# Image Processing Introduction and Overview

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# Today's Lecture

- All the dull administrative stuff first
- Introduction to the type of things I would like to cover in the class
- Maybe we can start covering some of it.

# Staff

- Lecturer contact information
  - Prof. Eric Miller
  - Halligan Hall, 216
  - elmiller@ece.tufts.edu (preferred method of contact)
  - x7-0835

# When and where

- Lectures:
  - When: Th 3.00 - 4.15 PM
  - Where: 108 Halligan
- Prof. Miller’s Office hours:
  - When: T/Th 1.30-2.30 PM or by appointment or by popping head in Prof. Miller’s office
  - Where: Prof. Miller’s office
- Web page: TBD

# Requisites

- Being a first year student at Tufts!

# Books

- Required textbook:
  - *Introduction to Digital Image Processing* by Alasdair M$^{c}$Andrew, Thomson, 2004
  - Blends theory and implementation
  - Matlab-based
  - Theory not very mathematical (no calculus required)
- Other helpful books
  - *Digital Image Processing* 2nd Edition by Gonzalez and Woods. Prentice Hall. 2002.
  - Digital Image Processing 6th edition, by Bernd Janhe, Springer 2005.
  - Fundamentals of Digital Image Processing, by Anil K. Jain. Prentice Hall, 1988.
  - Digital Image Processing 2nd edition by Kenneth R. Castleman. Prentice Hall, 1995.
- Will draw on these from time to time.

# Grading

- Take home problems:
  - A couple per week
  - Mostly Matlab-based experiment
  - 35%
- Midterm
  - In class
  - 30%
- Final Project
  - Many topics we will not be able to cover
  - Opportunity to apply and/or extend knowledge to new areas.
  - Small group
  - Report and oral presentation
  - 35%

# Goals of the Class

- Image processing is a gigantic subject that can never be covered in a single semester
- Huge commercial and research base drawing on folks in a wide range of areas
  - Engineering (electrical, computer, biomedical)
  - Computer science (especially computer vision but also data bases)
  - Mathematics (applied)
- Each is concerned with different elements of DIP
- Each has their own way of approaching each facet of DIP. Everything from problem formulation and solutions to mathematical notation

# Goals of the class

- Exposure to fundamental problems and electrical engineering-type solutions
- Exposure to Matlab as a tools for solving computational problems
- Maybe a bit of programming practice/experience??

# What is Digital Image Processing

Basically, we are concerned with the study and the implementation of methods for the

- Formation (a.k.a acquisition)
- Enhancement (a.k.a. pre-processing)
- Analysis (segmentation, feature extraction, recognition, ….)
- Communication/Transmission

of digital “images” in two, three, and four (3 space + 1 time) dimensions

# (Some) places where image processing is needed

- Optical imaging (cameras, microscopes),
- Medical imaging (CT, MRI, ultrasound, diffuse optical, advanced microscopes)
- Astronomical Imaging (telescopes)
- Geophysical Imaging (seismics, electromagnetics)
- Radar and hyperspectral imaging (surveillance and remote sensing)
- Printing (color, dot matrix)
- Video and Imaging Compression and Transmission (JPEG, MPEG, HDTV,…)
- Computer vision (robots, license plate reader, tracking human motion)
- Computer graphics: rendering and shading, representation
- Commercial software (Photoshop)
- Hardware (FPGA, DSP, cell processor implementation of compute intensive algorithms)
- Security and Digital Rights Management (watermarking, biometrics)

# (Some) things people need to do

## All of this in 2D and 3D plus (often) time

- Form imagery from indirect data
  - CAT, MRI, synthetic aperture radar, seismics, …
- Clean up noisy and blurred images
  - Removal of blur due to imperfect lenses or noise due to imperfect imaging sensors
  - Balance gray scale due to illumination issues
- Display images on paper or screen
- Find “things”
  - Edges, American flags in an image database, tanks vs. schoolbus, tumors, oil pockets, buried landmines, “eyes” for redeye removal, white matter and gray matter in an MRI
- Compress images for transmission
  - Inherent, PDAs, Cell phones, HDVT, …
- Detect and track motion
  - People walking, cells moving and growing
- Implement all of these things efficiently
  - Provably efficient algorithms
  - Hardware options (parallel processing, FPGA, DSP, ASIC, …)

# (Some) tools they use

- Represent images in various "domains"
  - Space: intensity at every pixel
  - Fourier: waves of varying frequencies
  - Wavelet: Half way between space and Fourier. Pixels of varying size
- Filtering:
  - Convolution in 2D and 3D (space and frequency)
  - Morphology: a form of nonlinear convolution using "and," "or," & "not" or rank order stats (min, max, median)
- Physics-based sensor models
  - Cameras and other sensors (MRI and CT)
- Statistics and probability
  - Noise in images or models for images
  - "Optimal" deblurring or denoising or tracking filters
  - Information theory needed for compression and transmission
- Linear algebra and optimization
  - We will not really touch these.

# Image Formation

## Camera

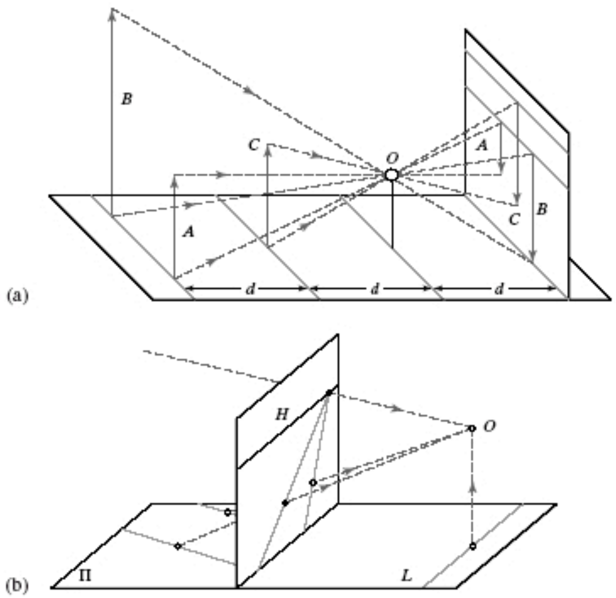
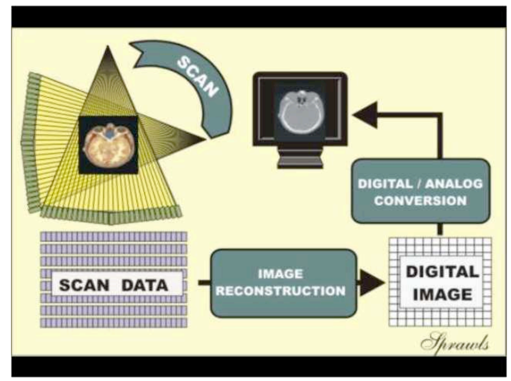



**Figure 1.3** Perspective effects: (a) far objects appear smaller than close ones: the distance *d* from the pinhole *O* to the plane containing *C* is half the distance from *O* to the plane containing *A* and *B*; (b) the images of parallel lines intersect at the horizon (after Hilbert and Cohn-Vossen, 1952, Figure 127). Note that the image plane is *behind* the pinhole in (a) (physical retina), and *in front* of it in (b) (virtual image plane). Most of the diagrams in this chapter and the rest of this book feature the physical image plane, but a virtual one is also used when appropriate, as in (b).

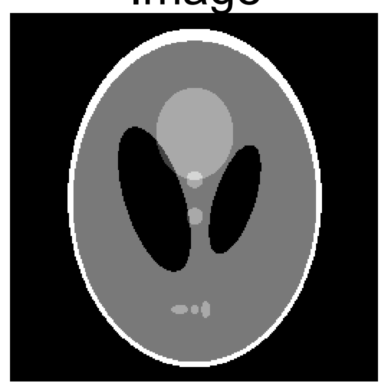
www.cs.berkeley.edu/~daf/bookpages/pdf/chap01-final.pdf

## Computed Tomography

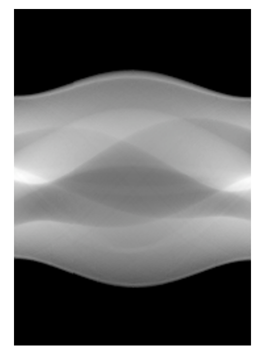



http://www.sprawls.org/resources/CTIMG/classroom.htm

Image



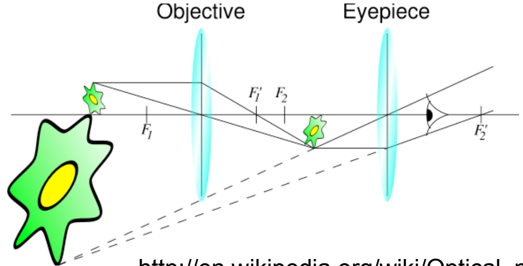
Scan Data



http://rsb.info.nih.gov/ij/plugins/radon-transform.html

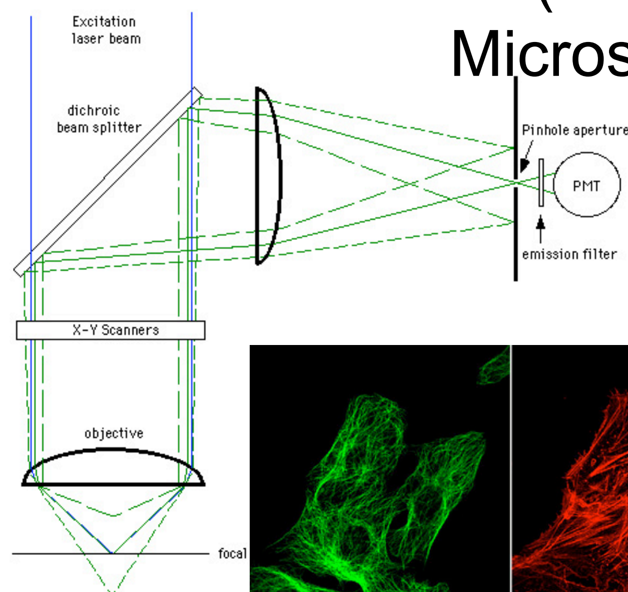
# Image Formation

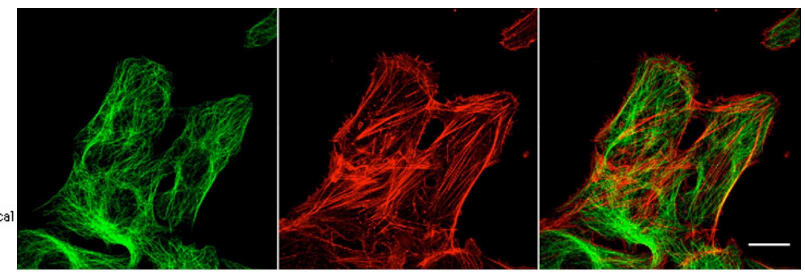
## Optical Microscopy




http://en.wikipedia.org/wiki/Optical_microscope

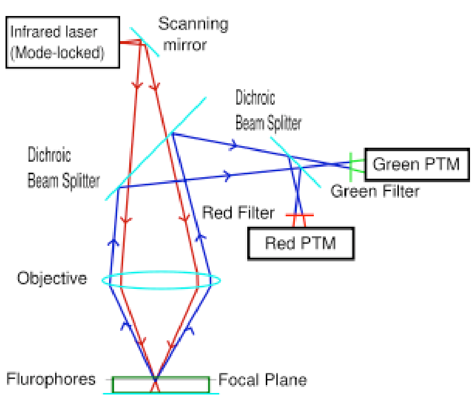
## Confocal (Fluorescence) Microscopy

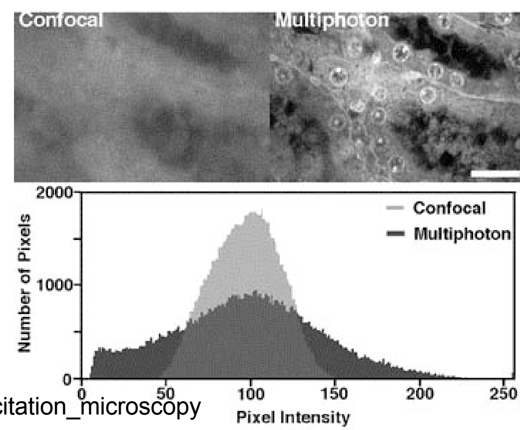


http://www.gonda.ucla.edu/bri_core/confocal.htm

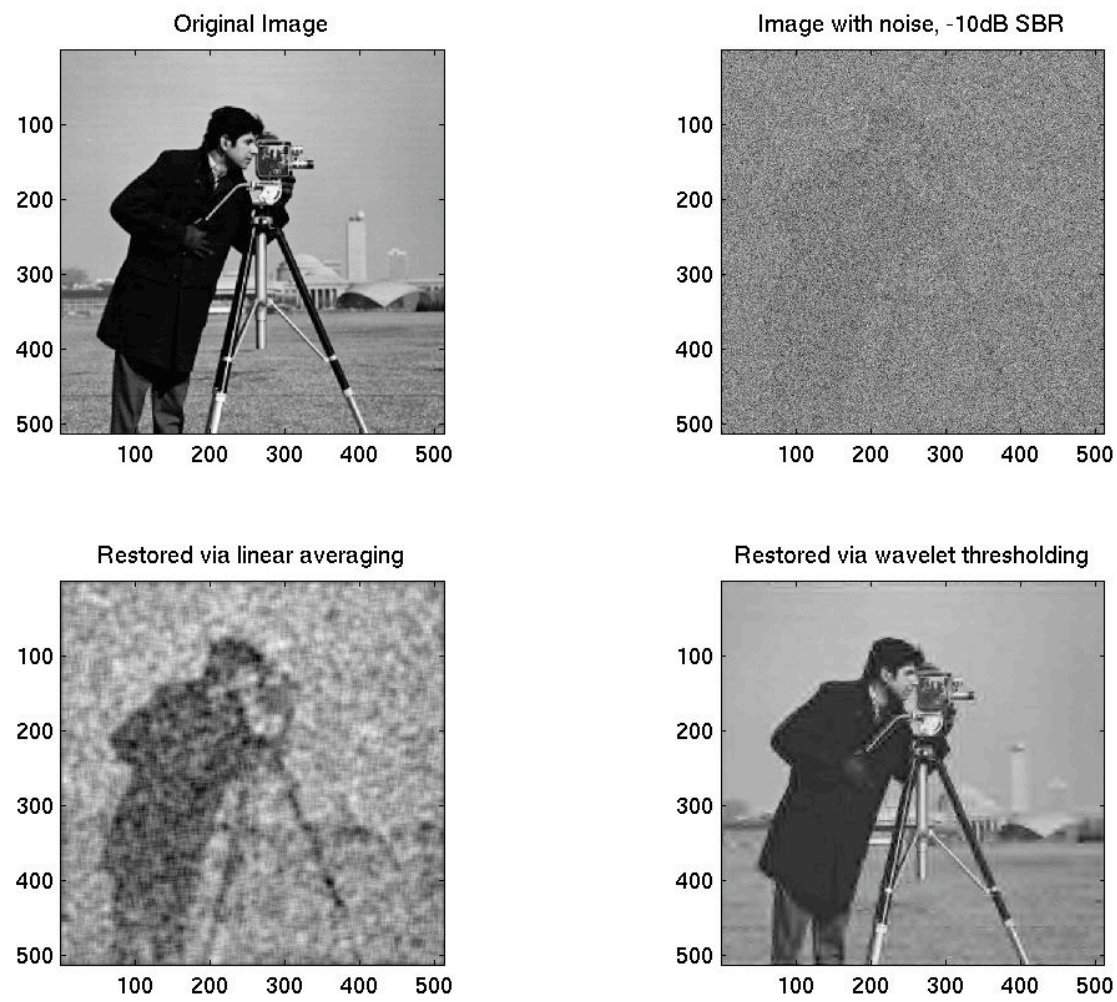
## Two Photon Microscopy



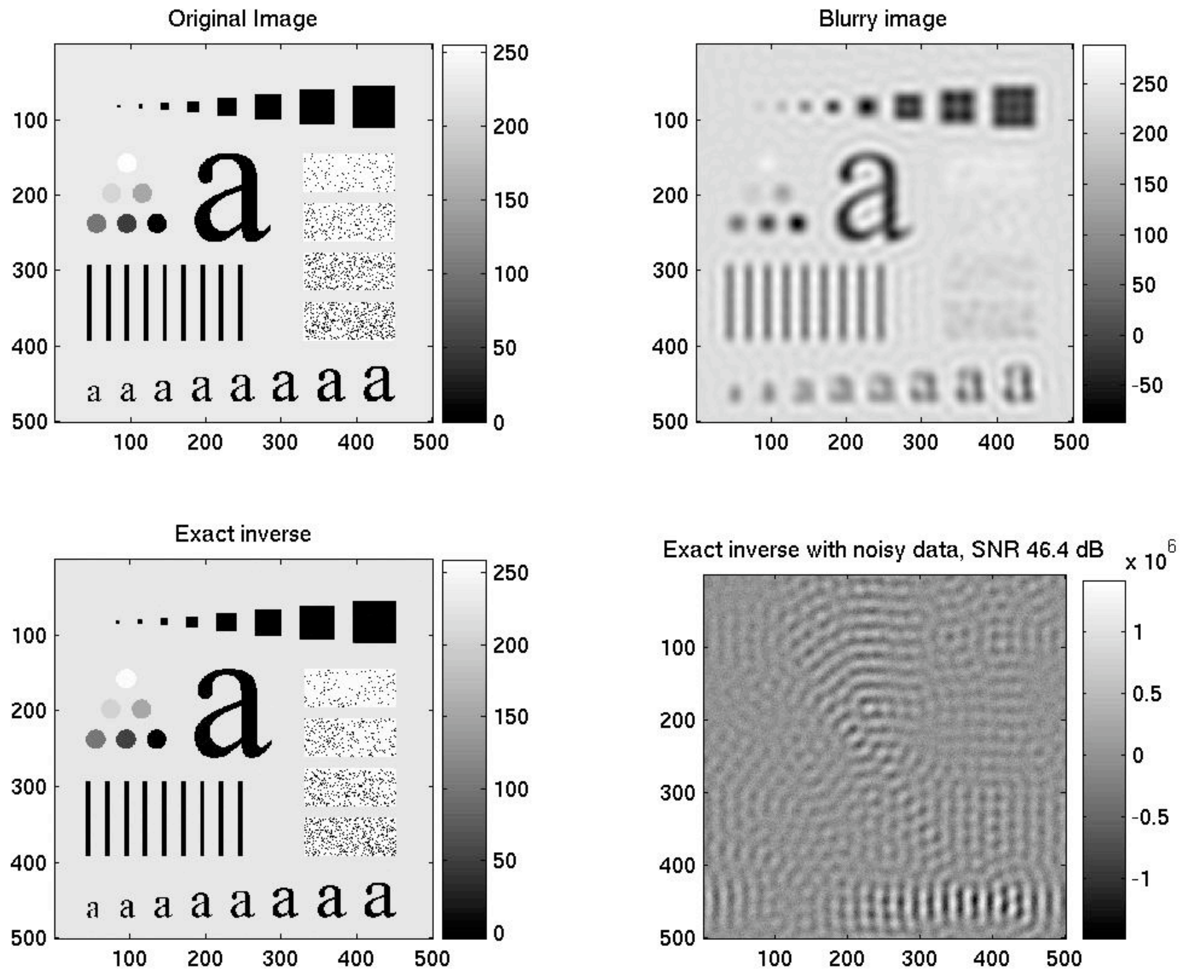




http://en.wikipedia.org/wiki/Two-photon_excitation_microscopy

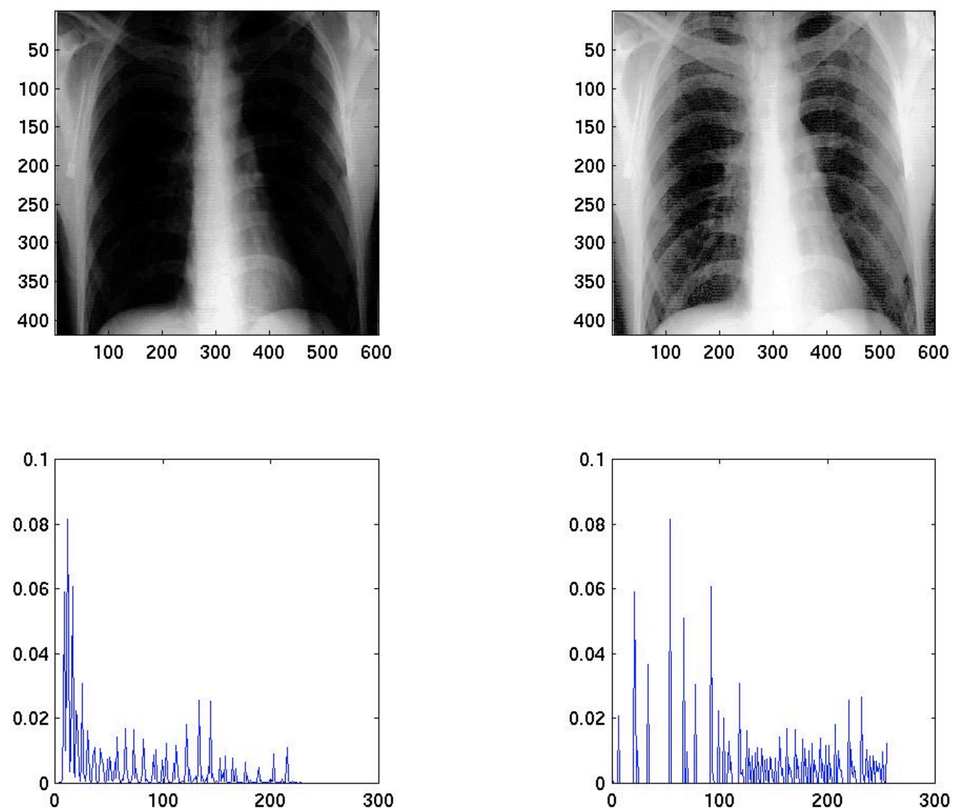
# Enhancement: Denoising



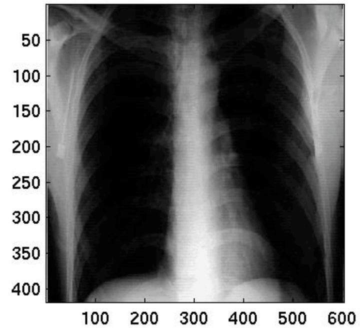
# Enhancement: Deblurring

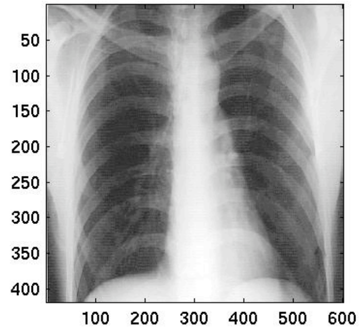


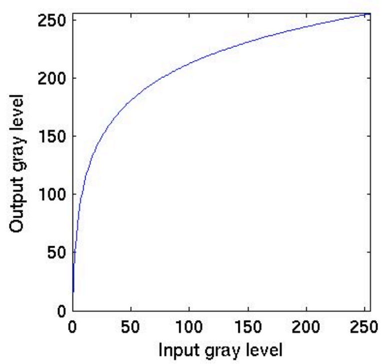
# Enhancement: Equalization



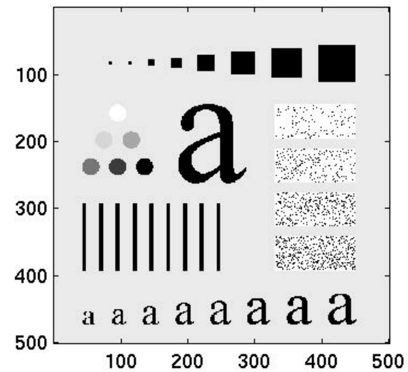
# Enhancement: Gray Value Modification



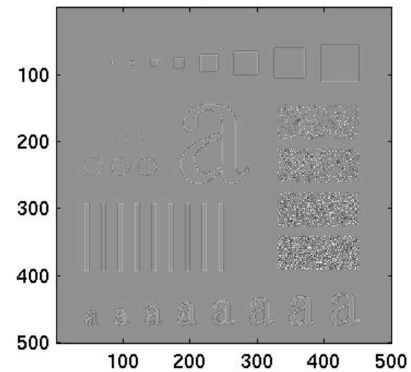



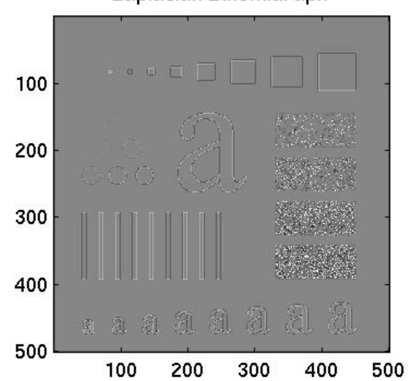
# Analysis: Finding Edges



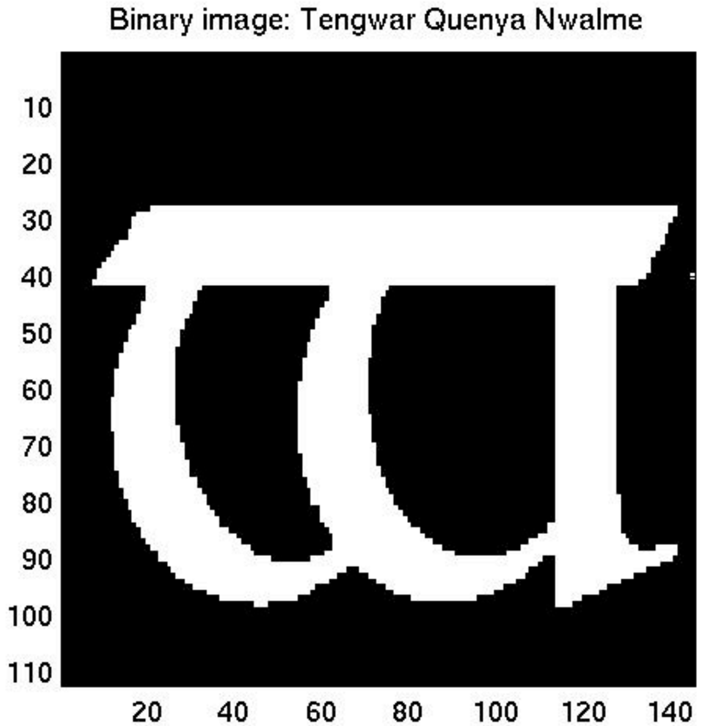

Laplacian

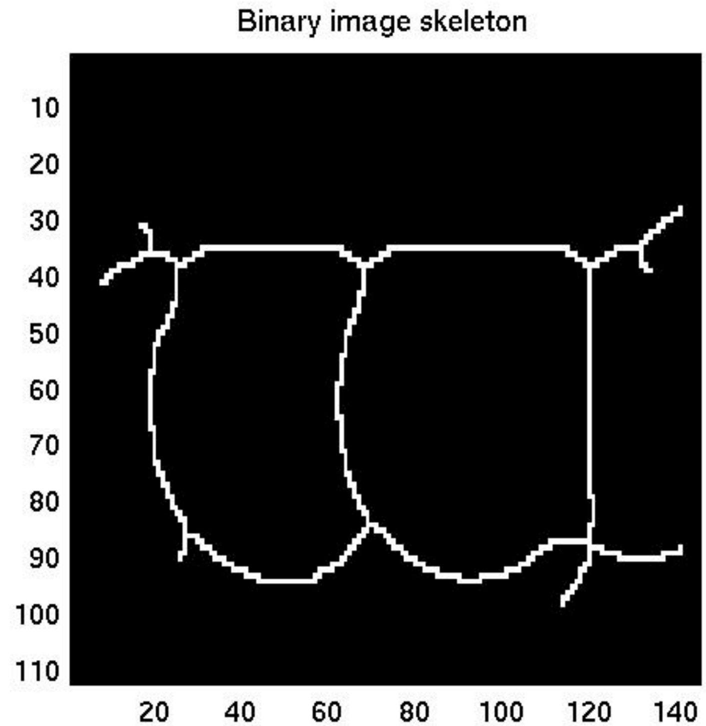



Laplacian Binomial apx

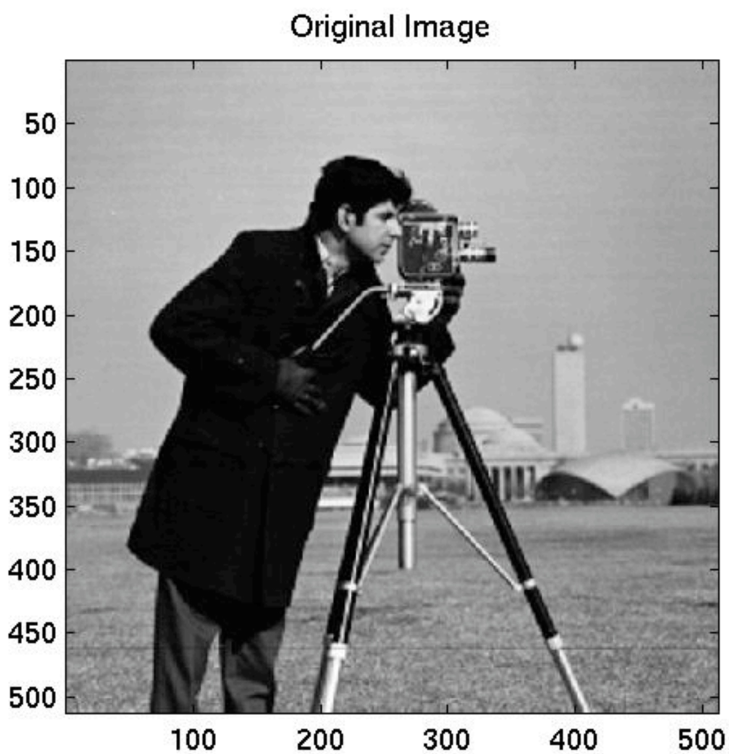


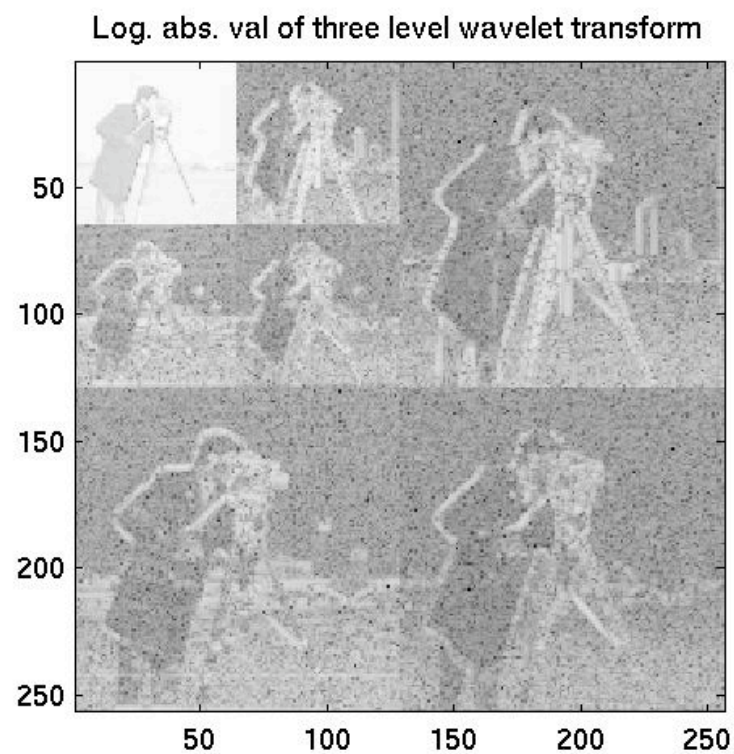
# Analysis: Skeleton



# Compression: Wavelets



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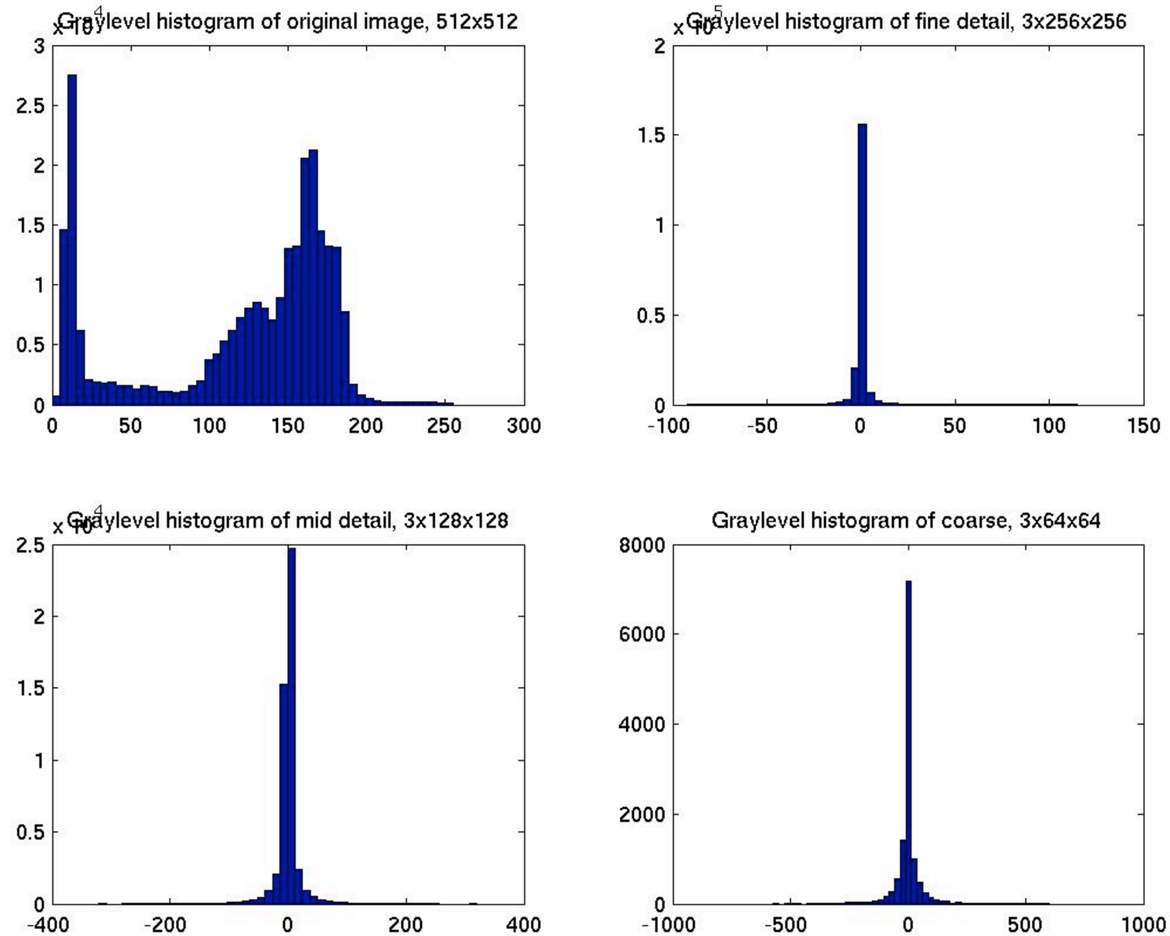

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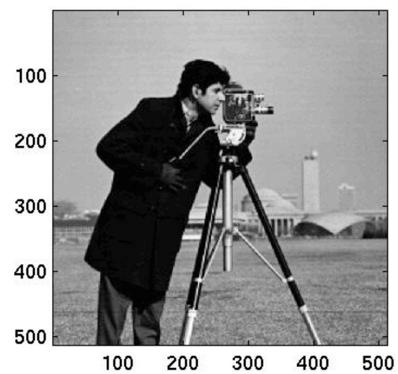


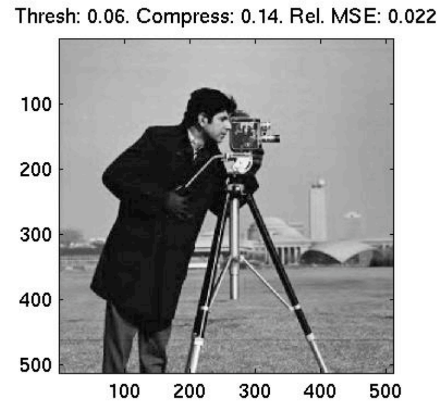


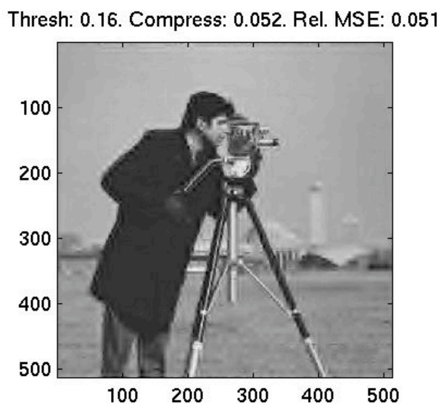


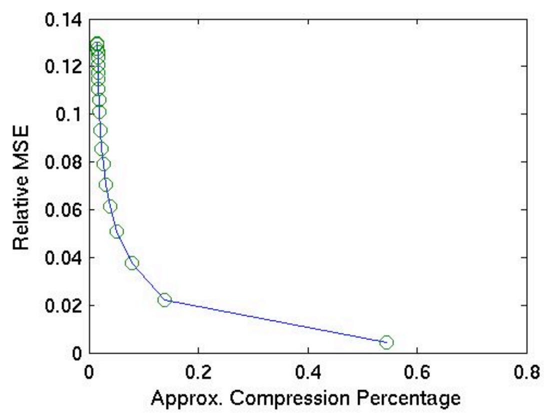

# What we will (hopefully) cover

- How images are stored and how they can be manipulated with Matlab
- Image enhancement
  - Gray level manipulation
  - Filtering to remove noise or to enhance features like edges
- Finding things in images: segmentation
  - Thresholding
  - Back to filtering
- Geometric image transformations
  - Rotations
  - Special effects
  - Maybe morphing

# Questions? Comments? Concerns?