

**Project notebook for Nasser Abbasi**

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**Monday June 5, 2008**

***Some notes on HYPR and related***

This section will contain useful notes I found related to this project

1. From paper “Multidimensional MRI of Cardiac Motion Acquisition, Reconstruction and Visualization” By Andreas Sigfridsson

“HYPR: Projection imaging has gained much interest, because of the forgiving appearance when using large undersampling factors and thus rapid image acquisition. Highly constrained backProjection (HYPR) [28] has demonstrated an impressive reduction factor of 225 for time resolved imaging. Temporal averaging is used to reconstruct a composite image, which is then used to constrain backprojections of individual radial read-outs, depositing the projection data only in the objects being imaged. This requires, however, that the objects in the imaging volume do not change position over time. Thus, while it might be useful for contrast enhanced vessel

angiography, it is not directly applicable for imaging of cardiac motion.”

my comment: Note that HYPR is useful for object that do not move. I also read somewhere else, that within the object, the blood flow should be changing at fixed rate (do HYPR might not work for using on places where one part of flow is higher. We then just need to assume that these conditions are met, and we do not need to worry about what if they are not for this project.

2. The term “gridding” used in the Mistretta paper seems to mean as follows I saw on this link <http://adsabs.harvard.edu/abs/2004JOSAA..21..499P> O'Sullivan JD. A fast sinc function gridding algorithm for Fourier inversion in computer tomography. IEEE Trans Med Imaging 1985; MI-4(4):200-207.

: “...by the use of gridding techniques that provide an efficient means to compute a uniformly sampled version of a function  $g$  from a nonuniformly sampled version of  $Fg$ , the Fourier transform of  $g$ , or vice versa....”

I am not sure what nonuniform sampled version of the spectrum means, I am guessing it means those slices that are taken from the k-space projection (first row in Mistretta paper) are not taken at uniform angles and at some time more slices are sampled than at other times.

3. I really need to try to implement HYPR to understand how it works more. But need to find how to obtain the k-space projection data and how to read it to start the process. But first need to write the full algorithm. There is Matlab code to do HYPR simulation from the paper, see if we can get that.

## Tuesday June 3, 2008

6/4/08 made a more detailed diagram of HYPR algorithm, to review with group at class tonight.

## Thursday June 5, 2008

Made a visio diagram of HYPR [hypr.png](#)

## Friday June 6, 2008

Working on the backprojection formulation using matrix based. The algorithm for backprojection is I currently do it in the simulation uses radon/iradon. However, this is FourierTransform based (i.e. to do backprojection, iradon uses the central slice theorem). We need to do it using as in first assignment, using matrices and transpose and all that.

The problem is how to formulate this with many projection to construct the composite image. I think it should be simply SUM over  $I$  of  $A^*g(i)$  as in my note above. Instructors said to stage the  $g(i)$  vectors (the projections) to make one large vector and then use  $A'$  on that. But the dimensions do not work out. Even if I make  $A$  to back a bunch of  $A$ 's stacked

next to each other, I get the same as if I did a SUM. So I am not sure why they said that. Need to sort this out.

Reading the PPT file that Dr Pineda send to us today to see if it will help me. Spend more time reading the Kak book. Very useful stuff.

## **Saturday June 7, 2008**

Cleaning up my notes on derivation of HYPR.

## **Monday June 9, 2008**

Updated my notes on HYPR. [PDF](#) [HTML](#)

Few things needs to understand:

What does this mean? “angular undersampling factors of 100 may be possible” from the main HYPR paper (A5). I am still now sure I understand how HYPR allows undersampling? Need to think more about this.

Why does appendix A talks about single projection then uses a sum over all projections? (part about SNR)

## **Tuesday June 10, 2008**

Reading the Wright-HYPR paper.

Questions on it:

1. It says the the composite image C is “time average”. Does this mean when making the composite image we need to average the resulting of the filtered backprojections?
2. What does this mean? “Since the profiles of the projection lines are normalized (divided) before they are summed, this is a nonlinear process.”

From Wright-HYPR

“Unfiltered backprojection has a significantly higher SNR than filtered backprojection due to the over-weighting of the low frequency data (data at the center of the  $k$ space).”

Some definitions from

“Projection lines: Projection lines are thin continuous parallel lines that project out from a drawing to help describe a component. They are drawn two at a time with a dimension and a dimension line between them.”

Wrote matlab function to generate disk image of different sizes and centered and simulate for different loci see my main project page for table

## **Wed June 11, 2008**

Worked on my HYPR report, read Wright paper and I-HYPR

## **Thursday June 12, 2008**

Corrected my HYPR report. There was a mistake in the GE PPT.

Added algorithm pseudo-code as well.

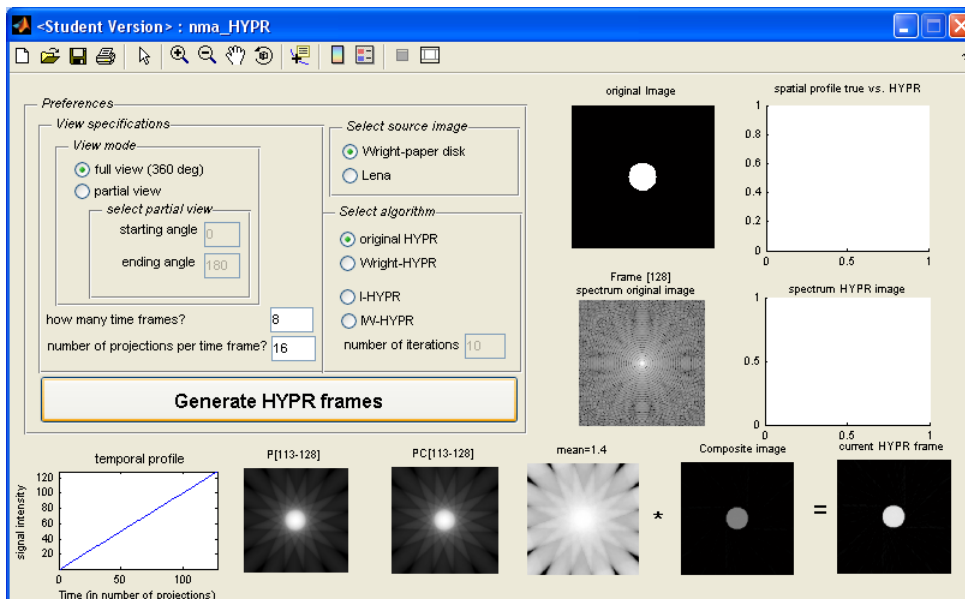
## Friday June 13, 2008

Starting work on HYPR implementation

## Saturday June 14, 2008

Working on HYPR implementation. I can now reproduce the plots in Wright Huang Paper using disk. I think I found an error in the paper. It is 16 projections per frame, not 8. Send email to the author Dr Huang.

This is how the UI look like now



Still need to implement W-HYPR and I-HYPR and make it more robust.

## Sunday June 15, 2008

W.H. paper is correct, it is 8 projections, but they count projection differently from what we do. So their 8 projections is what I call 16 projections. So all is ok.

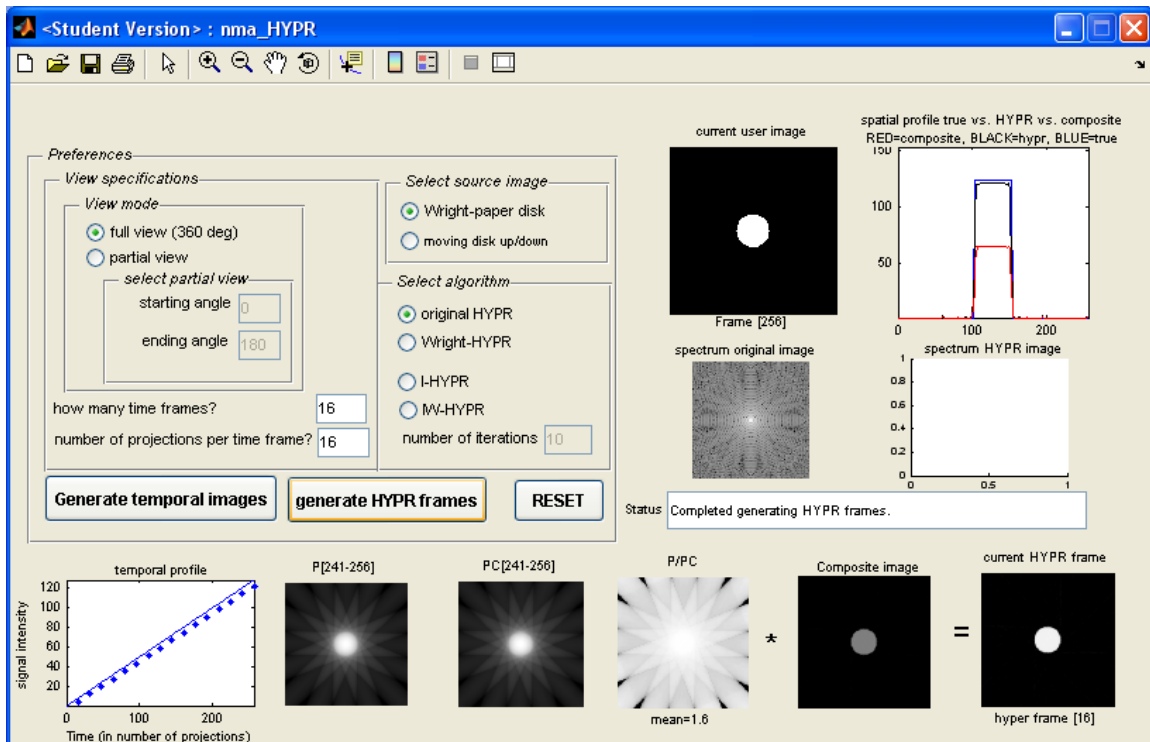
9AM: Things needs to do for today

1. if spatial images already created for current image, do not redo it. This needs for me to use UserData and keep track of this.
2. generate the profile for intensity
3. check for no power of 2 number of projections, and if so, do not use bitordering since that works only for power of 2.
4. Try to do the HYPR for moving disk as well.
5. add plot/result of error between current HYPR frame and average of real frames used to generate the HYPR frame.

6. Updated my document on HYPR projections and clarified it.
7. 11:15 pm: Need to add error, and 3D view of spectrum. Finished HYPR and WH-HYPR. Tommorrow I can do I-HYPR

Now it is all complete for HYPR, I get the same results for all the plots of the paper. Here is what the UI looks like now.

Next, I need to implement WH hyper and I-Hyper. Should be easy to do. Next, add 2 small objects (disks) next to each other and see the effect of small objects, and compare to 2 disks further apart. HYPR should do better with objects with more space between them I think



Some observations:

To obtain a good HYPR frame reconstruction, projections per frame must be taken at angles that are uniformly distributed around 360. If one takes a time frame projections at angles such as 1,2,3,4,...,20 degrees say, then HYPR frames reconstruction will not resemble the original images well. Hence use bitordering, and for this user must supply a power of 2 total number of projections.

## Monday June 16, 2008

Adding more stats

Original, RMSE 2.937

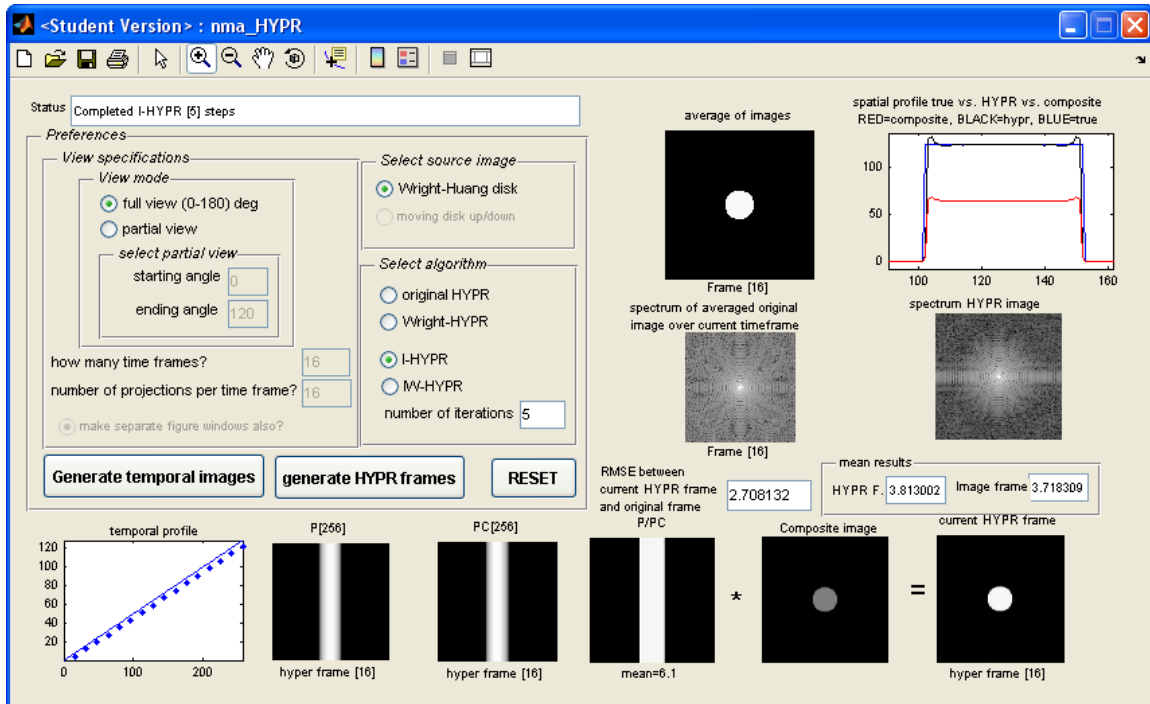
WH hyper RMSE 3.064

HYPR frame in W-HYPR is more than image frame (averaged) than in the case with original HYPR. So W-HYPR for somereason generates HYPR frames with more intensity?

I-HYPR is working. RMSE after 2 steps went down to 2.754

3 PM. Moving sotware to laptop. Completed initial report with results. [See my updated HYPR report.](#)

Current UI



## Tuesday June 17, 2008

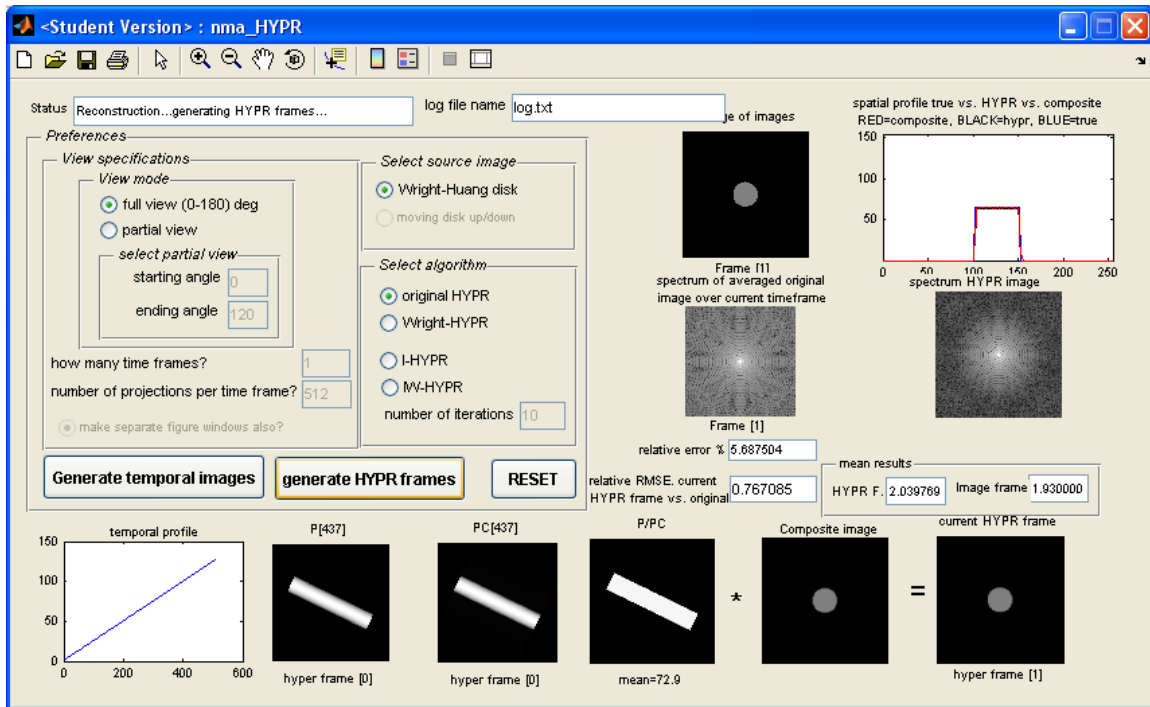
From Wright-Huang paper

“A uniform acquisition order, such as the bit-reversed order, is required to reduce imaging artifacts.”

“Spatial resolution, temporal resolution, signal-to-noise ratio (SNR), field of view (FOV), and the extent of artifacts are common tradeoffs in magnetic resonance imaging (MRI).”

Send email to Dr Huang. With this one simple test (disk, change intensity) original HYPR gives less relative error and less RMSE. Should I be trying different configurations?

Current UI. Added log file, more statistics



Send email to Dr Huang with result of simulation in the hope to get his input on why WH-HYPR produces larger relative error in the HYPR image with the above simple simulation. May be the disk simulation does not reflect or show the main strength of WH-HYPR ?

Here is the [PDF](#) file with results of a test described in the pdf file.

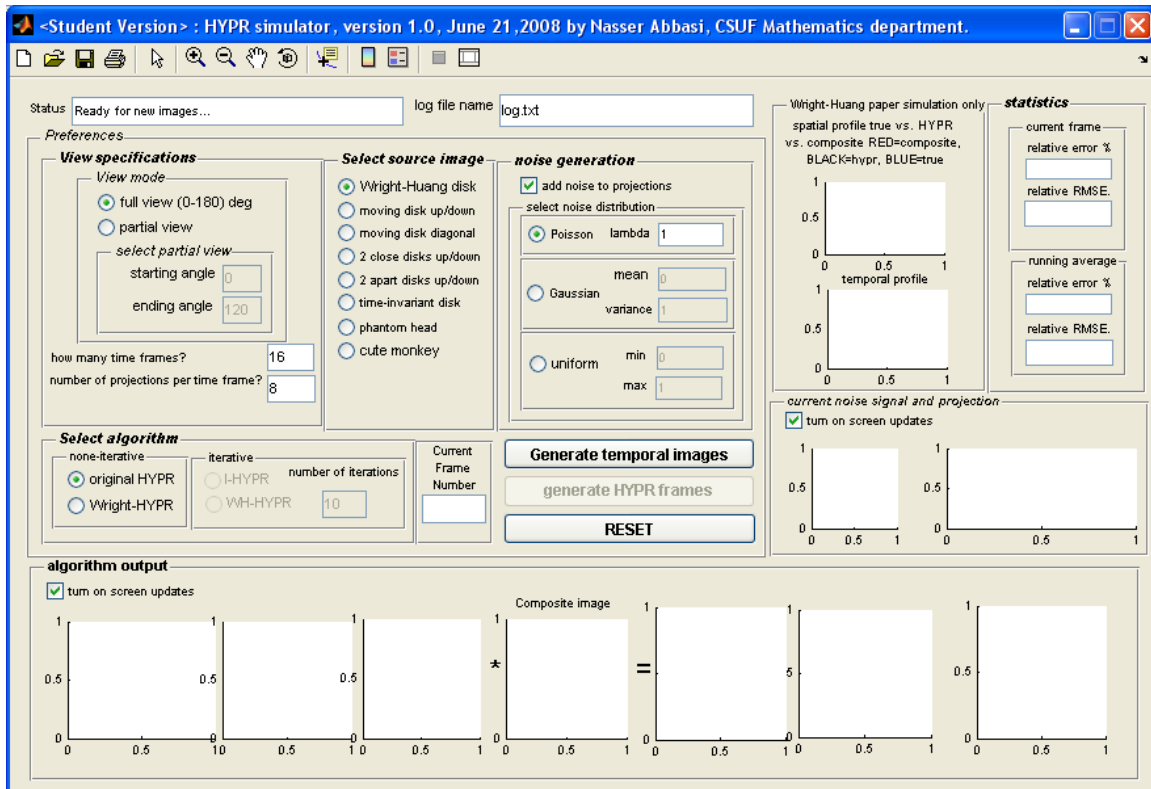
## Wednesday to Saturday June 21, 2008

Been working on running experiments on HYPR and developing a HYPR simulator to help me with this.

## Thursday to Monday June 24, 2008

Completed version 1.0 of the HYPR simulator and also completed the midterm report. Helped with editing for the PPT slides.

This is how the UI looks now



## Tuesday to Thursday 6/26/08

Made version 1.1 of the HYPR simulator. See [HERE](#) for web page and more information.

Class.

At time, worked for few more hours to add support to dynamics phantom clip and another image from Dr Pineda he send.

## Friday 6/27/08

Read a little from the book the mathematics of medical imaging on radon transform and filter theory (which is really nothing but linear system stuff studied in my mechanical eng.).

Working on splitting the 2 windows. One is a configuration only UI (where preferences are entered) and a separate window for all the plots. This allow more real estate for displaying the images and it also allows me to improve the preferences entry and add more options as I am running out of space already.

## Saturday 6/28/08

Work on simulator. Looking at adding noise



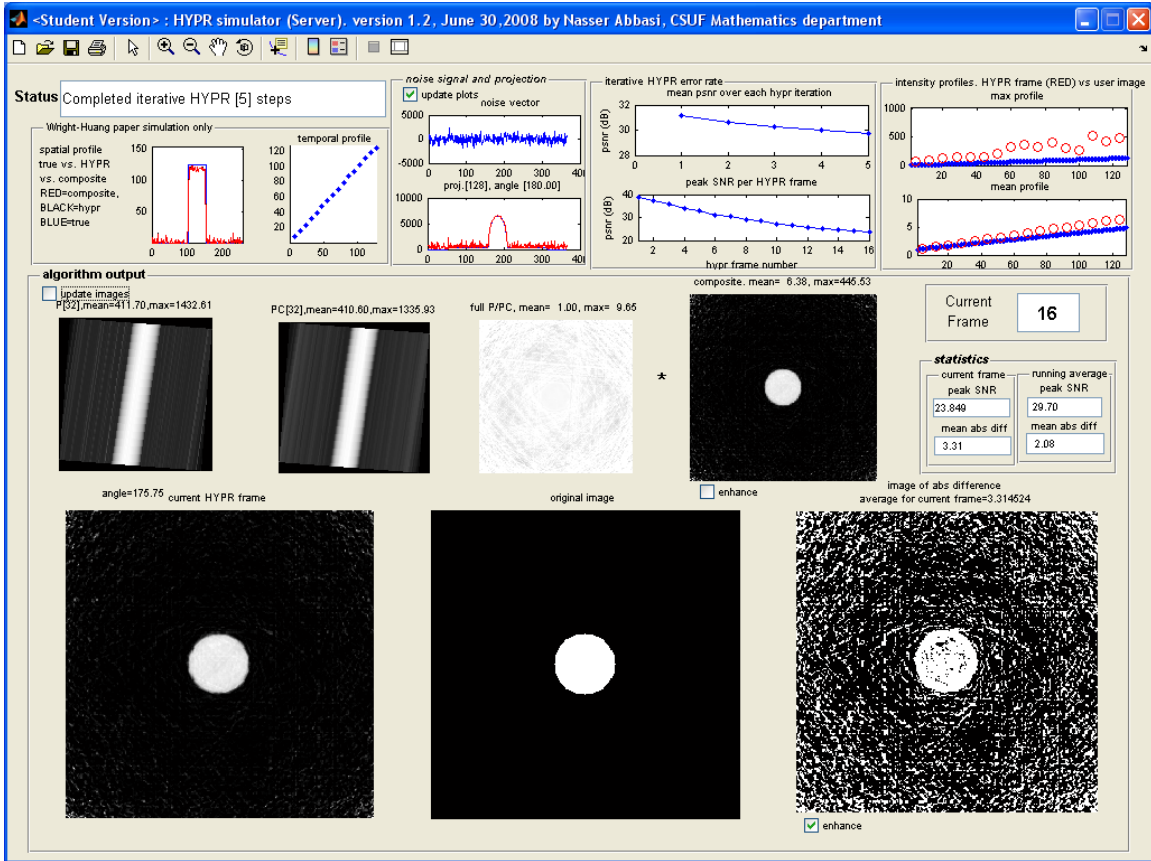
Sunday 6/29/08

Work on HYPR, read papers

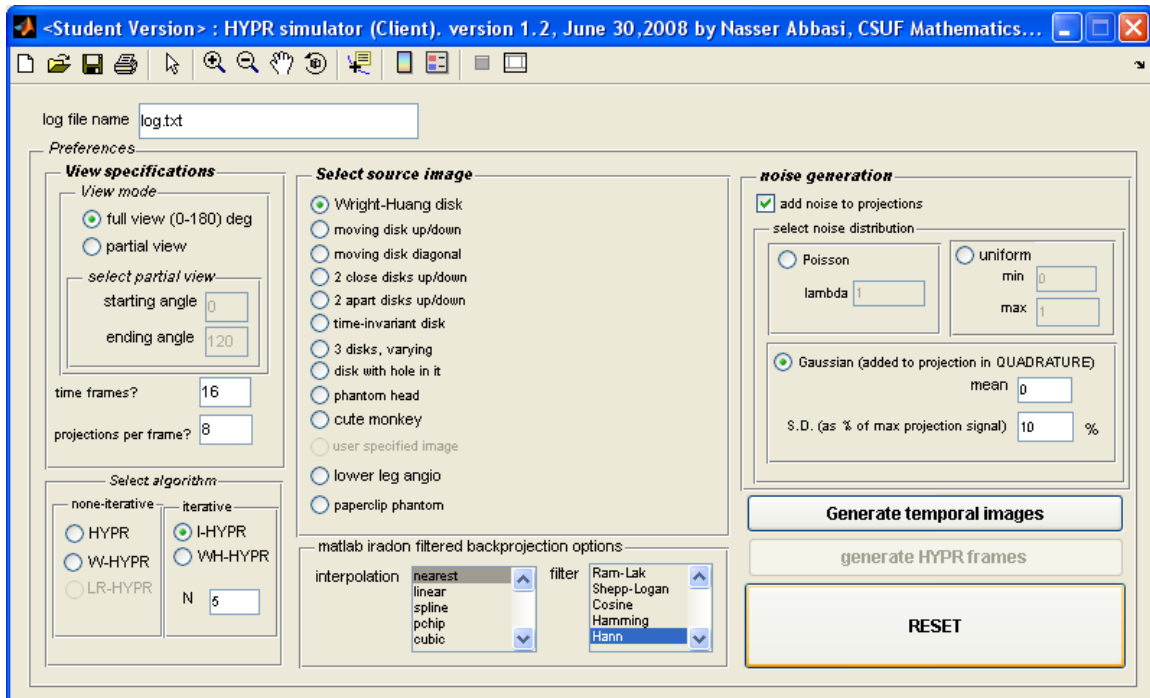
Monday 6/30/08

Work on HYPR, class

Server UI



Client UI



## Tuesday to Thursday 7/03/08

Worked on “initial findings and animation” report.

Updated HYPR simulator to 1.2.1 (fixed 2 small boundary conditions problems and changed RMSE to become normalized).

Read papers, learn about SNR, Contrast, and CNR.

Update my HYPR report, concentrate on I-HYPR for class talk

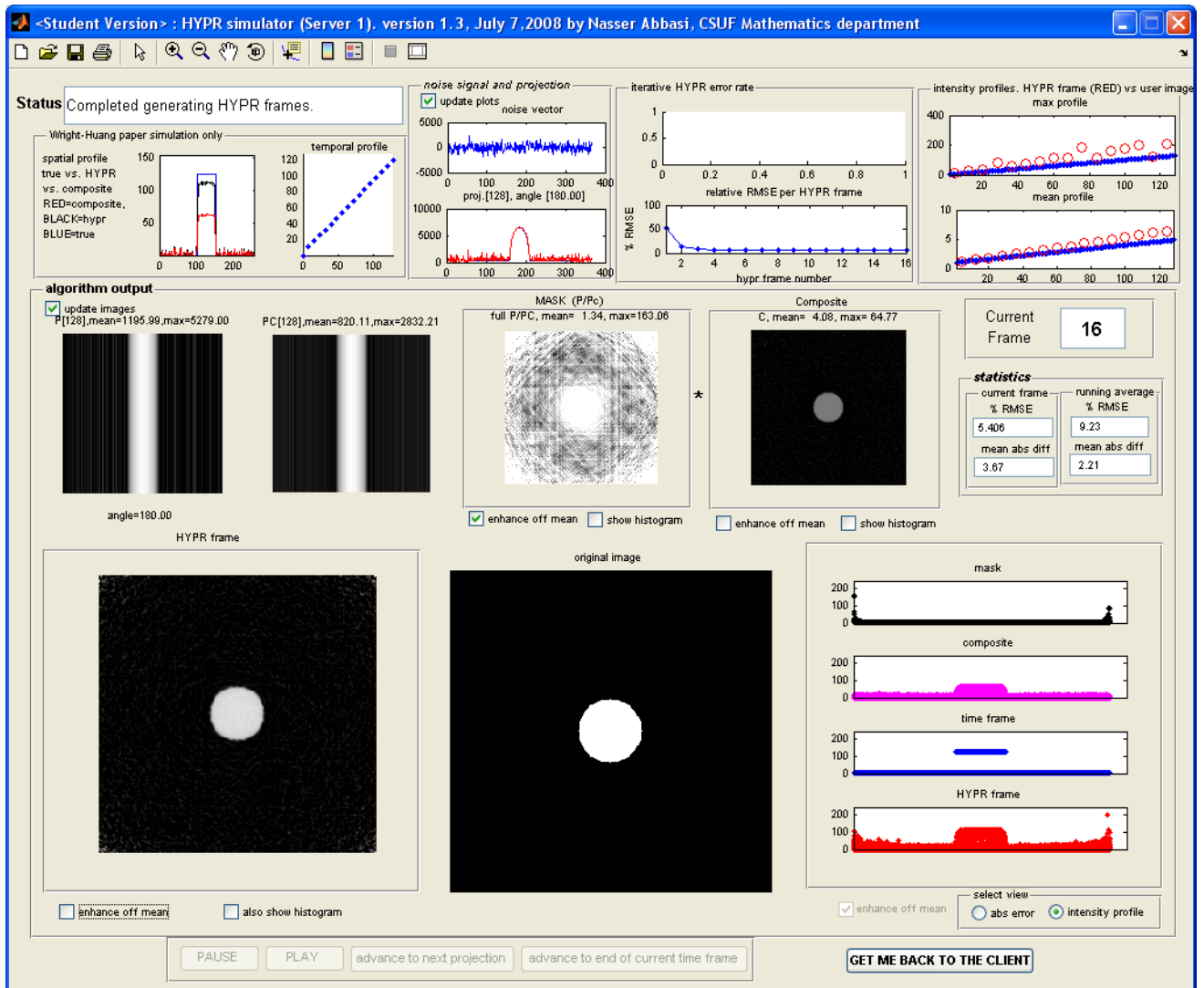
## Friday, Saturday and Sunday 7/6/08

Working on adding more analysis features to simulator.

Need to know the following on HYPR

How is a time frame determined? i.e. what are the basic of it? It must have something to do when acquisition occurs.

5:00 AM Sunday. Ok, go to sleep. All what is left now is to clean up stuff, and synch things up. Should be done by Thursday. Here is the UI now. Added intensity profile plot also.



## Monday 7/7/08 to Thursday 7/17/08

Went to SIAM on Monday 7/7/08. Then spend all the next week working on v 1.3 of simulator. Many things added. Plane to finish it by next Monday so we can start using it to analyze the algorithms in detail and write the final report.

Wrote a small report on matlab iradon and why the all-at-once does not give the same result as the one-at-time method.

## Friday 7/18/08 to Monday 7/28/08

Completed HYPR simulator. Final version is 1.4.1

Made report on HYPR-LR and reviewed finding in class

Working now on final report (4 pages) and power points (4 slides) for summary of work done.

## **Tuesday 7/29/08 to Friday 8/1/08**

Worked on power points and report. Did review in class and handed out my reports.

Applied changes to power point slides and emailed updated copy.

Working on documentation for HYPR.