Introduction

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What is computer vision?

- Analysis of digital images by a computer.
- Stockman and Shapiro: making useful decisions about real physical objects and scenes based on sensed images.
- Trucco and Verri: computing properties of the 3D world from one or more digital images.
- Ballard and Brown: 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 study computer vision?

- Possibility of building intelligent machines is fascinating.
- Capability of understanding the visual world is a prerequisite for such machines.
- Much of the human brain is dedicated to vision.
- Humans solve many visual problems effortlessly, yet we have little understanding of visual cognition.

Why study computer vision?

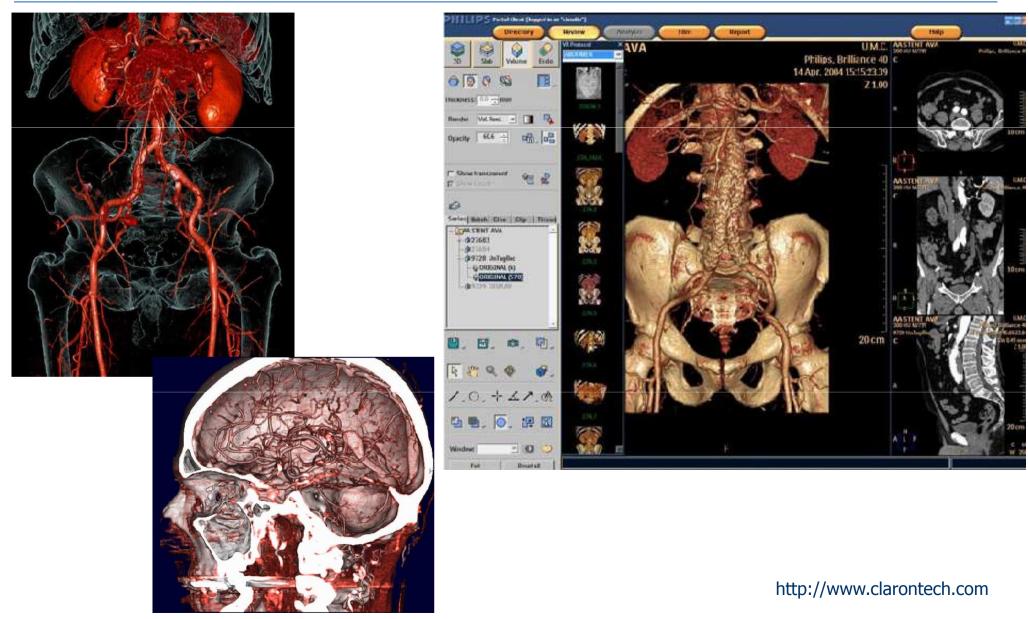
- An image is worth 1000 words.
- Images and videos are everywhere.
- Fast growing collections and many useful applications.
- Goals of vision research:
 - Give machines the ability to understand scenes.
 - Aid understanding and modeling of human vision.
 - Automate visual operations.

Applications

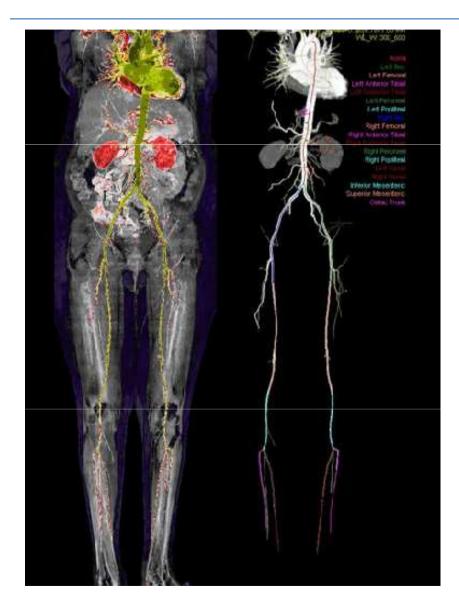
- Medical image analysis
- Security
 - Biometrics
 - Surveillance
 - Tracking
 - Target recognition
- Remote sensing
- Robotics

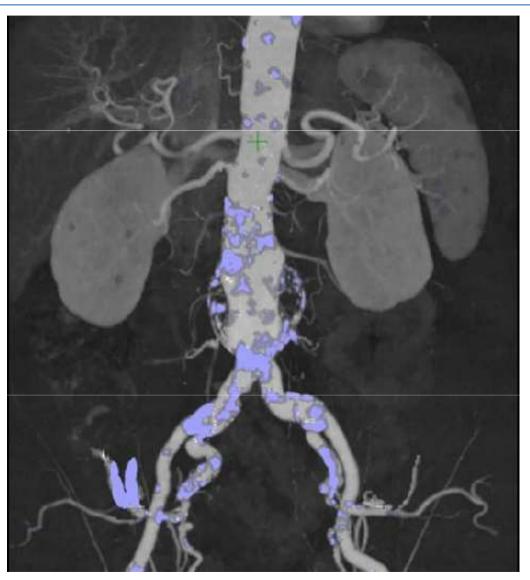
- Industrial inspection, quality control
- Document analysis
- Multimedia
- Assisted living
- Human-computer interfaces



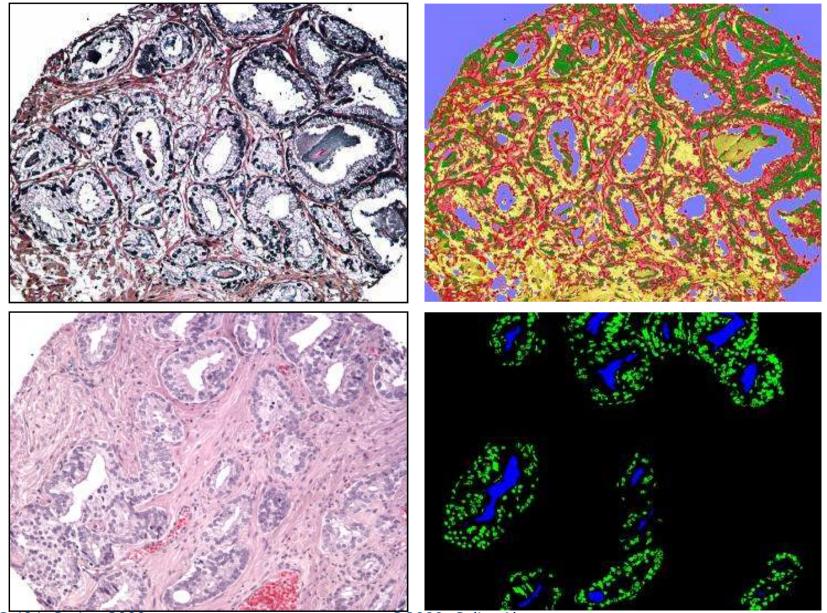


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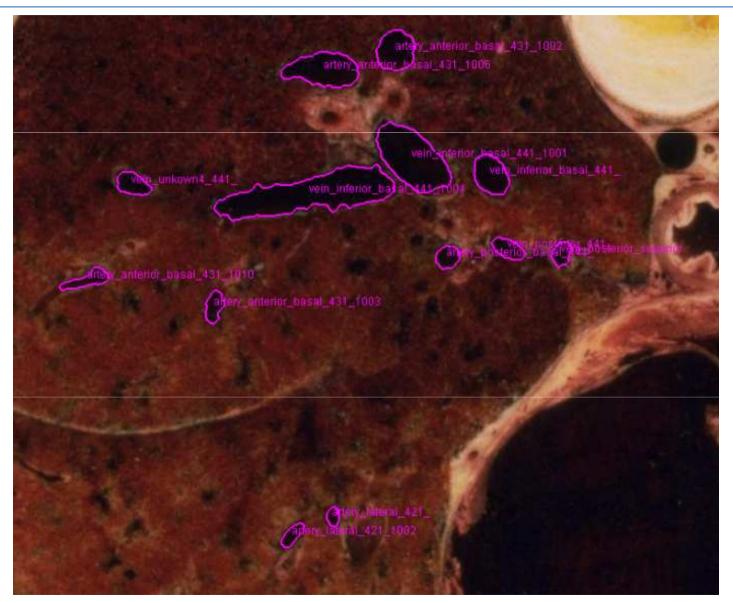
http://www.clarontech.com



Cancer detection and grading

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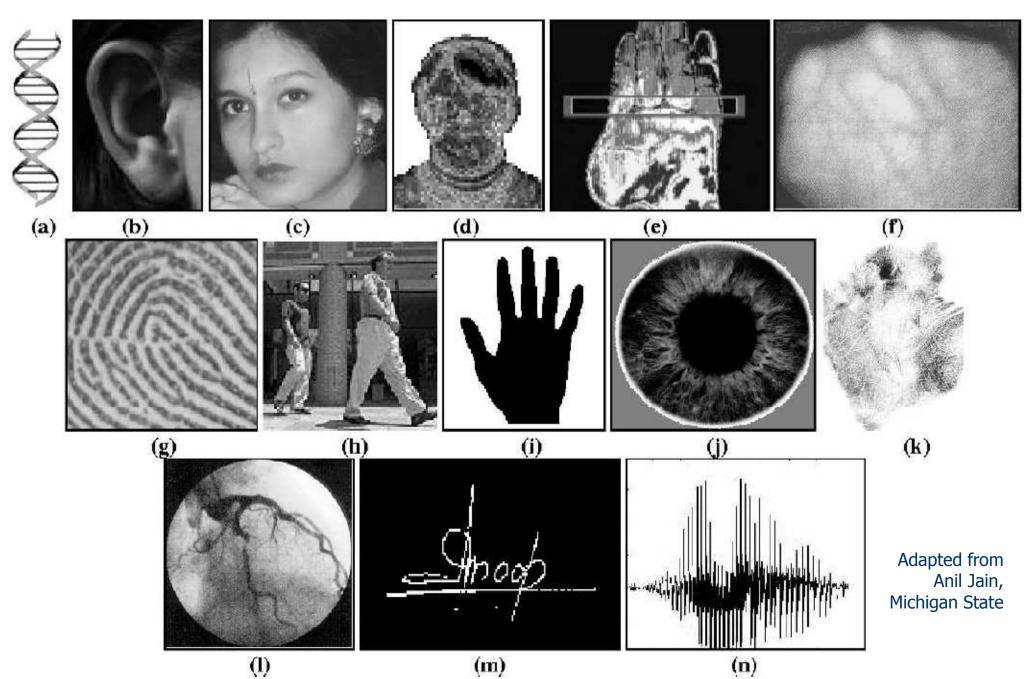
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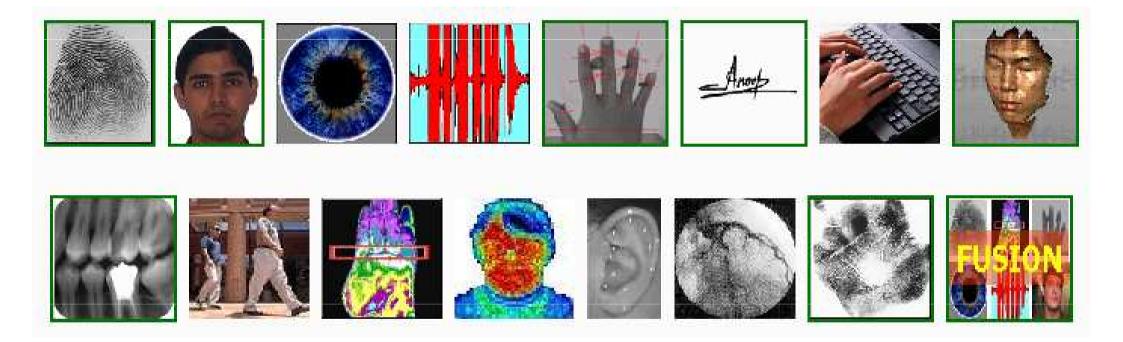
Slice of lung

Adapted from Linda Shapiro, U of Washington

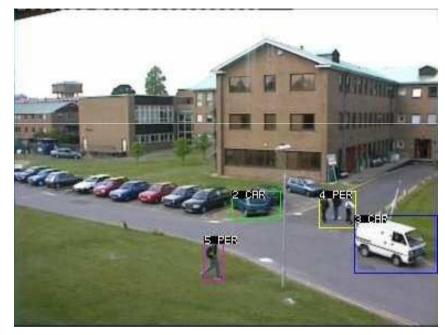
Biometrics

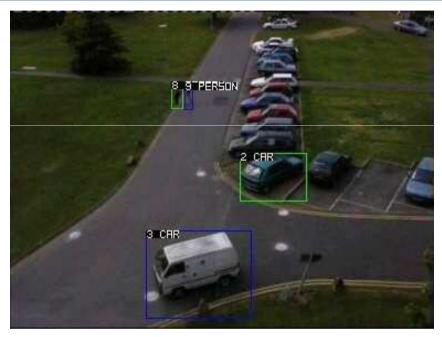


Biometrics

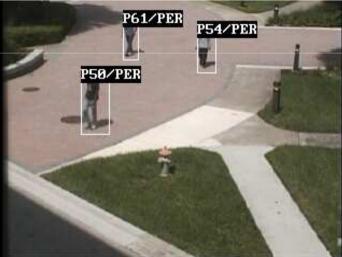


Adapted from Anil Jain, Michigan State



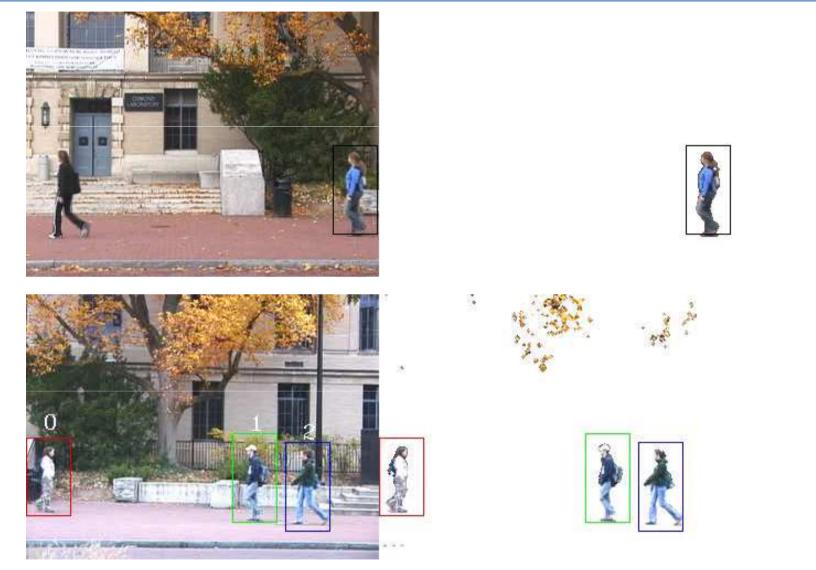




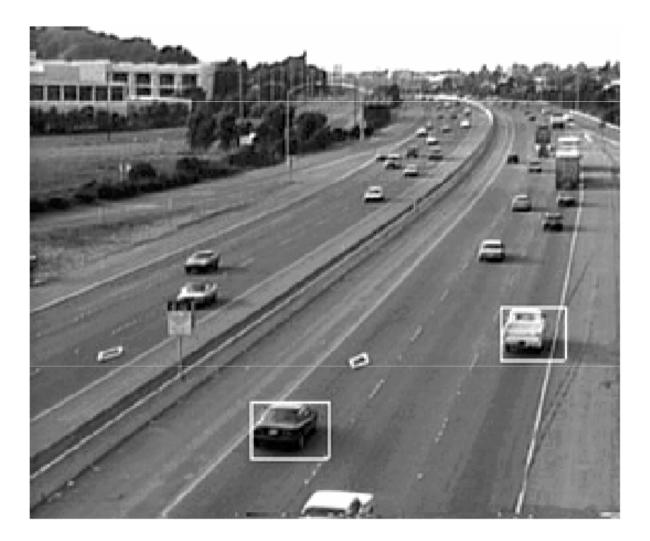


University of Central Florida, Computer Vision Lab

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Adapted from Octavia Camps, Penn State



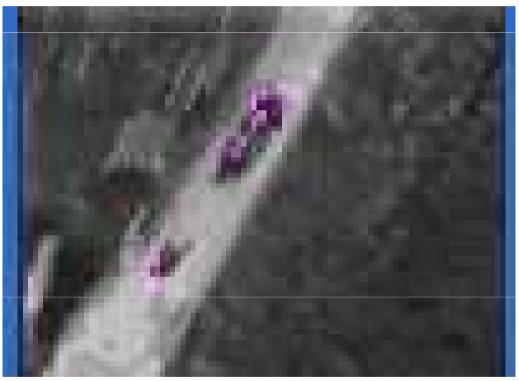
Adapted from Martial Hebert, CMU



Generating traffic patterns

University of Central Florida, Computer Vision Lab





Tracking in UAV videos

Adapted from Martial Hebert, CMU, and Masaharu Kobashi, U of Washington

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Vehicle and pedestrian protection



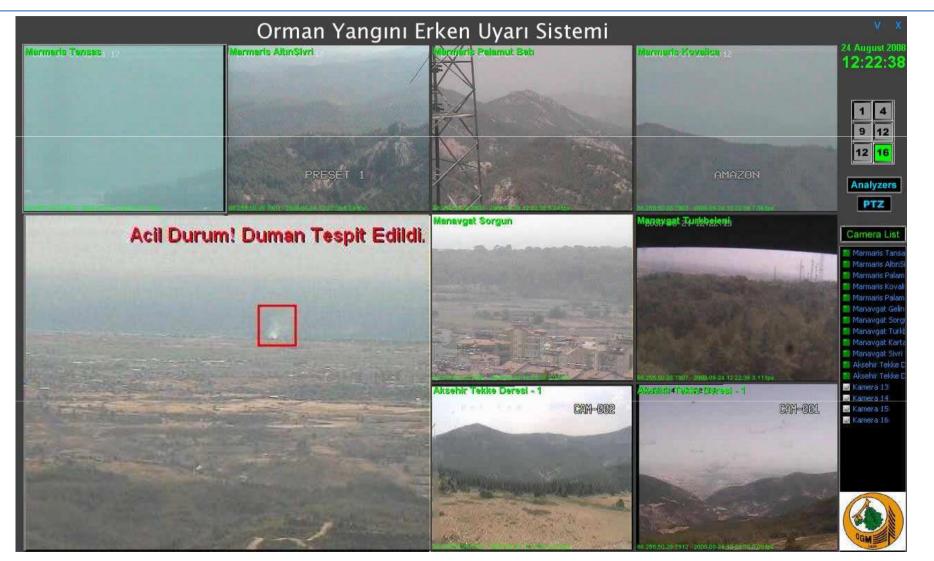
Lane departure warning, collision warning, traffic sign recognition, pedestrian recognition, blind spot warning

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http://www.mobileye-vision.com

Forest fire monitoring system



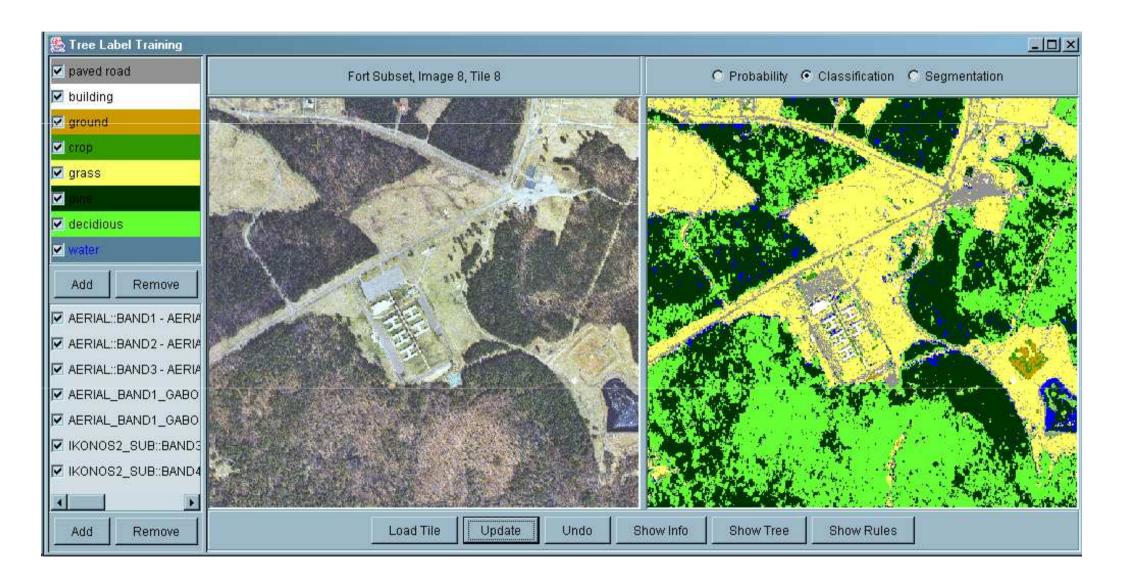
Early warning of forest fires

Adapted from Enis Cetin, Bilkent University

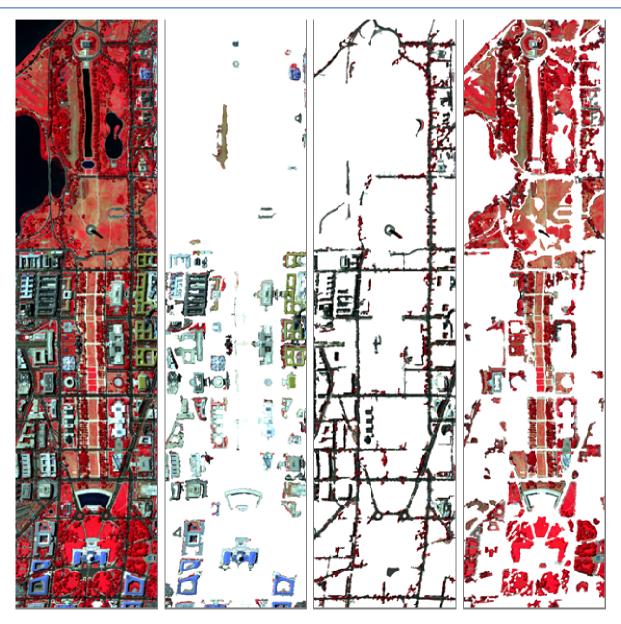
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Land cover classification



Object recognition



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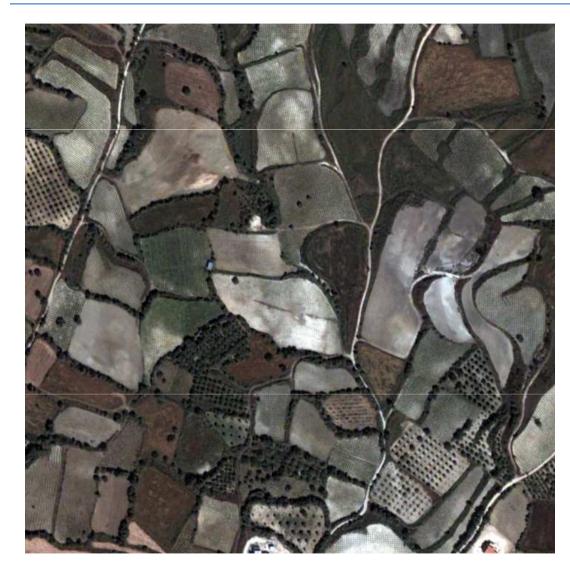
©2009, Selim Aksoy

Object recognition



Recognition of buildings and building groups

Object recognition



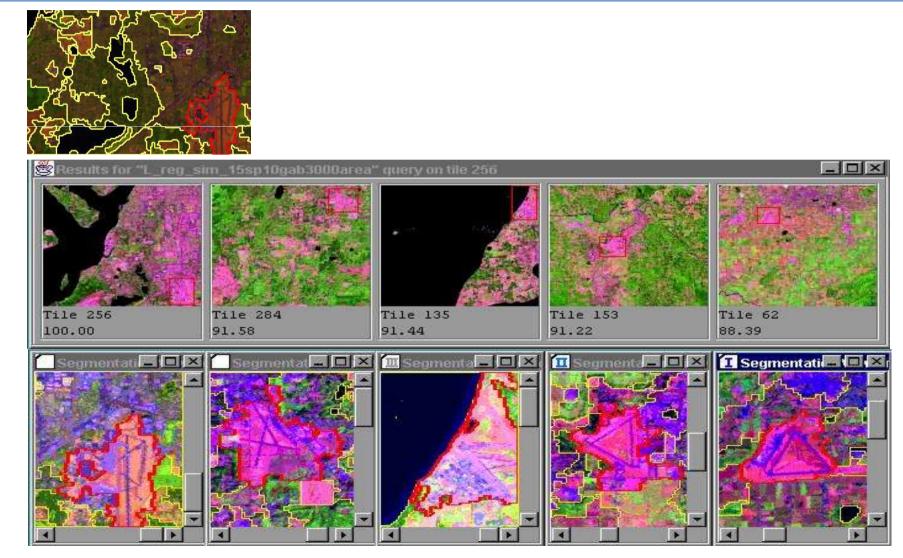
Automatic mapping; agriculture





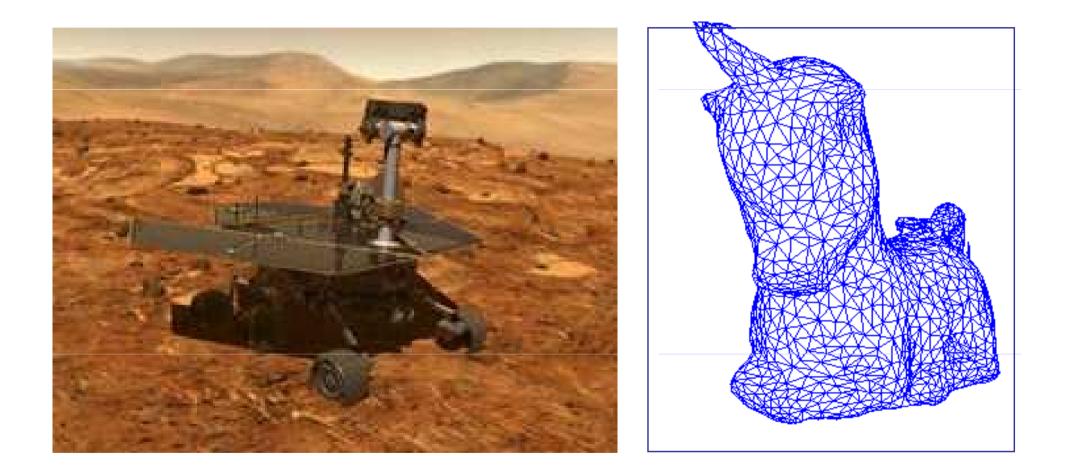
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Content-based retrieval



Finding similar regions: airports

Robotics



Adapted from Linda Shapiro, U of Washington

Robotics



Adapted from Steven Seitz, U of Washington

Autonomous navigation



Michigan State University





General Dynamics Robotics Systems http://www.gdrs.com

Industrial automation



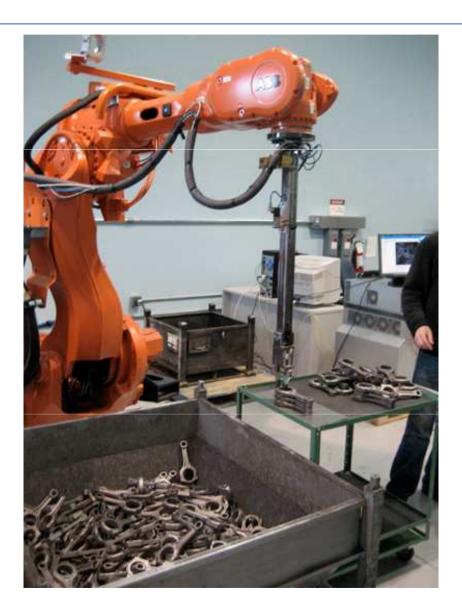




Automatic fruit sorting

Color Vision Systems http://www.cvs.com.au

Industrial automation



Industrial robotics; bin picking

http://www.braintech.com

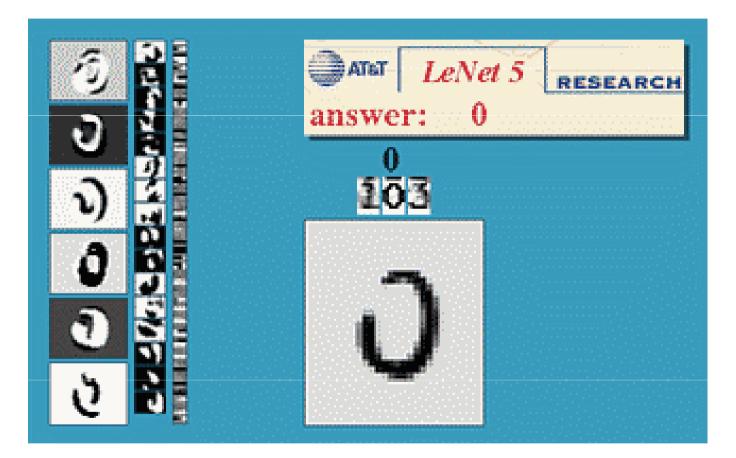
Postal service automation





General Dynamics Robotics Systems http://www.gdrs.com

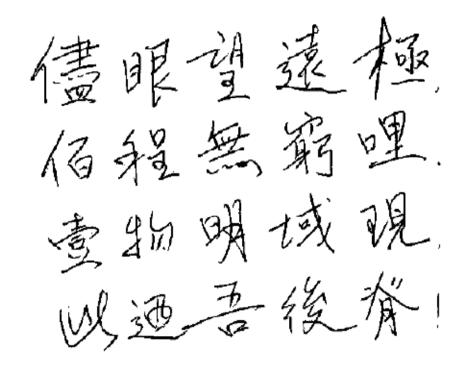
Document analysis



Digit recognition, AT&T labs http://www.research.att.com/~yann

Adapted from Steven Seitz, U of Washington

Document analysis

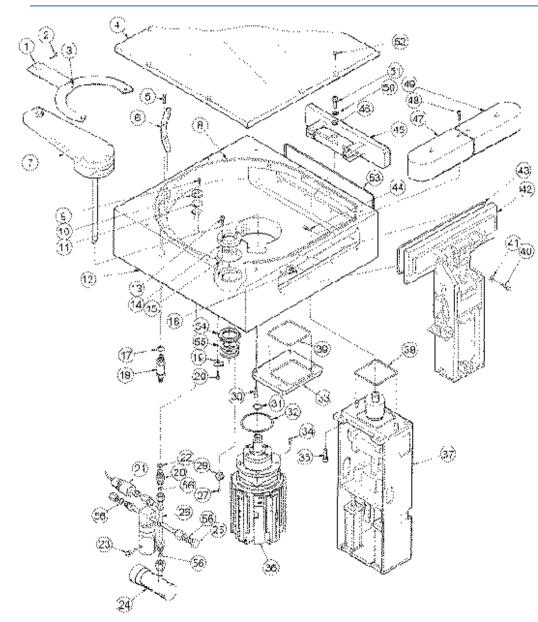


I looked as hard as I could see, beyond 100 plus infinity an object of bright intensity - it was the back of me!

Figure 1.5: (Left) Chinese characters and (right) English equivalent. Is it possible that a machine could automatically translate one into the other? Chinese characters and poem courtesy of John Weng.

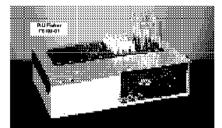
Adapted from Shapiro and Stockman

Document analysis



CMS/Fisher HealthCare

Blood Bank /Dylmbans



Model 145 Isotemp* Dry Bath Incubator

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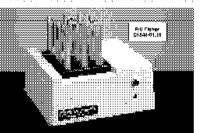
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Model 147 Isotemp" Dry Balb

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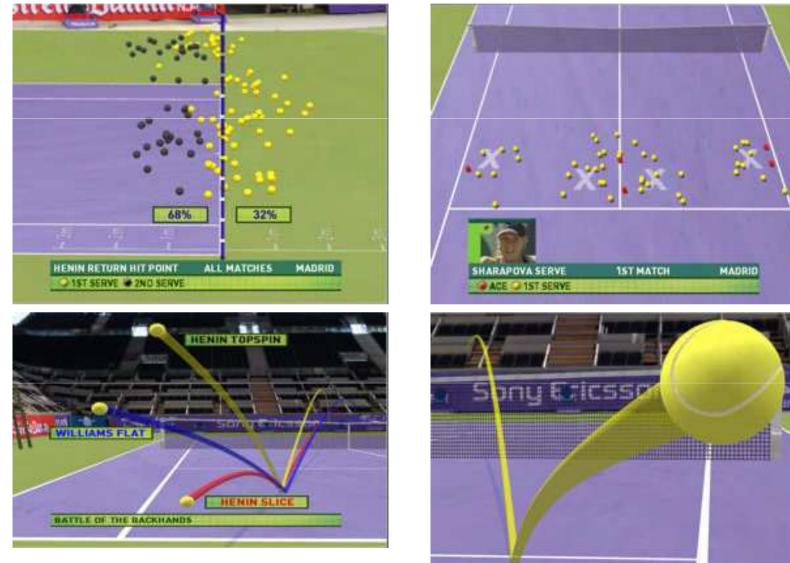
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Adapted from Linda Shapiro, U of Washington

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Sports video analysis



Tennis review system

http://www.hawkeyeinnovations.co.uk

SPEED 144 KPH

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SHARAPOVA FOREHAND WINNER

Scene classification



Organizing image archives

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Photo tourism: exploring photo collections

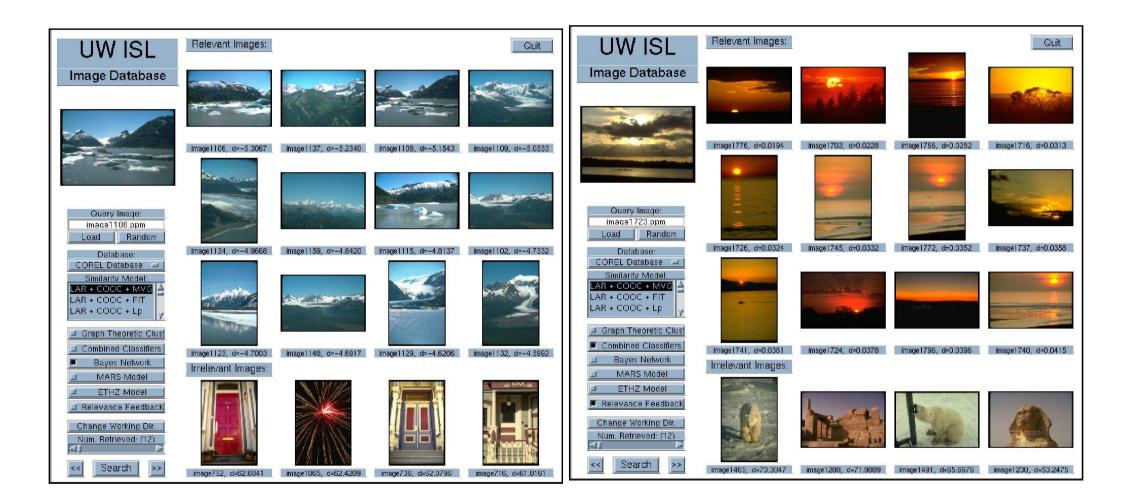


Building 3D scene models from individual photos

Adapted from Steven Seitz, U of Washington

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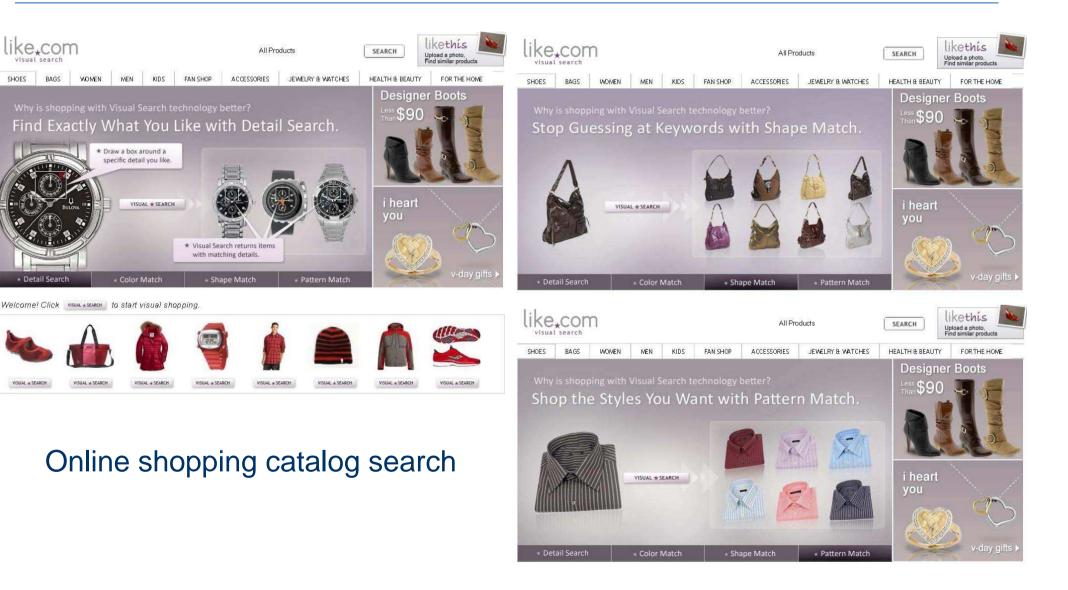
Content-based retrieval



Content-based retrieval

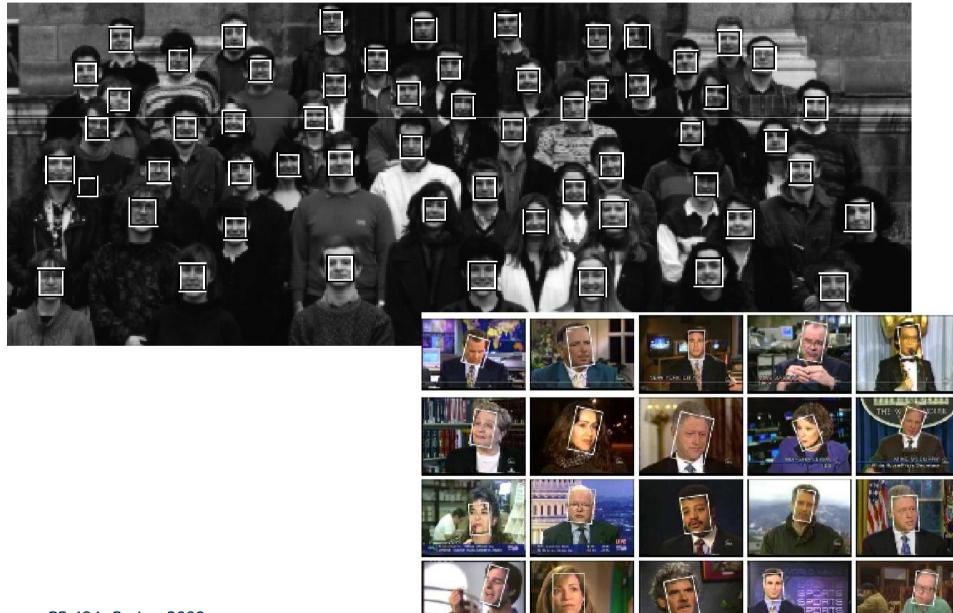
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Content-based retrieval



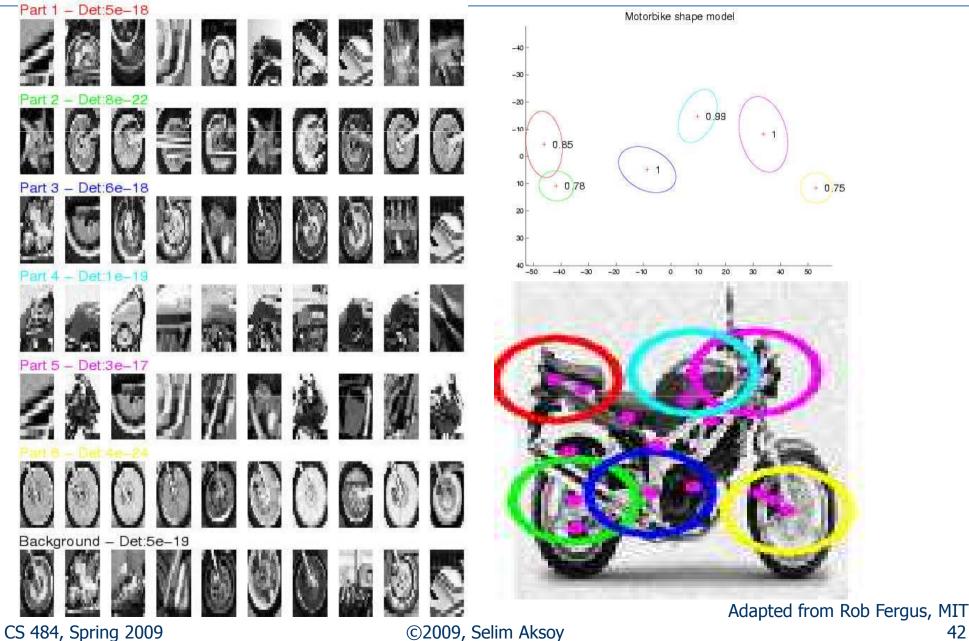
http://www.like.com

Face detection and recognition

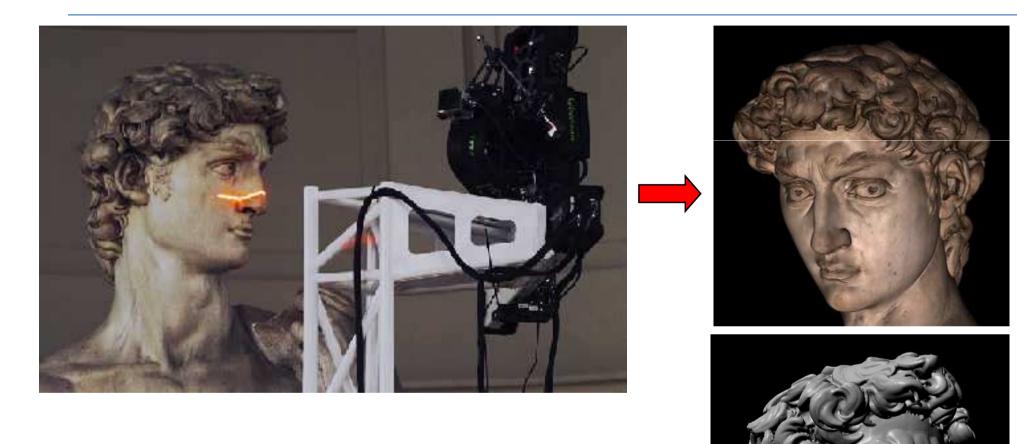


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Object recognition



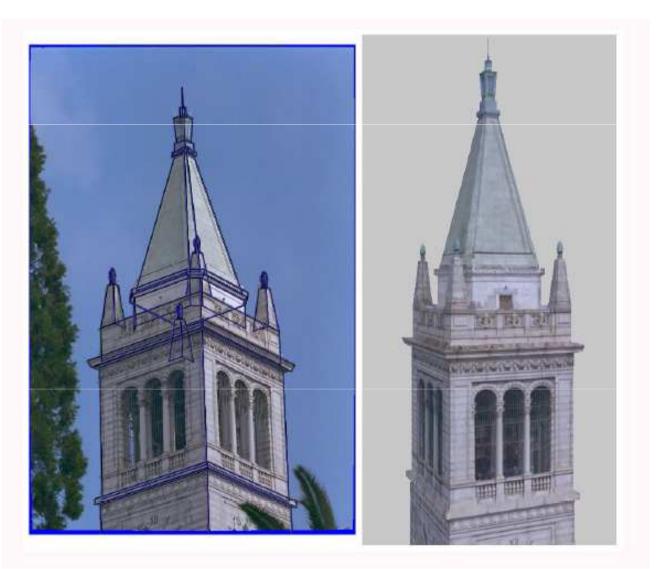
3D scanning



Adapted from Linda Shapiro, U of Washington

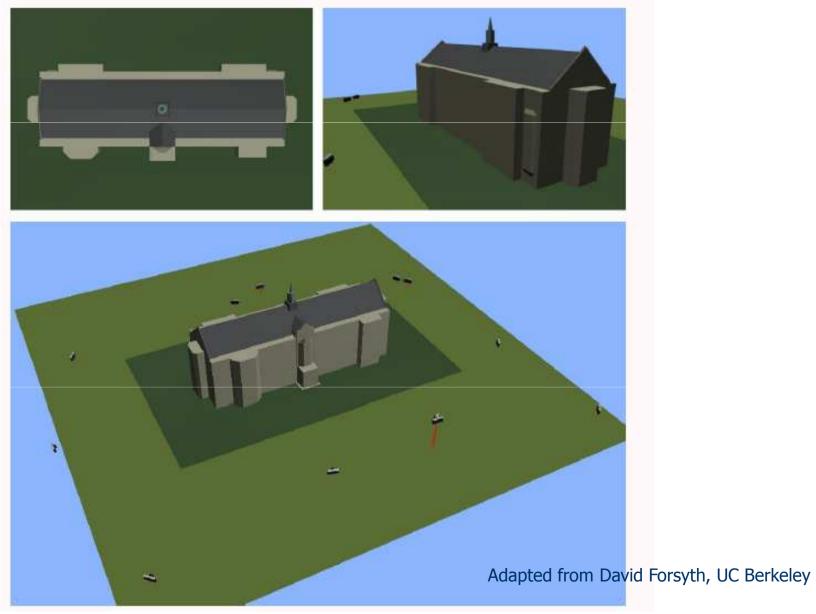
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3D reconstruction



Adapted from David Forsyth, UC Berkeley

3D reconstruction



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Motion capture



Adapted from Linda Shapiro, U of Washington

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Visual effects



Adapted from Linda Shapiro, U of Washington

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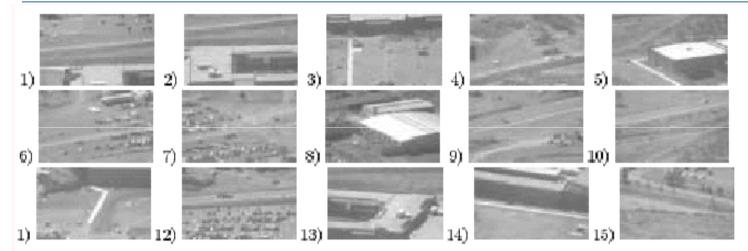
Mozaic





Adapted from David Forsyth, UC Berkeley

Mozaic



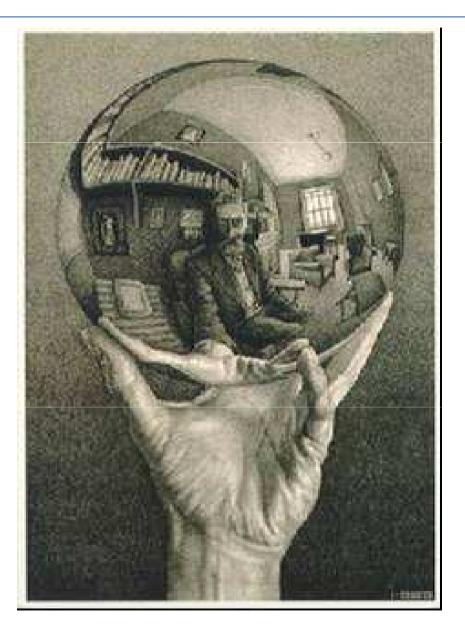


Adapted from David Forsyth, UC Berkeley

Critical issues

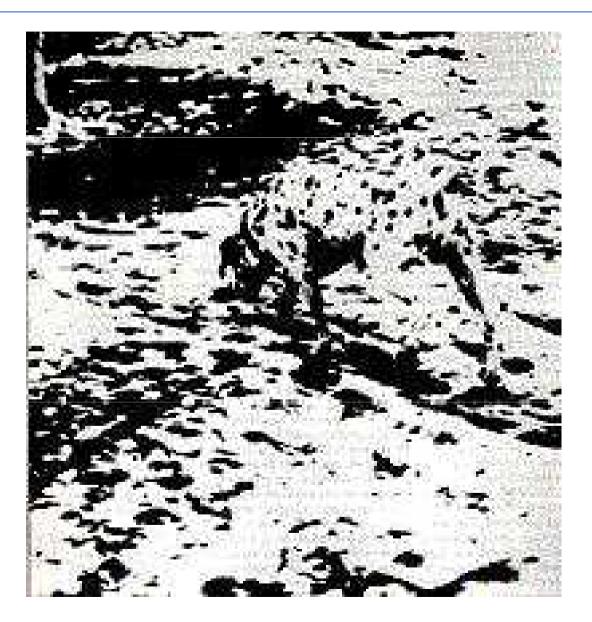
- What information should be extracted?
- How can it be extracted?
- How should it be represented?
- How can it be used to aid analysis and understanding?

Challenge

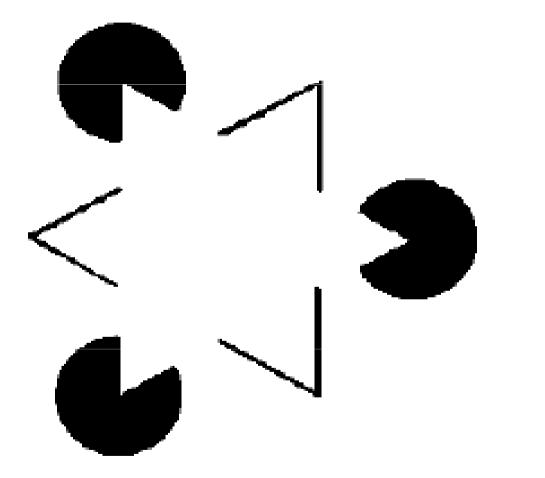


What do you see in the picture?

- A hand holding a man
- A hand holding a shiny sphere
- An Escher drawing

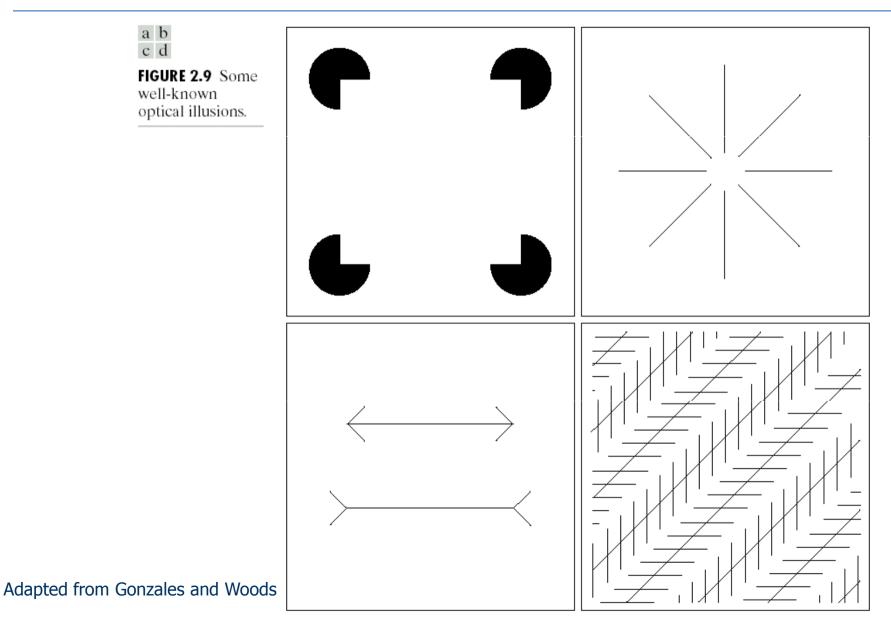


Subjective contours

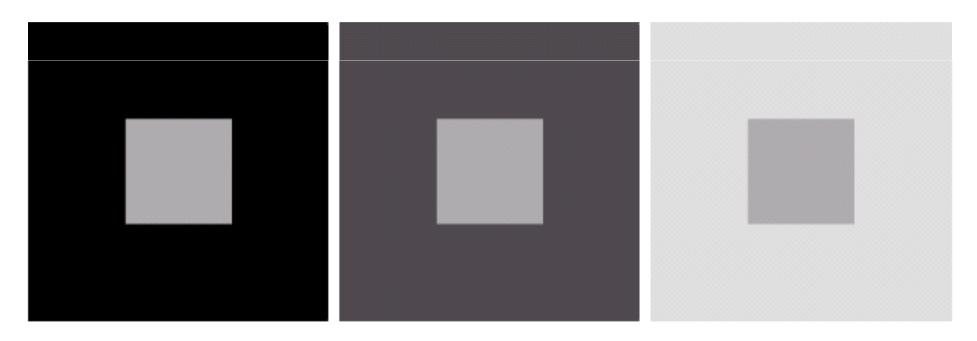


Subjective contours

Adapted from Michael Black, Brown University



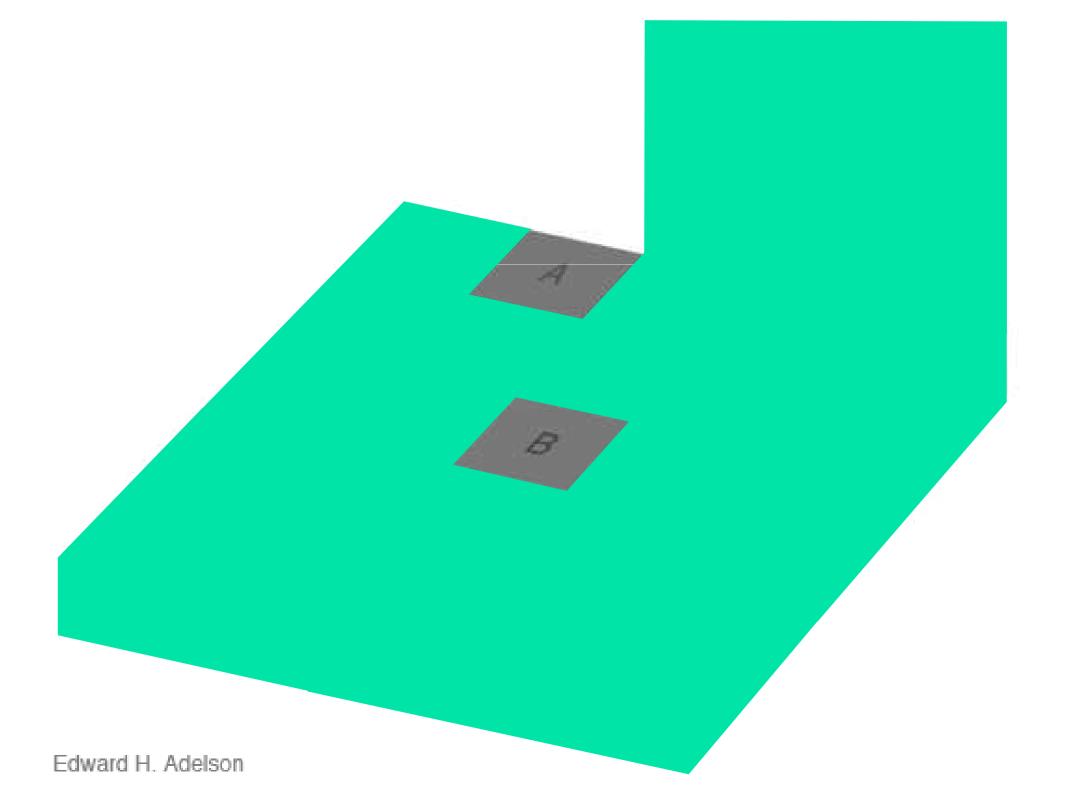
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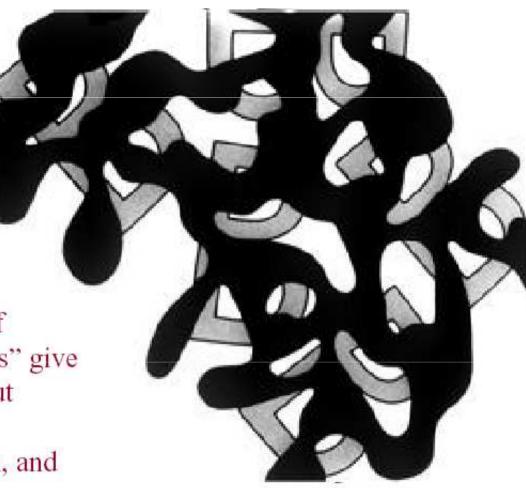


a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Adapted from Gonzales and Woods



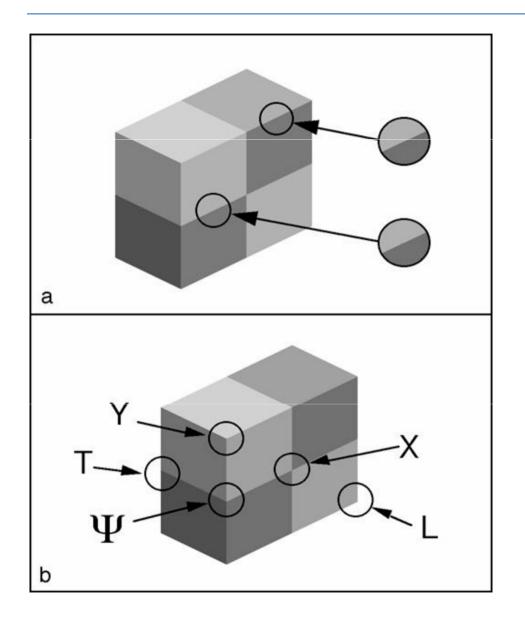


Occlusion

* types of "junctions" give cues about surfaces, occlusion, and light.

I. Rock, The Logic of Perception, 1983.

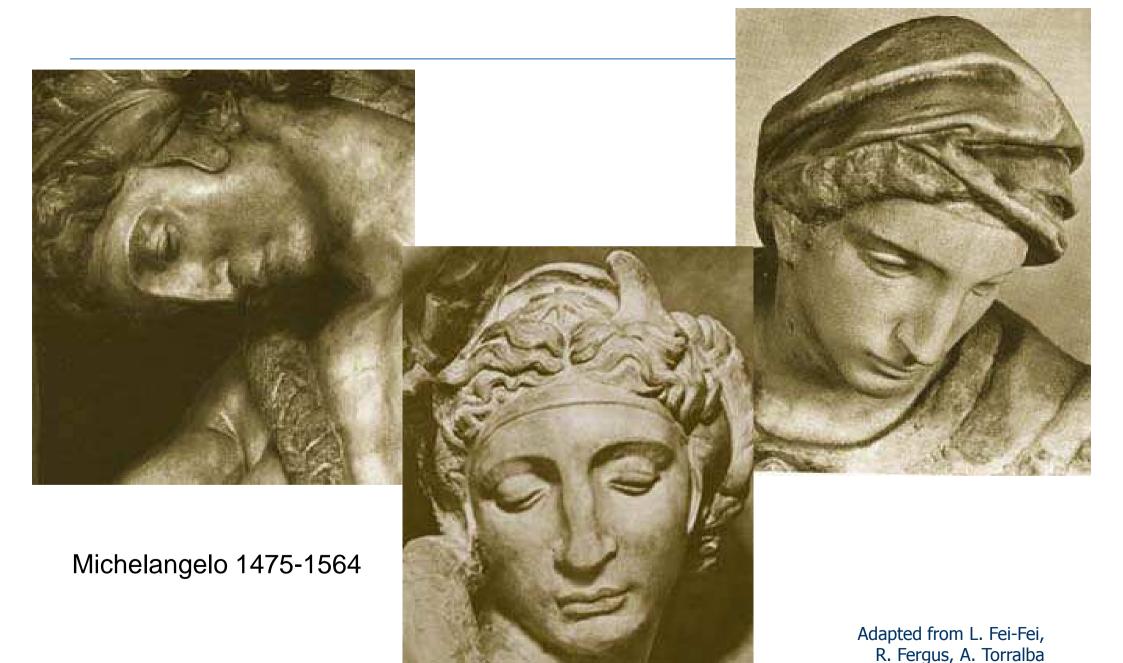
Adapted from Michael Black, Brown University



- The shape of junctions constrains the possible interpretations of the scene.
- Ambiguous: paint and surface boundaries can be confused.

Adapted from Michael Black, Brown University

Challenges 1: view point variation



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Challenges 2: illumination



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Adapted from L. Fei-Fei, R. Fergus, A. Torralba 60

Challenges 3: occlusion

Magritte, 1957

Adapted from L. Fei-Fei, R. Fergus, A. Torralba

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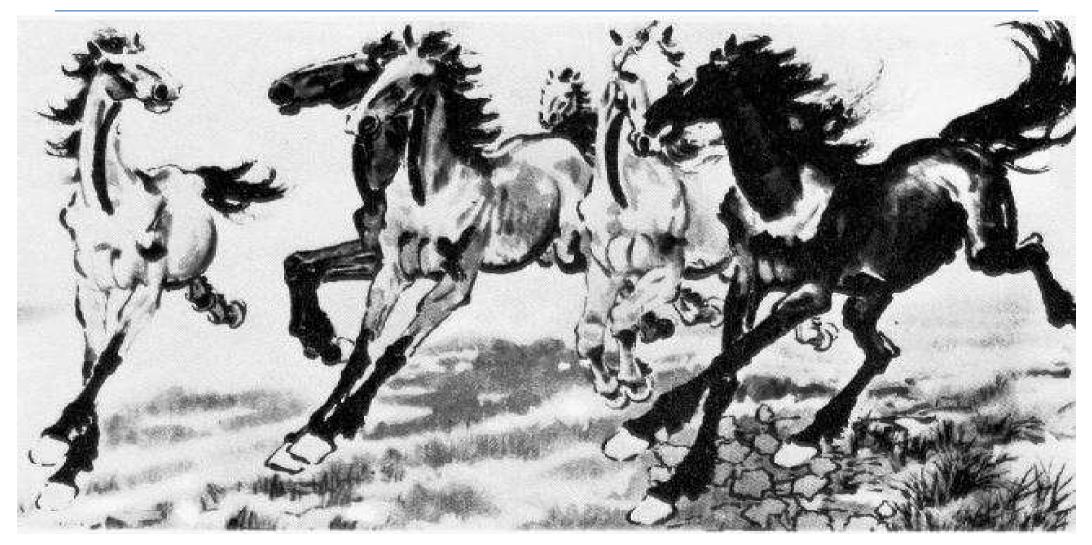
Challenges 4: scale



Adapted from L. Fei-Fei, R. Fergus, A. Torralba

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Challenges 5: deformation



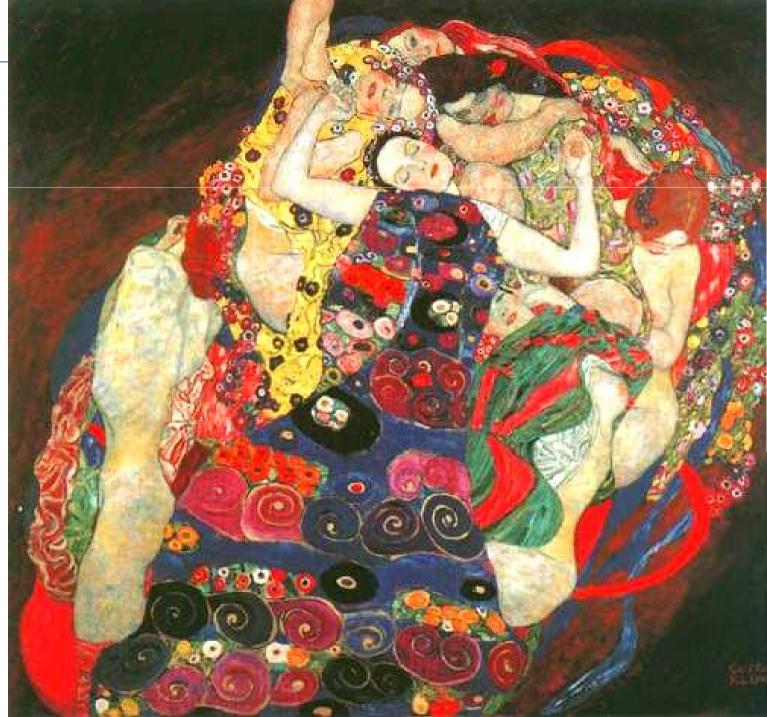
Xu, Beihong 1943

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Adapted from L. Fei-Fei, R. Fergus, A. Torralba 63

Challenges 6: background clutter



Klimt, 1913

Adapted from L. Fei-Fei, R. Fergus, A. Torralba

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Challenges 7: intra-class variation



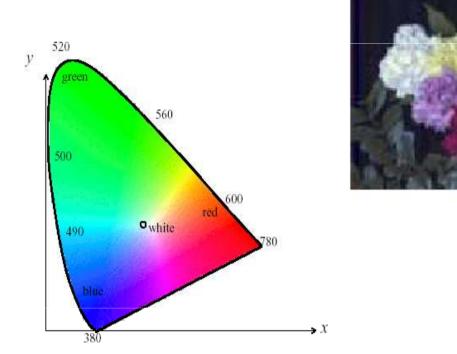
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Adapted from L. Fei-Fei, R. Fergus, A. Torralba 65

Recognition

- How can different cues such as color, texture, shape, motion, etc., can be used for recognition?
 - Which parts of image should be recognized together?
 - How can objects be recognized without focusing on detail?
 - How can objects with many free parameters be recognized?
 - How do we structure very large model bases?

Color





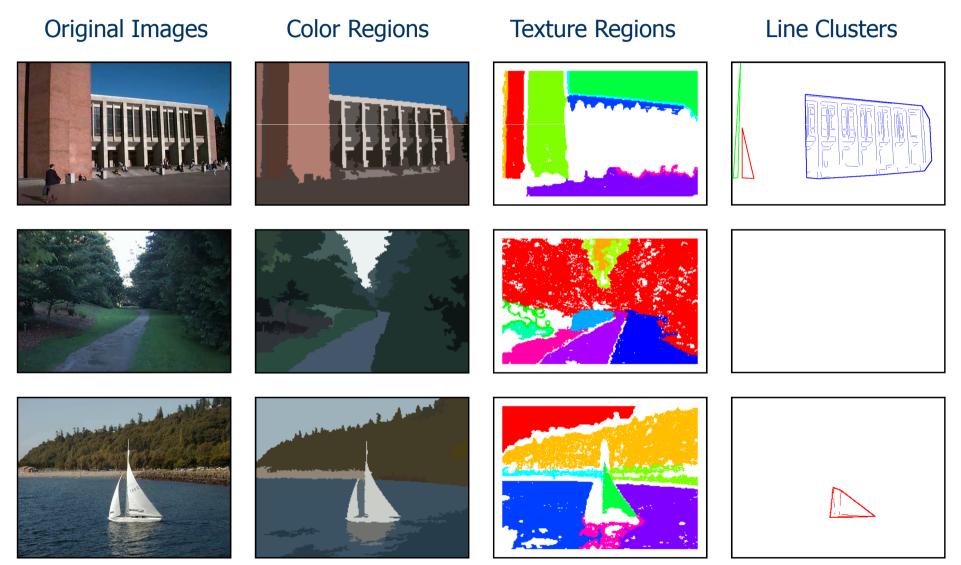
Adapted from Martial Hebert, CMU

Texture



Adapted from David Forsyth, UC Berkeley

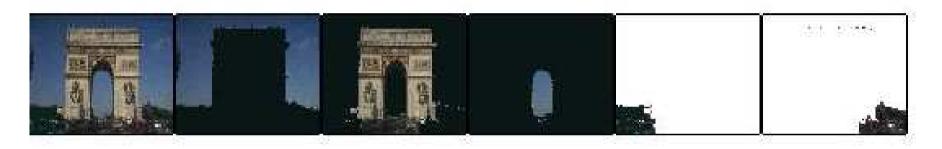
Segmentation

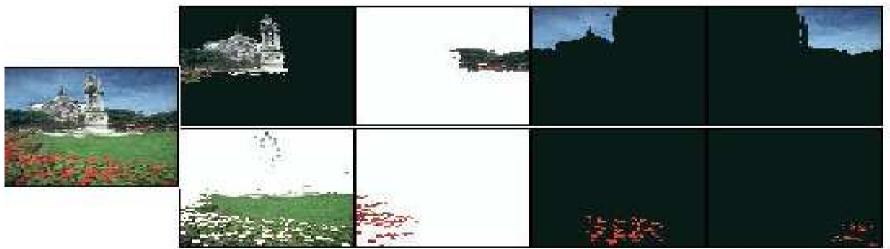


Adapted from Linda Shapiro, U of Washington

Segmentation

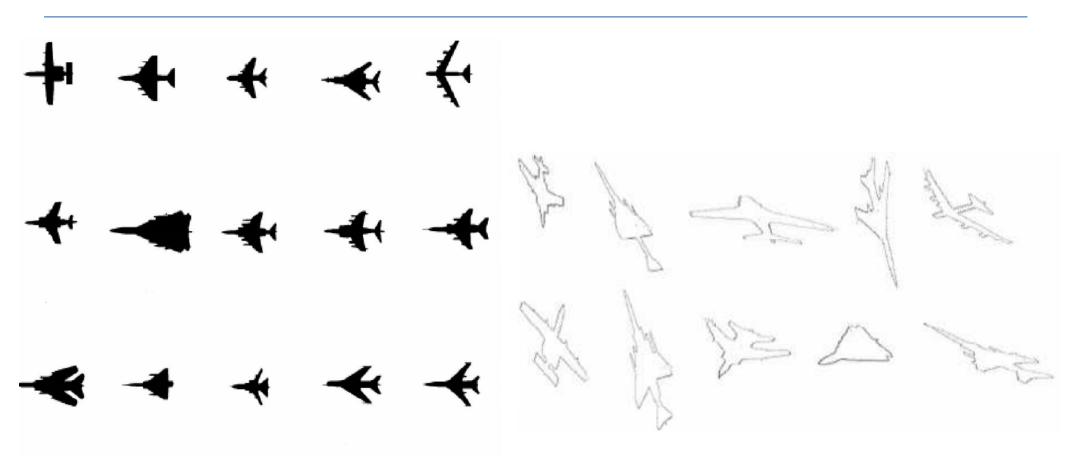






Adapted from Jianbo Shi, U Penn

Shape



Recognized objects

Adapted from Enis Cetin, Bilkent University

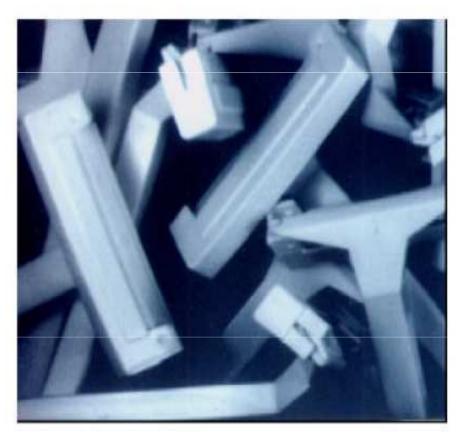
Model database

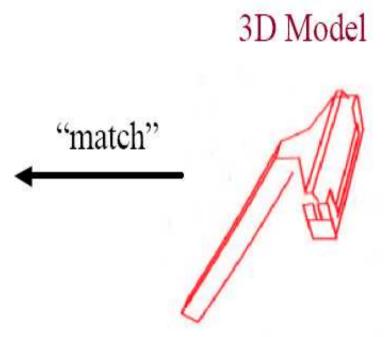
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Motion

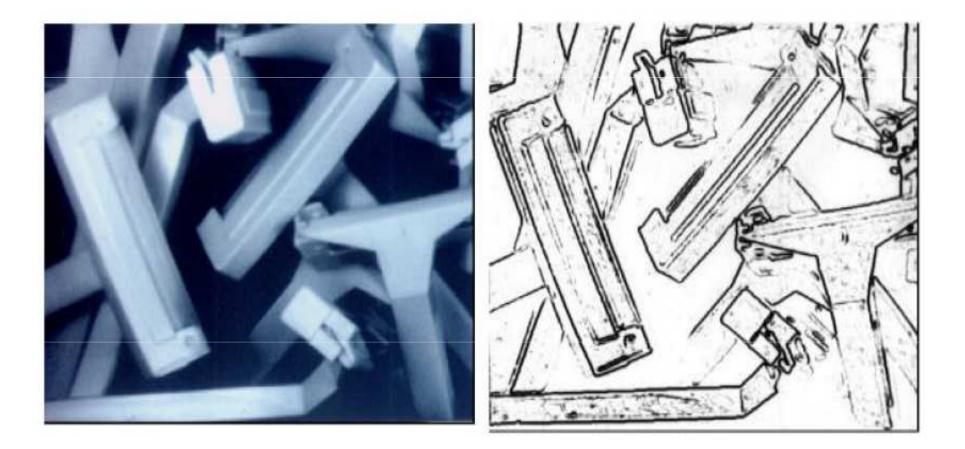


Adapted from Michael Black, Brown University





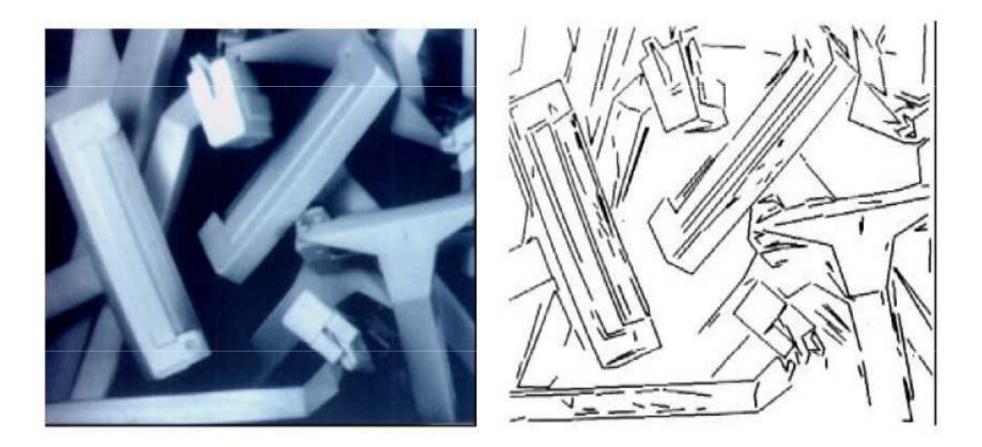
Parameters: 3D position and orientation



"Filter" image to find brightness changes.

Adapted from Michael Black, Brown University

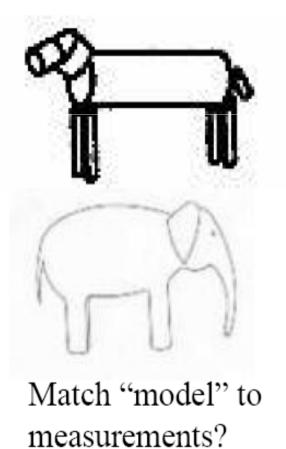
©2009, Selim Aksoy

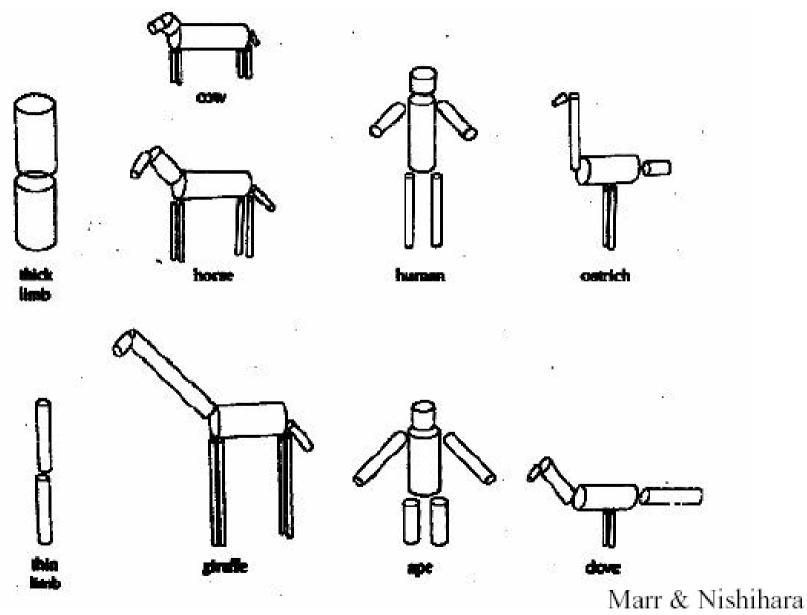


"Fit" lines to the raw measurements.



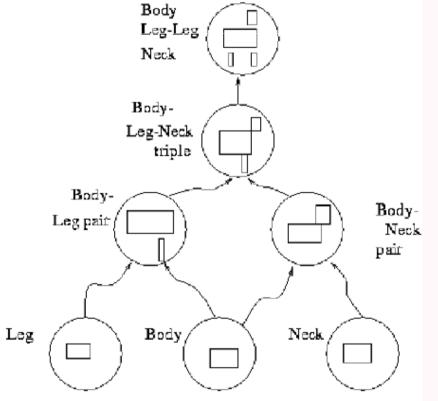
"Project" model into image and "match" to lines (solving for 3D pose).





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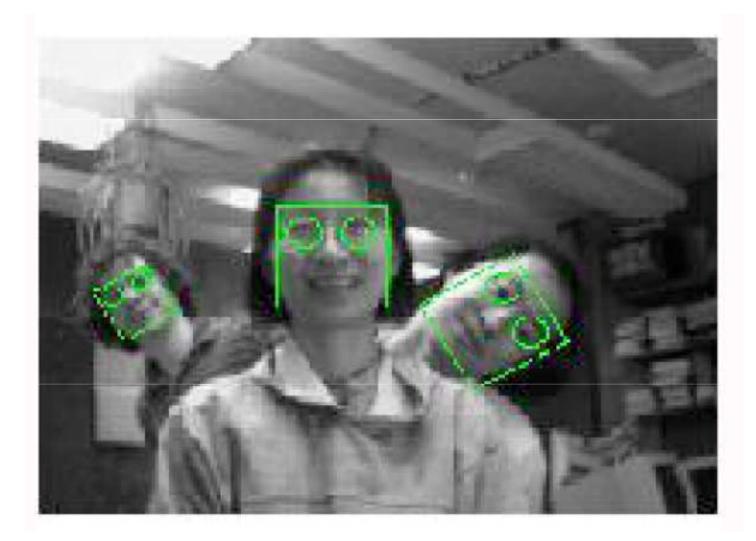
©2009, Selim Aksoy





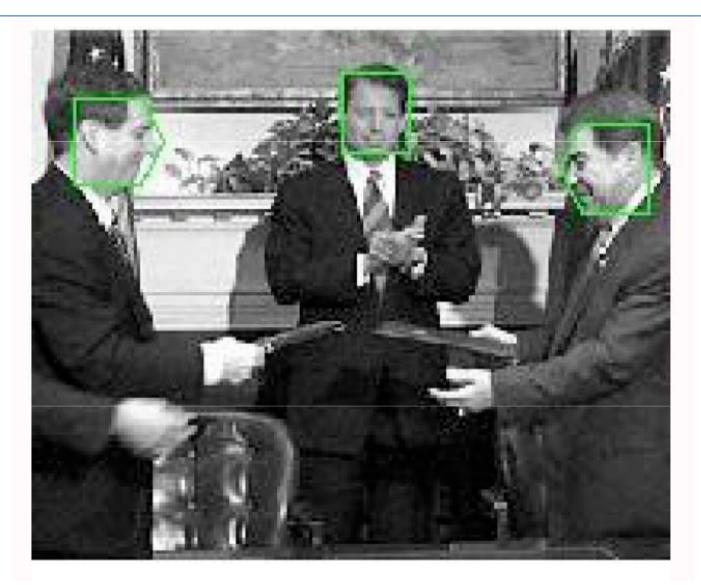
Adapted from David Forsyth, UC Berkeley

Detection



Adapted from David Forsyth, UC Berkeley

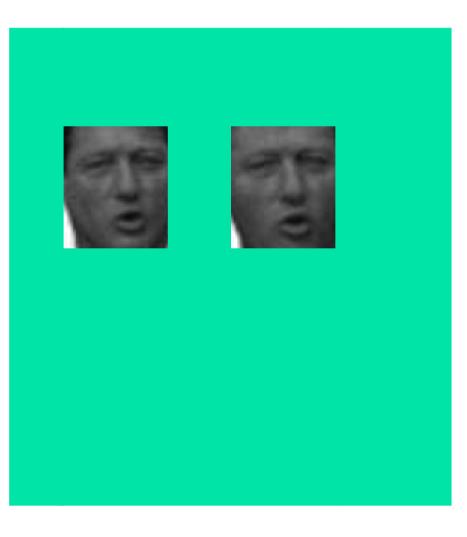
Detection



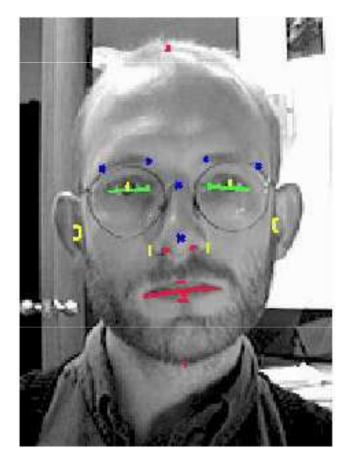
Adapted from David Forsyth, UC Berkeley

Detection

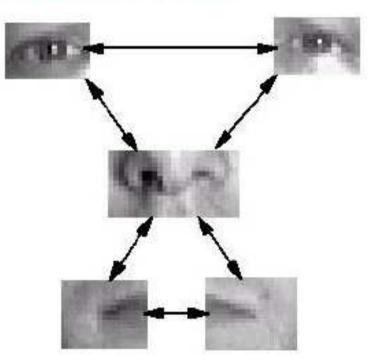
What are our "models"? How good are they?



Parts and relations



Patch Model



http://www.research.ibm.com/ecvg/biom/facereco.html Adapted from Michael Black, Brown University

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Parts and relations



How flexible are the spatial relations of the parts?



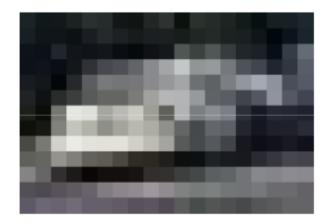
Adapted from Antonio Torralba, MIT



Adapted from Antonio Torralba, MIT







Adapted from Derek Hoiem, CMU



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Adapted from Derek Hoiem, CMU

Stages of computer vision

- Low-level
 - image \rightarrow image
- Mid-level

 image → features / attributes
 Image analysis / image understanding

 High-level

 features → "making sense", recognition

Low-level

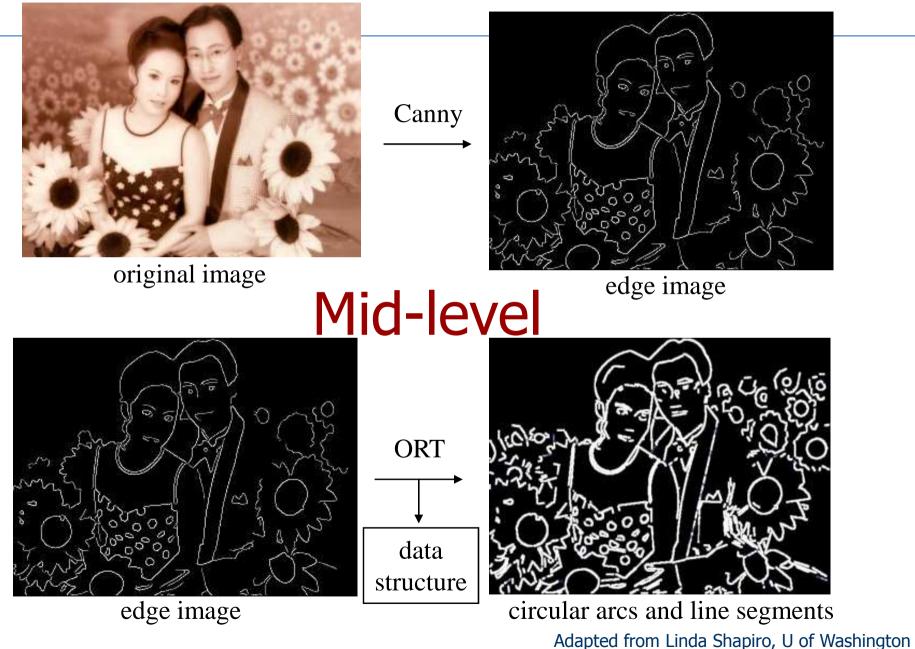
sharpening



blurring

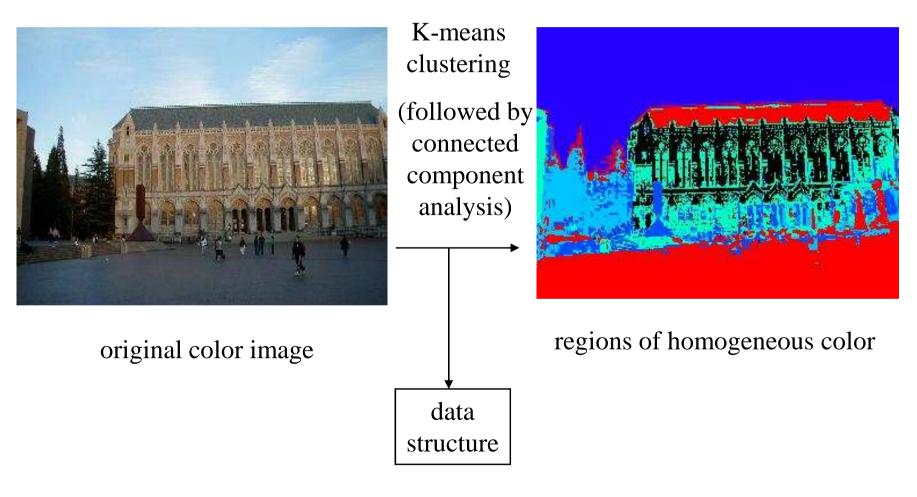
Adapted from Linda Shapiro, U of Washington

Low-level



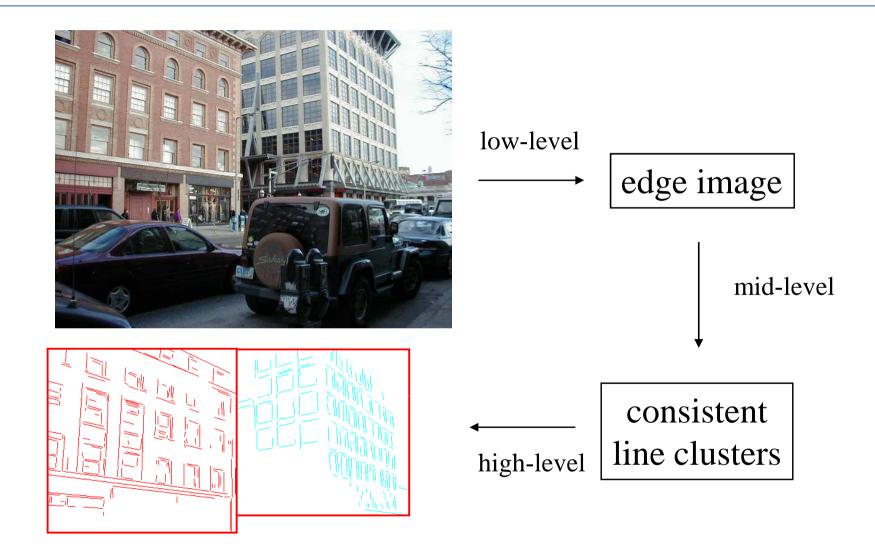
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Mid-level



Adapted from Linda Shapiro, U of Washington

Low-level to high-level



Adapted from Linda Shapiro, U of Washington