Findings Related to the Effect of Using Sliding Window Composite of varying sizes on the Accuracy of Original HYPR, Wright-Huang HYPR and HYPR-LR Using HYPR Simulator Software applied to GE phantom clip and to Crosstalk test case

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Notice: This whole report with all supporting documentations and images are contained in this one ZIP file (8 MB)

Introduction

This report contains results obtained using simulation to compare the accuracy of HYPR image reconstruction using the original HYPR, Wright-Huang HYPR and HYPR-LR algorithms applied to two different input data: The first using the GE phantom clip (images in this clip exhibit large spatial and temporal dynamic), and the second input data using a test case which exhibits cross talk problem (2 objects close to each others with different temporal dynamics). This second case was obtained from the I-HYPR paper(4) and shown under figure 4 in that paper. This paper if available to download from my project web page in the Papers table under item #2.

In this simulation (version 1.5 of HYPR simulator was used, which now supports composite sliding window) we used a sliding window composite algorithm to generate a new composite image when a new HYPR image is being reconstructed.

The sliding window algorithm for generating the composite image is a known method which attempts to improve the result of the final HYPR images by reducing cross talk effects, but can increase streak artifacts. See LR-HYPR paper(1) for more discussion on this topic. This paper can be downloaded from the above mentioned table as well at item #9.

We have modified the original HYPR(2), Wright-HYPR(3) and HYPR-LR(1) algorithms to be able to support a sliding window composite in the HYPR simulation software.

In this small study, our goal was to determine how each algorithm's accuracy changes with window size.

We used windows of varying sizes and in each case, we ran simulation using noise and without noise. We also run the algorithm without the use of sliding window. Two different tests were done.

Simulation results

First test case: GE phantom clip

In this test, we used as input to HYPR algorithm the GE phantom clip which exhibits large spatial and temporal dynamics.

This set of data we broken into 8 time frames with 8 projections per time frame. Then we ran the modified O-HYPR and W-HYPR which now supports sliding window and compared the accuracy as the window size is changed. This is the result.

GE Phantom Clip, No Noise case

Algorithm	Window Size			No sliding window
	3	5	7	
O-HYPR	8.32	6.76	6.65	6.83
W-HYPR	8.45	6.69	6.54	6.77
LR-HYPR[1]	18.49	9.79	7.34	6.70

GE Phantom Clip, noise is zero mean and 5% S.D.

Algorithm	Window Size			No sliding window
	3	5	7	
O-HYPR	12.44	12.20	11.08	10.73
W-HYPR	10.86	9.65	9.55	9.60
LR-HYPR[1]	20.67	17.23	14.50	13.87

RMSE results (Lower values means more accurate reconstruction)
Data contains total of 8 time frames

(1) LR-HYPR was run using circular filter with size 20

Observations on the above test results

We first notice that W-HYPR had the best results with and without noise. We also observe that the most accurate results was obtained using the sliding window method by limiting the composite size to smaller size than the case would be without the use of sliding window. W-HYPR with sliding window of 7 was more accurate than when using all the available time frames.

Second test case: Cross talk

In this test case, we used the test case as described in the I-HYPR paper[4] under figure 4.

Fig-4 I-HYPR paper, noise is zero mean and 5% S.D.

Algorithm	Window Size							No sliding window
	3	5	7	9	11	13	15	
O-HYPR	57.76	204.54	40.76	56.77	44.33	37.74	39.78	33.45
W-HYPR	31.22	24.79	22.02	22.01	20.80	21.07	21.87	22.06
LR-HYPR[1]	124.39	93.89	87.17	84	85.91	86.11	84.12	75.65

Fig-4 I-HYPR paper, No Noise added

Algorithm	Window Size							No sliding window
	3	5	7	9	11	13	15	
O-HYPR	33.95	13.25	9.88	8.66	7.22	5.97	5.79	5.85
W-HYPR	21.88	12.40	10.22	9.16	7.75	6.54	6.54	6.63
LR-HYPR[1]	86.06	18.46	10.67	8.52	6.97	5.96	5.58	5.59

RMSE results (Lower values means more accurate reconstruction)
Data contains total of 16 time frames, 8 projections per frame

(1) LR-HYPR was run using circular filter with size 20

Observations on the above test results

In this test case, we wanted to determine the effect of sliding window on cross talk. There were 16 time frames with 8 projections per time frame.

When noise was present, W-HYPR was the most accurate. The accuracy of W-HYPR was improved more with the use of sliding window where we see that the most accurate result was obtained with window of size 11.

With no noise present, LR-HYPR was the most accurate. The use of sliding window with LR-HYPR did not result in improvement of accuracy compared to the case when no sliding window was used (5.58 with window of size 15 vs. 5.59 with no sliding window). By the nature of LR-HYPR, it works best with objects that are close to each others and exhibit large temporal dynamics.

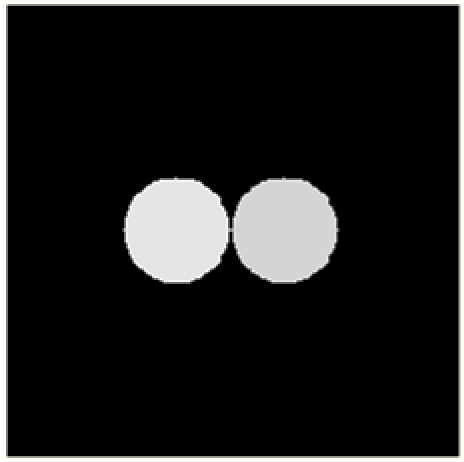
Conclusions

1. The use of sliding window with Original HYPR and Wright-Huang HYPR results in more accurate HYPR reconstruction.
2. In both test cases, O-HYPR and W-HYPR did better with sliding window than without sliding window. However, the size of the sliding composite window is difficult to predict. Doing some earlier simulations on typical images that are expected to be acquired could help in determining the size.
3. With smaller sliding composite window, cross talk was reduced; however, in place of it streak artifacts showed up (see images below in appendix). LR-HYPR had the least amount of streaks show up at small window sizes.
4. It is recommended that O-HYPR and W-HYPR be implemented with sliding window algorithm, however, since the wrong size of the sliding window could result in worst reconstruction, the determination of the correct size for each different conditions can be difficult to predict. More research is required to study the affect of sliding window composite on accuracy of reconstruction as it can depend on the nature of the images being reconstructed.
5. The more parameters are available to adjust (we have now introduced a new parameter which is the sliding window size), the more combinations that are available to adjust and this can make it more difficult to determine the optimal set of parameters. However, the advantage comes from when we are able to determine the most optimal set of parameters for a given input, as this can result in a more accurate HYPE reconstruction as was demonstrated above.

Appendix

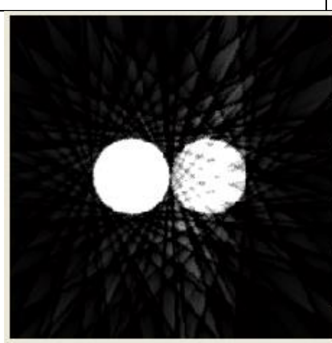
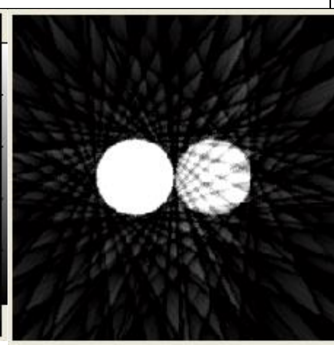
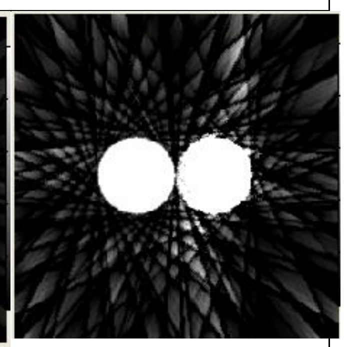
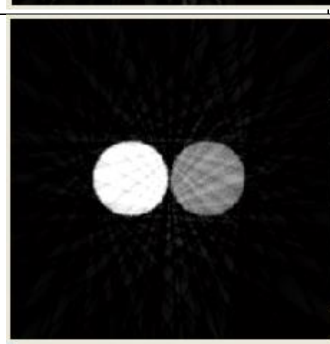
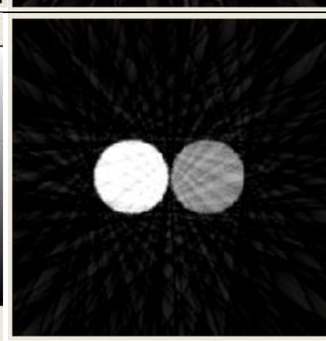
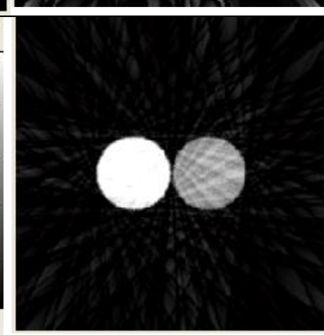
This appendix contains a detailed look at how the different window size affected the cross talk problem. We show the HYPR image reconstructed at the end of time frame 4 for sliding windows of size 3, 5,7,9,11,13, and 15. We do this for O-HYPR, W-HYPR and LR-HYPR. And compare each to the original image at the same time frame.

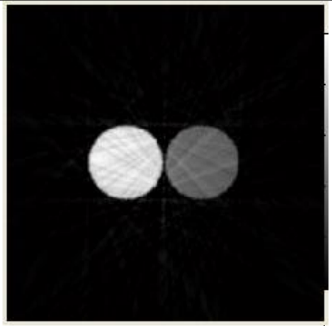
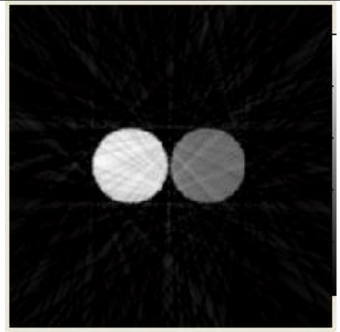
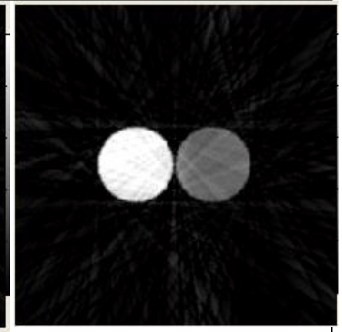
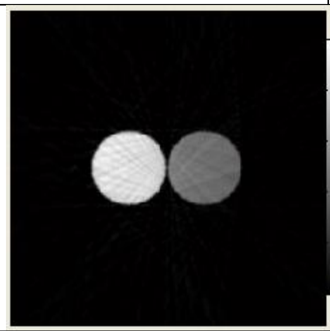
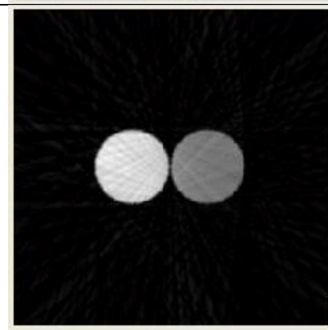
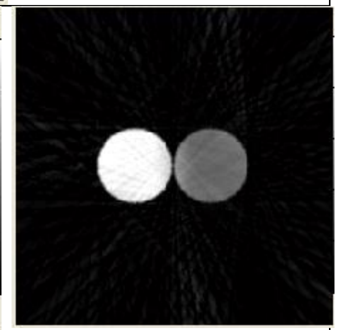
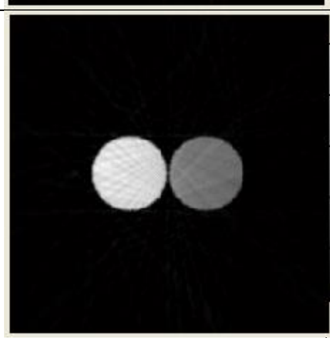
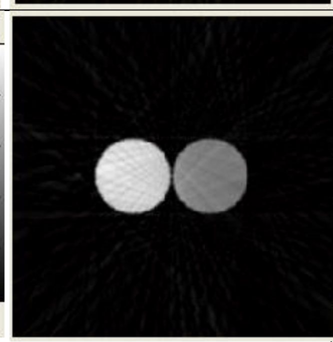
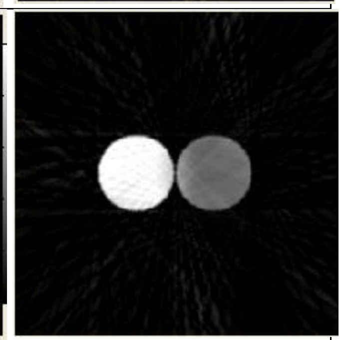
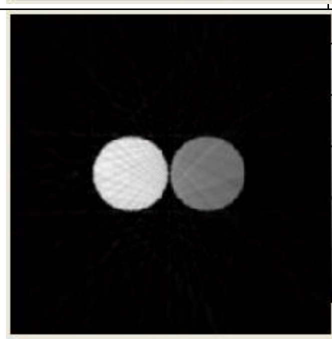
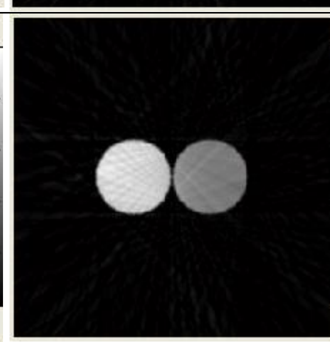
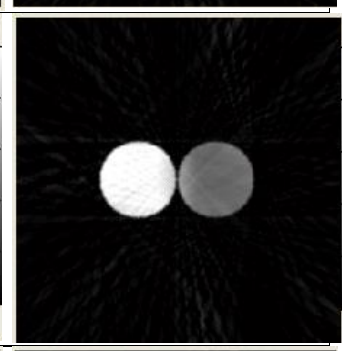
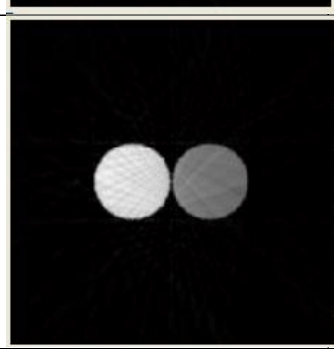
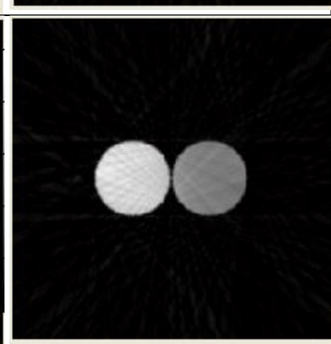
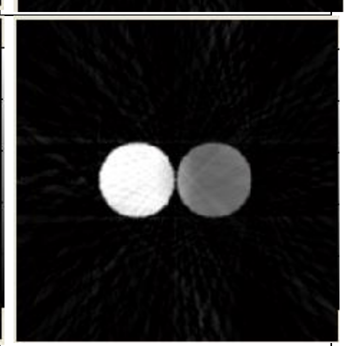
At the end of the time frame 4, the following is the actual image at input and how it looked like

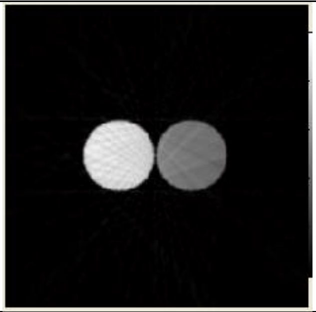
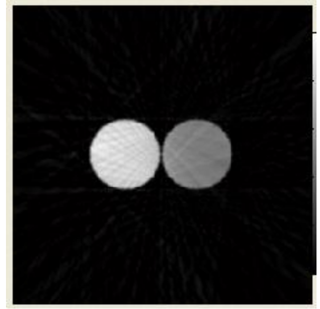
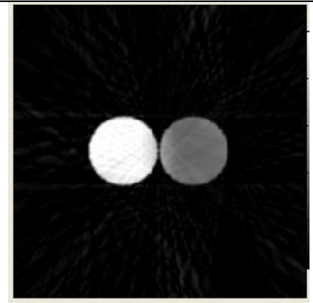


Cross talk test. 2 images close to each other with varying intensities.

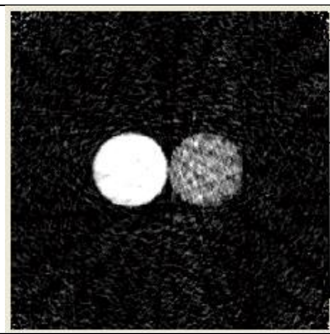
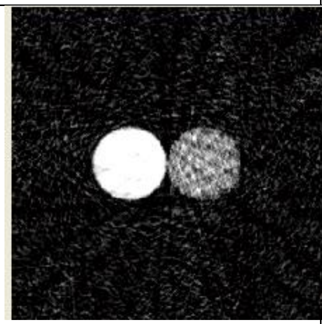
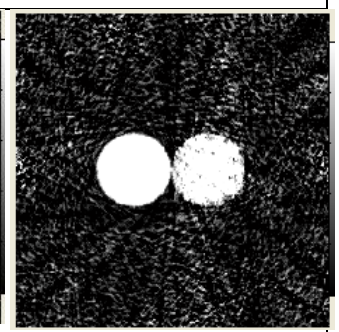
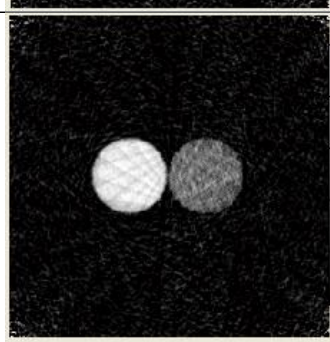
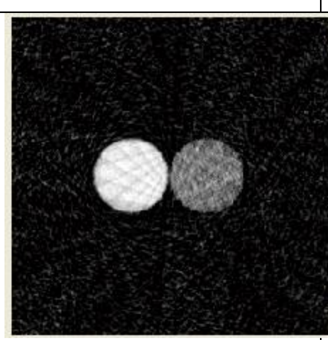
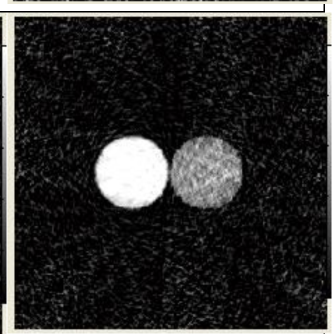
NO NOISE. Showing cross talk at time frame 4 as window size changes

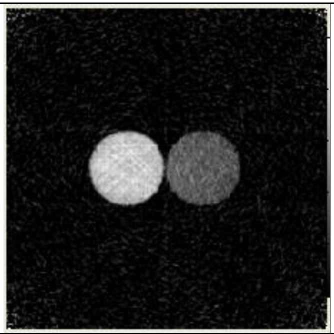
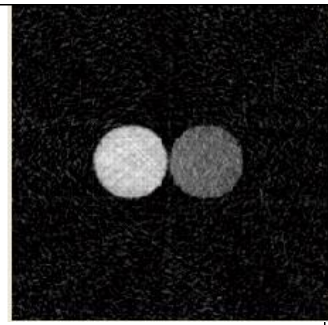
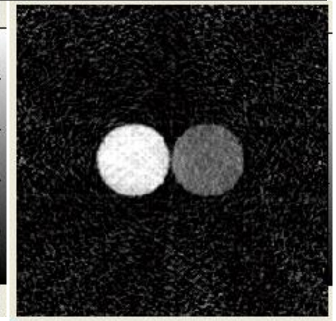
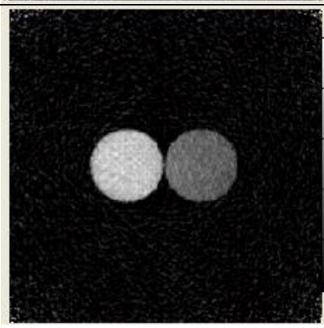
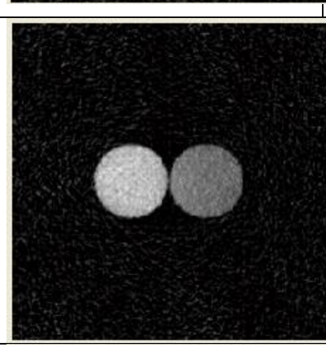
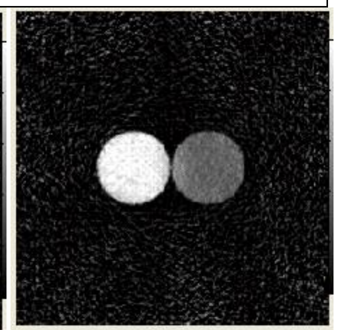
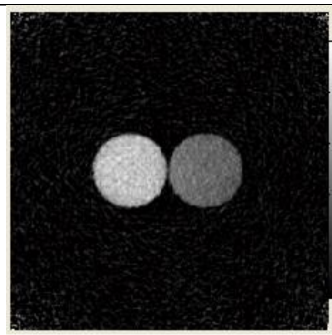
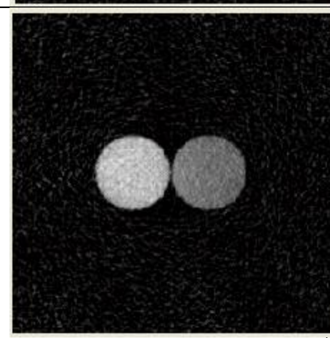
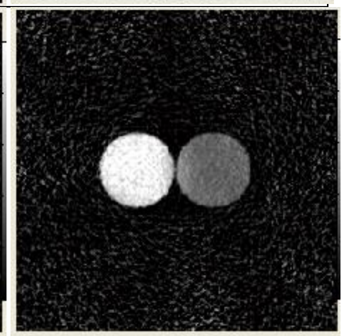
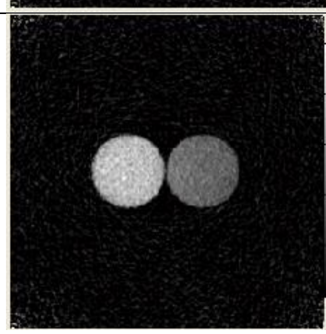
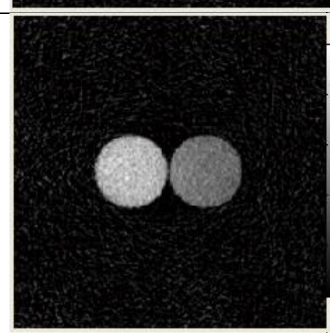
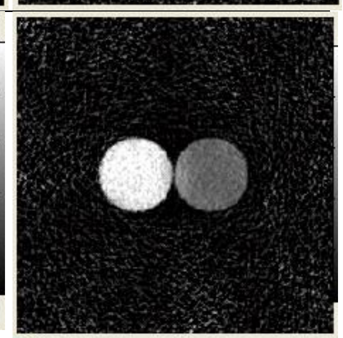
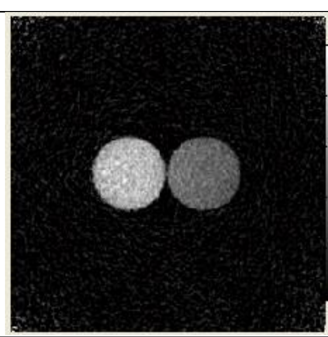
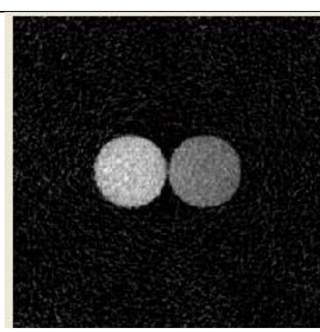
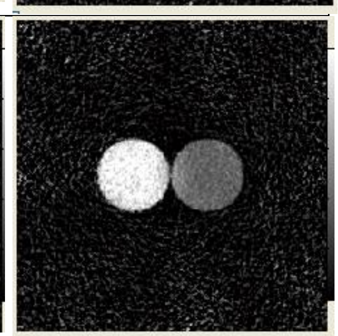
Window size	O-HYPR	W-HYPR	LR-HYPR
3			
5			

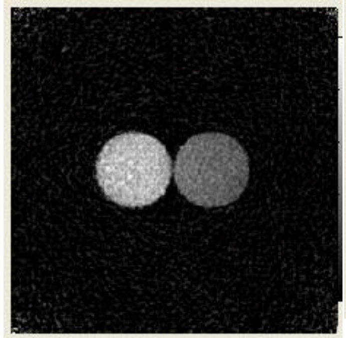
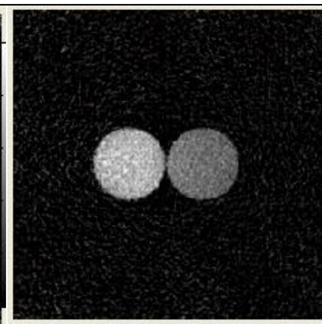
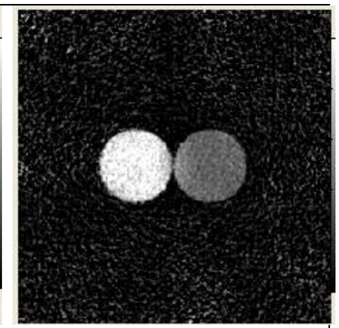
7			
9			
11			
13			
15			

NONE			

NOISE ADDED. Showing cross talk at time frame 4 as the window size was changed. Noise is Gaussian with zero mean and 5% S.D. of maximum projection signal.

Window size	O-HYPR	W-HYPR	LR-HYPR
3			
5			

7			
9			
11			
13			
15			

NONE			

References

(1)Improved Waveform Fidelity Using Local HYPR Reconstruction (HYPR LR) Kevin M. Johnson, Julia Velikina,Yijing Wu, Steve Kecskemeti,, Oliver Wieben, and Charles A. Mistretta

(2) Highly Constrained Back projection for Time-Resolved MRI by C. A. Mistretta, O. Wieben, J. Velikina, W. Block, J. Perry, Y. Wu, K. Johnson, and Y. Wu

(3) Time-Resolved MR Angiography With Limited Projections by Yuexi Huang1,and Graham A. Wright

(4) Iterative projection reconstruction of time-resolved images using HYPR by O'Halloran et.all

(5) Various reports on HYPR from the Mathematics 597 project at CSUF Fullerton, summer 2008 http://12000.org/my_courses/FULLERTON_COURSES/summer_2008/project/