Final Project: EEE 473/573 - Medical Imaging

No grade periods for project-related deadlines!

Group List Due: 21 November 2020, Saturday at 23:59
One-Paragraph Proposal Due: 20 December 2020, Sunday at 23:59
Project Due: 10 January 2021, Sunday (Last Day of Finals) at 23:59

Motivation: In lectures, we simplified our imaging equations so that we can analytically model the imaging systems. This allowed us to express the resulting images mathematically in closed form. While the simplifications enabled us to understand the main working mechanisms of the imaging systems and provide us an intuitive picture about the shortcomings of each technique, one needs to consider more complex cases in real life. In this project, you will simulate a more realistic version of an imaging system that we covered in class. Alternatively, you will introduce a new imaging system not covered in class and simulate its basic working mechanisms.

Groups: You are expected to form groups of 2 or 3 students. Groups can include both graduate and undergraduate students. Individual projects will not be accepted, unless you are a graduate student. Students without groups will be grouped together after the group list deadline.

Quick Instructions:

1. Submit a list of your group members by the abovementioned deadline.
2. **Only one student should submit project related information/documents on behalf of the entire group.**
3. Submit **a single-paragraph proposal** for your project by the above-mentioned deadline. List group members, briefly explain the project topic, and list the data sets you plan to use (the latter can be changed during the final report).
4. By the project deadline, prepare a report in the format of **a single PDF file** to be uploaded on Moodle. The report should contain a link (e.g., a YouTube or Dropbox link) to a video presentation. The report should be **at most 10 pages long** (not counting the Appendix), and the video should be **at most 10 minutes long** (see the following pages for details).
5. **No late submissions are allowed. If any part of your report or presentation is missing, your submission will be ignored.**

General Instructions

Topics: The project that you choose must fall along the topics covered in EEE 473/573. The scope of the project should be something beyond what you have done in homeworks. A good choice is simulation of a system non-ideality that demonstrates the implications of the simplifying assumptions we made in class.

Rules: Regardless of your chosen project topic, the rules listed below must be strictly followed:

a) Simulating a simple imaging equation covered in class is NOT allowed.

b) You have to write your own code for your project. You may use external software packages/codes for parts of your implementation, with appropriate referencing to where you found the codes. However, then the remaining parts of your project will be expected to be more sophisticated and challenging to implement in-house.

c) Any act of plagiarism is prohibited during the implementation of the project and the presentation of the project report.

Grading: The distribution of grading will be as follows:

1. Proposal: 0% (Submitted only to get quick feedback on the project topic)
2. Report: 50% (Will be graded by the instructor)
3. Presentation: 50% (Will be graded by the instructor and the TAs)

For both the report and the presentation, assessment will be based based on the following:

- Comprehensiveness: Your simulations should be as comprehensive as possible (i.e., should take into account non-idealities of the system, such as potential sources of blur or noise).
- Presentation: Your report should clearly explain the work done and discuss the results in detail, which sufficient references. Your video presentation should clearly explain the project and show demo simulations.
- Difficulty: Some of the potential topics are inherently more difficult to address than others (some are ongoing research topics in medical imaging). Hence, the overall grading will take into account the difficulty level of the project.
- Demo and codes: The demo should be sufficiently explained, and the codes should show clean coding practices. Readable codes with comments will be rewarded.

Details About the Report

Your report should contain **at most 10 pages** (not counting the Appendix), typeset in **10 pts font or larger**, in PDF format. The report should contain the following sections: Title, Group Members, Abstract, Introduction, Methods, Results, Discussion, References, Appendix.

Title: A title that reflects the content of the project.

Group Members: List of group member names and student IDs.

Video Link: The link to your video presentation (e.g., a YouTube or Dropbox link). The video should be **at most 10 minutes long**, should describe your project and the main results, and contain **a demo of your simulations**. The presentation should summarize what is described in the report and should present all major aspects of the project. **All group members should contribute to the presentation** (i.e., you should take turns presenting). Power Point presentations with screen recording are preferred.

Abstract: A one-paragraph summary of all major aspects of your report from Introduction to Discussion. No references should be given, and the abstract should be self-contained.

Introduction: Briefly overviewing the imaging technique. State the purpose of your work, and how it improves on the results that we covered in class.

Methods: Explain the approach in your simulations. Explain which non-idealities you are incorporating into your simulations. Explain your data sets. Are they simulated data sets that you prepared? Are they models that you downloaded? Did you make any assumptions in your simulations? What imaging parameters/conditions did you assume? The methods section should be fully referenced, and should contain subheadings for explaining different methods/analyses.

Results: Present your key results and illustrate your outputs visually with the help of figures. You should demonstrate your simulations on two separate cases/data sets. Each figure should contain a paragraph-long caption that explains the contents of the figure. The text should further explain the results in detail, referencing the figures/tables in appropriate sections and explaining the main trends.

Discussion: Interpret your results. What did you see different than what we covered in class? Which parts of your simulation worked and which failed? What could you do to improve your results?

References: A list of all referenced material formatted according to standard conventions used in journals. Crude, unformatted lists are not acceptable.

Appendix: ALL codes written or used during the implementation of the project (including all stages of file handling, data processing, reconstruction, visualization) should be placed in this section.

List of Potential Projects

These are **only suggestions** to give you an idea about what kind of projects you can work on. Other topics related to medical imaging are welcome.

1. A more comprehensive X-ray simulator. In class, we have considered point sources with 3D objects (very simple objects such as cylinders), or extended sources with planar objects only. We ignored obliquities when they complicated our analysis. You can simulate extended sources with 3D objects (such as a model of a human chest), while taking obliquities and detector blur into account. Ensure that the parameters that you use (such as source size, detector size, attenuation coefficients, etc.) are realistic.

2. A cone beam CT simulator. We have only analyzed the parallel-ray CT systems in class. You can simulate a cone beam CT scanner. Present both the raw data from the scanner (i.e., projections) and the reconstructed images.

3. An MRI simulator. Simulate the k-space data and reconstruct the MRI image for given parameters (e.g., TE/TR) for a particular sequence (e.g., gradient echo sequence, spin echo sequence, etc.). To make it realistic, parameters such as chemical shift or B_0 inhomogeneity can be taken into account.

4. Effects of T_2 weighting during readout in MRI. In class, we assumed a short data acquisition window and ignored the effects of T_2 weighting during readout. What would be the effect of T_2 weighting if the readout window is not sufficiently short?

5. Non-ideal projections. Imagine a line that has a certain thickness, but that the thickness changes as a function of space. Projecting over this line would result in non-ideal projection images. What would the reconstructed images look like in that case? This is a relevant problem, for example, for Magnetic Particle Imaging (MPI).

Reference Websites

You can create your own data sets or download data sets from other sources. Here are a few websites that may be helpful for this.

1. Brain Web: A simulated brain database. While this database is primarily targeting MRI, you can utilize the brain models for other imaging techniques, as well.
   http://brainweb.bic.mni.mcgill.ca/

2. Simulated Phantoms for Human Torso:
   https://olv.duke.edu/xcat
   http://www.cmr.ethz.ch/research/download-software/mrxcat.html

3. The Zubal Phantoms: Voxel-based segmented models of human body.
   http://noodle.med.yale.edu/zubal/info.htm

4. Public Image Databases. A list of database websites is provided on this webpage:
   http://www.via.cornell.edu/databases/

5. About other computational human phantoms:
   https://en.wikipedia.org/wiki/Computational_human_phantom