# CSE 527: Intro. to Computer Vision

**www.cs.sunysb.edu/~cse527**

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## Vision

- What does it mean, to see?
  - "to know what is where by looking".
- How to discover from images
  - what is present in the world,
  - where things are,
  - what actions are taking place.

from Marr, 1982

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## Vision Problems

- Recognize objects
  - people we know
  - things we own
- Locate objects in space
  - to pick them up
- Track objects in motion
  - catching a baseball
  - avoiding collisions with cars on the road – auto navigation
- Recognize actions
  - walking, running, pushing

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## 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)
    - face finding
  - movie post-processing
  - HCI
- Various deep and attractive scientific mysteries
  - how does object recognition work?
- Greater understanding of human vision

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## Structure from Motion
### (Tomasi and Kanade 1992)



Video

Features
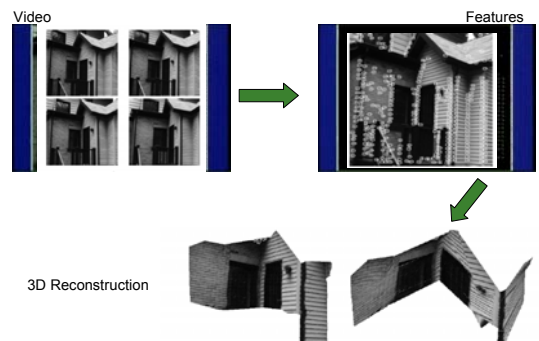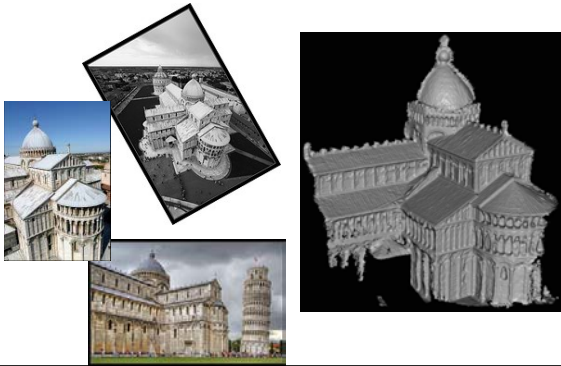
3D Reconstruction

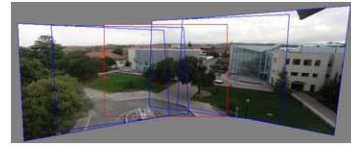## Photo Collections



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Panoramic imaging



Image and video registration



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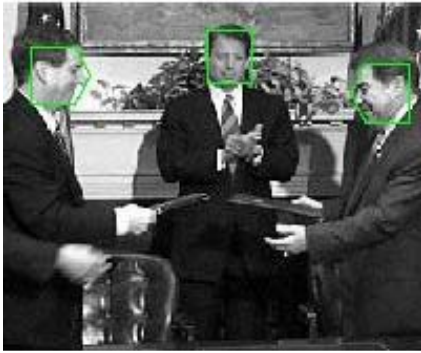- Greater understanding of human vision

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## Tracking



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http://www.ri.cmu.edu/projects/project_271.html

http://www.ri.cmu.edu/projects/project_320.html

## Nintendo Game Boy Camera

- Several million sold (most of any digital camera). Imaging chip is Mitsubishi Electric's "Artificial Retina" CMOS detector.



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## Detect ground plane in video and introduce pictures on them
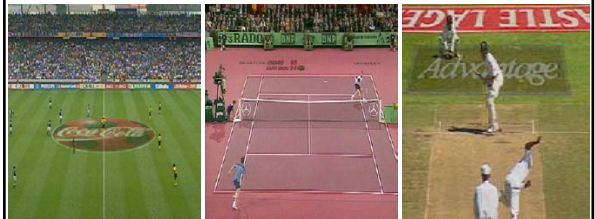


## Insert new objects



Video example: **http://break.com/index/ufo-lands-on-guys-desk.html**

## Video Summary

## Black or White

- Face Detection
- Face Localization
- Segmentation
- Face Tracking
- Facial features localization
- Facial features tracking
- Morphing

www.youtube.com/watch?v=ZI9OYMRwN1Q



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## Game: Decathlete
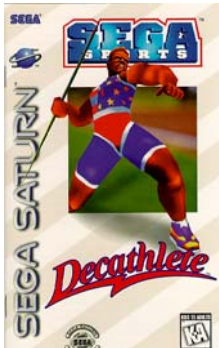


## Optical-flow-based Decathlete figure motion analysis
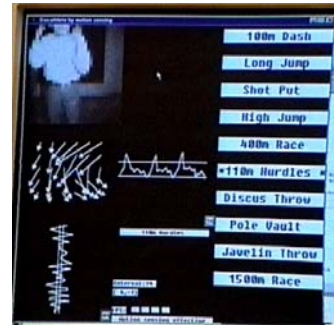


## Decathlete javelin throw



## Decathlete javelin throw

## Decathlete 100m hurdles



## Course Outline

- Introduction and Math Review
  - What is Computer Vision?
  - Tutorial on Linear Algebra and Matlab
- PART I: 2D Vision
  - Image Formation
  - Appearance-Based Methods
  - Feature Extraction
  - 2D Shape Models
- PART II: 3D Vision
  - 3D Shape Estimation from Shading, from Motion
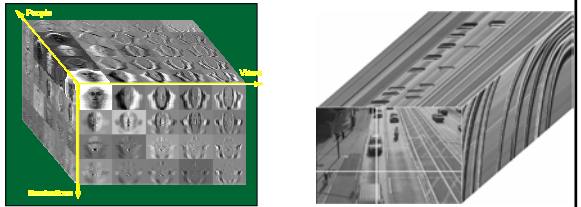  - Surface Reconstruction

## PART I: 2D Vision

- Image Formation
  - Cameras, Lenses, and Sensors
  - Color and Image Statistics
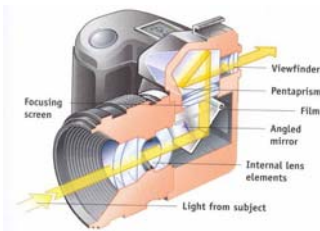


## PART I: 2D Vision

- Appearance-Based Methods
  - Statistical Linear Models: PCA, ICA, FLD
  - Non-negative Matrix Factorization, Sparse Matrix Factorization
  - Statistical Tensor Models: Multilinear PCA, Multilinear ICA
  - Person and Activity Recognition



## PART I: 2D Vision



- Feature Extraction:
  - Linear filters and edges
  - Feature extraction (corners and blobs)
  - Representations: Gaussian Pyramids, Laplacian Pyramids, Steerable Pyramids
  - Application: face detection
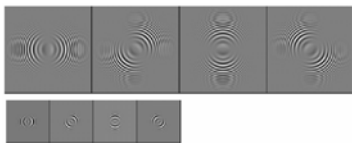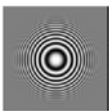


*Image*

*Oriented, multi-scale representation*

## PART I: 2D Vision

- 2D Shape Models
  - Physically Based Models:
    - Mass-Spring Systems
    - Active Contours (Snakes) - energy minimization, regularization
      *www.youtube.com/watch?v=5se69vcbqxA*
  - Statistical Shape Models
  - Active Shape Models
  - Active Appearance Models
  - Kalman Filters
  - Particle Filters
  - Mean Shift

## PART II: 3D Vision

- Estimation of 3D Geometry:
  - Camera calibration, Epipolar Geometry
  - Stereo, Multi-View Geometry
  - Shape from Shading
  - Structure from Motion, Optical Flow
  - Surface Reconstruction – energy minimization, regularization
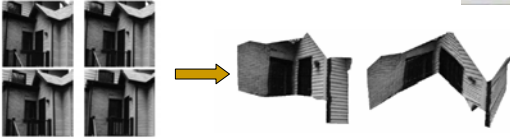
## General Comments

- Prerequisites:
  - Linear Algebra!!!
  - Some image processing, signal processing is useful, but not required

- Emphasis on programming projects!
  - Building something from scratch (Matlab!)

- Textbooks and Reading material:
  - Computer Vision: A Modern Approach, David Forsyth and Jean Ponce., Prentice Hall, 2003.
  - Robot Vision, Berthold Horn
  - Selected journal articles

## Grading

| | | |
|---|---|---|
| Problem Sets (~6) with lab exercises in Matlab. Problem sets may be discussed, but all written work and coding must be done individually. | 40% | 60% |
| One take-home exam. (Take-home exams may not be discussed.) | 20% | 0% |
| Class Participation | 10% | 10% |
| Final Project: <br> ▫An original implementation of a new or published idea <br> ▫A detailed empirical evaluation of an existing implementation of one or more methods <br> ▫5-10 page report <br> Project proposal not longer than two pages must be submitted and approved before the end of March. | 30% | 30% |

## Administrative Stuff

- Late Policy
  - Seven late days total, to be spent wisely
- Cheating
  - Let's not embarrass ourselves
  - All resources must be acknowledged
- Software
  - MATLAB!!!

## Internet Resources

- Matlab:
  - University of Colorado Matlab Tutorials
    - A decent collection of Matlab tutorials, including one focusing on image processing.
  - Matlab Image Processing Tutorial
    - A short introduction to the manipulation of images in Matlab, including an introduction to principal components analysis via eigenfaces.

- Computer Vision:
  - Computer Vision Homepage
  - Face Recognition Homepage
  - Face Detection Homepage

## Introductions

- Name, year, supervisor
- Why do you want to take this class?
- What are you hoping to learn?