Predicting visibilities in MeqTrees with UVBrick

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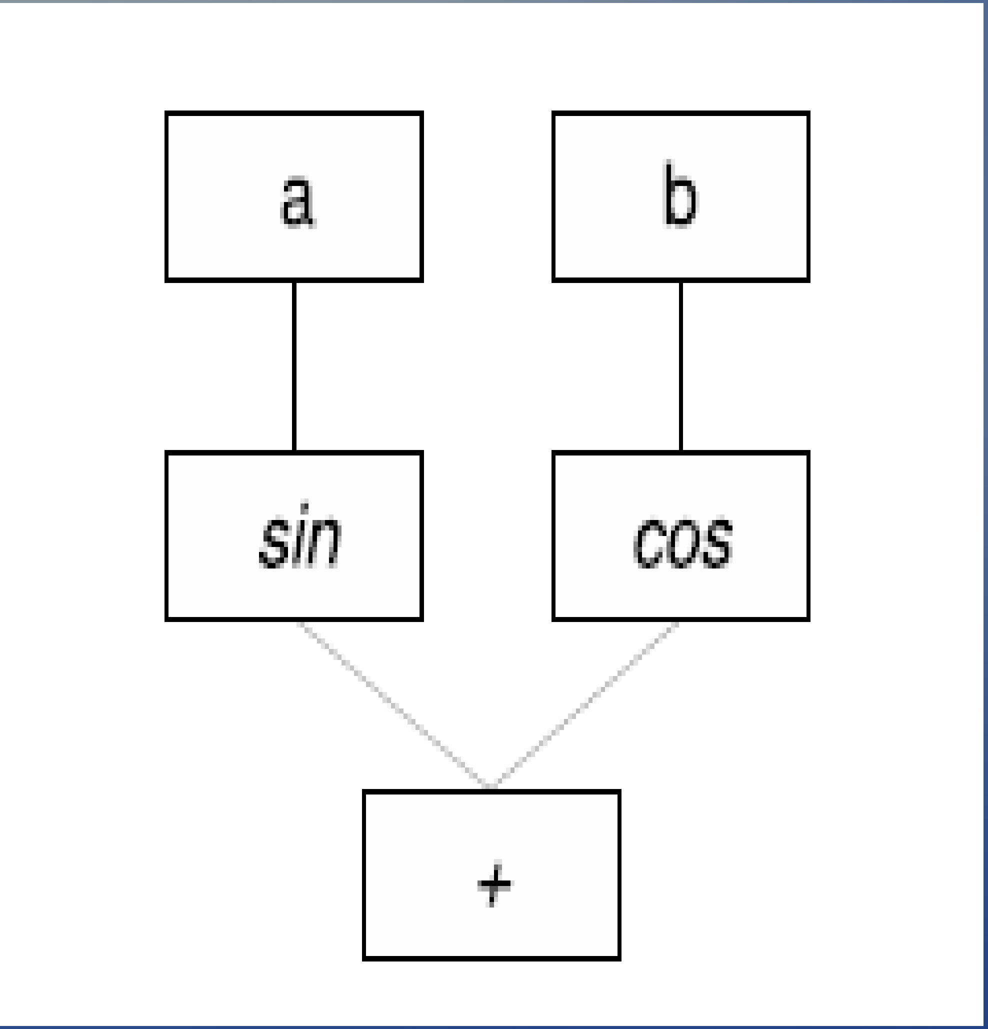
Outline

- MeqTrees software structure
- UVBrick – Introduction
- Current implementation
- Future path for UVBrick

MeqTrees Design and Impl.



- MeqTrees makes use of tree structures to represent mathematical expressions.
- In the traditional view, a tree data structure consists of a hierarchy of nodes with parent-child relationship with the leaf nodes consisting of values that are propagated upwards (or downwards) towards the root node.

(O.M.Smirnov, MeqTrees, 2010)

MeqTrees Design and Impl.

- In MeqTrees, the result of each node is a *function* of N real/complex variables.
- For our purpose, we can consider our functions to be dependent on the two variables, t and *v*.
- A *Request* object in MeqTrees consists of these variables represented as vectors (among other parameters).
- A *Result* object that is returned by a node consists of values that populate the grid formed by these vectors and the input vectors themselves.

UVBrick

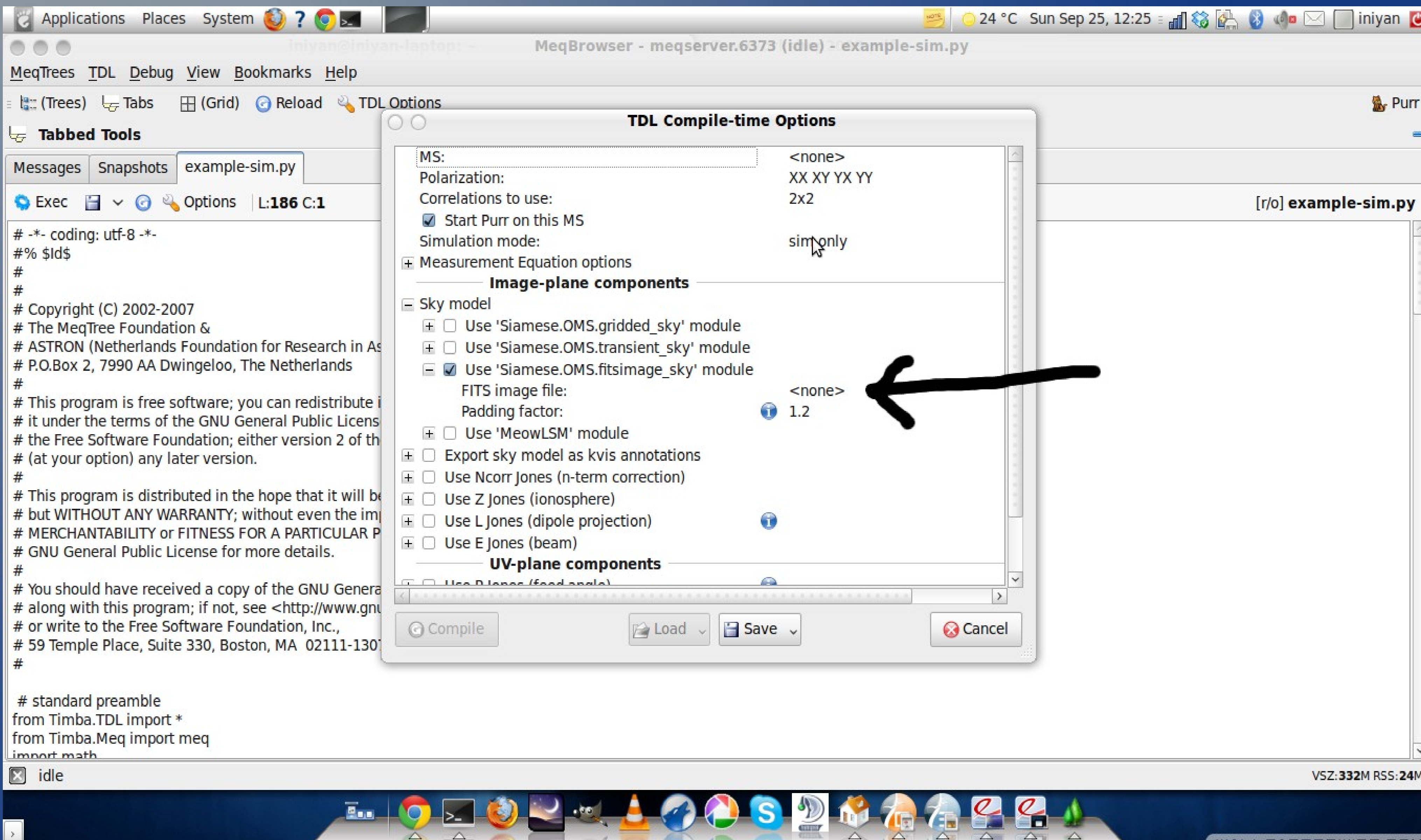
UVBrick is not...

W-projection

UVBrick is...

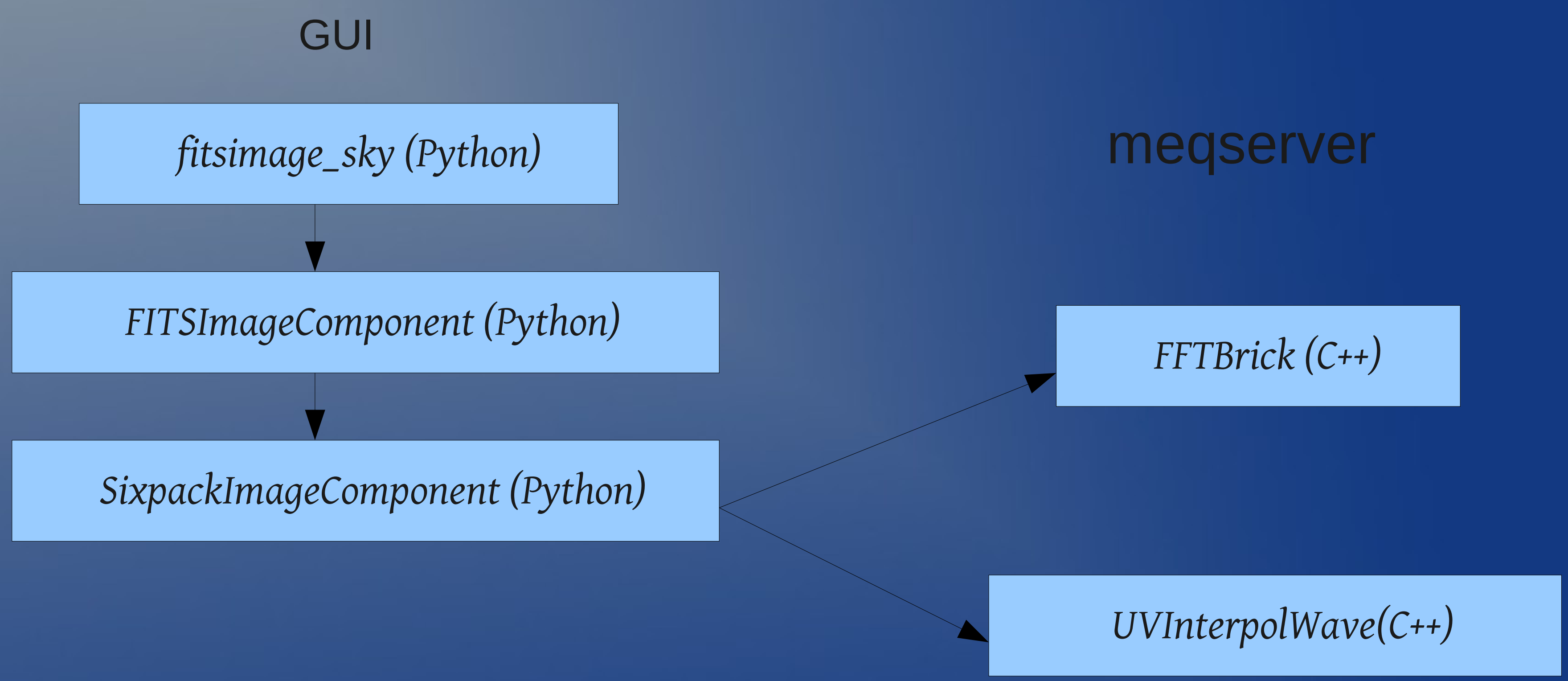
a collection of code (that forms a part of MeqTrees) that aims to predict uv-data from a given image including corrections for DDEs.

U[VBrick] are here!



UVBrick

The UVBrick is currently structured as follows:



UVBrick

$$\vec{I}(u,v,w) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \mathrm{A}(l,m)\vec{I}(l,m)\exp^{-2\pi i\left[ul+vm+w\left(\sqrt{1-l^2-m^2}-1\right)\right]}\frac{\mathrm{d}l\mathrm{d}m}{\sqrt{1-l^2-m^2}},$$

(Nijboer, UVBrick, 2005)

- *FFTBrick* is the part of UVBrick that takes as input an image in the sky plane and performs a 2D FFT on it to produce a uv plane image.
- The input lm-plane image and the padding factor to perform FFT are passed on by the user as compile-time options in the meqbrowser.

UVBrick

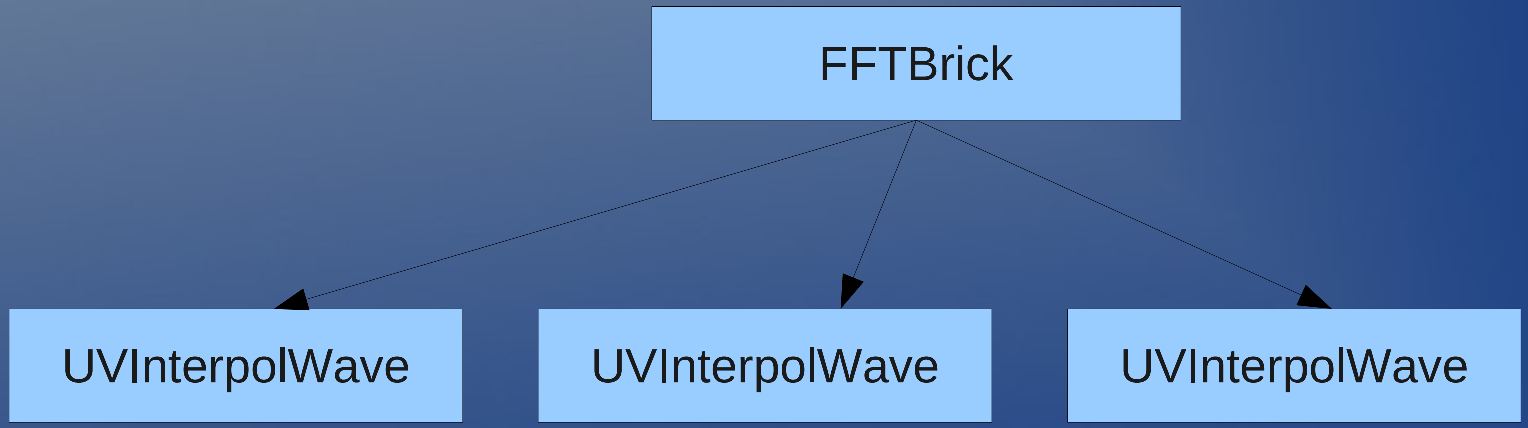
$$\vec{I}(u,v,w) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \mathrm{A}(l,m)\vec{I}(l,m)\exp^{-2\pi i\left[ul+vm+w\left(\sqrt{1-l^2-m^2}-1\right)\right]}\frac{\mathrm{d}l\mathrm{d}m}{\sqrt{1-l^2-m^2}},$$

(Nijboer, UVBrick, 2005)

- *FFTBrick* outputs a grid of visibilities as a function of u and v. This brick is created only once.
- This is passed on to *UVInterpolWave* along with a vector of required frequencies.

UVBrick

- *UVInterpolWave* takes the uv-grid and returns the interpolated visibilities as a function of frequency and time.



UVBrick - Future

Frequency dependence
W-projection capability
Forward application of other DDEs

Frequency dependence

- As it stands, UVBrick accepts a sky image of constant frequency.
- The first functionality that will be added to uvbrick is to enable it to accept a multi-frequency image cube as input and interpolate for the in-between frequencies.

  Eg. Take an image with two frequencies and interpolate for N frequencies in between.

w-projection in the brick

$$V(u,v,w) = \int \frac{I(\ell,m)}{\sqrt{1-\ell^2-m^2}} G(\ell,m,w)\, e^{-2\pi i[u\ell+vm]} d\ell\, dm$$

$$G(\ell,m,w) = e^{-2\pi i[w(\sqrt{1-\ell^2-m^2}-1)]}.$$

- The w-projection algorithm (Cornwell et al.) enables one to calculate V(u,v,w) from V(u,v,w=0) by convolution with the F.T of the known function G(l,m,w).

$$V(u,v,w) = \tilde{G}(u,v,w) * V(u,v,w=0)$$

w-projection in the brick

- Currently, uvbrick does not include corrections for w-term effects while predicting the visibilities.
- Choosing a suitable convolution kernel F(G) that takes the w-term effects into account will be the next step.

Extending to other DDEs

$$\mathsf{V}_{pq}(t) = \mathsf{X}_{pq}[t](u_{pq}(t)),$$
$$\mathsf{X}_{pq}[t] = U_p[t] \circ \mathsf{X} \circ U_q^H[t],$$
$$\mathsf{X} = \mathcal{F}\mathsf{B},\ U_p[t] = \mathcal{F} E_p[t]$$

(OMS, RIME, 2011)

- In the presence of DDEs, each baseline 'sees' a different apparent sky.
- DDEs are multiplicative terms in the sky plane whose effects can be represented using convolution functions in the uv domain.

Extending to other DDEs

- This means that by choosing appropriate convolution kernels while degridding, the direction-dependent effects can be introduced in the predicted visibilities.
- This method is called AW-projection (Bhatnagar et al.), which is a generalization of the more specific w-projection algorithm.
- By using multiple such convolutional kernels during the predict stage, other DDEs can be applied to the visibilities in uvbrick.

Thank You