# Introduction

***CSc I6716***
***Spring 2012***

## *3D Computer Vision*

Introduction

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## Course Information

- Basic Information:
  - Course participation
  - Books, notes, etc.
  - Web page – check often!
- Homework, Assignment, Exam
  - Homework and exams
  - Grading
- *Goal*
  - What I expect from you
  - What you can expect from me
  - Resources

## Book

- Textbook
  - Online lecture notes (in the form of book chapters) provided with the class
- Additional readings when necessary
  - “Computer Vision – A Modern Approach” Forsyth and Ponce, 2003
  - “Three-Dimensional Computer Vision: A Geometric Viewpoint” O. Faugeras, 1998
  - “Image Processing, Analysis and Machine VIsion” Sonika, Hlavac and Boyle, 1999
  - “Introductory Techniques for 3-D Computer Vision” Trucco and Verri, 1998
- On-Line References

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## Prequisites

- Linear Algebra
- A little Probability and Statistics
- Programming Experience
- Reading Literature (A little)
- An Inquisitive Nature (Curiosity)
- No Fear

## Course Web Page

***http://www-cs.engr.ccny.cuny.edu/~zhu/CSCI6716-2012s/VisionCourse-Spring-2012.html***

- Lectures available in Powerpoint format
- All homework assignments will be distributed over the web
- Additional materials and pointers to other web sites
- Course bulletin board contains last minute items, changes to assignments, etc.
  - **CHECK IT OFTEN!**
  - You are responsible for material posted there



## Course Outline

- Complete syllabus on the web pages (14 meets)
- Rough Outline ( 3D Computer Vision):

### Part 1. Vision Basics (Total 4)

1. Introduction (1)
2. Image Formation and Processing (1) (hw 1, matlab)
3-4. Features and Feature Extraction (2) ( hw 2)

### Part 2. 3D Vision (Total 7)

5. Camera Models (1)
6. Camera Calibration (2)(hw 3)
7. Stereo Vision (2) (project assignments)
8. Visual Motion (2) (hw 4)

### Part 3. Exam and Projects (Total 3)

9. Midterm exam (1)
10. Project and Exam discussions (0.5)
11. Student Project presentations (1.5)

## Grading

- Homework (4): 40%
- Exam (midterm): 40%
- Course Project + Presentation: 20%
  - Groups (2-3 students) for discussions
  - Experiments – independently + collaboratively
  - Written Report - independently + collaboratively
- All homework must be yours….but you can work together until the final submission

- **Teaching Assistant:**
  - Mr. Wai L. Khoo <WKhoo@gc.cuny.edu>

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## C++ and Matlab

- C++
  - For some simple computation, you may use C++

- Matlab
  - An interactive environment for numerical computation
  - Available on Computer Labs machines (both Unix and Windows)
    - Matlab primer available on line (web page)
    - Pointers to on-line manuals also available
  - Good rapid prototyping environment

- Use C++ and/or Matlab for your homework assignments and project(s); However Java will also be fine

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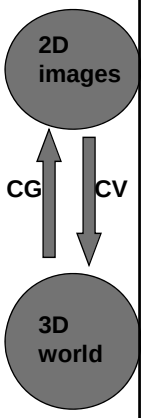
## Course Goals and Questions

- What makes (3D) Computer Vision interesting ?
  - Image Modeling/Analysis/Interpretation
    - Interpretation is an Artificial Intelligence Problem
      - Sources of Knowledge in Vision
      - Levels of Abstraction
    - Interpretation often goes from 2D images to 3D structures
      - since we live in a 3D world
  - Image Rendering/Synthesis/Composition
    - Image Rendering is a Computer Graphics problem
    - Rendering is from 3D model to 2D images

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## Related Fields

- Image Processing: image to image
- Computer Vision: Image to model
- Computer Graphics: model to image

***All three are interrelated!***

- Pattern Recognition: image to class
  - image data mining/ video mining
- Artificial Intelligence: machine smarts
  - Machine perception

***AI***

***Applications***

- Photogrammetry: camera geometry, 3D reconstruction
- Medical Imaging: CAT, MRI, 3D reconstruction (2nd meaning)
- Video Coding: encoding/decoding, compression, transmission

- Physics & Mathematics: basics
- Neuroscience: wetware to concept

***basics***

- Computer Science: programming tools and skills?

## Applications

- Visual Inspection (*)
- Robotics (*)
- Intelligent Image Tools
- Image Compression (MPEG 1/2/4/7)
- Document Analysis (OCR)
- Image and Video on the Web
- Virtual Environment Construction (*)
- Environment (*)
- Media and Entertainment
- Medicine
- Astronomy
- Law Enforcement (*)
  - surveillance, security
- Traffic and Transportation (*)
- Tele-Conferencing and e-Learning (*)
- Human Computer Interaction (HCI)

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## Job Markets

- Homeland Security
  - Port security – cargo inspection, human ID, biometrics
  - Facility security – Embassy, Power plant, bank
  - Surveillance – military or civilian
- Media Production
  - Cartoon / movie/ TVs/ photography
  - Multimedia communication, video conferencing
- Research in image, vision, graphics, virtual reality
  - 2D image processing
  - 3D modeling, virtual walk-thorugh
- Consumer/ Medical Industries
  - Video cameras, Camcorders, Video phone
  - Medical imaging 2D -> 3D

## IP vs CV

- Image processing (mainly in 2D)
  - Image to Image transformations
  - Image to Description transformations
  - Image Analysis - extracting quantitative information from images:
    - Size of a tumor
    - distance between objects
    - facial expression
  - Image restoration. Try to undo damage
    - needs a model of how the damage was made
  - Image enhancement. Try to improve the quality of an image
  - Image compression. How to convey the most amount of information with the least amount of data



## What is Computer Vision?

Vision is the art of seeing things invisible.

**-Jonathan Swift (1667-1745)**
**"Thoughts on Various Subjects"**
**Miscellanies in Prose and Verse**
**(published with Alexander Pope),**
**vol. 1, 1727**

- Computer vision systems attempt to construct meaningful and explicit descriptions of the world depicted in an image.
- Determining from an image or image sequence:
  - The objects present in the scene
  - The relationship between the scene and the observer
  - The structure of the three dimensional (3D) space

## Cues to Space and Time

**Directly Measurable in an Image**

- Spectral Characteristics
  - Intensity, contrast, colors and their
  - Spatial distributions
- 2D Shape of Contours
- Linear Perspective
- Highlights and Shadows
- Occlusions
- Organization
- Motion parallax and Optical Flow
- Stereopsis and sensor convergence

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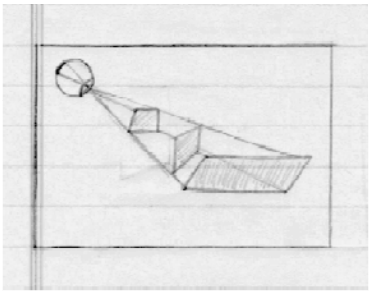
## Cues to Space and Time

**Inferred Properties**

- Surface connectivity
- 3D Volume
- Hidden sides and parts
- Identity (Semantic category)
- Absolute Size
- Functional Properties
- Goals, Purposes, and Intents
- Organization
- Trajectories

## Cues to Depth

- Question:
  - How do we perceive the three-dimensional properties of the world when the images on our retinas are only two-dimensional?
- Stereo is not the entire story!





## Cues to Depth

- Monocular cues to the perception of depth in images
  - Interposition: occluding objects appear closer than occluded objects
  - Relative size: when objects have approximately the same physical size, the larger object appears closer
  - Relative height: objects lower in the image appear closer
  - Linear Perspective: objects appear smaller as they recede into the distance
    - texture gradients
  - Aerial Perspective: change in color and sharpness as object recede into the distance
  - Illumination gradients: gradients and shadow lend a sense of depth
  - Relative Motion: faster moving objects appear closer

## Cues to Depth

- Physiological cues to depth:
  - Focus (accomodation): change in curvature of the lens for objects at different depths
  - Convergence: eyes turn more inward (nasal) for closer objects
  - Retinal disparity: greater for objects further away



## Interposition

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## Interposition

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## Interposition

## Different viewpoint




## Different viewpoint

**Edgar Degas: Dance Class at the Opéra, 1872**

## Different viewpoint

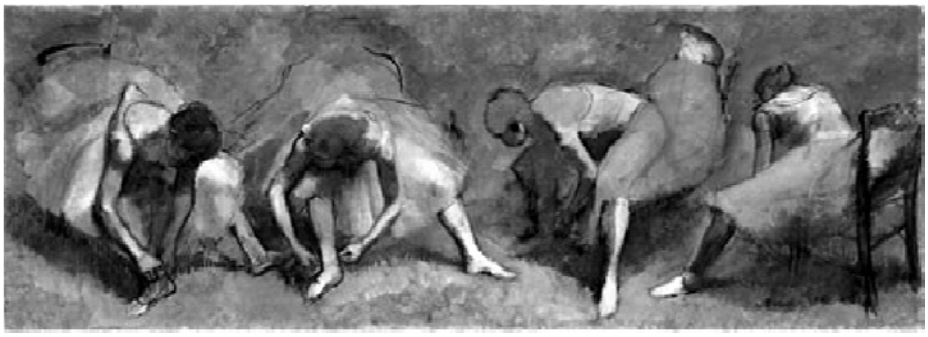
**Edgar Degas:**

**Green Dancer,**

**c.1880**



## Different viewpoint



**Edgar Degas: Frieze of Dancers, c.1895**

## Different viewpoint

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## Different viewpoint

**Edgar Degas: Frieze of Dancers, c.1895**

## Aerial Perspective

- Constable



## Aerial Perspective

- Classic Chinese Paintings

## Absolute Size



## Relative Size

## Relative Size



## Absolute Size

## Relative Size



## Light and Surfaces

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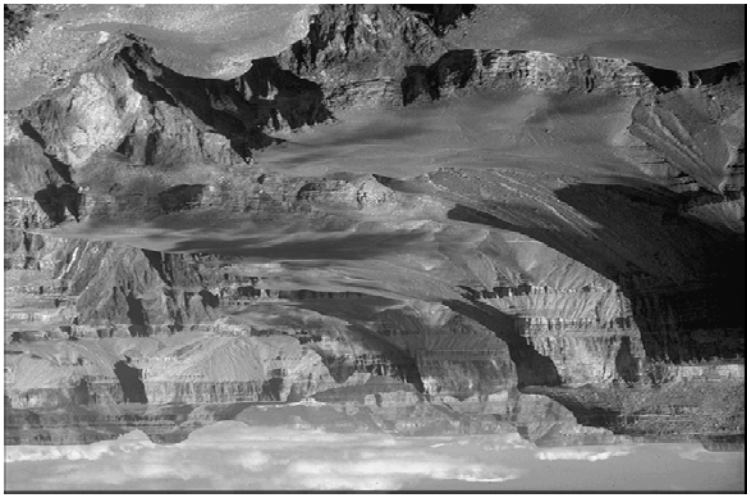
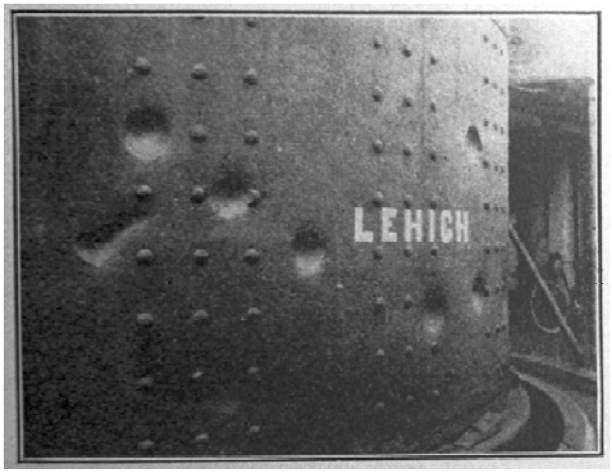
## Light and Surfaces



## Light and Surfaces

- C. H. Stoelting Company

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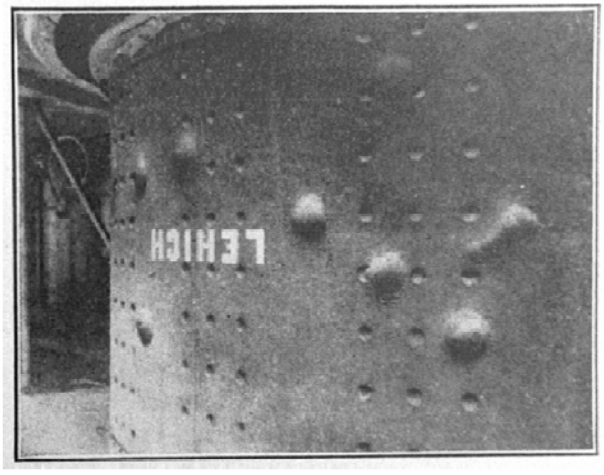

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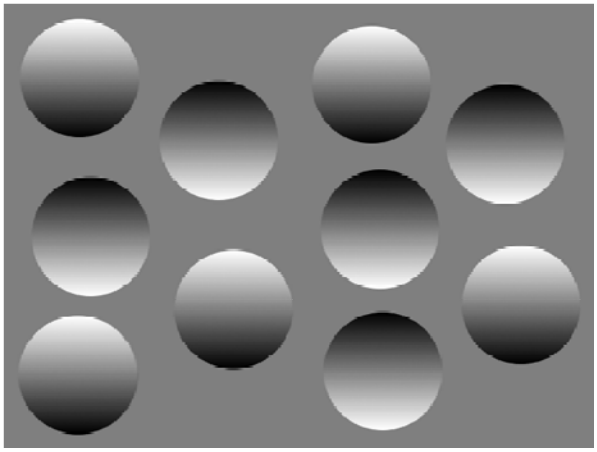

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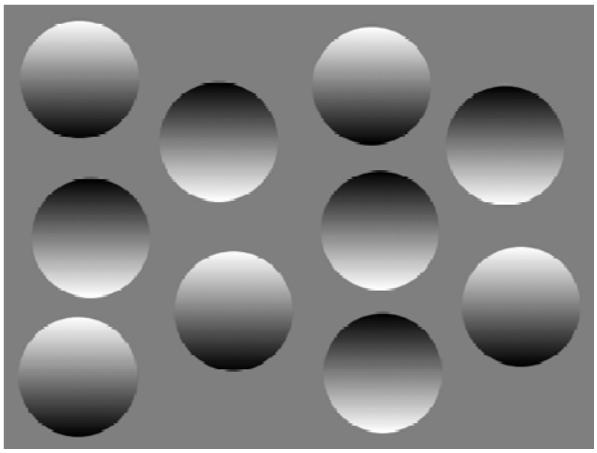

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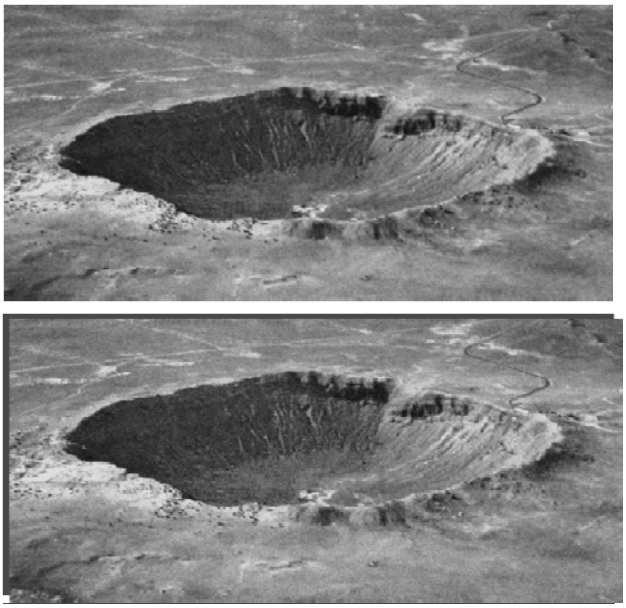
## Light and Surfaces



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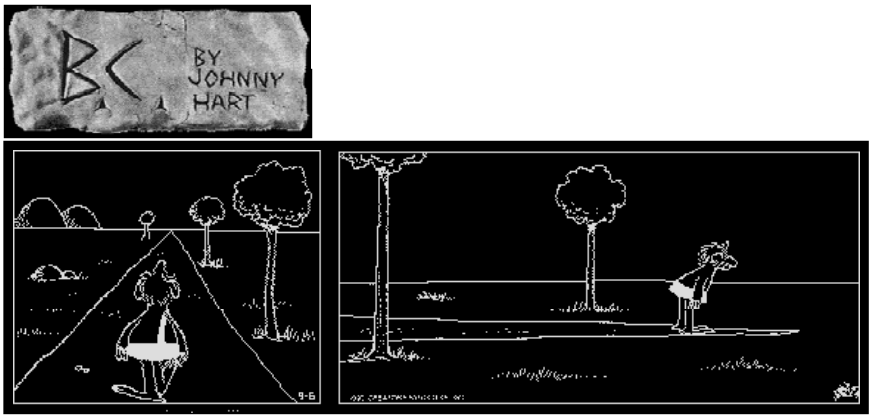
## The Effect of Perspective



## Texture Gradient

***Sunflowers in Fargo, ND***
***Photo by Bruce Fitz***

*http://www.ars.usda.gov/is/graphics/photos/*



## Texture Gradients

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## Edges

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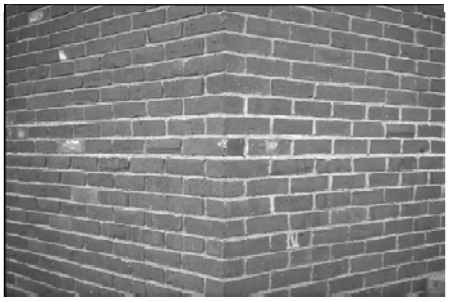
## Texture Edges



## Who Knows



## Next

**Anyone who isn't confused really doesn't understand the situation.**

*--Edward R. Murrow*

**Next:**
**Image Formation**