Cameras everywhere
Facial recognition technology is improving by leaps and bounds. Some commercial software can now tell the gender of a person in a photograph.

When the person in the photo is a white man, the software is right 99 percent of the time.

But the darker the skin, the more errors arise — up to nearly 35 percent for images of darker skinned women, according to a new study that breaks fresh ground by measuring how the technology works on people of different races and gender.
What is vision?

“What does it mean, to see? The plain man's answer (and Aristotle's, too) would be, to know what is where by looking.”

— David Marr, 1982
Computational Photography
Biometrics

- "the most recognized photograph" in the history of the National Geographic magazine
- No one knew her identity…

1984
Biometrics

1984  2002
Optical Character Recognition
“The work was painstaking and mind-numbing: One agent watched the same segment of video 400 times. The goal was to construct a timeline of images, following possible suspects as they moved along the sidewalks. It took a couple of days” Washington Post
Health
Gaming
Shopping
Special Effects
Visual Search
Self-driving Cars
Space Exploration
Augmented Reality
Worldwide Insight

Walmart in Wichita, Kansas
What is vision?

Slide credit: Kristen Grauman
Image Formation

Object

Film
Image Formation

Add a barrier to block off most of the rays
Representing Digital Images

Slide credit: Deva Ramanan
Representing Digital Images
Representing Color Images

Color images, RGB color space
THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".
Illumination

“Neither Autopilot nor the driver noticed the white side of the tractor trailer against a brightly lit sky, so the brake was not applied.” — Tesla Company Blog
Occlusion

René Magritte, 1957
Class Variation
Clutter and Camouflage
Color
Motion

Slide credit: S. Lazebnik
Ill-posed Problem

[Sinha and Adelson 1993]
Ill-posed Problem
Ill-posed Problem
Cambrian Explosion
Cambrian Explosion

"The Cambrian Explosion is triggered by the sudden evolution of vision," which set off an evolutionary arms race where animals either evolved or died. — Andrew Parker

Slide credit: Fei-Fei Li
Evolution of Biological Eye

- A region of photosensitive cells
- A depressed/folded area allows limited directional sensitivity
- "Pinnole" eye allows finer directional sensitivity and limited imaging
- Transparent humor develops in an enclosed chamber
- Distinct lens develops
- Iris and separate cornea develop

Key structures:
- Nerve fibres
- Photoreceptors
- Water-filled chamber
- Area of photoreceptors/retina
- Retina
- Transparent humor
- Cornea
- Lens
- Aqueous humor
- Vitreous humor
A quick experiment
Animals or Not?

150 ms !!
Why not build a brain?

About 1/3rd of the brain is devoted to visual processing

[picture from Simon Thorpe]
Do we have the hardware?

$10^{11}$ parallel neurons

$10^8$ serial transistors
We don’t know the software

[picture from Simon Thorpe]
Adelson Illusion
Illusionary Motion

Copyright A. Kitaoka 2003
Scale Ambiguity
The Ames Room
The Ames Room

(Effect used in Lord of the Rings)
Heider-Simmel Illusion
What objects are here?
Context
Context
Tool 1: Physics and Geometry

Photo Tourism
Exploring photo collections in 3D

Noah Snavely  Steven M. Seitz  Richard Szeliski
University of Washington  Microsoft Research

SIGGRAPH 2006
Tool 2:
Data and Learning
Two Extremes of Vision

Extrapolation problem
- Generalization
- Diagnostic features

Interpolation problem
- Correspondence
- Finding the differences

Number of training samples

Slide credit: Aude Oliva
Evolution of Vision Datasets

Created here in 1996

- COIL-20
- Caltech 101
- MNIST (1998)
- PASCAL (2005)
- IMAGENET (2009)
- 2 year old kid

# images

Slide credit: Aude Oliva
Course Information

Computer Vision
Fall 2018
Columbia University
About Me

UC Irvine
About Me

UC Irvine → MIT
About Me

UC Irvine
Google
MIT
Columbia
What about you?

- Major?
- Year?
- Research area?
Staff and Office Hours

• **Carl Vondrick**
  Office Hours: Monday 4:30pm to 5:30pm
  CSB 502 (temporary)

• TAs:
  • **Oscar**: TBA
  • **Xiaoning**: Monday, 5-6pm, CS TA Room
  • **Bo**: Tuesday, 3-4pm, CS TA Room
  • **James**: TBA
  • **Luc**: TBA
FAQ: Can you add me?

- We’re at capacity: 110 people enrolled
- 200 people on wait list
- If you don’t plan to take class, please drop soon
FAQ: Do I need to know C?

- No. The problem sets will use Python.
- Familiarity with linear algebra and calculus will be helpful but not required.
FAQ: How to contact you?

• No emails — please use Piazza

• You can send private messages on Piazza

• Course staff goes offline 7pm to 10am and weekends
<table>
<thead>
<tr>
<th>#</th>
<th>Date</th>
<th>Topic</th>
<th>Reading</th>
<th>Assignments</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Sep 5</td>
<td>Introduction</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><strong>Image Processing</strong></td>
<td></td>
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<tr>
<td>2</td>
<td>Sep 10</td>
<td>Image Processing I</td>
<td></td>
<td>HW1 Out</td>
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<tr>
<td>3</td>
<td>Sep 12</td>
<td>Image Processing II</td>
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<td><strong>Cameras and Physics</strong></td>
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<td>4</td>
<td>Sep 17</td>
<td>Image Formation</td>
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<td>5</td>
<td>Sep 19</td>
<td>Image Sensing</td>
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<td>6</td>
<td>Sep 24</td>
<td>Radiometry and Reflectance</td>
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<td>HW1 Due, HW2 Out</td>
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<td><strong>Recognition and Matching</strong></td>
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<tr>
<td>7</td>
<td>Sep 26</td>
<td>Grouping: Edges and Boundaries</td>
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<tr>
<td>8</td>
<td>Oct 1</td>
<td>Image Alignment and Stitching</td>
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<td>9</td>
<td>Oct 3</td>
<td>2D Recognition using SIFT</td>
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<td>10</td>
<td>Oct 8</td>
<td>Learning-based Vision I</td>
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<td>HW2 Due, HW3 Out</td>
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<tr>
<td>11</td>
<td>Oct 10</td>
<td>Learning-based Vision II</td>
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<tr>
<td>12</td>
<td>Oct 15</td>
<td>Object and Face Detection</td>
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<td>13</td>
<td>Oct 17</td>
<td>Image Segmentation</td>
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<td>Date</td>
<td>Day</td>
<td>Topic</td>
<td>Notes</td>
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<td>14</td>
<td>Oct 22</td>
<td>Photometric Stereo</td>
<td>HW3 Due, HW4 Out</td>
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<td>15</td>
<td>Oct 24</td>
<td>Shape from Shading</td>
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<td>16</td>
<td>Oct 29</td>
<td>Depth from Focus/Defocus</td>
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<td>17</td>
<td>Oct 31</td>
<td>Camera Calibration and Simple Stereo</td>
<td>Project Proposal Due</td>
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<td>-</td>
<td>Nov 5</td>
<td>Academic Holiday</td>
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<tr>
<td>18</td>
<td>Nov 7</td>
<td>Uncalibrated Stereo</td>
<td>HW4 Due, HW5 Out</td>
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**Video**

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<th>Day</th>
<th>Topic</th>
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<tbody>
<tr>
<td>19</td>
<td>Nov 12</td>
<td>Motion and Optical Flow</td>
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<tr>
<td>20</td>
<td>Nov 14</td>
<td>Object Tracking</td>
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<tr>
<td>21</td>
<td>Nov 19</td>
<td>Structure from Motion</td>
<td>HW5 Due</td>
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<tr>
<td>-</td>
<td>Nov 21</td>
<td>Academic Holiday (Thanksgiving)</td>
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**Frontiers**

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<th>Date</th>
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<tr>
<td>22</td>
<td>Nov 26</td>
<td>Vision, Sound, and Touch</td>
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<tr>
<td>23</td>
<td>Nov 28</td>
<td>Unsupervised and Transfer Learning</td>
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<tr>
<td>24</td>
<td>Dec 3</td>
<td>Bias and Ethics</td>
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<tr>
<td>25</td>
<td>Dec 5</td>
<td>Project Presentations</td>
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<tr>
<td>26</td>
<td>Dec 10</td>
<td>Project Presentations</td>
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Grading

- 60% Problem Sets
- 40% Final Project
- No exams or quizzes
Problem Sets

- 5 problem sets, equally weighted

- Turn in via CourseWorks before class starts. Submit both PDF writeup and code online.

- One problem set may be a week late. No other extensions.

- Solutions available during TA office hours.

- Done individually, but you can have high-level discussion in pairs. Write up assignments individually.
Final Project

• Individually or pairs (recommended)

• Final poster presentations: **Dec 5 and Dec 10**

• 4 page report in CVPR format

• Suggested projects and grading rubric to be announced
Academic Honesty

• Academic dishonesty may result in...
  • You fail course.
  • We refer your case to the Dean’s office.
Readings (Optional)

http://szeliski.org/Book/
New Course

• Feedback appreciated.

• Please let us know if something works or not!
Deep Learning to Learn

SEPT. 10, 2018 (MONDAY)
11:30AM–12:30PM
DAVIS AUDITORIUM
(412 CEPSR)

Pieter Abbeel (UC Berkeley)
Next Class: Linear Filters