Middle East Technical University
Department of Electrical and Electronics Engineering

EE 519 Medical Imaging
2021-2022 Spring Semester

Term project I:

Attenuation of x-rays as they propagate through biological tissues inside the body, and dependence of the attenuation rate on tissue characteristics can be used to reconstruct medical images. In this term project, some of the mathematical tools, which are widely used for many other imaging modalities with non-diffracting sources, will be implemented for **Fan-Beam** x-ray **Tomographic Imaging with curvilinear (equal angularly spaced) array of detectors**.

Line Integrals and Projections

A line integral is the integral of a physical parameter of the object along a line. For the case of x-ray tomography, the line integral is the total attenuation of an x-ray beam when the ray passes through the object along a straight line. A projection function can be formed, by combining a set of line integrals corresponding to multiple x-ray beams. In fan-beam projection, the object is illuminated by x-ray beams fan out from a point source and line integrals for equal angularly spaced beam paths are combined to form a projection. Calculation of projections for known attenuation coefficient distribution and incident beam intensity is defined as ***forward problem*** of x-ray imaging. Calculated projections are then used to reconstruct images by using **convolution backprojection** algorithm. You are expected to explore different filter types and compare their relative performances.

Term Project Evaluation

- Every student is expected to prepare the project individually.
- MATLAB, Python, C++, C, …, can be used for programming. MATLAB is highly recommended for its built-in functions (e.g. FFT, convolution, and graphical tools). Program should include a graphical user interface (GUI).
- For projection and backprojection stages of the project, the developed program code is to be tested with the sample images provided via METU Class as input attenuation coefficient distributions.
- The students are required to make a demonstration to the instructor and submit a complete final report in an IEEE manuscript (paper) format.

Requirements

The algorithm which calculates projections (i.e. line integrals) for an object with known attenuation coefficients is to be implemented for a fan-beam source and curvilinear (equal angularly spaced) array of detectors.

Input distribution will be specified by the user (while the program is running) through the GUI of the program:

- Definition of the input distribution (filename, size etc.),
- Projection angle step size (in degrees/radians) or number of projections,
- Number of sampling points in each projection (number of detectors) are specified by the user via the GUI.

- Outputs of the projection calculation:
- The output (vectors containing the projections) should be presented in a graphical format, selectively.
- Projections from all view angles should be displayed in the form of a sonogram.

Input to the backprojection stage:

- Calculated projections from the projection step.

The projection data should be available in MATLAB .mat file format. The .mat file contains a matrix where each row corresponds to a single projection. The number of rows gives the number of projections, thus the angle step size. The number of columns or the length of each row is the number of sampling points in each projection. Size of the reconstructed image should be also specified.
The reconstruction stage should include filtering.

Note: The inverse problem can be tested using the output of the forward problem, but correct result can be obtained if you repeat the same error in forward and inverse problem. This situation is named as inverse crime*. Algorithms could be tested by inputs generated using different approaches (e.g. analytical solution) in order to avoid such problems.*

Other requirements
Minimum image size = 50x50 pixels
Minimum distance between the source and the centre of the detector array = 71 pixels
Number of detectors = VARIABLE (min=10, Total number of beams should be equal angularly spaced to cover the entire image space).
Length of the detector array = VARIABLE
Number of projections = VARIABLE

PROJECT REPORT:
Your report should contain at least the following illustrations:

- Projections at 0, 45 and 90 degrees when 0 degree is located at 3 o'clock,
- Images of each phantom (provided at METU Class) reconstructed with and without filter for 180 fans and 71 detectors (beams).

Project report must be written on a scientific article format and should at least contain the parts:

- Abstract (brief summary of your work)
- Introduction (a short history about x-ray imaging, purpose and summary of report)
- Theory (mathematical background)
- Results (sample outputs for forward and inverse problems; use quantitative evaluation measures)
- Discussion and conclusion (discussion on the presented results)
- List of References (Use IEEE Transactions Bibliography Style)

This outline can be extended or subsections can be added. The logical flow of the content and use of language will also be considered during grading.

Developed algorithms will be tested using sample inputs. Note that usability of the program and quality of outputting features will be considered in determination of the demonstration grade.

You are not allowed to use MATLAB's built-in functions such as "radon," "iradon," and "imrotate" other than for comparison with your own code. You must write the main functions of the project yourself.

Make sure that your code and report are your own work, otherwise **disciplinary action will be taken** and **zero grade will be given** to your project.

Project reports should be submitted to the instructor at the latest on the due date.
The program files will also be submitted in electronic format. Do not forget to submit all necessary files required while running the program (i.e. library files for C and C++, unit files for PASCAL or m-files for MATLAB which are not common).

The MSWord document file of the report and the software must be zipped into a single file and attached to an e-mailed to: meyub@metu.edu.tr
A pdf of the report must also be submitted via METU Class.

The following honor pledge should be added to the title page of the project report and signed by the student:

Honor pledge: I declare that each step of this term project is my own work and all information in this report has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Student's name: ……..Signature:……

Due date: 23:59 on April 24th, 2022