Assignment #6

Due date: June 12 (Mon.)

Submission

E-mail a zip file including the source codes, a report and test images to TA. **You must submit function m-files per problems like Appendix at the end of this document. If you don't follow the code structure in Appendix, the score will be deducted.** The filename should be named as student idn_name.zip (e.g. 20173000_kdhong.zip).
TA's e-mail address is **wschoi@issserver.kaist.ac.kr**

Due date: **06/12 23:59**. (Refer to the delay policy in the web site)

Test images in the web site:
shepp_proj_256x180.raw
bridge_gray_256x256.raw,   cameraman_gray_256x256.raw

Notice

All the programming assignments are based on MATLAB. (Do not use any function in MATLAB. But **you can use basic functions available in C++ standard library** like round, ceil, floor, rand, bitshift, sqrt, sum, exponential, log, trigonometric and abs etc. functions **and vectorization**.) All source codes for submission should include comments.
Describe your work and analyze the corresponding results in the report. A proper length of the report is 10 pages of A4 size with figures. Report exceeding the recommended length will get a penalty. The report should include the followings.

1. Simple theoretical backgrounds & programming strategies
2. Result images
3. Analysis of the results

If a **copy version** is found, the score will be **zero** point without any exception.

Scoring policy: implementation (60), processing time (10), and report (30)

The criteria of the scoring deduction applied to common problems:

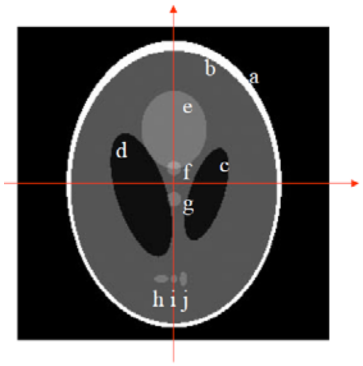
1. Using MATLAB functions
   - Related to 'Language Fundamental' except to basic functions available in C++ standard library: -2 points per problem.
     'Language Fundamental':
     https://kr.mathworks.com/help/matlab/language-fundamentals.html?lang=en
   - the other MATLAB functions: -50% per problem.
2. Inexecutable code: -50% per problem.

1. Parallel beam image reconstruction algorithm

A sinogram is given for the 2D Shepp phantom in shepp_proj_256x180.raw (32bit). The corresponding specifications are as follows.

Range: (-1.0, 1.0), number of samples: 256, number of views: 180

Data type: float (4 byte for each sample)



Ellipse	Center	Major	Minor	θ	Gray
a	0,0	.69	.92	0	2
b	0,-.0184	.6624	.874	0	-.98
c	.22,0	.11	.31	-18°	-.02
d	-.22,0	.16	.41	18°	-.02
e	0,.35	.21	.25	0	.01
f	0,.1	.046	.046	0	.01
g	0,-.1	.046	.046	0	.01
h	-.08,-.605	.046	.023	0	.01
i	0,-.605	.023	.023	0	.01
j	.06,-.605	.023	.046	0	.01

2D Shepp phantom* (level: 1.02, window: 0.04)

(1) Perform the back projection.
(2) Perform the filtered back projection using the Ram-Lak and Shepp-Logan filters.
(3) Compare the results from two different filters in (2), by showing cut views of obtained images. Also, compare the results from (1) and (2).

Ram-Lak filter

$$h_{\mathrm{RL}}(0) = B^2 = \frac{1}{4\Delta x^2} \qquad \text{(if } k = 0\text{)}$$

$$h_{\mathrm{RL}}(k) = 0 \quad \text{(if } k \text{ even)} \qquad h_{\mathrm{RL}}(k) = \frac{-4B^2}{\pi^2 k^2} = \frac{-1}{\pi^2 k^2 \Delta x^2} \quad \text{(if } k \text{ odd)}$$

Shepp-Logan filter

$$h_{\mathrm{SL}}(k) = \frac{-2}{\pi^2 \Delta x^2 (4k^2 - 1)} = \frac{-8B^2}{\pi^2 (4k^2 - 1)}$$

2. Bit-plane coding

(1) For the given bridge image, apply the bit-plane coding to Gray coded bit planes, by using the white block skipping (WBS) with N = 2, 4, and 8. Recover the original image from the coded data.
(2) Compare the compression ratio for N = 2, 4, and 8, and discuss the results.

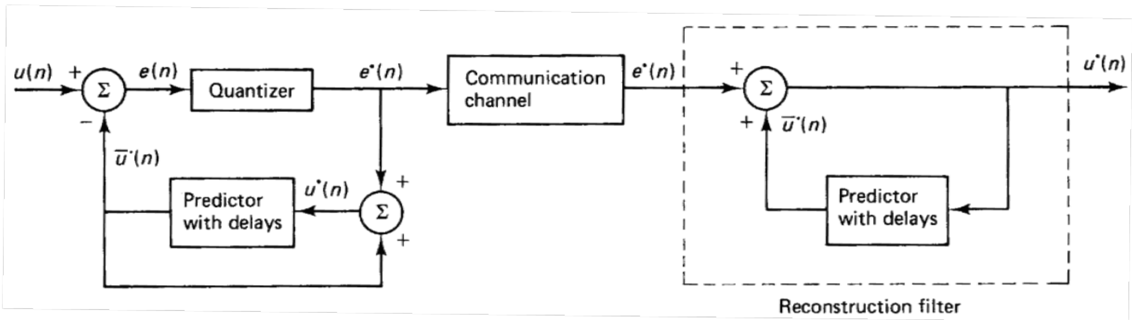
3. Differential Pulse Code modulation (DPCM)

(1) For the given cameraman image, perform the DPCM with quantization parameters of 4, 8, and 16, respectively.

(2) Show the PSNRs of the reconstructed images for each quantization parameter, and analyze those images.
Output the PSNR value by using `'psnr_Q4'`, `'psnr_Q8'` and `'psnr_Q16'` in case of quantization parameter 4, 8, and 16.

(3) Calculate the mean square values of coding errors of $u(n)$ and $e(n)$, respectively, for each result.
Output the mean square values coding errors of $u(n)$ value by using
`'MSE_u_Q4'`, `'MSE_u_Q8'` and `' MSE_u_Q16'`
in case of quantization parameter 4, 8, and 16.
Also, Output the mean square values coding errors of $e(n)$ value by using
`'MSE_e_Q4'`, `'MSE_e_Q8'` and `'MSE_e_Q16'`
in case of quantization parameter 4, 8, and 16.

(4) Explain why DPCM quantizes the prediction error $e(n)$ rather than $u(n)$.



Differential Pulse Code Modulation (Feedback prediction)

Hint)

Quantization: (error coefficients)/(quantization parameter)

Predictor : $\bar{u}^{\bullet}(m,n) = 0.95 \cdot u^{\bullet}(m-1,n) + 0.95 \cdot u^{\bullet}(m,n-1) - 0.95 \cdot 0.95 \cdot u^{\bullet}(m-1,n-1)$

Results

1.

(1) Back projection image

(2) - Backprojection image with Ram-Lak filter applied

- Backprojcection image with Shepp-Logan filter applied

(3) - Cutview of back projection image

- Cutview of back projection image with Ram-Lak filter applied

- Cutview of back projection image with Shepp-Logan filter applied

2.

(1) Gray coded images for each bit plane.

Recovered images (N = 2, 4, 8)

(2) Compression ratio table according to N in each bit plane (in report, not in result images)

3.

(1) Reconstruction images (Quantization parameters of 4, 8, 16)