Introduction

Computer Vision I
CSE 252A
Lecture 1

- We'll begin with some introductory material …
- … and end with
  - Syllabus
  - Organizational materials
  - Wait list

What is computer vision?

Done?

What is Computer Vision?

- Trucco and Verri: Computing properties of the 3-D world from one or more digital images
- Stockman and Shapiro: To make useful decisions about real physical objects and scenes based on sensed images
- Ballard and Brown: The construction of explicit, meaningful description of physical objects from images.
- Forsyth and Ponce: Extracting descriptions of the world from pictures or sequences of pictures

Why is this hard?

What is in this image?
1. A hand holding a man?
2. A hand holding a mirrored sphere?
3. An Escher drawing?

- Interpretations are ambiguous
- The forward problem (graphics) is well-posed
- The "inverse problem" (vision) is not

Underestimates

"640K ought to be enough for anybody."
– Bill Gates, 1981

"... in three to eight years we will have a machine with the general intelligence of an average human being ... The machine will begin to educate itself with fantastic speed. In a few months it will be at genius level and a few months after that its powers will be incalculable ..."
– Marvin Minsky, LIFE Magazine, 1970

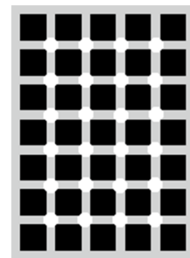
Should Computer Vision follow from our understanding of Human Vision?

Yes & No

1. Who would ever be crazy enough to even try creating machine vision?
2. Human vision "works", and copying is easier than creating.
3. Secondary benefit – in trying to mimic human vision, we learn about it.

1. Why limit oneself to human vision when there is even greater diversity in biological vision
2. Why limit oneself to biological vision when there may be greater diversity in sensing mechanism?
3. Biological vision systems evolved to provide functions for "specific" tasks and "specific" environments. These may differ for machine systems
4. Implementation – hardware is different, and synthetic vision systems may use different techniques/methodologies that are more appropriate to computational mechanisms

Hermann Grid



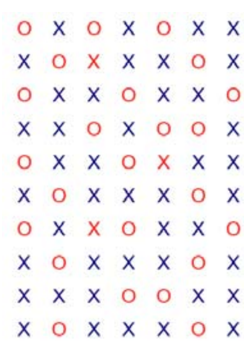
Scan your eyes over the figure. Do you see the gray spots at the intersections? Stare at one of them and it will disappear.

How many red X's are there?

Raise your hand when you know.

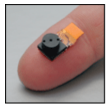
How many red X's are there?

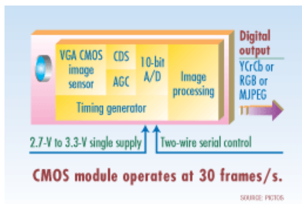
Raise your hand when you know.



The Near Future: Ubiquitous Vision

- Digital video has become very inexpensive.
- It's widely embedded in cell phones, cars, games, etc.
- 99.9% of digitized video isn't seen by a person.
- That doesn't mean that only 0.1% is important!





Applications: touching your life

- Optical Character Recognition
- Football
- Movies
- Surveillance
- HCI – hand gestures
- Aids to the blind
- Face recognition & biometrics
- Road monitoring
- Industrial inspection
- Virtual Earth; street view
- Robotic control
- Autonomous driving
- Space: planetary exploration, docking
- Medicine – pathology, surgery, diagnosis
- Microscopy
- Military
- Remote Sensing
- Digital photography
- Google Goggles
- Video games

Earth viewers (3D modeling)

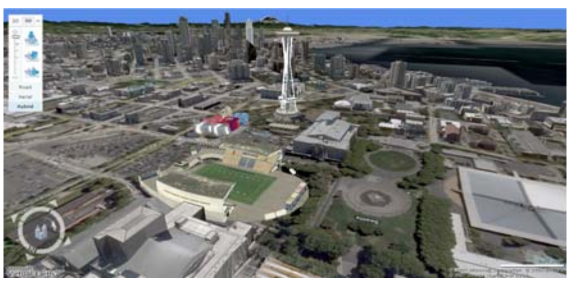


Image from Microsoft's Virtual Earth (now Bing Maps)
(see also: Google Earth)

Photosynth

http://photosynth.net
Based on Photo Tourism technology developed by Noah Snavely, Steve Seitz, and Rick Szeliski

Optical character recognition (OCR)

Technology to convert scanned docs to text

- If you have a scanner, it probably came with OCR software

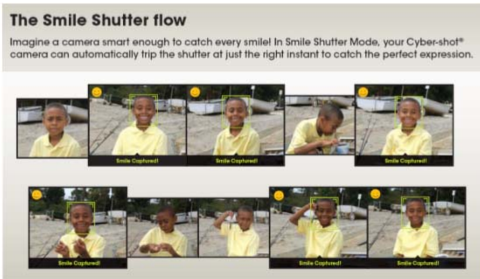
Digit recognition, AT&T labs

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Face detection

- Most new digital cameras now detect faces, so do smart phones…
  - Canon, Sony, Fuji, …

Smile detection

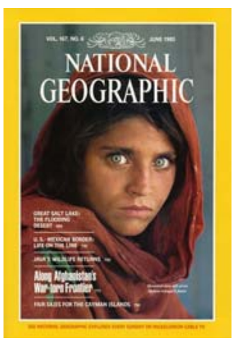


Sony Cyber-shot® T70 Digital Still Camera

Object recognition (in supermarkets)

LaneHawk by EvolutionRobotics (now part of iRobot)
"A smart camera is flush-mounted in the checkout lane, continuously watching for items. When an item is detected and recognized, the cashier verifies the quantity of items that were found under the basket, and continues to close the transaction. The item can remain under the basket, and with LaneHawk, you are assured to get paid for it… "

Face recognition



Who is she?

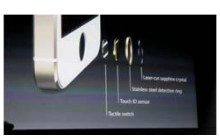
Vision-based biometrics

1984
Age 12

2002
Age 30

"How the Afghan Girl was Identified by Her Iris Patterns" Read the story

Login without a password…



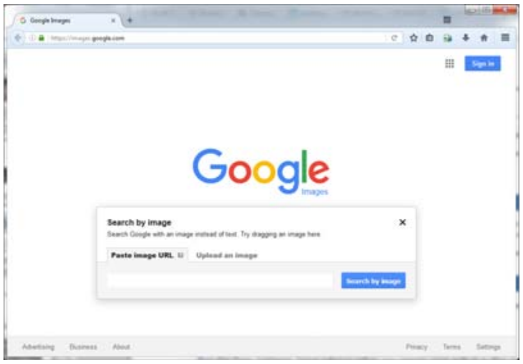
Fingerprint scanners on smartphones, laptops, mice, other devices

Face recognition systems now beginning to appear more widely on computers and smart phones

Object recognition (in mobile phones)

- Point & Find, Nokia
- SnapTell.com (now Amazon)
- Mobile Acuity
- Google Goggles

Image-based search



Special effects: shape capture

The Matrix movies, ESC Entertainment, XYZRGB, NRC

Special effects: motion capture

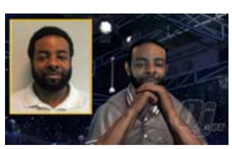
- Vicon

Sports

Sportvision first down line
Nice explanation on www.howstuffworks.com

Vision-based interaction (and games)

Nintendo Wii has camera-based IR tracking built in.



Your face on a 3D avatar.

Playmotion game a Disney Epcot

Xbox Kinnect

Structured light-based sensor

Vision in space

NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read "Computer Vision on Mars" by Matthies et al.

Robotics

NASA's Mars Spirit Rover
http://en.wikipedia.org/wiki/Spirit_rover

http://www.robocup.org/

Smart cars

- Mobileye
  - Vision systems currently in high-end BMW, GM, Volvo models

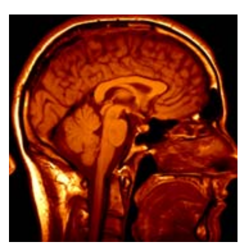
Autonomous Vehicles

First person vision

Google Glass

Oracam

Medical imaging



3D imaging
MRI, CT

Image guided surgery
Grimson et al., MIT

Current state of the art

- You just saw examples of current systems.
  - Many of these are less than 5 years old
- This is a very active research area, and rapidly changing
  - Many new applications in the next 5 years
- To learn more about vision applications and companies
  - David Lowe maintains an excellent overview of vision companies
    - http://www.cs.ubc.ca/spider/lowe/vision.html

Image Interpretation - Cues

- Variation in appearance in multiple views
  - stereo
  - motion
- Shading & highlights
- Shadows
- Contours
- Texture
- Blur
- Geometric constraints
- Prior knowledge

An example of a cue: Shading and lighting

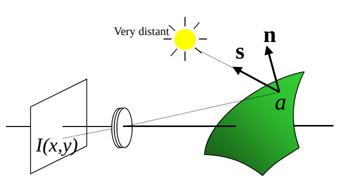
Shading as a result of differences in lighting is

1. A source of information
2. An annoyance

Illumination Variability An annoyance

"The variations between the images of the same face due to illumination and viewing direction are almost always larger than image variations due to change in face identity."
-- Moses, Adini, Ullman, ECCV 1994

Image Formation



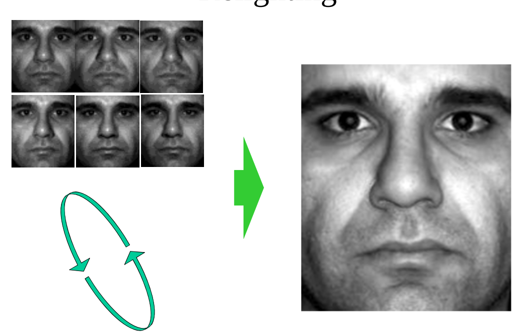
At image location (x,y) the intensity of a pixel $I(x,y)$ is

$$I(x,y) = a(x,y)\,\mathbf{n}(x,y)^T\mathbf{s}$$

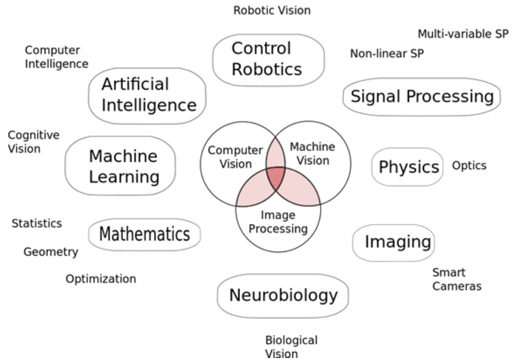
where

- $a(x,y)$ is the albedo of the surface projecting to (x,y).
- $\mathbf{n}(x,y)$ is the unit surface normal.
- $\mathbf{s}$ is the direction and strength of the light source.

An implemented algorithm: Relighting



Related Fields



Four Rs of computer vision

- Reprojection
  - Rendering a scene from a different view, under different illumination, under different surface properties, etc.
- Reconstruction
  - Multiple view geometry, structure from motion, shape from X (where X is texture, shading, contour, etc.), etc.
- Registration
  - Tracking, alignment, optical flow, correspondence, etc.
- Recognition
  - Recognizing objects, scenes, events, etc.

Others may have slightly different Rs

Rudiments: The implied fifth R

- image filtering
- interest point detection
- edge detection
- probability
- statistics
- linear algebra
- projective geometry
- optics
- Fourier analysis
- sampling
- algorithms
- photometry
- physics of color
- human vision
- psychophysics
- performance evaluation

From Serge Belongie

The course

- Part 1: The Physics of Imaging
- Part 2: Early Vision
- Part 3: Reconstruction
- Part 4: Recognition

Part I of Course: The Physics of Imaging

- How images are formed
  - Cameras
    - What a camera does
    - Projection models (projective spaces, etc.)
    - How to tell where the camera was located
  - Light
    - How to measure light
    - What happens to light at surfaces
    - How the brightness values we see in images are determined
  - Color
    - The underlying mechanisms of color
    - How to describe it and measure it

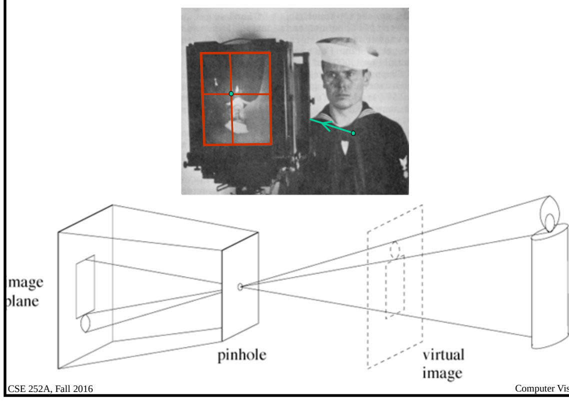
Cameras, lenses, and sensors

Figure 1.16 The first photograph on record, *la table servie*, obtained by Nicéphore Niepce in 1822. *Collection Harlinge–Viollet*.

- Pinhole cameras
- Lenses
- Projection models
- Geometric camera parameters

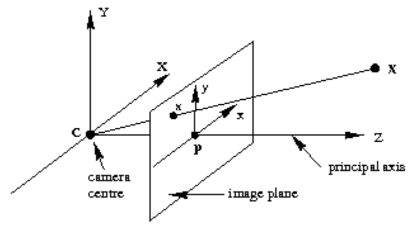
From Computer Vision, Forsyth and Ponce, Prentice-Hall, 2002.

A real camera ... and its model



Geometry

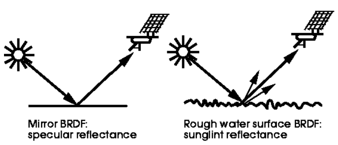
- How do 3D world points project to 2D image points?



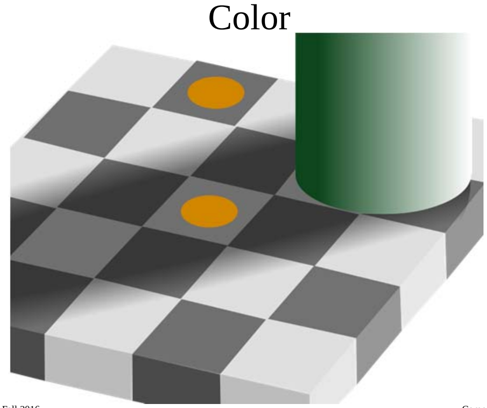
Lighting & Photometry

- How does measurement relate to light energy?

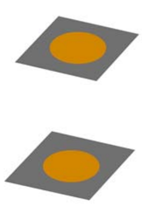
- Sensor response
- Light sources
- Reflectance



Color



Color



Part II: Early Vision in One Image

- Representing small patches of image
- Noise
- Filtering
- Edge detection
- Corner detection
- Texture
- Segmentation

Segmentation

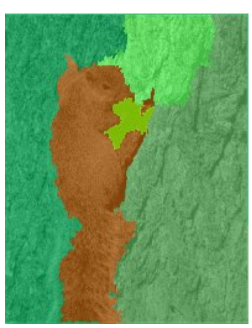
- Which image components “belong together”?
- Belong together ≅ lie on the same object
- Cues
  - Similar color
  - Similar texture
  - Not separated by contour
  - Form a suggestive shape when assembled

Boundary Detection

http://www.robots.ox.ac.uk/~vdg/dynamics.html

Boundary Detection: Local cues

(Sharon, Balun, Brandt, Basri)



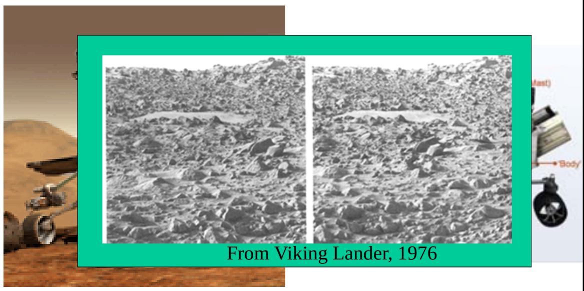
Part 3: Reconstruction from Multiple Images

- Photometric Stereo
  - What we know about the world from lighting changes
- The geometry of multiple views
- Stereopsis
  - What we know about the world from having two eyes
- Structure from motion
  - What we know about the world from having many eyes (or, more commonly, our eyes moving)

Mars Rover

Spirit

Curiosity

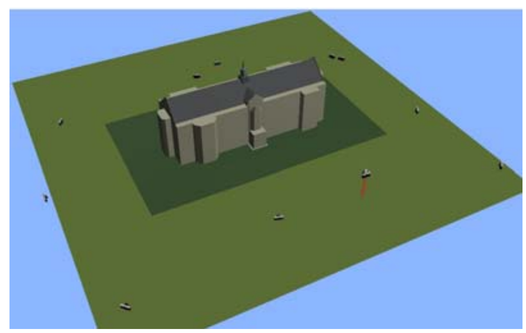


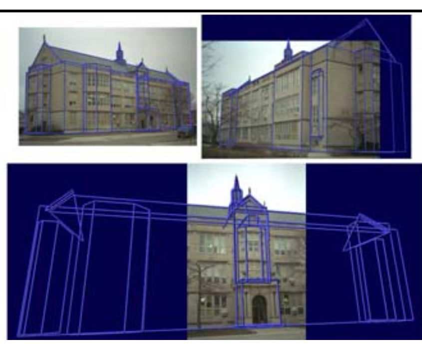
Façade (Debevec, Taylor and Malik, 1996)
Reconstruction from multiple views, constraints, rendering

Architectural modeling:
• photogrammetry;
• view-dependent texture mapping;
• model-based stereopsis.

Images with marked features

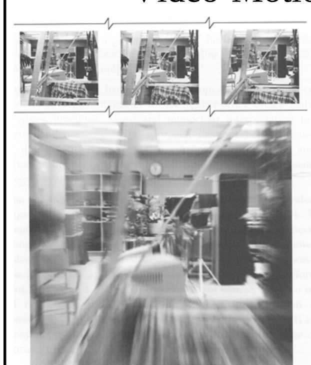
Resulting model & Camera Positions





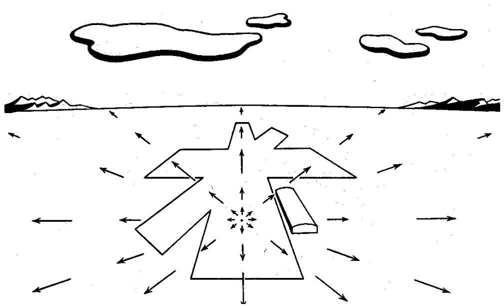
Recovered model edges reprojected through recovered camera positions into the three original images

Video-Motion Analysis



- Where "things" are moving in image – segmentation
- Determining observer motion (egomotion)
- Determining scene structure
- Tracking objects
- Understanding activities & actions

Forward Translation & Focus of Expansion [Gibson, 1950]



Part 4: Recognition

Given a database of objects and an image determine what, if any of the objects are present in the image

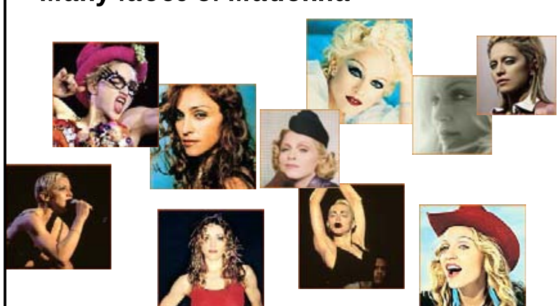
Recognition Challenges

- Within-class variability
  - Different objects within the class have different shapes or different material characteristics
  - Deformable
  - Articulated
  - Compositional
- Pose variability:
  - 2-D image transformation (translation, rotation, scale)
  - 3-D pose variability (perspective, orthographic projection)
- Lighting
  - Direction (multiple sources & type)
  - Color
  - Shadows
- Occlusion – partial
- Clutter in background -> false positives

Recognition Example: Face Detection: Classify face vs. non-face

Why is Face Recognition Hard?

Many faces of Madonna



Syllabus

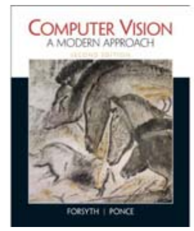
- Instructor: Ben Ochoa
- TAs: Abhijit Tripathy, Mihir Patankar, and Lenord Melvix
- Course website
  - http://cseweb.ucsd.edu/classes/fa16/cse252A-a/
- 19 lecture meetings
  - No university holidays for MW classes, but no meeting on day before Thanksgiving (Wednesday, November 23)
- Class discussion
  - Piazza

Syllabus

- Grading
  - 4 homework assignments + Homework 0
    - By hand and programming using MATLAB
    - Prepare reports using LaTeX
  - Piazza
    - Ask (and answer) questions using Piazza, not email
    - Good participation could raise your grade (e.g., raise a B+ to an A-)
  - No midterm exams
  - No final exam

Textbook

- Computer Vision: A Modern Approach, second edition (do not use first edition)
  - David A. Forsyth and Jean Ponce



Academic Integrity Policy

Integrity of scholarship is essential for an academic community. The University expects that both faculty and students will honor this principle and in so doing protect the validity of University intellectual work. For students, this means that all academic work will be done by the individual to whom it is assigned, without unauthorized aid of any kind.

Collaboration Policy

It is expected that you complete your academic assignments on your own and in your own words and code. The assignments have been developed by the instructor to facilitate your learning and to provide a method for fairly evaluating your knowledge and abilities (not the knowledge and abilities of others). So, to facilitate learning, you are authorized to discuss assignments with others; however, to ensure fair evaluations, you are not authorized to use the answers developed by another, copy the work completed by others in the past or present, or write your academic assignments in collaboration with another person. If the work you submit is determined to be other than your own, you will be reported to the Academic Integrity Office for violating UCSD's Policy on Integrity of Scholarship.

Wait List

- Number of enrolled students is limited by
  - Size of room
  - Number of TAs
- General advice
  - Wait for as long as you can
- Concurrent enrollment (Extension) students have lowest priority