Right).

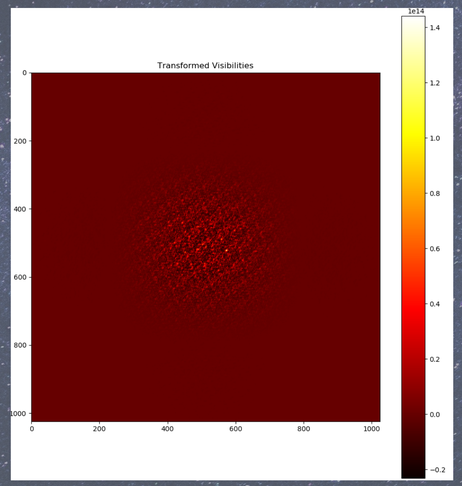
Fourier Transform

An inverse Fourier transform is used to take data from the frequency domain to pixel values.

A fast Fourier transform is used as its runtime is O(Nlog(N)) compared to a basic transform which has a runtime of $O(N^2)$.

The algorithm used is a radix 2 DFT (Cooley & Tukey, 1965) . This requires data to be in an organized array and the amount of point to be a power of 2, hence why the grid is of size 1024 and we grid the points.

The algorithm is optimised by using multiple threads to transform multiple arrays of data at a time.



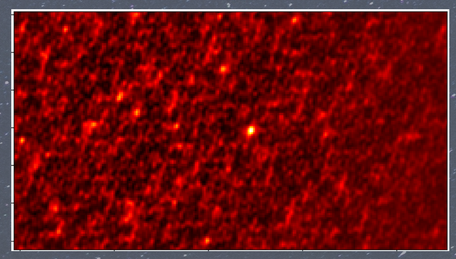


Figure 2. The image transformed (Top). A zoomed in view showing a strong signal (Bottom).

Deconvolution

This stage removes the noise from the image. This method by (Högbom, 1974) uses the original data to form a "dirty beam". The beam gets subtracted from the brightest points and that value added to a empty image. Iteratively performing this process removes the effects of the convolution to the best extent.

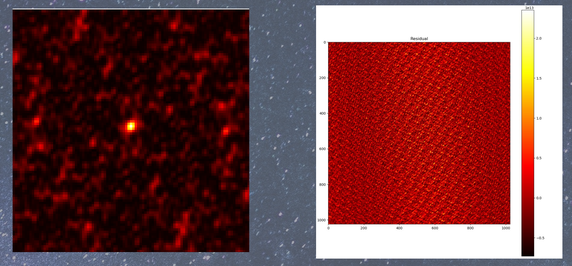


Figure 3. The dirty beam, only the center is used to isolate signals, (Left). Residuals from CLEAN, note more red as no significantly bright points.

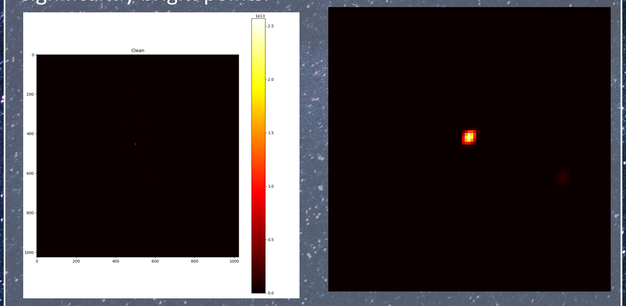


Figure 4. The CLEAN image after 1000 iterations (Left). A zoomed in view showing the strongest point (Bottom).

Conclusion

The pipeline can successfully produce images of a region of the sky from interferomic data.

Significant improvements in runtime were implemented throughout the development of the software.

Key References:

Cooley, J., & Tukey, J. (1965). An algorithm for the machine calculation of complex Fourier series. Mathematics of Computation, 297-301.

Högbom, J. (1974). Astronomy and Astrophysics Supplement Series, 417.