EECS C145B / BioE C165: Image Processing and Reconstruction Tomography: Spring 2004

1 Course details

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Lectures:	12:30 pm - 2:00 pm
	Tuesday and Thursday
Location:	458 Evans Hall
Course control numbers:	07375 and 07378
Discussion section:	11:00 am - 12:00 pm Friday
Location:	293 Cory Hall
Course control numbers:	25518 and 25521
Scheduled office hours:	TBA
Extra office hours:	Always available by appointment.
Location:	462 Evans Hall
Course website:	http://muti.lbl.gov/145b

2 Course texts and recommended references

Required texts: Digital Image Processing, 2nd Edition
Gonzalez & Woods, Prentice Hall (2002).
Book website: www.imageprocessingbook.com

Course reader
Available from Copy Central on Hearst Ave
just west of Euclid.

Recommended additional reference texts:

Discrete-time Signal Processing 2nd Edition
Alan V. Oppenheim and Ronald W. Schafer
Prentice Hall (1998)

Signals and Systems
Simon Haykin and Barry Van Veen, John Wiley and Sons (2003)

Fundamentals of Digital Image Processing
Anil K. Jain, Prentice Hall (1989).

Digital Image Processing
Kenneth R. Castleman, Prentice Hall (1996).

Digital Image Restoration
H.C. Andrews and B.R. Hunt, Prentice-Hall (1977)

Two-dimensional Imaging
Ronald N. Bracewell, Prentice Hall (1995)

3 Prerequisites

This course has no official prerequisites. Knowledge of basic linear systems, convolution and basic Fourier analysis is desirable.

4 Grading policy

Your grade will be determined as follows:

- 20% Written homework problems
- 25% Matlab programming exercises
- 15% Midterm: Thursday March 18, in class
- 40% Final

Homework

Collaboration in groups of up to three people is encouraged. The individual responsible for writing up the completed assignment should alternate.

1. Please submit all homework as hardcopy.
2. Submit only one completed assignment per group.
3. List the names of all collaborators and reference texts used at the top of each completed assignment. The individual responsible for writing up the assignment should be identified. Acknowledge collaboration with other groups.
4. If you cannot print out a complex image, place it on a web page and give a reference to the picture in the hardcopy. Please do not e-mail large images or files to the instructor or TA.
5. Submit all source code used to solve a homework problem. Comment the code so that the logic behind your work is clear to the evaluator.
6. Label all graphs and axes. Use colorbars to show color scales where appropriate.
7. Organize material in a clear and logical way.

Assignments submitted late without prior arrangements or reasonable excuse will be penalized as follows:

1 day	5 %
2 days	10 %
additional days	20 % per day

5 Provisional lecture and discussion schedule (subject to change)

January 20

1. What is an image?
2. Digital images
3. Color images
4. Luminance and contrast
5. Examples of image formation and contrast mechanisms
6. What will be covered in this course?
7. Student background and interests questionnaire

January 22

1. Review of linear time/shift invariant systems
2. Review of discrete convolution in 1D
3. 1D convolution as a matrix operation
4. Convolution in 2D
5. 2D convolution as a matrix operation

January 23 Discussion

Convolution and Fourier analysis review.

January 27

1. The inverse problem of deconvolution (image restoration)
2. Motivation for studying the discrete Fourier transform in 2+D
3. Review of the 1D Fourier transform
4. The discrete Fourier transform (DFT)
5. Introduction to the 2D FT
6. The fast Fourier transform (self study)

January 29

Introduction to Matlab for image processing. Part I.

January 30 Discussion

Hands-on Matlab tutorial.

February 3

1. Definition of several important 2D functions
2. Important 2D Fourier transform pairs
3. Some 2D Fourier transform properties and theorems
4. Separability of the n-D Fourier transform
5. Sampling in 2D
6. Aliasing in 2D

February 5 and 10

1. The 2D discrete Fourier transform (DFT).
2. Properties of the 2D DFT.
3. Implementation of the 2D DFT.
4. Introduction to Matlab for image processing. Part II.

February 6 Discussion

1. Circular convolution.
2. The convolution theorem in discrete time and space.
3. Review of the 2D Fourier transform.

February 12 and 17

1. 2D low-pass filters in space domain (smoothing)
2. 2D high-pass filters in space domain (sharpening)
3. Use of derivatives for edge enhancement
4. High-boost filtering
5. Non-linear space domain filters
6. The image histogram

February 13 Discussion

Image filtering examples and practical implementation.

February 19, 24 and 26

1. Linear models
2. Solving overdetermined systems of equations using the least squares method
3. Review of the concepts of range and nullspace of a matrix.
4. The singular value decomposition (SVD)
5. Application of the SVD to deconvolution and image compression.

February 20 Discussion

Example least squares problem. Discussion of SVD implementation.

March 2 and 4

1. Basic concepts in tomography
2. Non-diffracting radiation
3. x-ray contrast and basic physics
4. x-ray projections
5. The Radon transform

6. The sinogram
7. Properties of the Radon transform
8. Review of polar coordinates
9. The Fourier slice theorem
10. The backprojection operator
11. Backprojection of filtered projections

March 5 Discussion

SVD noise removal and image compression example.

March 9

1. Step-by-step description of analytical reconstruction algorithms involving filtering and backprojecting
2. Sampling requirements for tomographic reconstruction
3. Projection as a matrix operation
4. Backprojection as a matrix operation
5. Reconstructing using the pseudoinverse
6. Relationship between pseudoinverse method and algorithms based on the filtering and backprojecting

March 11

1. Introduction to iterative methods
2. Introduction to the algebraic reconstruction technique (ART) (See tomographic reconstruction primer)
3. Modeling image statistics: The Gaussian distribution
4. The maximum likelihood (ML) principle
5. Relationship between Gaussian ML and least squares
6. Modeling image statistics: The Poisson process

7. Introduction to optimization
8. Solving ML problems using optimization algorithms

March 12 Discussion

1. Projecting and backprojecting using Matlab.
2. Reconstruction tomography in Matlab.
3. Radon transform and reconstruction example.
4. Reconstruction using the projection slice theorem.

March 16

Review of practice midterm.

March 18

Midterm.

March 19 Discussion

No discussion.

March 30

Field trip to Department of Nuclear Medicine and Functional Imaging, LBNL.

April 1 and 6

1. Introduction to single photon emission tomography (SPECT)
2. Examples of SPECT studies
3. Components of SPECT systems
    - Gantry
    - Collimators
    - Detectors
4. Scattering physics

5. Photon attenuation
6. Radiotracers
7. Image reconstruction
8. Frontiers in SPECT

April 2 Discussion

Midterm feedback. Review of papers on SPECT in the reader.

April 8

1. Fundamentals of PET
2. Basic detector design
3. Real world considerations
4. Performance evaluation
5. Tracer isotopes
6. Clinical uses
7. Motion compensation
8. Application to monitoring gene therapy for Parkinson's disease

April 9 Discussion

Review of papers on PET in reader.

April 13

1. Introduction to dynamic imaging.
2. Tracer kinetic models.

April 15 and 20

1. Introduction
2. Basic nuclear magnetic resonance (NMR) physics
3. Relaxation processes
4. Instrumentation for NMR and magnetic resonance imaging
5. Pulse sequences and contrast determination
6. Physics of contrast
7. Tissue contrast in MRI
8. MR Frontiers: using paramagnetic tracers to image gene expression

April 16 Discussion

1. NMR and MRI review and examples
2. Chemical shift imaging

April 22

1. Encoding position in MRI
2. Frequency encoding
3. Projection MRI
4. Phase encoding
5. Slice selection
6. The spin warp sequence
7. Mathematical basis of joint frequency and phase encoding (2D FT MRI)
8. MRI frontiers: high field human imaging
9. MRI frontiers: diffusion tensor imaging
10. Comparison of MRI, x-ray CT and ECT.

April 23 Discussion

Detailed discussion and review of phase encoding MRI. Simple worked example.

April 27 and 29

1. History of ultrasonic imaging
2. The A-mode scan
3. The piezoelectric transducer
4. The M-mode scan
5. The B-mode scan
6. Ultrasound systems
7. Multielement transducers
8. Imaging flow
9. Continuous wave Doppler
10. The sonogram
11. Pulsed wave systems
12. Ultrasound physics
13. Ultrasound computed tomography

April 30 Discussion

Artificial contrast in ultrasound imaging.

May 4

1. Optical imaging: bioluminescence, fluorescence and laser Doppler imaging
2. Infrared imaging

May 6

1. Student-motivated review of course material
2. Hand out practice final

May 11

Review practice final.

May 19

Final exam 5-8pm.