Robert Collins
CSE486, Penn State

# CSE/EE 486: Computer Vision I
# Fall 2007 Course Overview

**Instructor:** Dr. Robert Collins, *email:* rcollins@cse.psu.edu
*Office:* IST 354H
*Office Hours:* TBA

**Teaching Assistant:** Yaman Aksu, *email:* ya1@psu.edu
*Office Hours:* TBA

**Class Schedule:** M W F, 11:15 -- 12:05 Willard 260
**Credits: 3**

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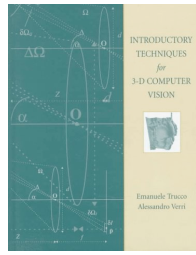
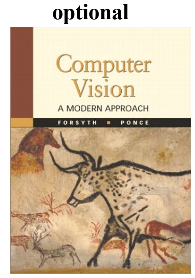
# Textbook

**required**




*Introductory Techniques for 3-D Computer Vision* by E. Trucco and A. Verri, Prentice Hall, 1998.

**optional**




*Computer Vision: A Modern Approach*, by D.Forsyth and J.Ponce, Prentice Hall, 2002.

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**Fall 2007 Syllabus (excerpts)**

**Grading:**

- ***Homework Assignments (6):*** **30%**
- ***Project Assignments (3):*** **30%**
- ***In-class Midterm Exams (2):*** **20%**
- ***Final Exam (Comprehensive):*** **20%**

Individual exams and assignments are not scaled or curved. However, I typically scale the overall numeric course scores (computed from everything) before assigning a letter grade at the end of the course.

**See full syllabus posted on Angel course web site**

**https://cms.psu.edu/**

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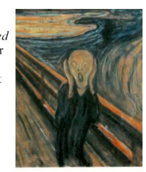
# Programming Groups

**excerpts from syllabus**



Projects are team efforts, performed in groups of three people. **The deadline to form these groups is Sep 10.** *Students not belonging to a group will be assigned one by alphabetical order.* From past experience, things seem to work out better when you form your own group, rather than being assigned to one, even if it means you have to take the initiative to introduce yourself to someone you don't know (yikes!). For some reason, working in assigned groups for the projects seems to be a considerable source of *angst* each semester. Please heed my call, and make a serious effort to put your own teams together.

Each group submits code, a written report, and a short description of what each member of the group contributed to the project. Typically, all members of the team receive the same grade for the submission, but a member who clearly is not contributing will receive a lower grade.

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Robert Collins

# CSE/EE 486 Fall 2007 Course Calendar

**tentative**

3 days in August! intro to vision | intensity surfaces | linear operators [H1

SEPTEMBER 2007

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| 3 | 4 | 5 smoothing | 6 | 7 edges H1] |
| 10 corners [P1 | 11 | 12 template matching | 13 | 14 intro to stereo [H2 |
| 17 stereo alg 1 | 18 | 19 stereo alg 2 | 20 | 21 pyramids H2] |
| 24 LoG/zero-cross | 25 P1] | 26 review | 27 | 28 midterm 1 M1 |

OCTOBER 2007

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| 1 extrinsics | 2 | 3 intrinsics [H3 | 4 | 5 transformations 1 |
| 8 transformations 2 | 9 | 10 RANSAC [P2 | 11 | 12 homography 1 H3] |
| 15 homography 2 | 16 | 17 mosaicing | 18 | 19 suicide day |
| 22 epipolar geom [H4 | 23 | 24 E/F matrices | 25 P2] | 26 8-pt alg |
| 29 stereo reconstruct | 30 | 31 review H4] | | |

NOVEMBER 2007

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| | | | 1 | 2 midterm 2 M2 |
| 5 camera motion | 6 | 7 flow estimate 1 [H5 | 8 | 9 flow estimate 2 |
| 12 change detect [P3 | 13 | 14 SFM | 15 | 16 color&light movie H5] |
| 19 | 20 | 21 | 22 | 23 |
| 26 color&light | 27 | 28 color histograms [H6 | 29 | 30 tracking |

DECEMBER 2007

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| 3 tracking LK | 4 P3] | 5 tracking MS | 6 | 7 ObjRec SIFT H6] |
| 10 ObjRec PCA | 11 | 12 texture synth | 13 | 14 review |
| 17 Final Exam Week | 18 *Final Exam Week | 19 | 20 *Final Exam Week | 21 |
| 24 | 25 | 26 | 27 | 28 |

http://www.myboatclub.com/printablecalendar.htm

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# Lecture 1: Introduction to Computer Vision

**Readings T&V: Section 1, Section 2.1-2.2**

## What is Vision?

**"Vision is the act of knowing what is where by looking." --Aristotle**

**Special emphasis: relationship between 3D world and a 2D image. Location and identity of objects.**



## What is Computer Vision?

**It is related to, but not equivalent to:**

- **Photogrammetry**
- **Image Processing**
- **Artificial Intelligence**



## Why study Computer Vision?

- Images and movies are everywhere
- Fast-growing collection of useful applications
  - building representations of the 3D world from pictures
  - automated surveillance (who's doing what)
  - movie post-processing
  - face finding
- Various deep and attractive scientific mysteries
  - how does object recognition work?
- Greater understanding of human vision



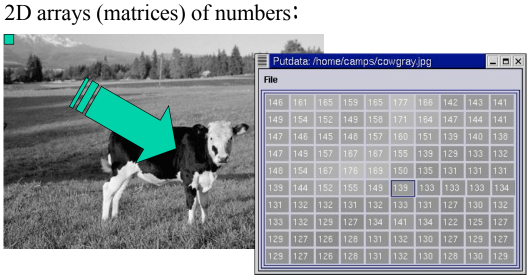
## Course Goals and Objectives

- Introduce the fundamental problems of computer vision.
- Introduce the main concepts and techniques used to solve those problems.
- Enable students to implement vision algorithms
- Enable students to make sense of the vision literature



## Input: Digital Images

2D arrays (matrices) of numbers:

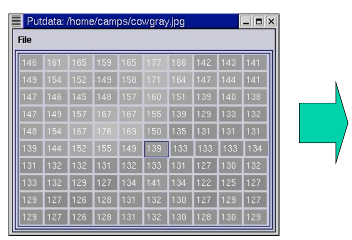



If color image, we have 3 arrays - red, green, blue



## Why is Computer Vision Hard?

**We are trying to infer things about the world from an array of numbers**




**Shoulder of a cow…**

**problems: too local; lack of context; mismatch between levels of abstraction. But wait, it's even worse than that...**

## Why is Computer Vision Hard?

**If we already know the geometry, surface material and lighting conditions, it is well-understood how to generate the value at each pixel. [this is Computer Graphics]**

**But this confluence of factors contributing to each pixel can not be easily decomposed. The process can not be inverted.**



**tell me what you see...**




## Congratulations! You just did something mathematically impossible.

How?
You used assumptions based on prior knowledge / experience about the way the world works.

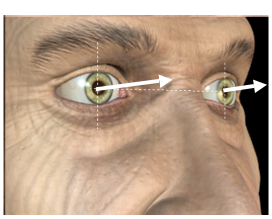


**Recovering 3D from a single image is a mathematically ill-posed problem.**

**So we can't solve the problem using only math.** ☹



## Good news: with more than one camera, we can recover 3D!

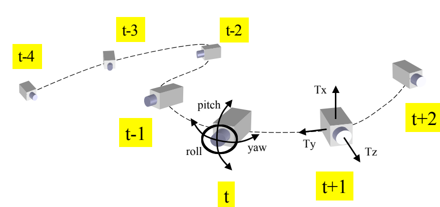


**Example: Stereo Vision**



## Structure from Motion

**We can also infer 3D from only one camera, provided we move it around "enough".**



## Structure from Motion

So how much is "enough" motion? It depends.

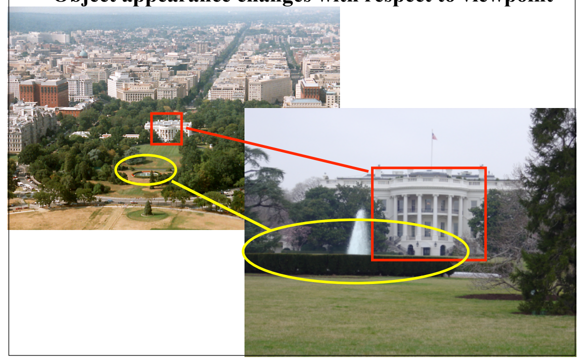
www.grand-illusions.com

(play movie in external player)



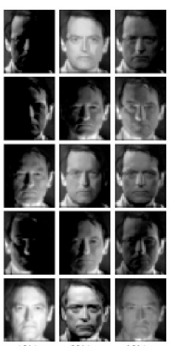
## More Difficulties

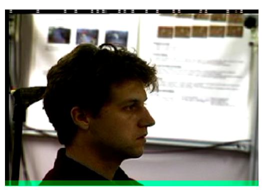
Object appearance changes with respect to viewpoint





## Effects of Lighting

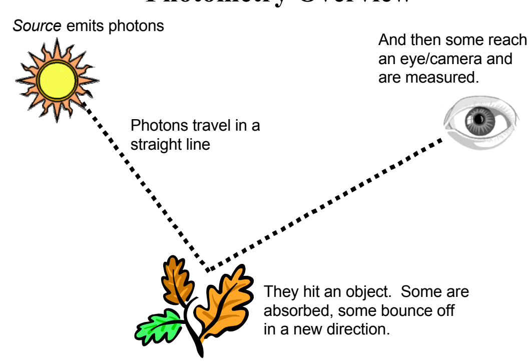


Object appearance also varies with respect to lighting magnitude and direction

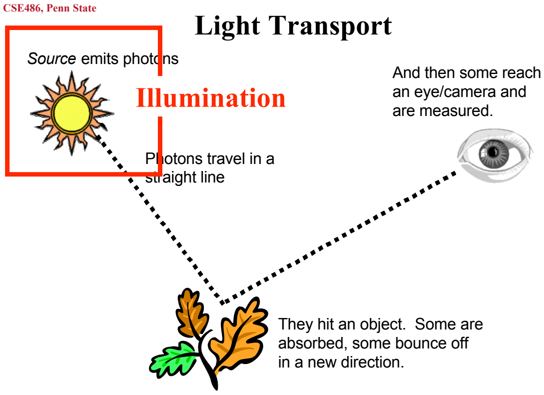


## Photometry Overview



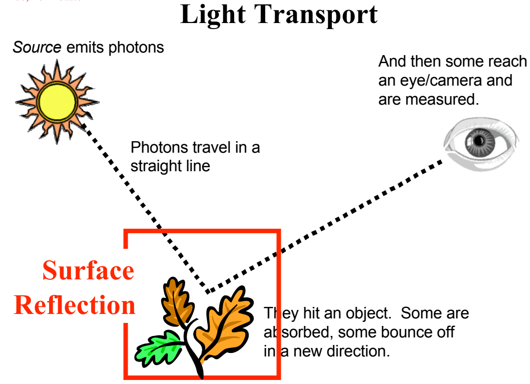



## Light Transport

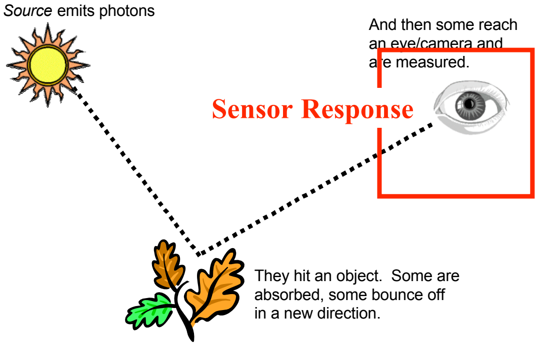





## Light Transport



## Light Transport






## What do we mean by "red"

Color percepts are a composition of three factors (illumination, surface reflectance, sensor response)

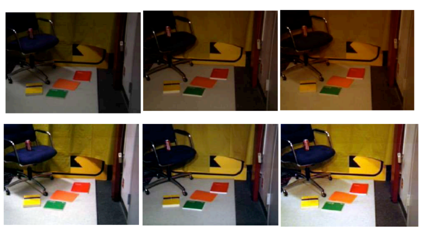
We can't easily factor the color we see in the image to infer illumination and material (even if sensor properties are fixed and known).

**Again, this is counterintuitive to human experience.**



## Perception: Color Constancy

Humans are very good at recognizing the same material colors under different illumination. Not clear how this is achieved in the general case.



**Again, math won't save us.**



## What do we mean by "red"

Color percepts are a composition of three factors (illumination, surface reflectance, sensor response)

Some things to think about:

- "red" typically means "appears red to a human observer under white light".
- white objects appear red under a red light.
- nothing looks red if you are red/green color blind.

"normal" color perception    red/green color blind



**perceived as a 3D scene**

**but really just a planar surface (screen) under nonuniform lighting (projector).**



## What we will be studying in thus course...

with a few examples of why.

## Filtering and Smoothing

Linear operators
Convolution
Smoothing



## Feature Extraction

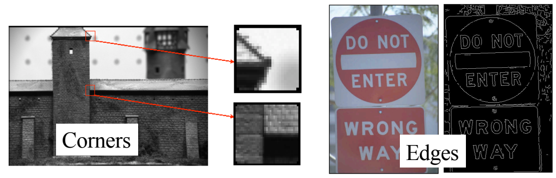
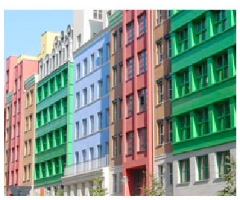


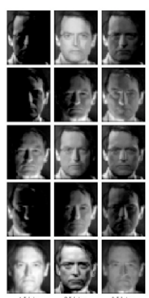

Image derivatives
Gradient operators
DoG/LoG operators
Harris corner detector

**Why?**
**Seek more unique descriptors (than pixels) for matching**



## Color and Light

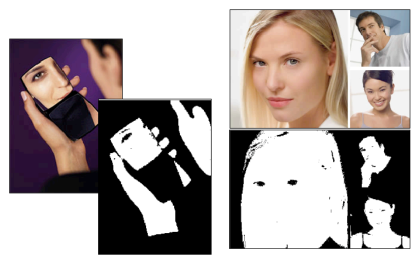





Radiance / Reflection
Illumination / Shading
Chromaticity
Color Constancy



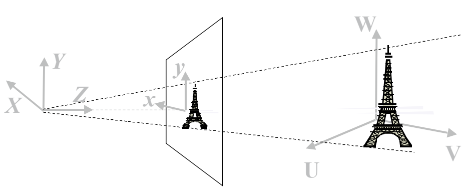
## Application : Skin Detection



Skin detection has been used for web filtering based on identifying adult content



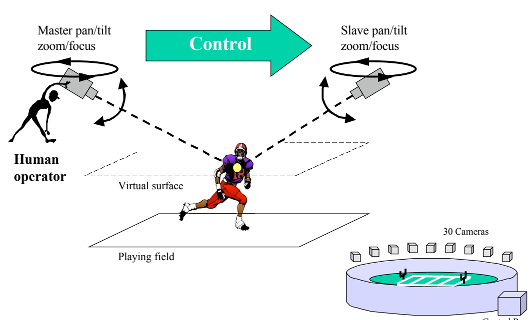
## Camera Projection Models




Projection Models
Intrinsic (lens) Paramters
Extrinsic (pose) Parameters
Camera Calibration

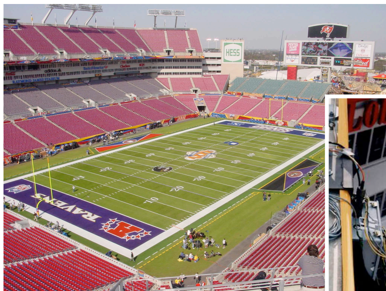


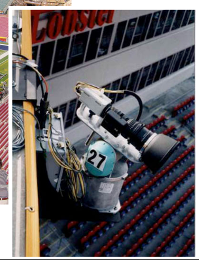
## Application: Eyevision System
## CAMERA CALIBRATION!



## Eyevision : SuperBowl XXXV

**January 28, 2001**





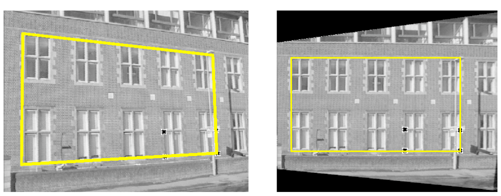


## EyeVision Examples


**Super Bowl XXXV**
**January 28, 2001**
**Courtesy of CBS Sports**



## Plane to Plane Mappings



Rigid, Similarity, Affine, & Projective Mappings
Homography Estimation
Image Warping

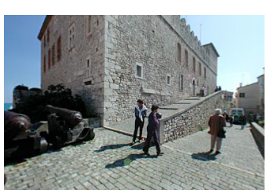


## Mosaicing and Stabilization

Camera Rotation Homography
Mosaicing
Video Stabilization



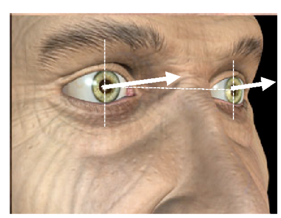
## Example : Quicktime VR



http://www.panoguide.com/gallery/

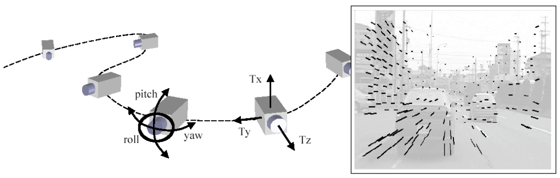


## Stereo Vision



Stereo Camera Setups
Stereo Disparity / Parallax
Epipolar Geometry
Correspondence Matching
Triangulation / Depth Recovery

## Camera Motion




Motion Field vs Optic Flow
Flow Estimation
Egomotion Estimation
Structure from Motion

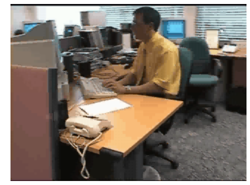


## Application: Match Move

**Track a set of feature points through a movie sequence**

**Deduce where the cameras are and the 3D locations of the points that were tracked**

**Render synthetic objects with respect to the deduced 3D geometry of the scene / cameras**



**"Graham Kimpton" example from www.realviz.com MatchMover Professional gallery. Copyrighted.**



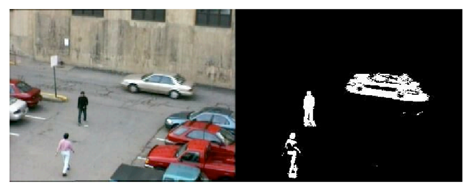
## Application: Autonomous Driving

**Have your vehicle chauffeur you around.**

**Stanley, winner 2005 Darpa Grand Challenge**



## Video Change Detection

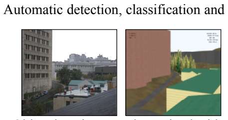


Video Sequences
Background Modeling
Change Detection

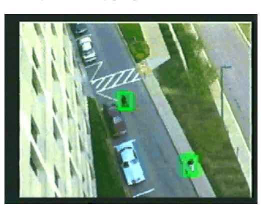


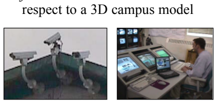
## Application: Video Surveillance

Automatic detection, classification and tracking of moving people and vehicles



Object locations are determined with respect to a 3D campus model



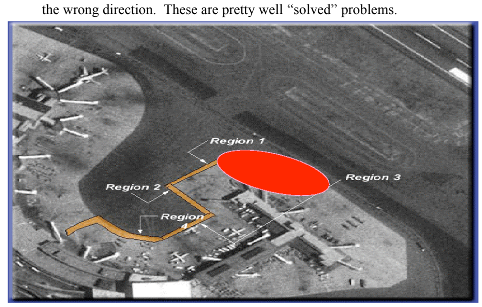


A single operator can monitor results from many sensors spread over a large area



## Automated Surveillance

Trigger regions for detecting motion and detecting motion going in the wrong direction. These are pretty well "solved" problems.

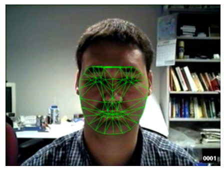



No traffic allowed in direction of terminal

No vehicle traffic when plane is docked

Guardian Systems

## Video Tracking

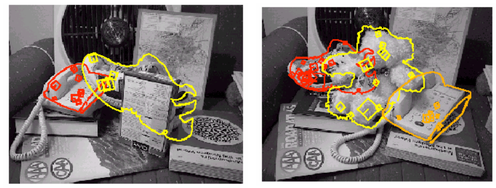


Appearance-Based Tracking
Sample Tracking Algorithms
(e.g. Mean-Shift, Lucas-Kanade)



## Object Recognition

**Library of models**



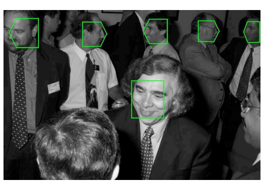
**Model matches (using Lowe's SIFT keys)**

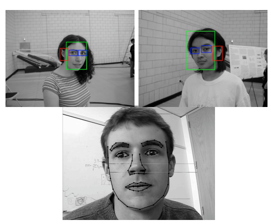
Approaches: PCA; Sift Keys; boosted cascade of detectors



## Application: Face/Eye Detection

**Henry Schneiderman**





**Finding users to interact with.**
**Red-eye removal from photos.**
**Drowsy-driver detection.**



## Reminder...

**"Vision is the act of knowing what is where by looking." --Aristotle**