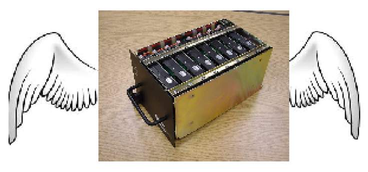
The Data Dilemma for Radio Astronomy

Stuart Weston - PhD Student
Institute for Radio Astronomy and Space Research

The Network Issue

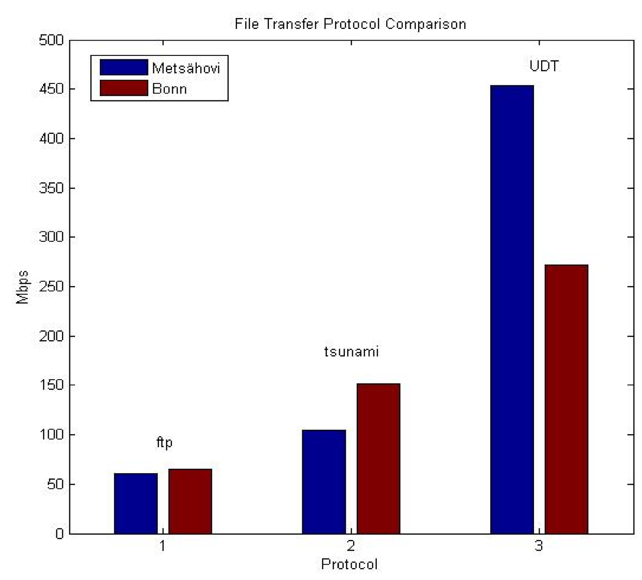
We are faced with transferring enormous volumes of data (10 TBytes) for a VLBI observation to our international partners in Australia, the USA and Europe in a timely manner. Previously data was recorded to magnetic tape or removable disk arrays, which were then sent via post or courier to a correlation centre.



With the connection of the AUT Radio Telescope at Warkworth to KAREN we are endeavouring to use this facility via network file transfer mechanisms to pass these large volumes of data to our international partners. We are investigating new more efficient protocols using UDP such as Tsunami and UDT (UDP-based Data Transfer).

Point to point with no hops FTP is efficient, but as the number of hops in the route increase the TCP congestion avoidance algorithm becomes a limitation to the throughput that can be achieved.

From discussions with Bonn we became aware of "tsunami", a udp protocol that they are using and through our research of another udp protocol UDT developed by Yunhong Gu. This has been used to distribute the 10+TB Sloan Digital Sky Survey universe image to astronomers around the world. Our testing transferring an actual 64GB lba vlbi file produced by an observation at the Warkworth Telescope to Bonn and Metsähovi indicates that UDT has great potential in our field as shown in the following graph.



UDT has some advantages over tsunami:

- It is a better citizen on the network leaving bandwidth for TCP and other UDP protocols, very important on a shared network such as KAREN
- It has a simple to use API allowing easy integration with existing or future applications

We have modified the Curtin lba 16bit-2bit conversion program to stream via UDT to a remote server in a fast and efficient manner ready for the correlator. We now use UDT for sending data to the Metsähovi Radio Observatory on a regular basis.

References:

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Wagner Jan. "Tsunami UDP Protocol". http://tsunami-udp.sourceforge.net/ (23rd July 2010)
"UDT UDP-based Data Transfer". http://udt.sourceforge.net/index.html (23rd July 2010)
Yunhong Gu (2005). UDT A High Performance Data Transport Protocol (Unpublished doctoral dissertation). University of Illinois, Chicago, USA.

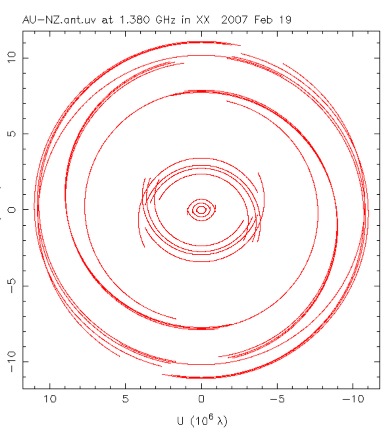
VLBI Imaging

To date CLEAN has been a widely used algorithm for deconvolution of an image from VLBI Earth Rotation Aperture Synthesis. Recently Compressive Sensing has come to the fore as a way to recover a sparse signal sampled below the Nyquist rate. Can this be applied to Radio Astronomy?

Consider the simplified imaging equation expressing visibilities V in terms of image brightness I:

$$V(u_j, v_j) = \sum_{k=1}^{N} I(l_k, m_k) e^{-i2\pi(u_j l_k + v_j m_k)}$$

In Matrix form this becomes: $y = \Phi x$



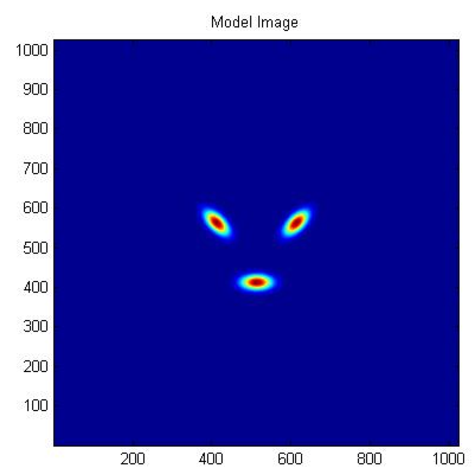
Consider the UV plot for a modelled 12hr observation using a VLBI array of Australian and New Zealand antennas on the right.

We can see that coverage of the UV plane is not complete, in fact our visibilities are sparse ! A signal is sparse or compressible if it contains only K << N non-zero or significant coefficients, in other words we have K measurments of an N dimensional signal taken at random.

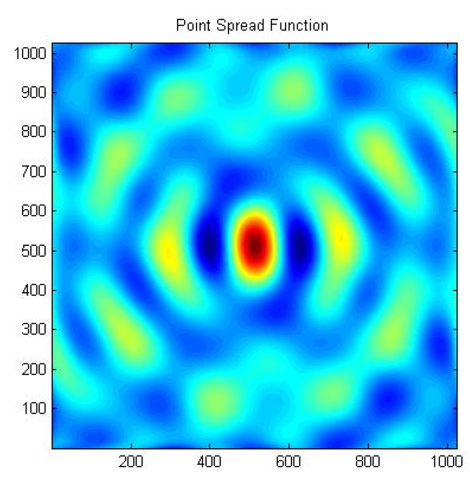
So can x be reconstructed from y? Yes so long as x is sparse.

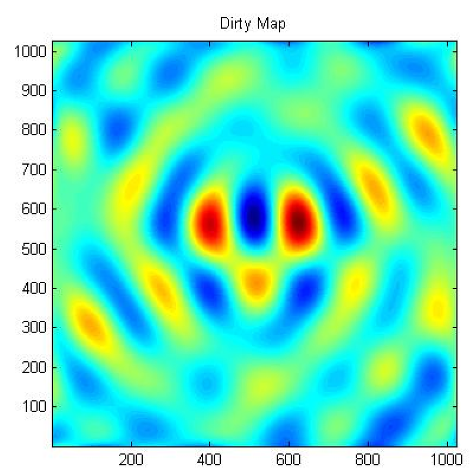
To demonstrate

Consider the model image on the right of three elliptical gaussian sources to represent a radio galaxy triplet.

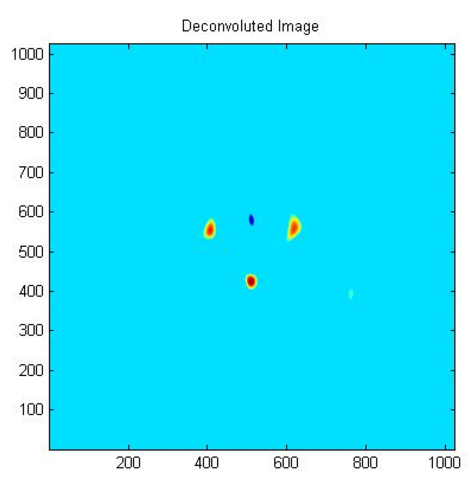


We can simulate an observation using tasks within MIRIAD and generate a dirty map and beam.





Using Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) we can recover the image. This was done in Matlab. We are aware that with noisy data this algorithm fails to converge.



We have other CS algorithms to investigate, and so the research has started to see if we can find a new method and algorithm to produce images from VLBI observations

References:

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https://safe.nrao.edu/wiki/pub/Software/CalIm09Program/Scaife_Calim09.pdf (3rd Sept 2010)
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S. Weston (2008). "Development of Very Long Baseline Interferometry (VLBI) Techniques in New Zealand: Array Simulation, Image Synthesis and Analysis". Auckland University of Technology, Thesis Master of Philosophy.
http://hdl.handle.net/10292/449

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