Computational MR imaging **Name:** *Navaneeth N*
Laboratory 3: Partial Fourier imaging
22/11/2022

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1. **Comparing zero-filled & Hermitian reconstructions of dataset with PF=9/16:**

    1.1 The plots of the given PF k-space data for the two Fourier reconstructions are presented below. The zero-filled reconstruction presents ringing artifacts. The Hermitian symmetry reconstruction in comparison also has ringing artifacts but appears to be a little smeared/blurry. This is cause we assume that the replicated k-space is truly real-valued which results in the phase not being accounted for.

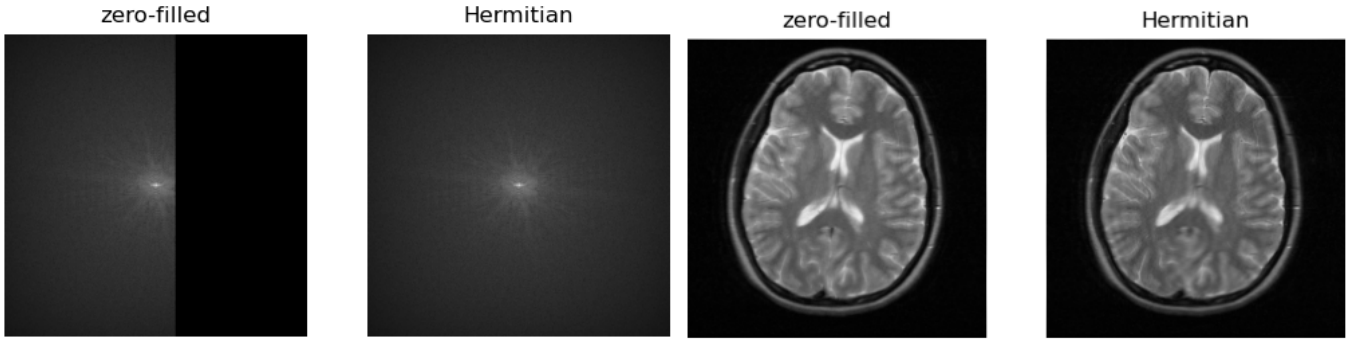

Figure 1: k-space & respective reconstruction images.

2. **Phase estimation using a symmetric region at the center of k-space:**

    2.1 The symmetric k-space, Hamming window and the estimated phase image are presented below:

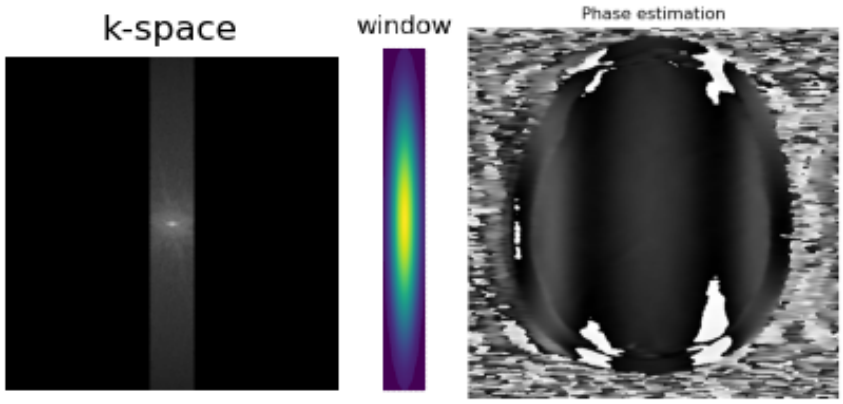

Figure 2: Phase estimation.

2.2 This phase estimation is acquired by taking a small set of symmetric central k-space lines (low resolution image) and multiply a Hamming window over it.

3. **Implement functions to perform partial Fourier MRI reconstruction using the Margosian approach: (results presented in 5)**

4. **Implement functions to perform POCS reconstruction: (results presented in 6,7)**

5. **Margosian reconstruction using ramp and Hamming filters on PF k-space data:**

5.1 The results presented below compare partial Fourier reconstructions using the Margosian approach with Ramp & Hamming filter against reconstructing a complete k-space(data from Lab 2).

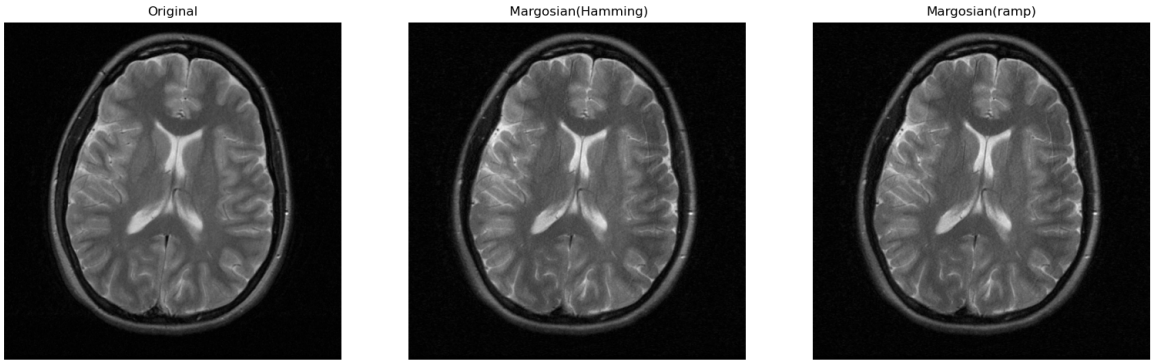

Figure 3: Full k-space and Margosian(Hamming, Ramp) reconstruction results.

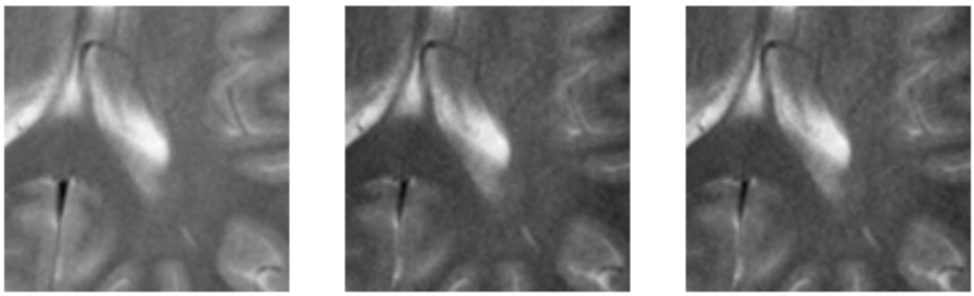
Figure 4: Zoomed in ROI of Full k-space, Margosian(Hamming) and Margosian(Ramp).

5.2 Reconstruction using Margosian method with both filters show fairly good results with respect to the original image in Figure 3. None of the images show excessive noise or ringing artifacts.

5.3 One difference that is noticed on zooming into any ROI (CSF-tissue), there seems to be a slight difference in the brightness. The Margosian images appear slightly darker and lower in spatial resolution when compared to the original image.

6. **Evaluating POCS reconstruction for PF k-space:**

6.1 The reconstruction results for POCS after 2, 4, 6, 8 & 10 iterations and respective zoomed ROIs are shown in Figures 5 & 6 respectively:

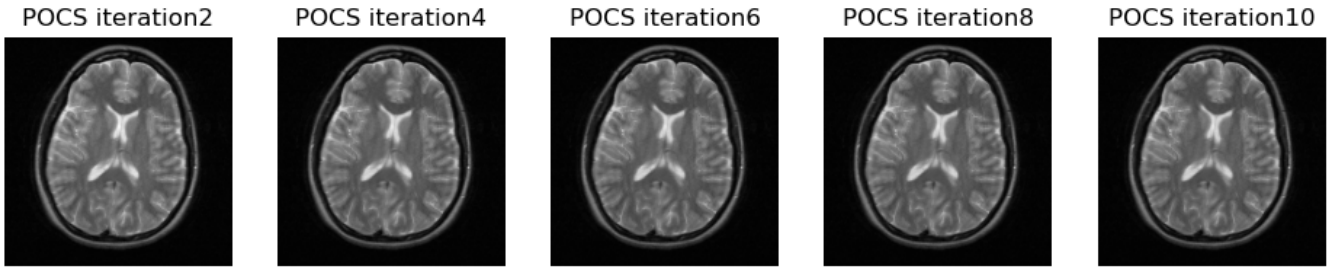

Figure 5: POCS iteration results.

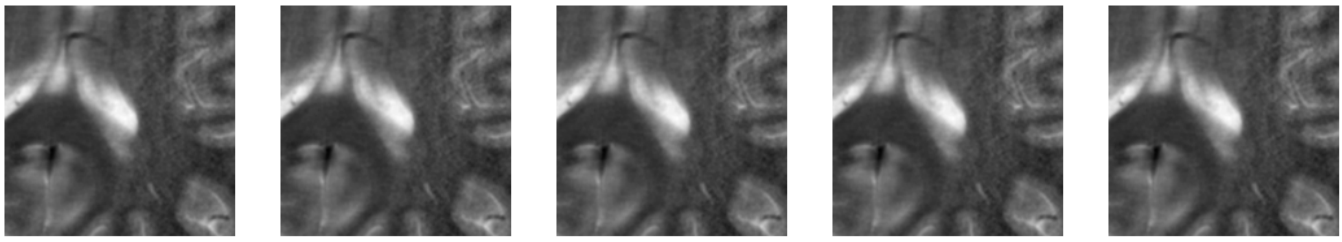

Figure 6: Zoomed into ROI.

6.2 The results presented above have very minor difference in reconstruction after every iterations. These are visually indistinguishable. Hence, the absolute difference measured for consecutive iterations presented in Figure 7 is evaluated to prove the algorithm's convergence:

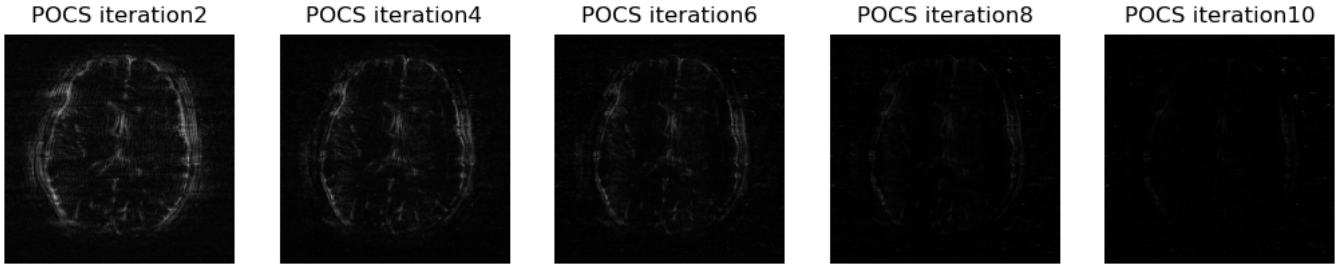

Figure 7: Difference images.

6.3 On analysing the difference images, it is clear that POCS converges after 8 iterations. It is also evident that the missing k-space samples filled after each iteration accounts not only for magnitude but also the phase obtained by the phase estimation step.

6.4 Additional evaluation metrics like Root Mean Squared Error (RMSE), Structural Similarity Index Measure (SSIM), SNR & PSNR was also measured for fully acquired k-space and every 2nd POCS iteration result. However, these metrics do not show any sharp variations that would indicate convergence.

Metric	POCS 2	POCS 4	POCS 6	POCS 8	POCS 10
RMSE	22.414	22.431	22.452	22.451	22.452
SSIM	0.946	0.945	0.944	0.944	0.944
SNR	15.07	14.97	14.94	14.94	14.93
PSNR	33.084	32.982	32.974	32.975	32.975

Table 1: RMSE, SSIM, SNR & PSNR for POCS results

7. **Evaluating overall reconstruction performance:**

7.1 The reconstruction results of all the methods used in this experiment are summarized in Figures 8 & 9 :

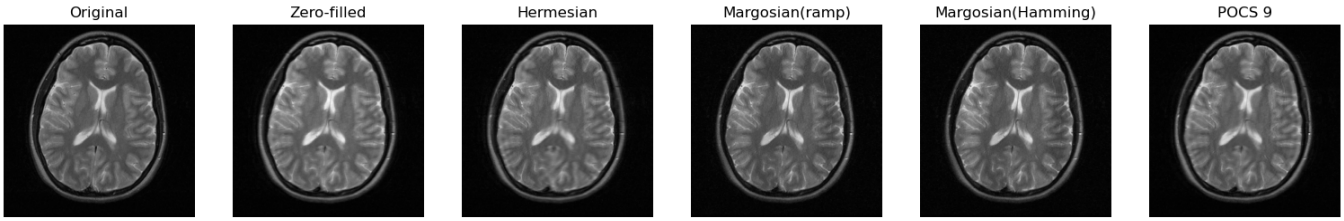

Figure 8: Summarizing reconstruction results.

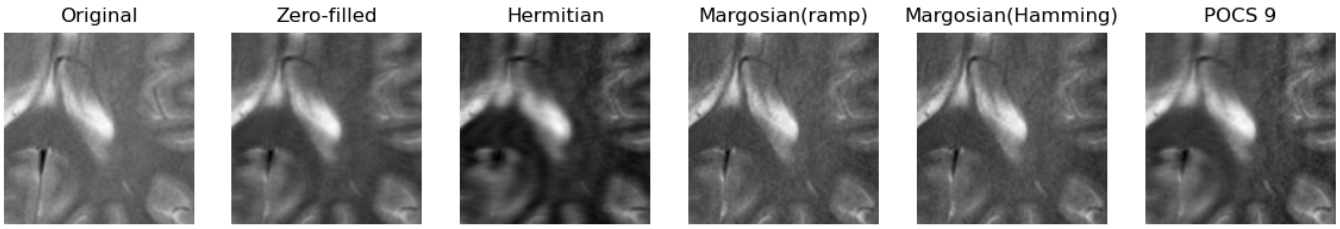

Figure 9: zoomed into ROI.

7.2 **Inference**:

(a) Observing Figure 8 closely, we see that the zero-filled and Hermitian results have Gibbs rings artifacts. Furthermore, they appear to have minor phase distortions when seen closely with the original reconstruction.

(b)The Margosian and POCS reconstructions in comparison appear to be closer to the original image. Gibbs ringing is present but is not as strong in contrast to the Zero-filled image.

(c) On analysing Figure 9, POCS 9 differs slightly in brightness but offers the closest reconstruct result to the original image visually while the Hermitian appears to be the worst.

7.3 In order to take a closer look at structural differences and underlying artifacts, the difference images of zero-filled, Hermitian, Margosian(ramp), Margosian(Hamming) and POCS results in the same order with original image were evaluated. These comparisons are summarized below:

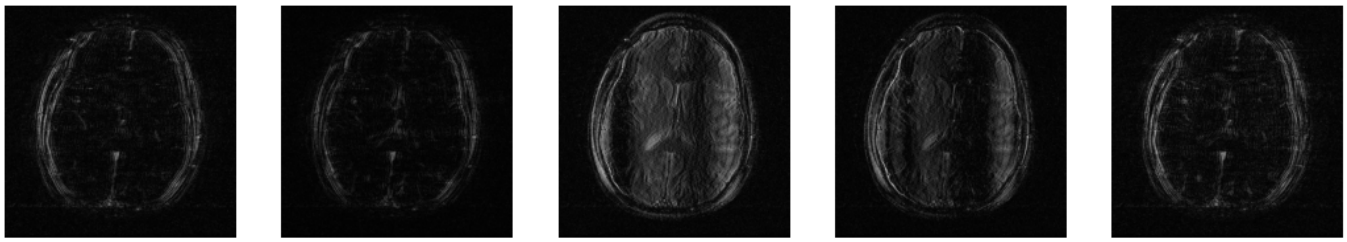

Figure 10: Difference images with respect to Original reconstruction.

7.4 Additionally, the RMSE, SSMI, SNR & PSNR were also measured between fully acquired k-space and the above reconstruction methods. These metrics are presented in the table below:

Metric	**Original**	**Zero-filled**	**Hermitian**	**Margosian (ramp)**	**Margosian (Hamm)**	**POCS 9**
RMSE	0.0	20.478	26.725	30.205	28.772	22.452
SSIM	1.0	0.950	0.928	0.937	0.933	0.949
SNR	13.91	15.668	12.977	10.31	10.70	15.02
PSNR	0.0	33.774	31.461	29.57	29.147	32.978

Table 2: RMSE, SSIM, SNR & PSNR summarized for all results.

7.5 **Inference**:

(a) The RMSE measures of zero-filled & POCS 9 are lower compared to the other methods while the SSIM values for the same are the highest. This suggests that these two methods offer the best performance in terms of achieving a reconstruction closest to that of a complete k-space.

(b)The zero-filled & POCS 9 also score the highest and measure similarly in SNR and PSNR. This indicates that the image reconstruction quality of these approaches is better than other reconstruction results.

(c) To summarize, POCS 9 & zero-padding offer better reconstruction results while the Margosian offers poor recontruction performance in terms of the discussed evaluation metrics. These metrics can also be correlated to the difference images evaluated in Figure 10 in terms of reconstruction performance.