

Introduction

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What is computer 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, Vision (1982)

- Automatic understanding of images and video
 - Computing properties of the 3D world from visual data (measurement).
 - Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities (perception and interpretation).

Adapted from Trevor Darrell, UC Berkeley,
Alyosha Efros, Carnegie Mellon

Why study computer vision?

- As image sources multiply, so do applications
 - Relieve humans of boring, easy tasks
 - Enhance human abilities: human-computer interaction, visualization
 - Perception for robotics / autonomous agents
 - Organize and give access to visual content
- Goals of vision research:
 - Give machines the ability to understand scenes.
 - Aid understanding and modeling of human vision.
 - Automate visual operations.

Adapted from Trevor Darrell, UC Berkeley

Why study computer vision?



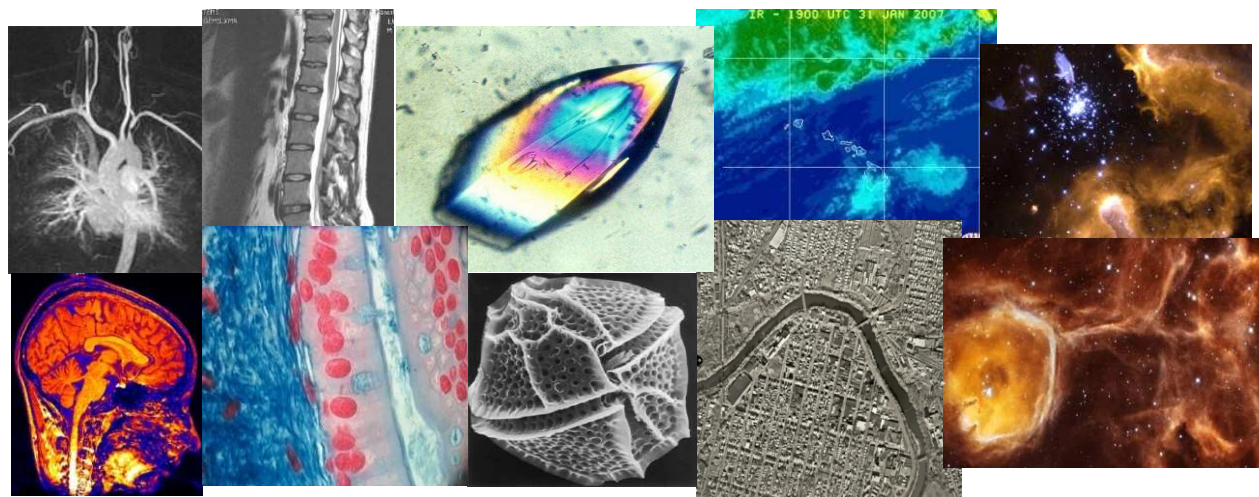
Personal photo albums



Movies, news, sports

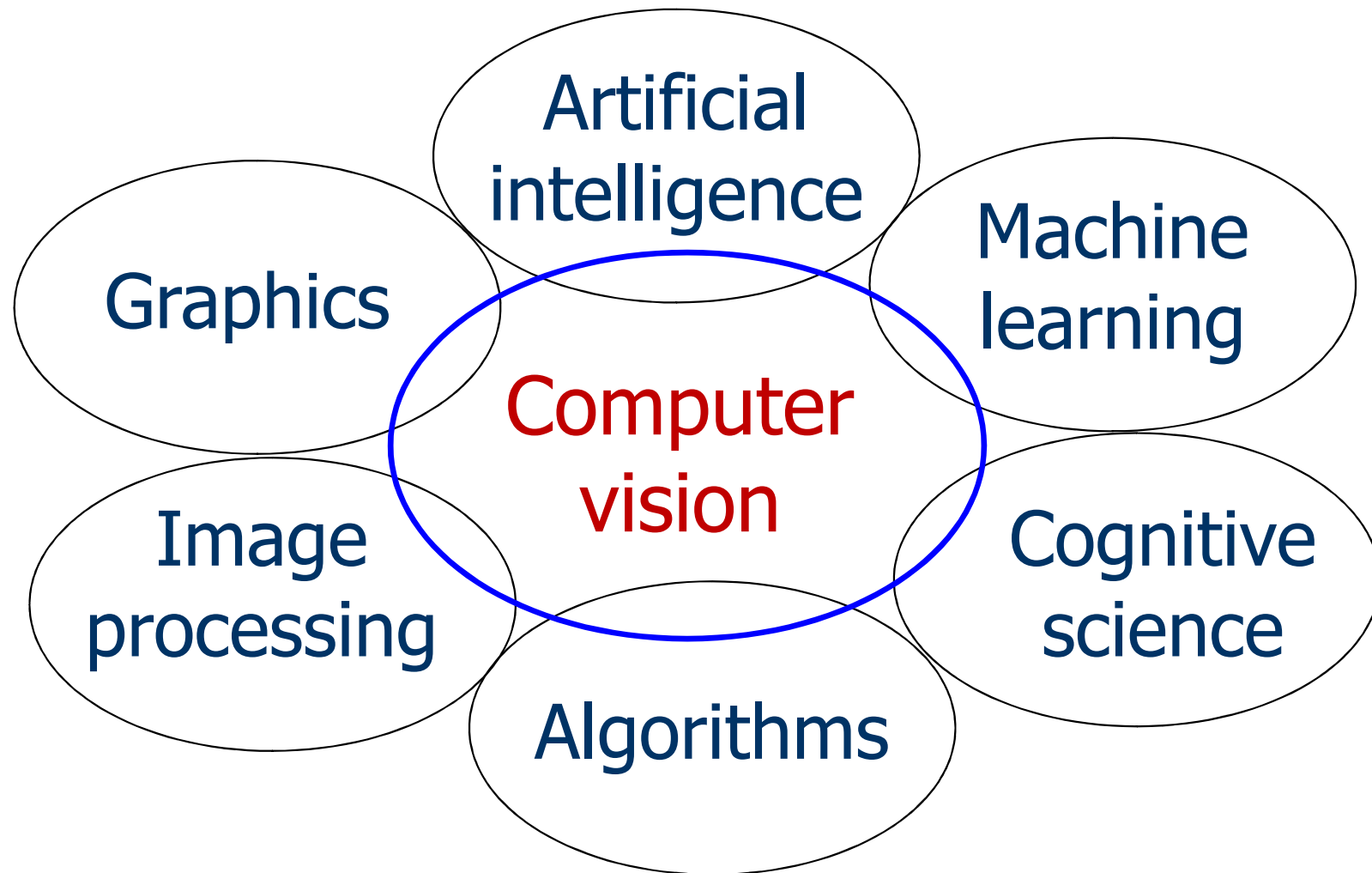


Surveillance and security



Medical and scientific images

Related disciplines



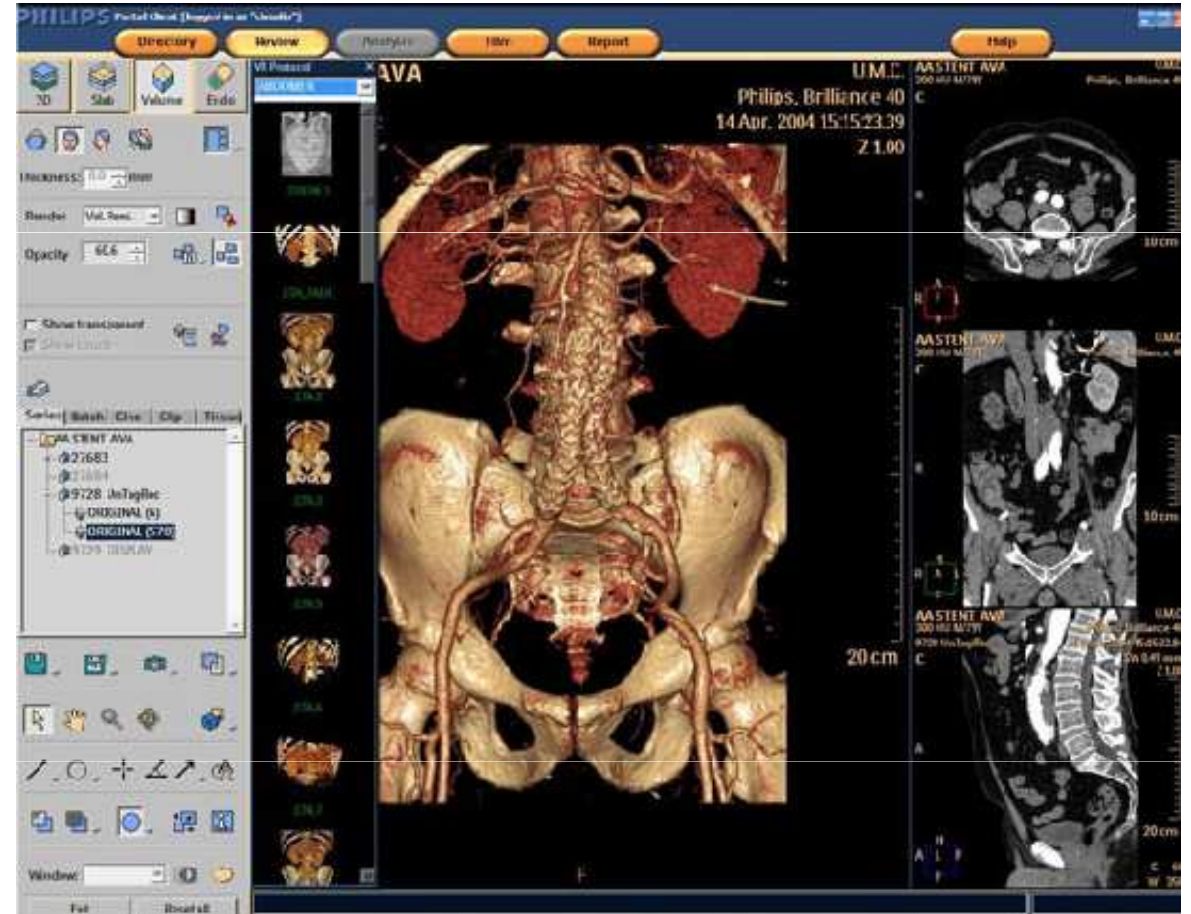
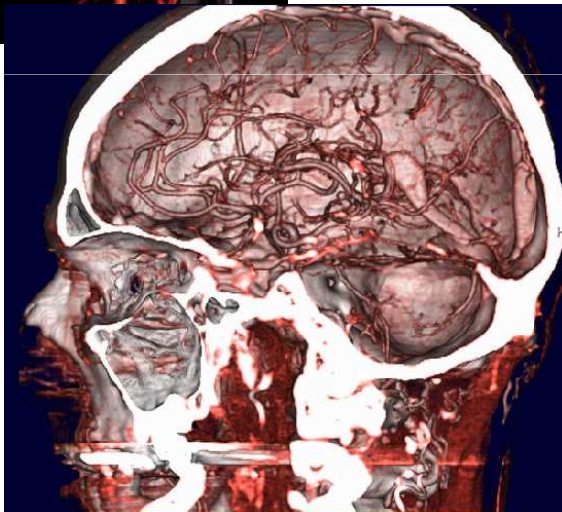
Applications

- Medical image analysis
- Security
 - Biometrics
 - Surveillance
 - Tracking
 - Target recognition
- Remote sensing
- Robotics
- Industrial inspection, quality control
- Document analysis
- Multimedia
- Assisted living
- Human-computer interfaces
- ...

Medical image analysis

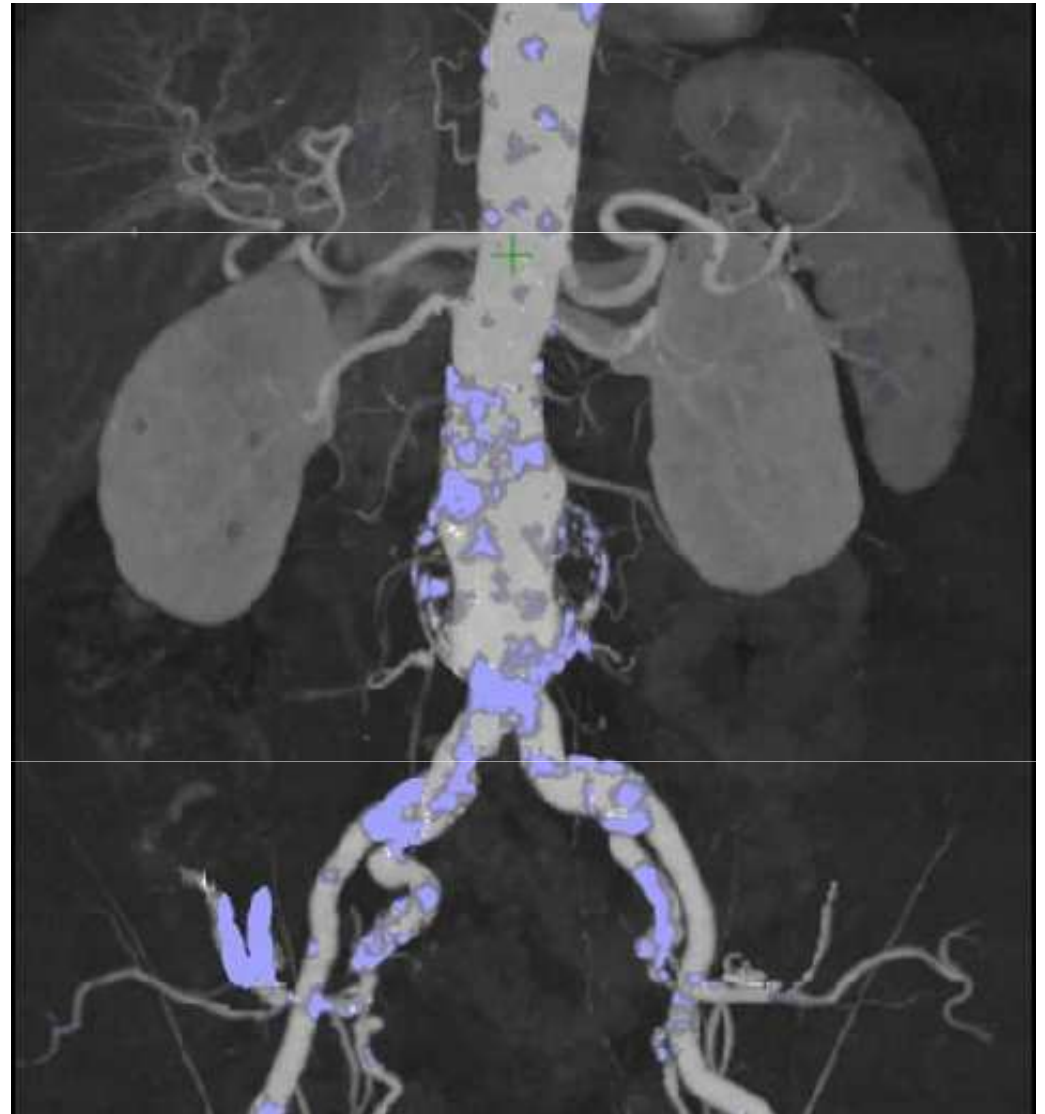
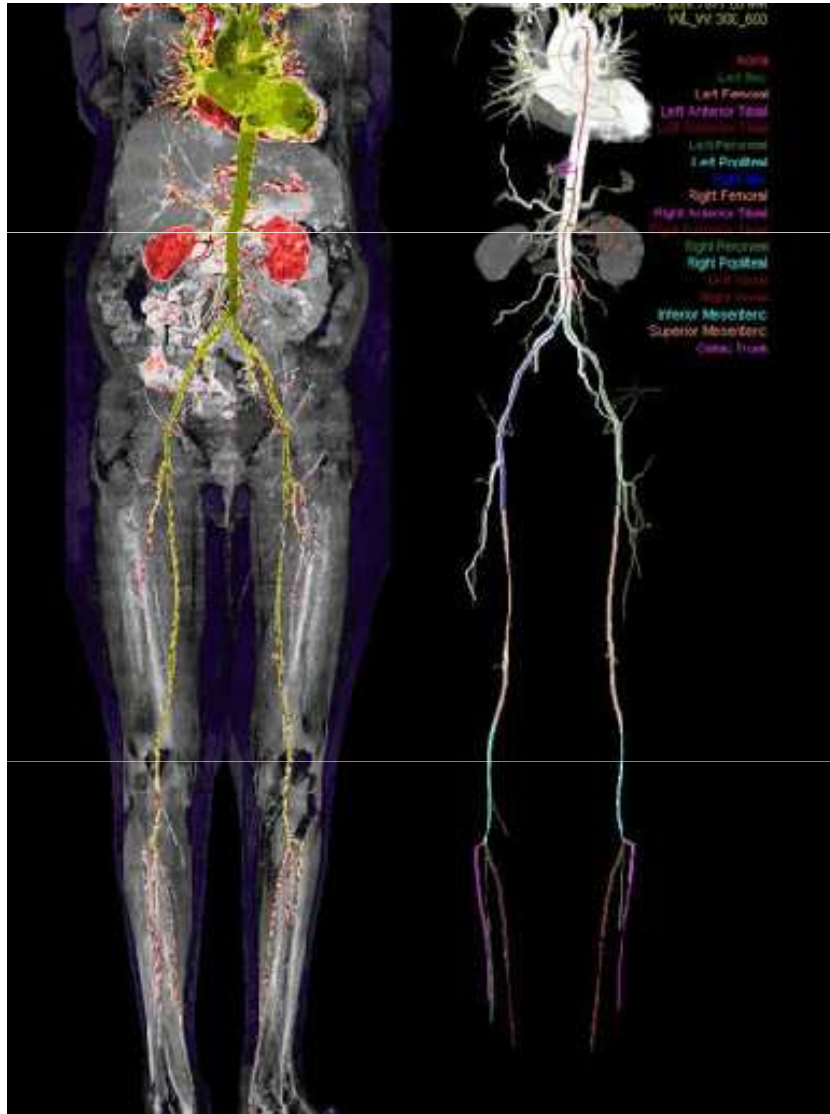


Medical image analysis

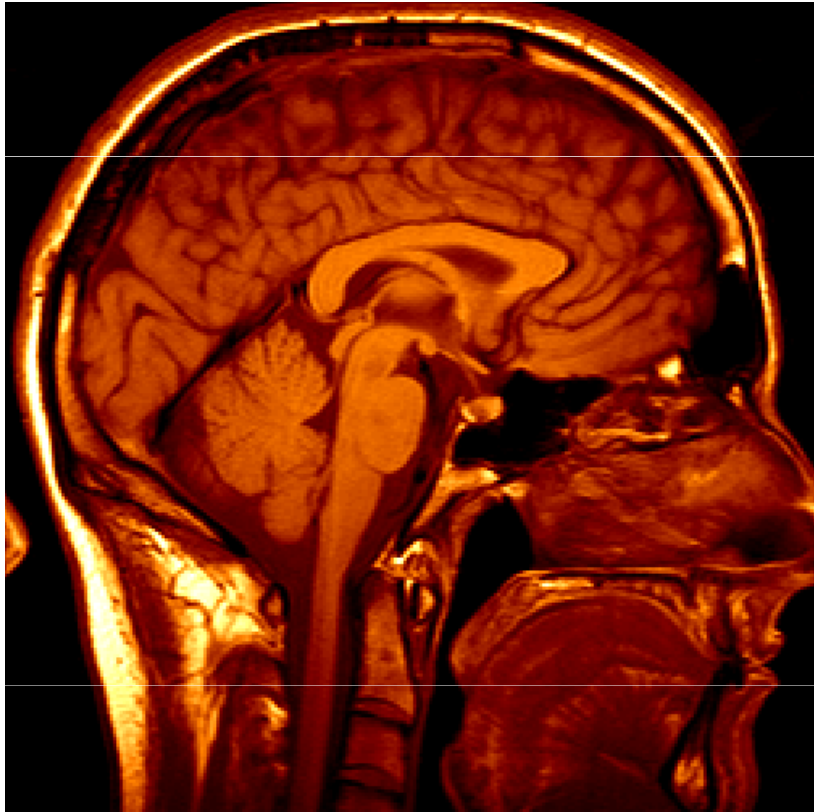


<http://www.clarontech.com>

Medical image analysis



Medical image analysis

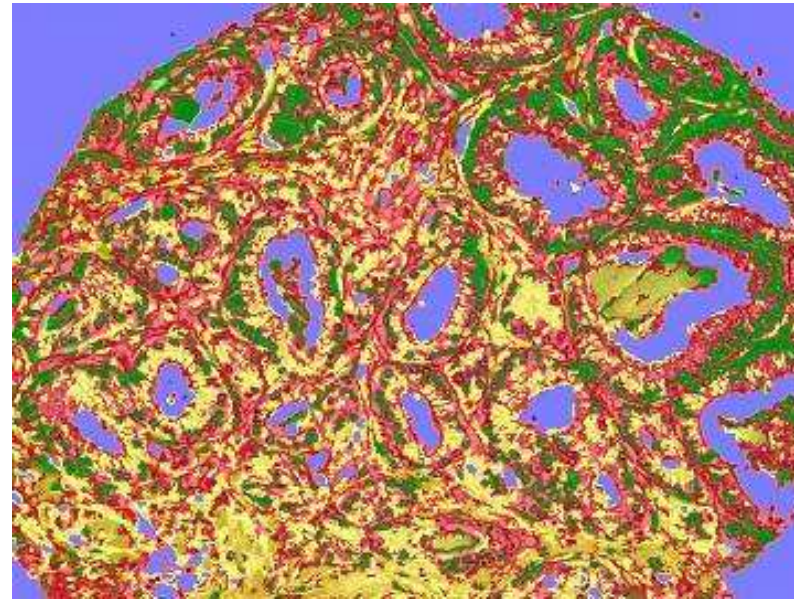
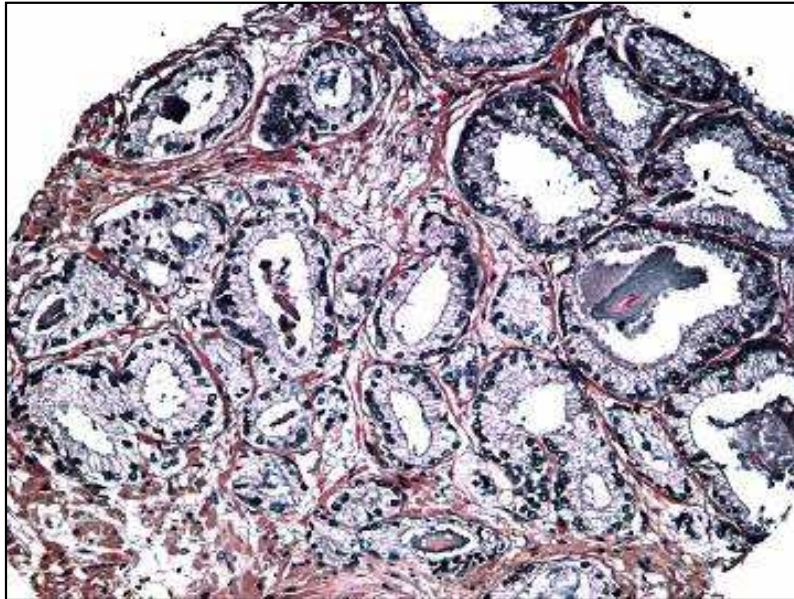


3D imaging: MRI, CT

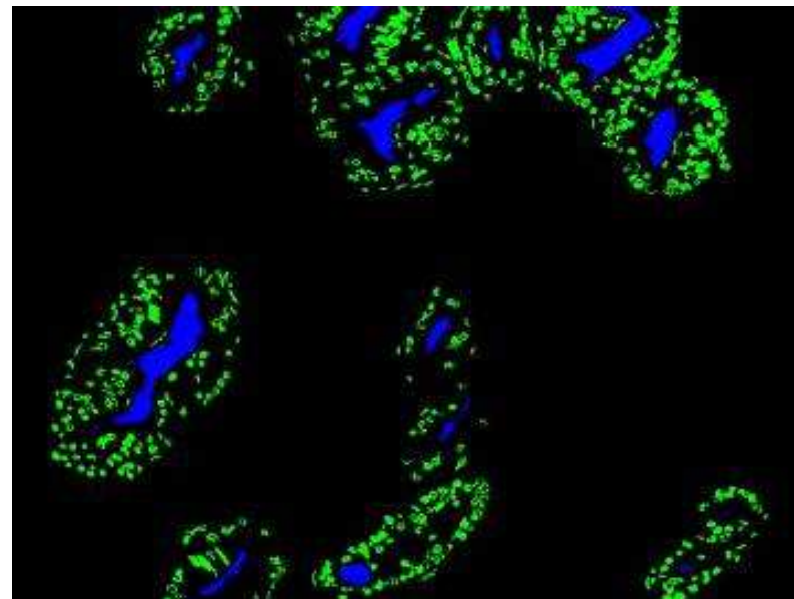
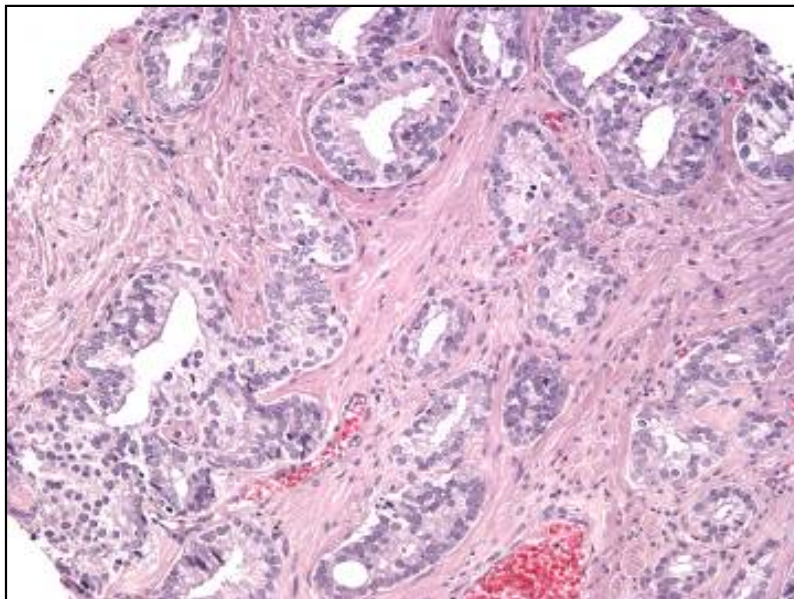


Image guided surgery
Grimson et al., MIT

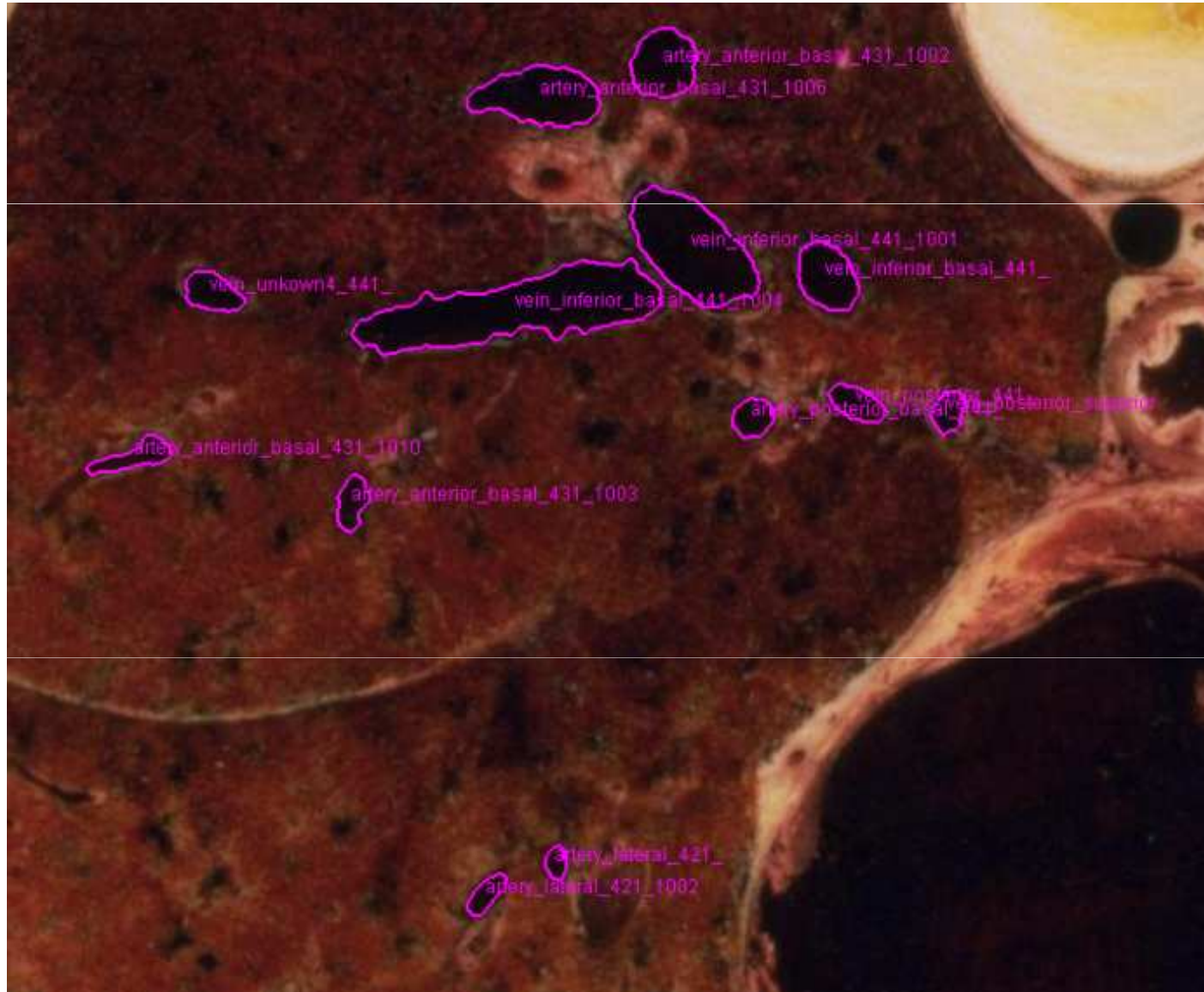
Medical image analysis



Cancer
detection
and
grading



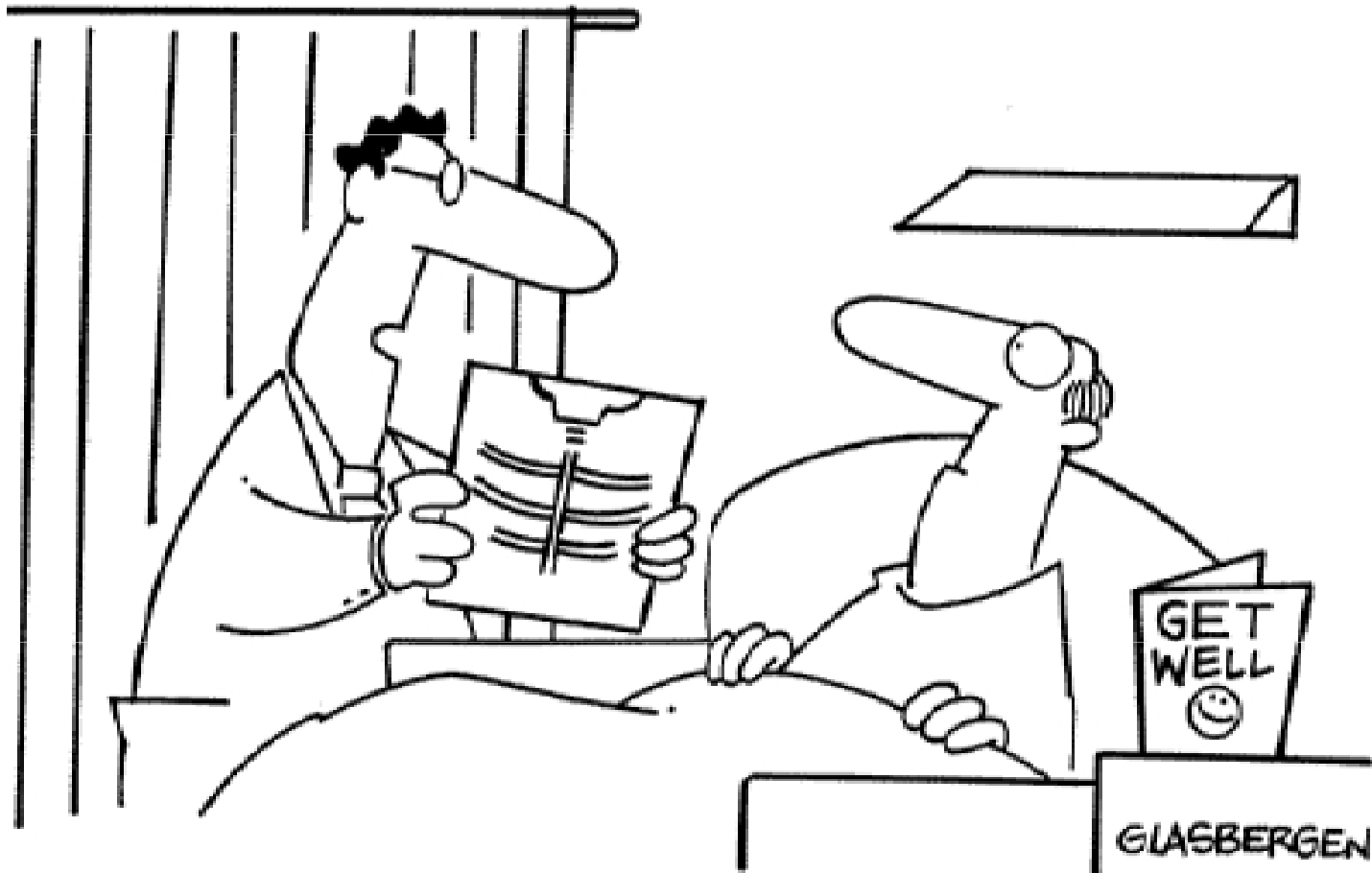
Medical image analysis



Slice of
lung

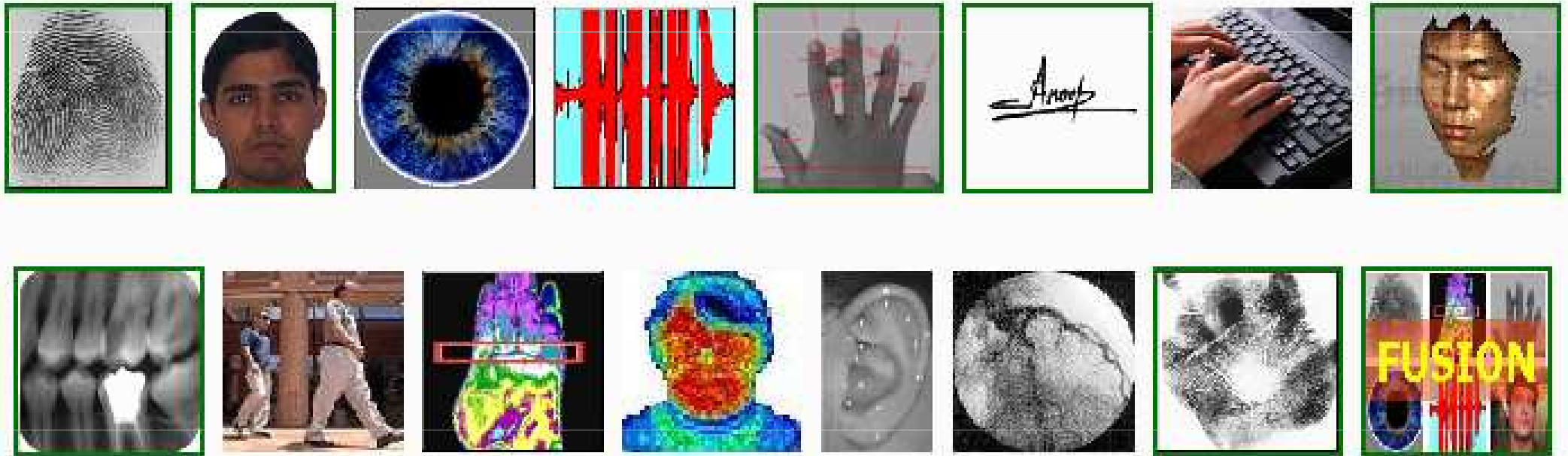
Medical image analysis

© 2000 Randy Glasbergen. www.glasbergen.com



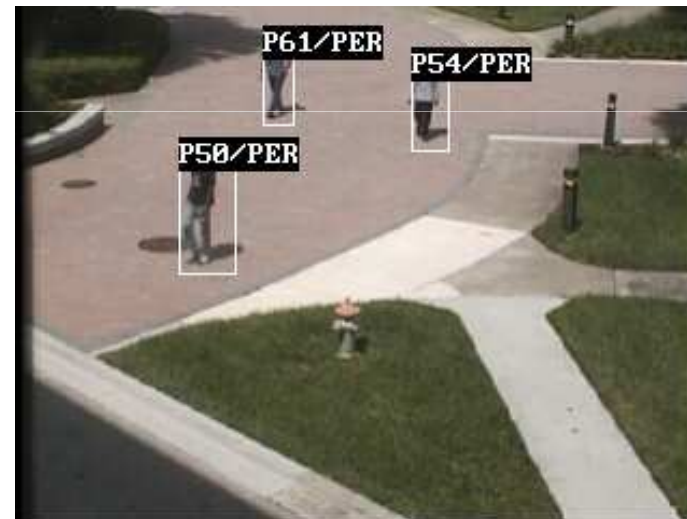
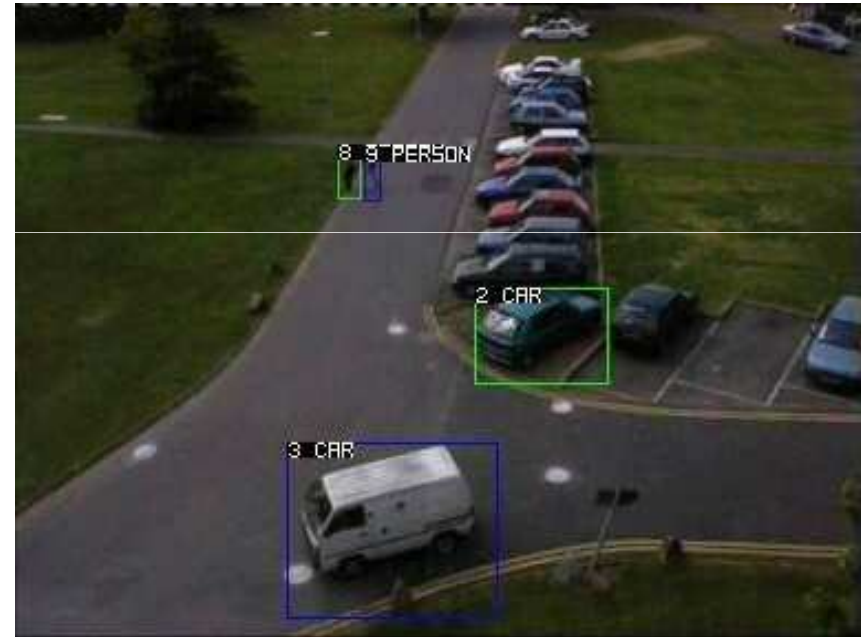
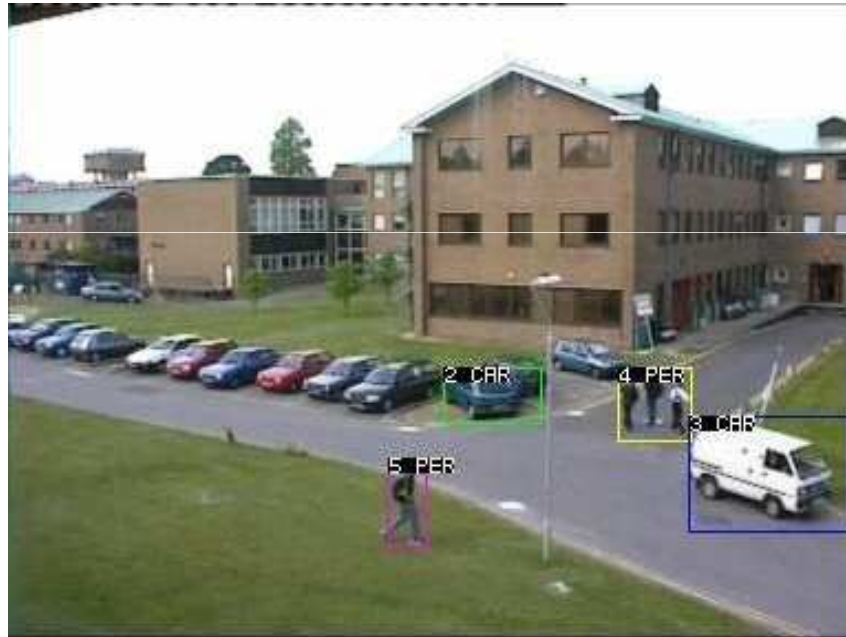
**“Your x-ray showed a broken rib,
but we fixed it with Photoshop.”**

Biometrics

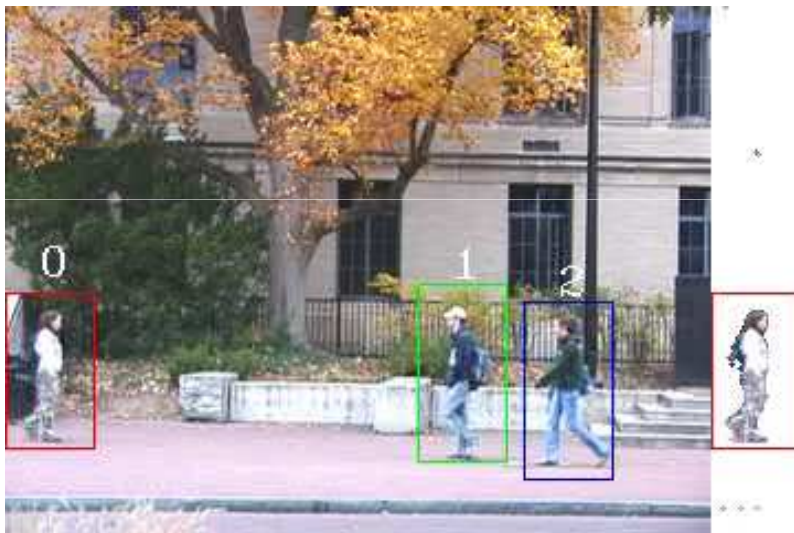


Adapted from Anil Jain, Michigan State

Surveillance and tracking



Surveillance and tracking



Adapted from Octavia Camps, Penn State

Surveillance and tracking



Adapted from Martial Hebert, CMU

Surveillance and tracking



Generating traffic patterns

Surveillance and tracking



Tracking in UAV videos

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

Smart cars

[▶▶ manufacturer products](#)[consumer products ◀◀](#)

Our Vision. Your Safety.



rear looking camera

forward looking camera

side looking camera

EyeQ Vision on a Chip

[> read more](#)

Vision Applications



Road, Vehicle, Pedestrian Protection and more

[> read more](#)

AWS Advance Warning System

[> read more](#)

News

- ▶ [Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System](#)
- ▶ [Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end](#)

[> all news](#)

Events

- ▶ [Mobileye at Equip Auto, Paris, France](#)
- ▶ [Mobileye at SEMA, Las Vegas, NV](#)

[> read more](#)

Adapted from CSE 455, U of Washington

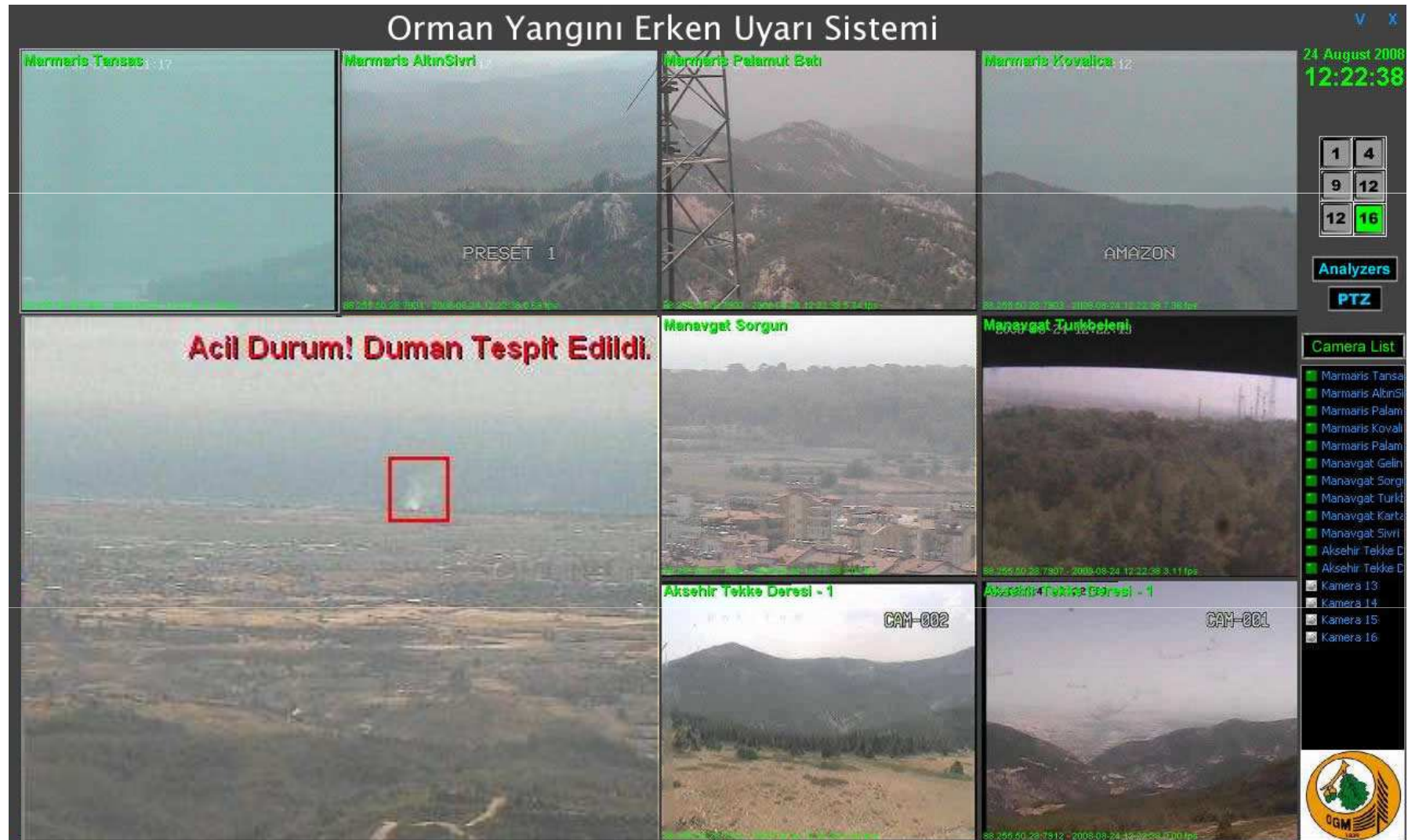
Vehicle and pedestrian protection



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

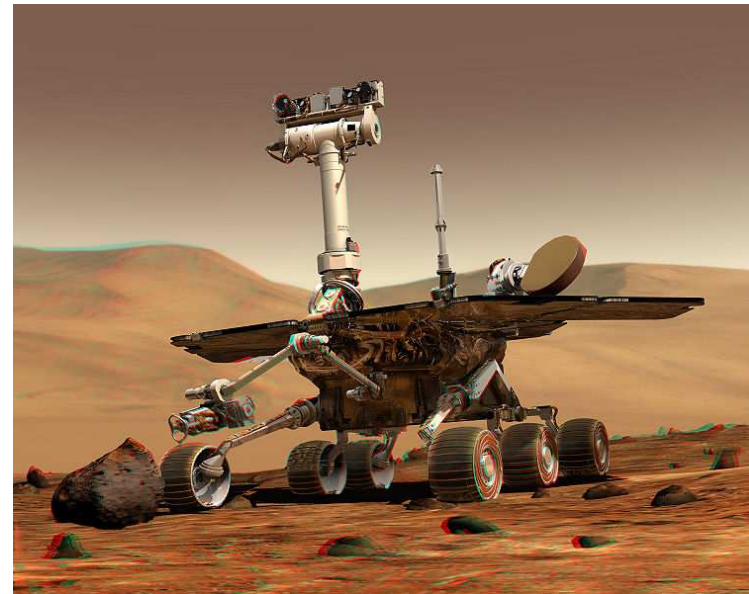
<http://www.mobileye-vision.com>

Forest fire monitoring system



Early warning of forest fires

Robotics



Adapted from CSE 455, U of Washington

Robotics



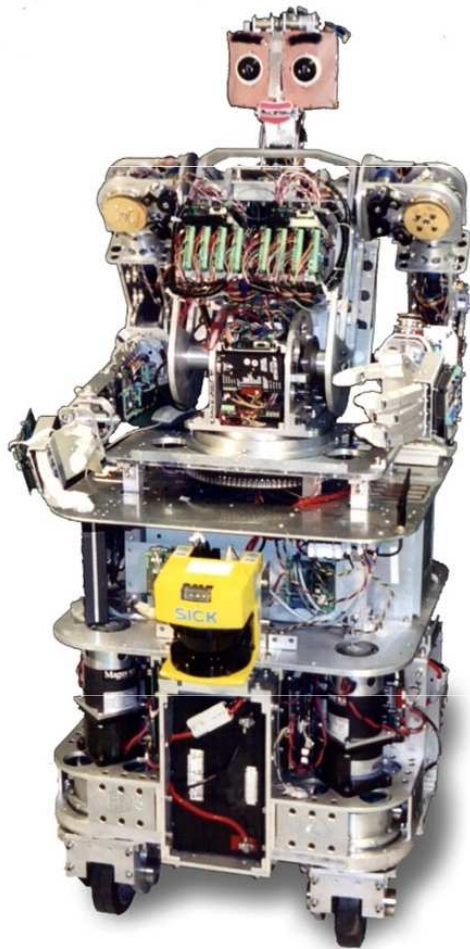
Adapted from Steven Seitz, U of Washington

Autonomous navigation



<http://www.darpa.mil/grandchallenge/index.asp>
http://en.wikipedia.org/wiki/DARPA_Grand_Challenge

Autonomous navigation



Michigan State University



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

Face detection and recognition



Adapted from CSE 455, U of Washington
27

Industrial automation



Automatic fruit sorting

Industrial automation



Industrial robotics;
bin picking

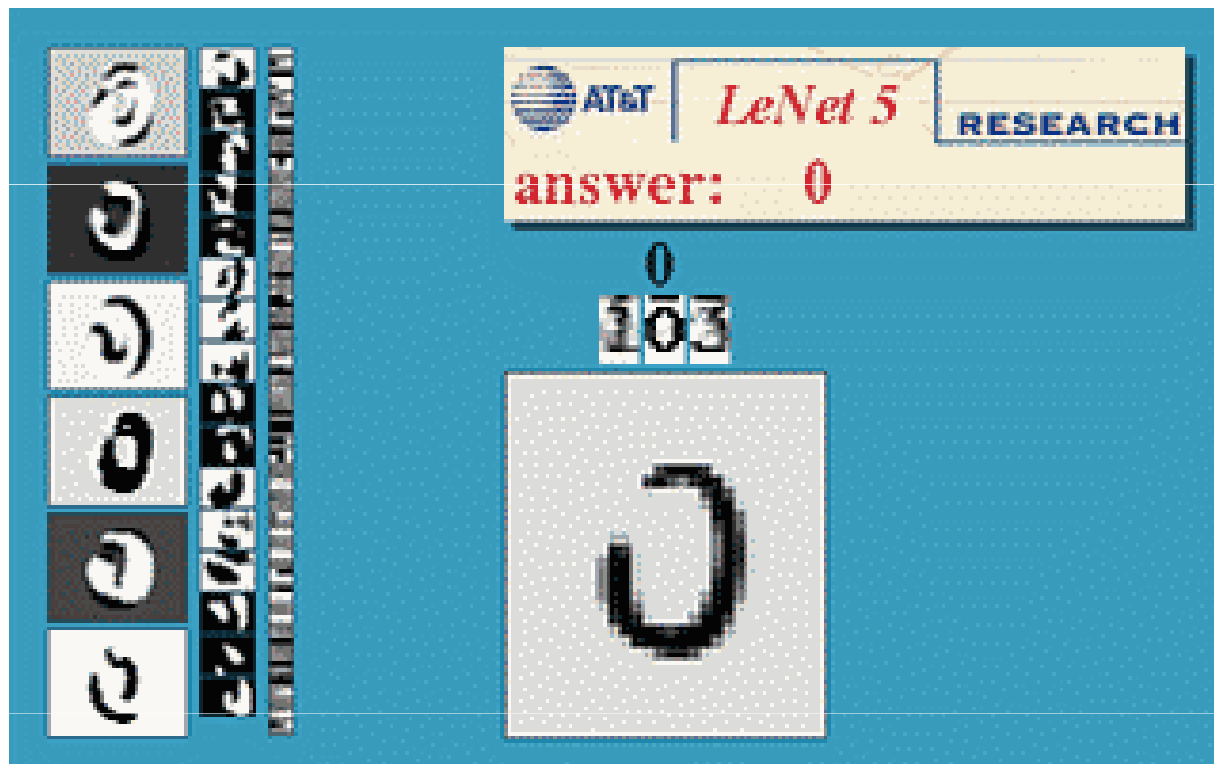
<http://www.braintech.com>

Postal service automation



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

Optical character recognition



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



License plate recognition

Adapted from Steven Seitz, U of Washington

Document analysis

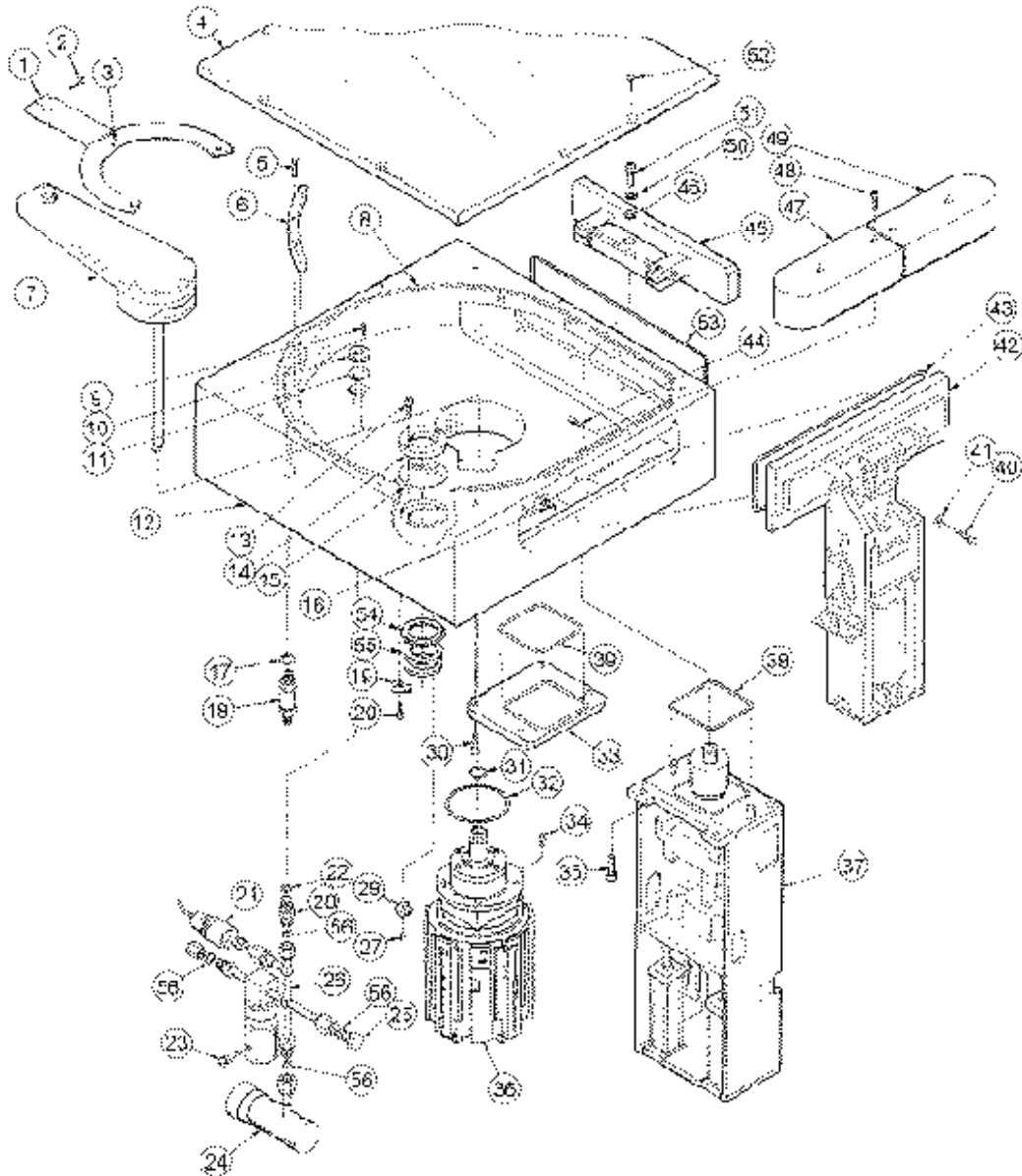
儘眼望遠極，
佰程無窮哩。
壹物明域現，
以迺吾後脊！

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

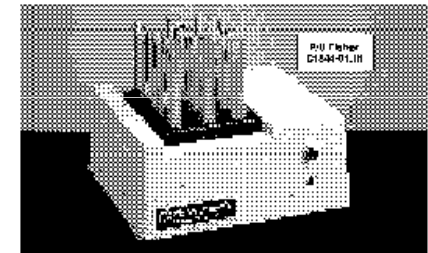
Figure 1.5: (Left) Chinese characters and (right) English equivalent. Is it possible that a machine could automatically translate one into the other? Chinese characters and poem courtesy of John Weng.

Adapted from Shapiro and Stockman

Document analysis



Blood Bank / Dylmabates

**Model 145 IsoTemp® Dry Bath Incubator**

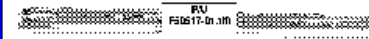
- Holds 1 in 4 heating blocks with chains of 11 wall sizes
- Maintains every sample in within $\pm 1^\circ \text{C}$ of temperature

In a pipe sample made of a π -shaped so that a π -ion runs clockwise delivers some amount of heat to a part of the sample tube. No temperature gradient is built up but at the bottom of the tube cold air flows that may involve some loss of heat with diffused cylindrical walls. Sample tubes register in the 30-40 °C range, in present localized setting. A flux was observed better in minutes on a thick π -ion in heat through the plate in the front of the tube. Plate is 60-70 °C at 5 mm. Dry both minimizes clearance problems because tubes are dry.

Amended to 125°C (255°F) each of 1" diameter. Heat temperature controlled just below 250°C (482°F) for any reactions. Inactive for glass. Rhodium, glass cross-matching and hydrogen determinations. Dimensions: 5.1 x 15.6 x 2.4 H. 125 x 28 x 13 mm. With inlets and plug. Heating blocks sold separately (see lower right).

| Electrical Requirements | Ctrl. Mch. | Each |
|------------------------------------|-------------|--------|
| 120V, 60Hz, 100VA (1/2 hp approx.) | 11-718-1010 | APR 14 |
| 240V, 50/60 Hz, 800VA | 11-718-1014 | BSE 33 |

Principio de la Ley de la Gravedad Universal



Input-Block[®] Partial Immersion Thermometers

For all standard heat, ice blocks and water baths. Critical temperatures (25°, 30°, 37°, 38° C) are marked with arrows. Available with shatter-resistant, contamination-proof Teflon® coating. Total length: 170 mm. In-mission: 35 mm.

| Range | The | Tailor, Charles | On | For |
|-------|------|-----------------|--------|-------|
| 15-57 | 0.54 | No | 14-989 | 45.24 |
| 25-57 | 0.57 | Yes | 14-989 | 45.15 |

Mini Thermometers

[For more thermometers, including digital types](#)

see page 952

* The number of people in the community who are involved in the project.

Model 147 Isotemp® Dry Bath

- Holds single heating block with choice of 17 well sizes

Similar to Model 25, using a 350- μ m (13.8-in.) plate. Ideal for labors with smaller volumes of enzyme and electrode assays. Electrodes and dry incubators. Forward-biased temperature control between ambient and up to 70°C. Observe thermometer placed in use see sample here. [Get adjustment manual through hole in front panel.](#) Maintains set temperature w/ consistency and reliability. $\pm 0.5^\circ\text{C}$.

Supplies with strong, low cost thermally stable enamel heater and indicator amp. line cord and plug and instructions. Dimensions: 8.1 x 6.5" W x 3 11/16 x 17 x 8 mm. CSA approved. Heating blocks sold separately (see below).

| Electrical Requirements | Cat. No. | Each |
|-------------------------|------------|--------|
| 120V 50/60 Hz, 120VA | 11-715-102 | 223.50 |

Interchangeable Heating Blocks for Isotemp® Dry Bathe

For Models 145 and 147, the PU is composed of Nove and sized alumina in a 1:1 ratio. (see also Dimensions: 1.1 x 0.9 x 0.4 mm (L x W x H))



The 11-715-120 clock is specifically designed to hold twenty 9.5 mm

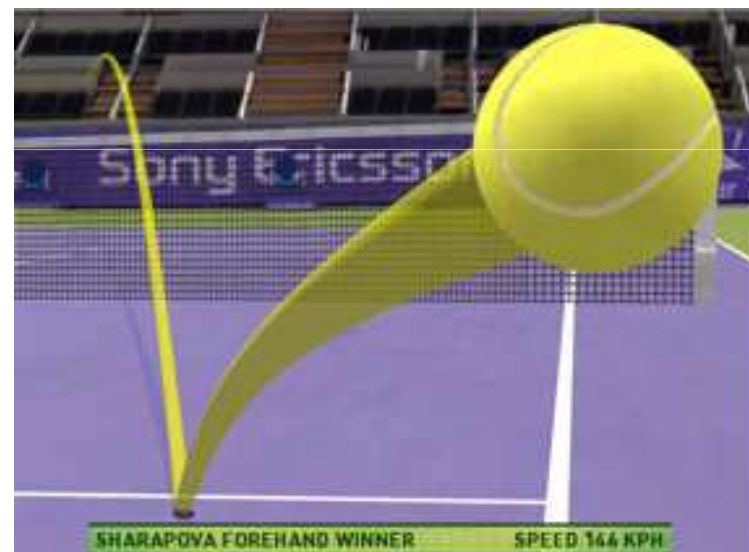
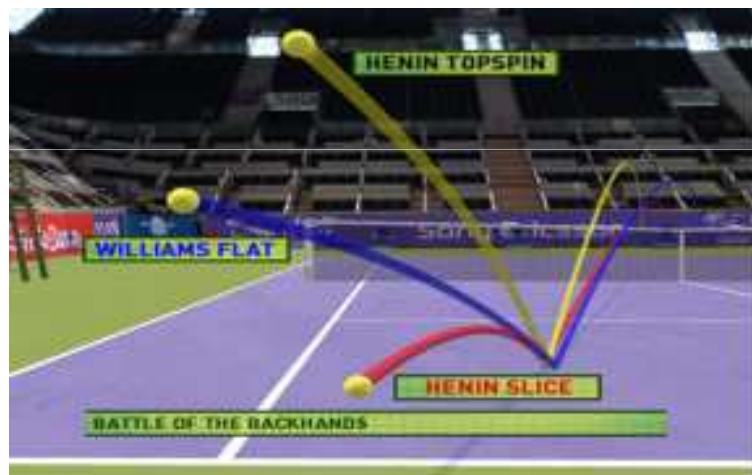
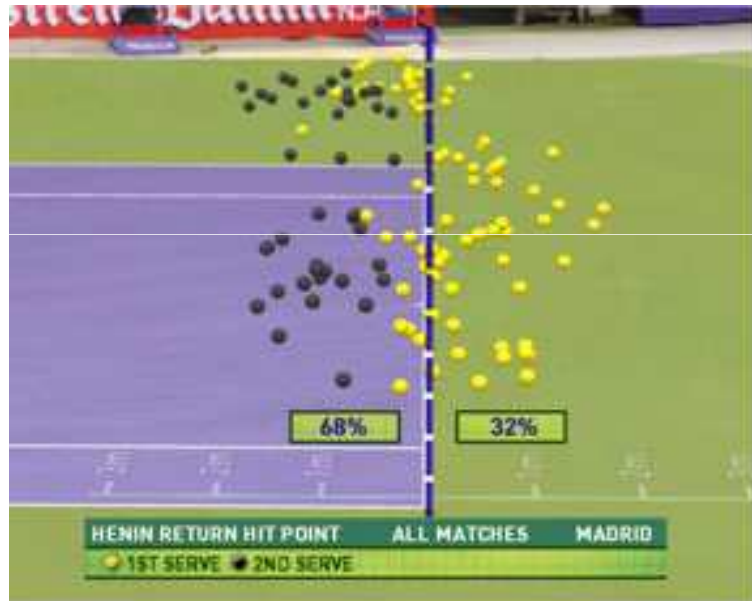
Barbed Diaphragms Placed at 1 m spacing in all tubes. This steel shall be well stock is similar to the other blocks with 1 mm welds, but the pipe walls are only 1/2" deep (1.3 cm) to meet test requirements. Wells in all other blocks are 1 1/2" deep (4.4 cm).

| Index | Start, mm | Width, mm | End, mm | Index |
|-------|-----------|------------|------------|-------|
| 0 | 0 | 35 | 11-215-105 | 74-8 |
| 01 | 35 | 201 | 11-215-107 | 73-5 |
| 15 | 201 | 2F-155-100 | 11-215-120 | 70-11 |
| 12 | 12 | 12 | 11-215-108 | 71-8 |
| 122-4 | 12 | 12 | 11-215-121 | 71-5 |
| 13 | 13 | 12 | 11-215-111 | 74-8 |
| 15 | 12 | 12 | 11-215-113 | 74-8 |
| 163 | 6 | 6 | 11-215-128 | 71-6 |
| 18 | 12 | 12 | 11-215-115 | 74-8 |
| 21 | 12 | 12 | 11-215-117 | 72-5 |
| 22 | 5 | 5 | 11-215-119 | 74-15 |

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To Order Call: 1-800-666-1768 Fax: 1-508-755-0960

Sports video analysis



Tennis review system

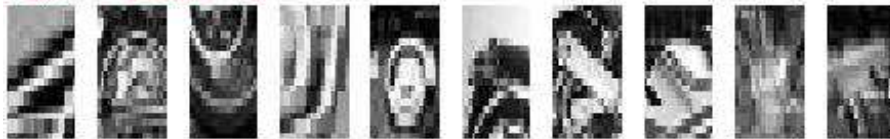
<http://www.hawkeyeinnovations.co.uk>

Scene classification

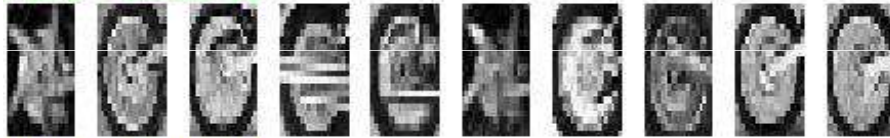


Object recognition

Part 1 – Det:5e-18



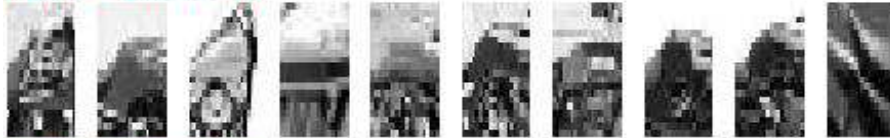
Part 2 – Det:8e-22



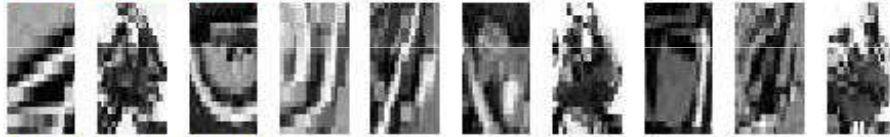
Part 3 – Det:6e-18



Part 4 – Det:1e-19



Part 5 – Det:3e-17



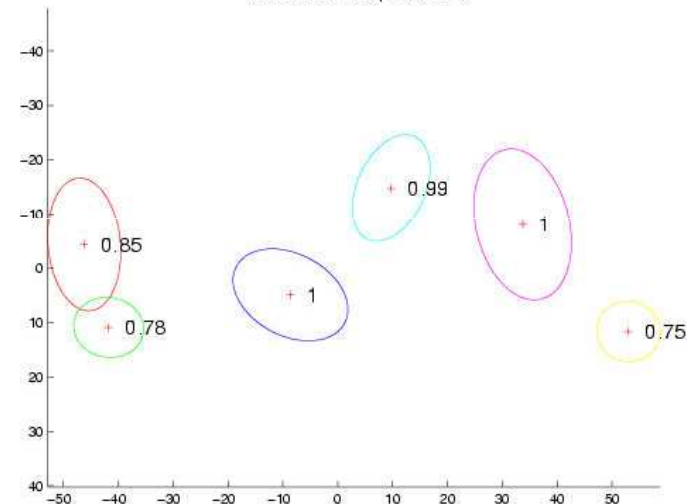
Part 6 – Det:4e-24



Background – Det:5e-19



Motorbike shape model



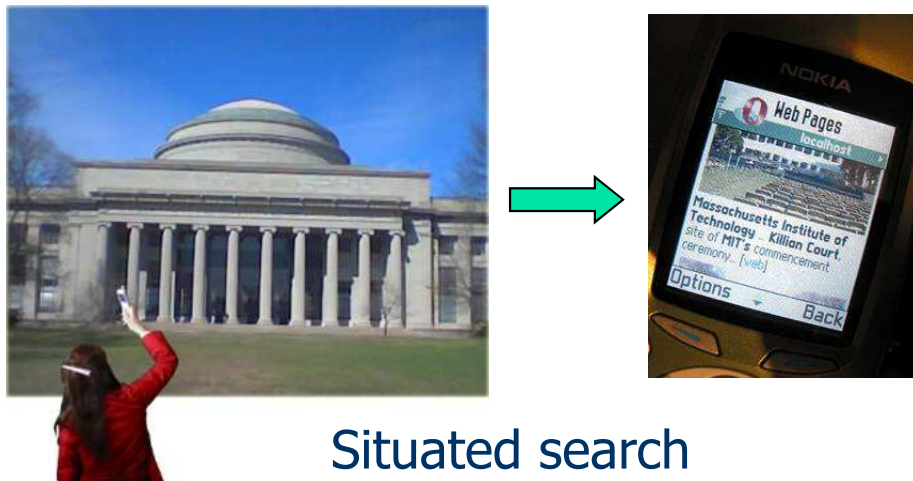
Object recognition



Lincoln, Microsoft Research



kooaba



Situated search
Yeh et al., MIT



Google Goggles
Bing Vision

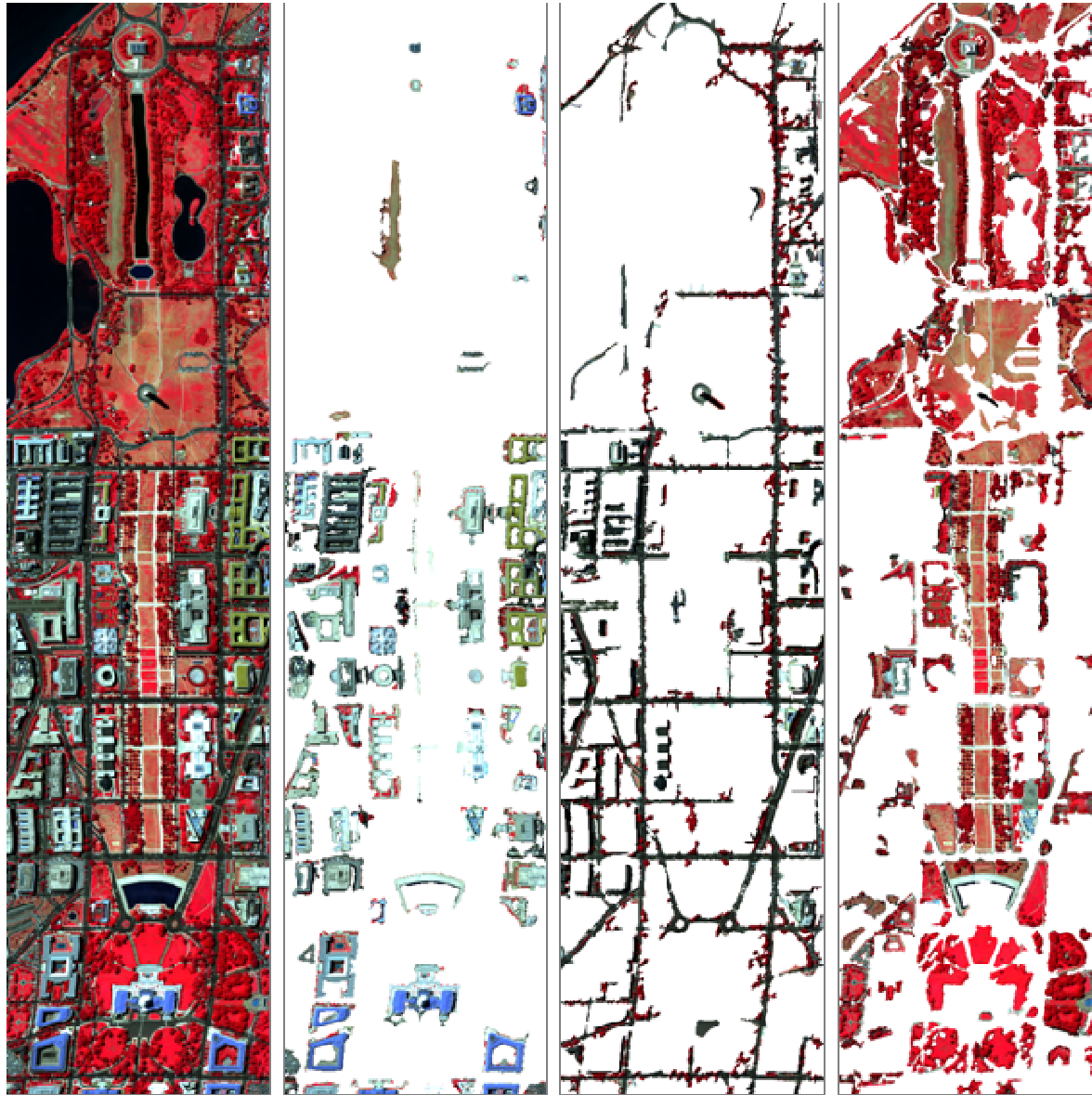
Land cover classification



Land cover classification



Object recognition

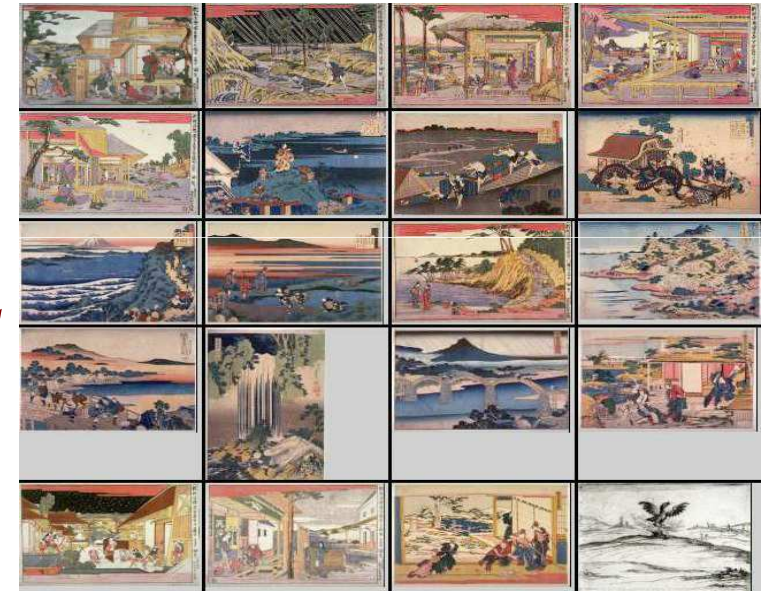
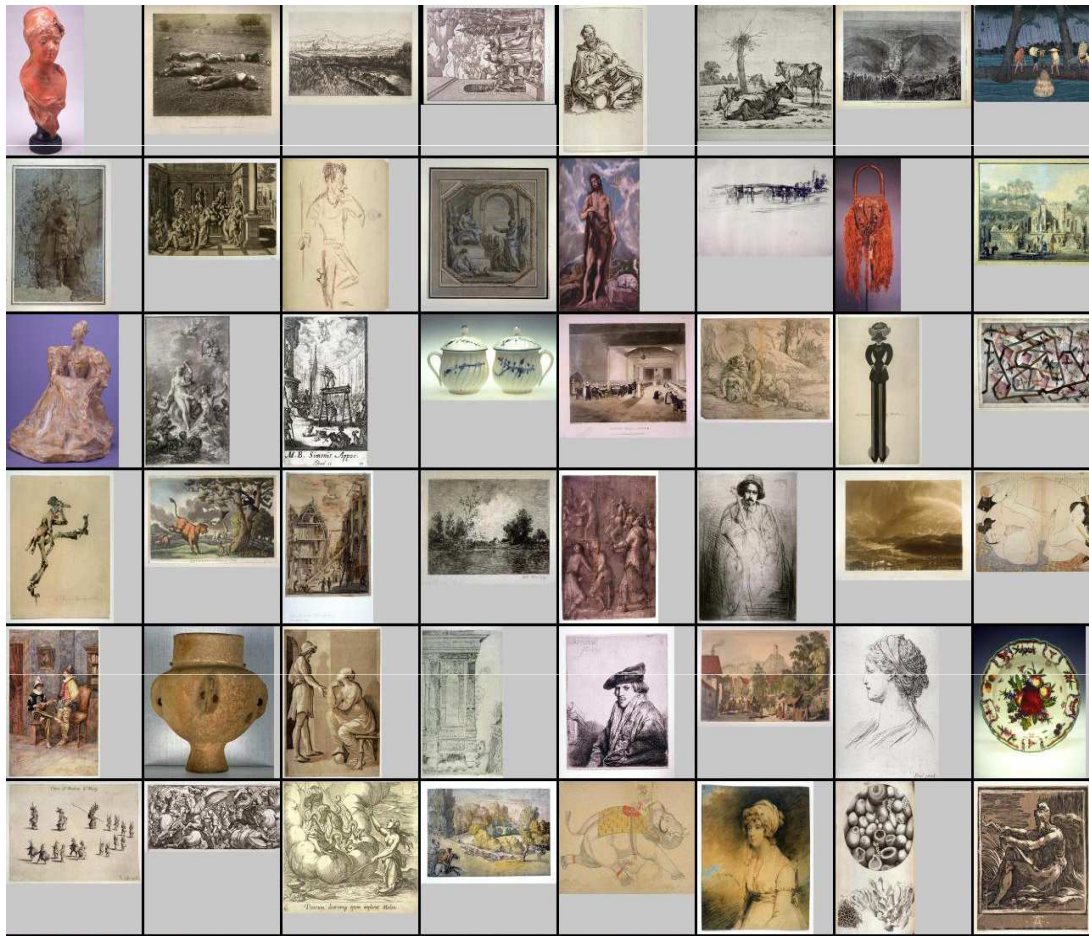


Object recognition



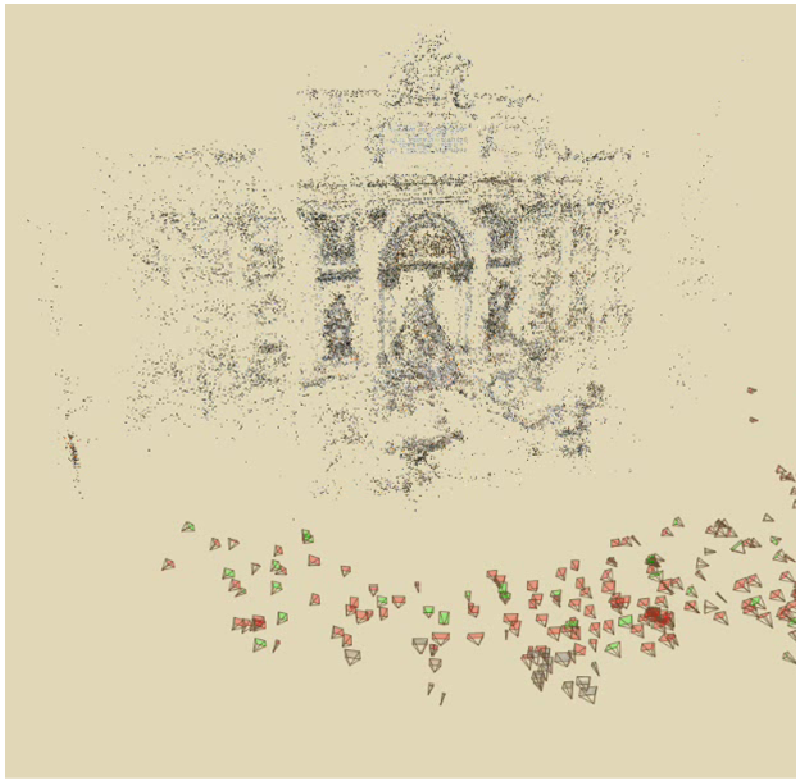
Recognition of buildings and building groups

Organizing image archives



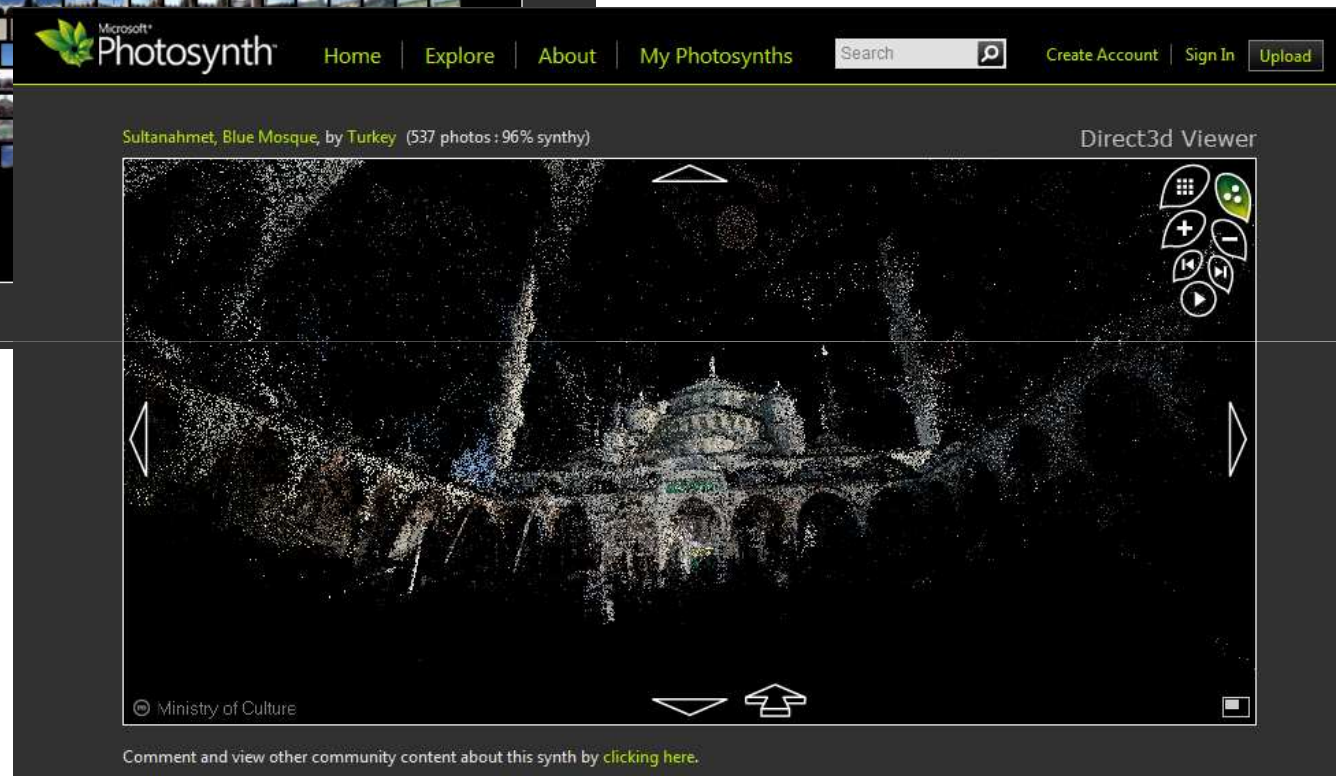
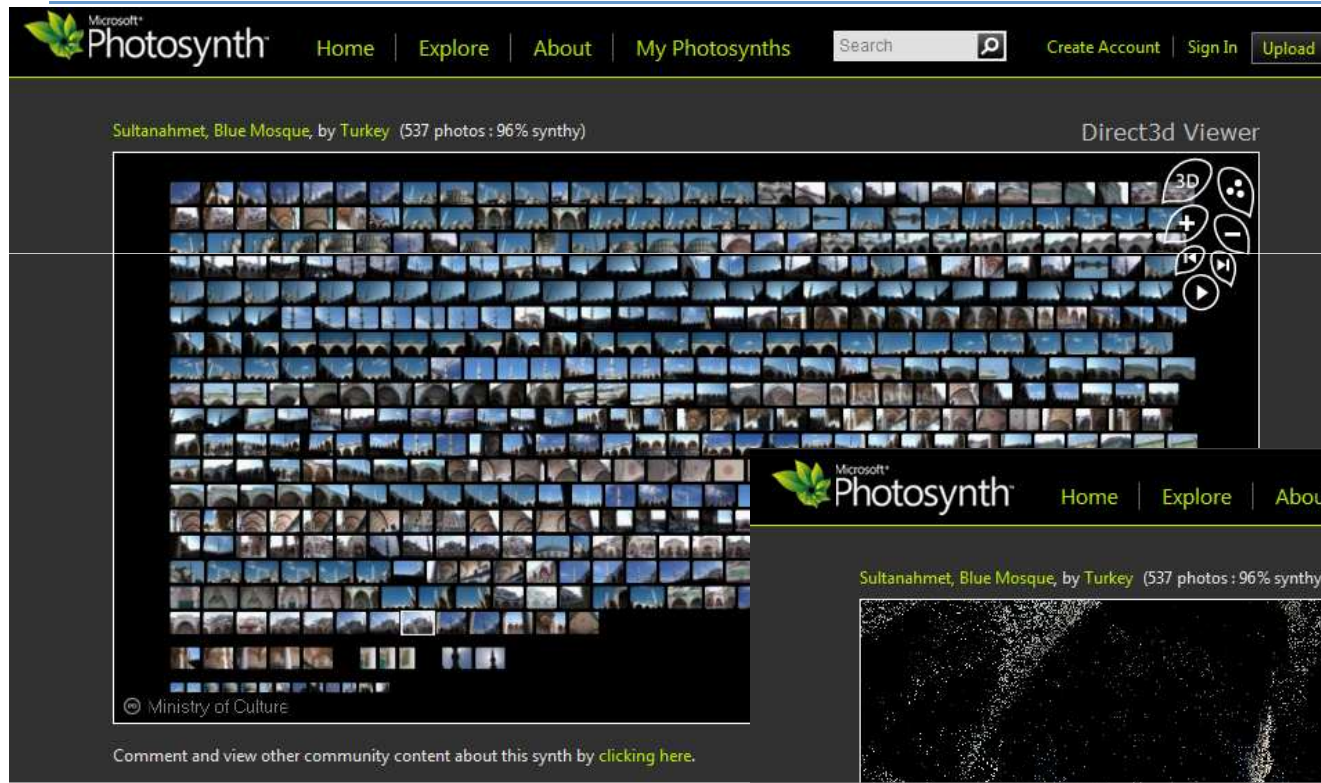
Adapted from Pinar Duygulu, Bilkent University

Photo tourism: exploring photo collections

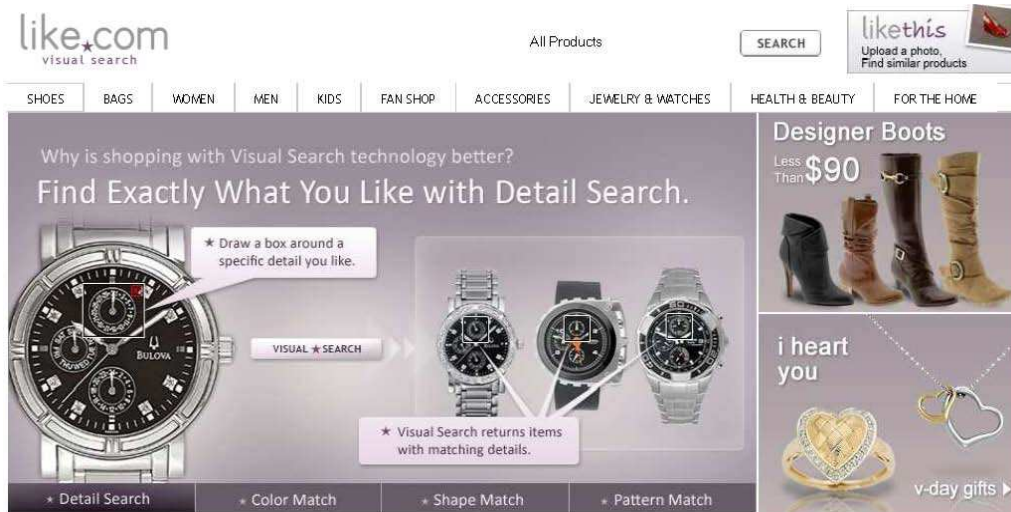


Building 3D scene models from individual photos

Photosynth



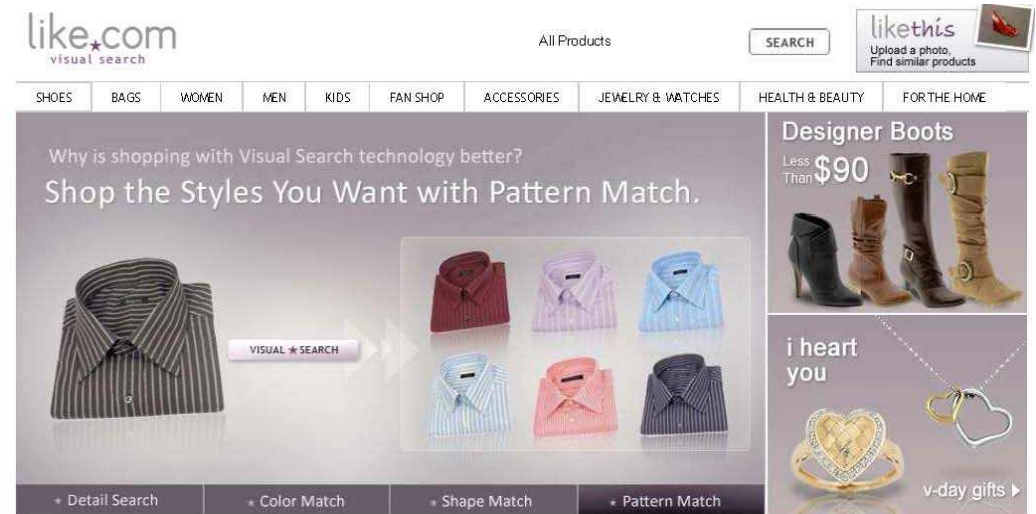
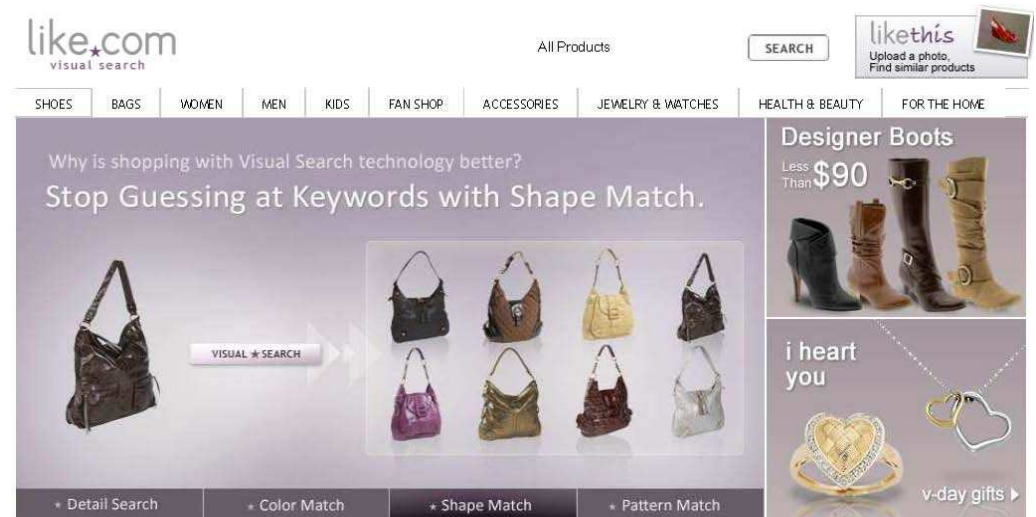
Content-based retrieval



Welcome! Click [VISUAL SEARCH](#) to start visual shopping.



Online shopping catalog search



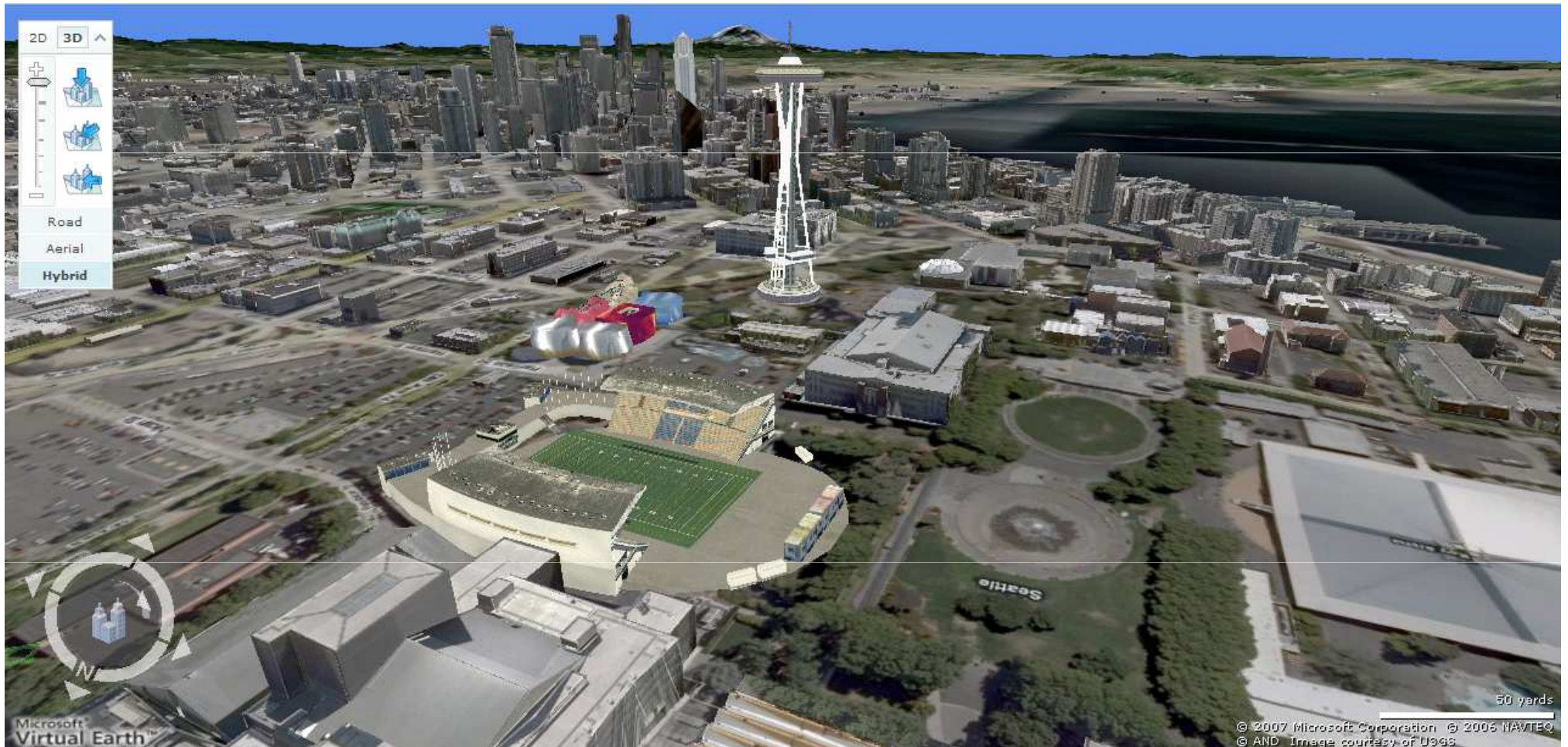
<http://www.like.com>

3D scanning and reconstruction



Adapted from Linda Shapiro, U of Washington

Earth viewers (3D modeling)



Motion capture



Visual effects



Adapted from CSE 455, U of Washington

Motion capture



Microsoft's XBox Kinect



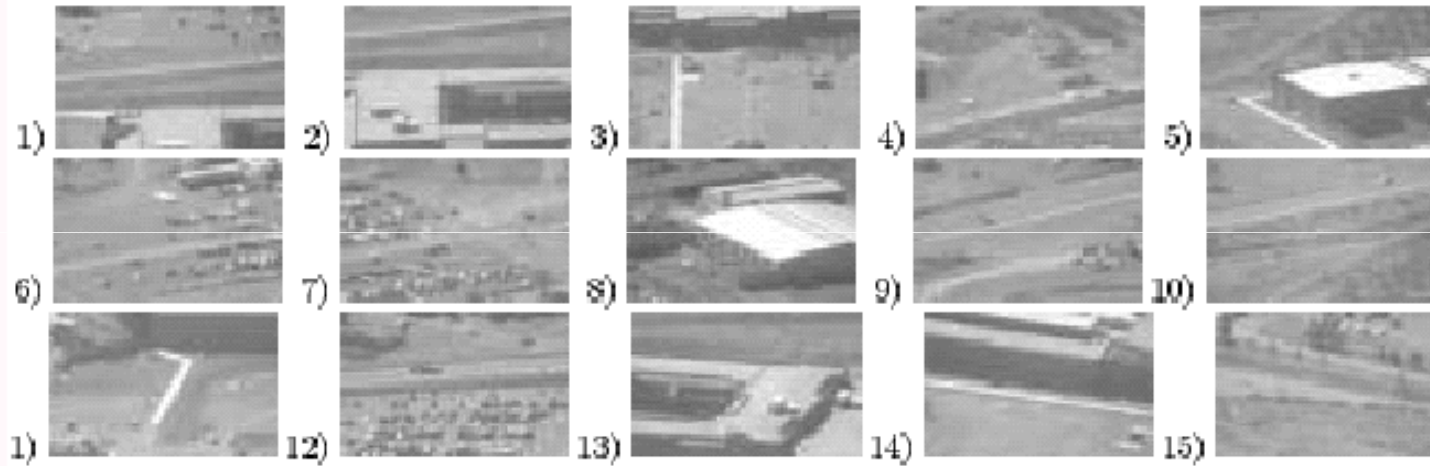
Adapted from CSE 455, U of Washington

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?

Perception and grouping

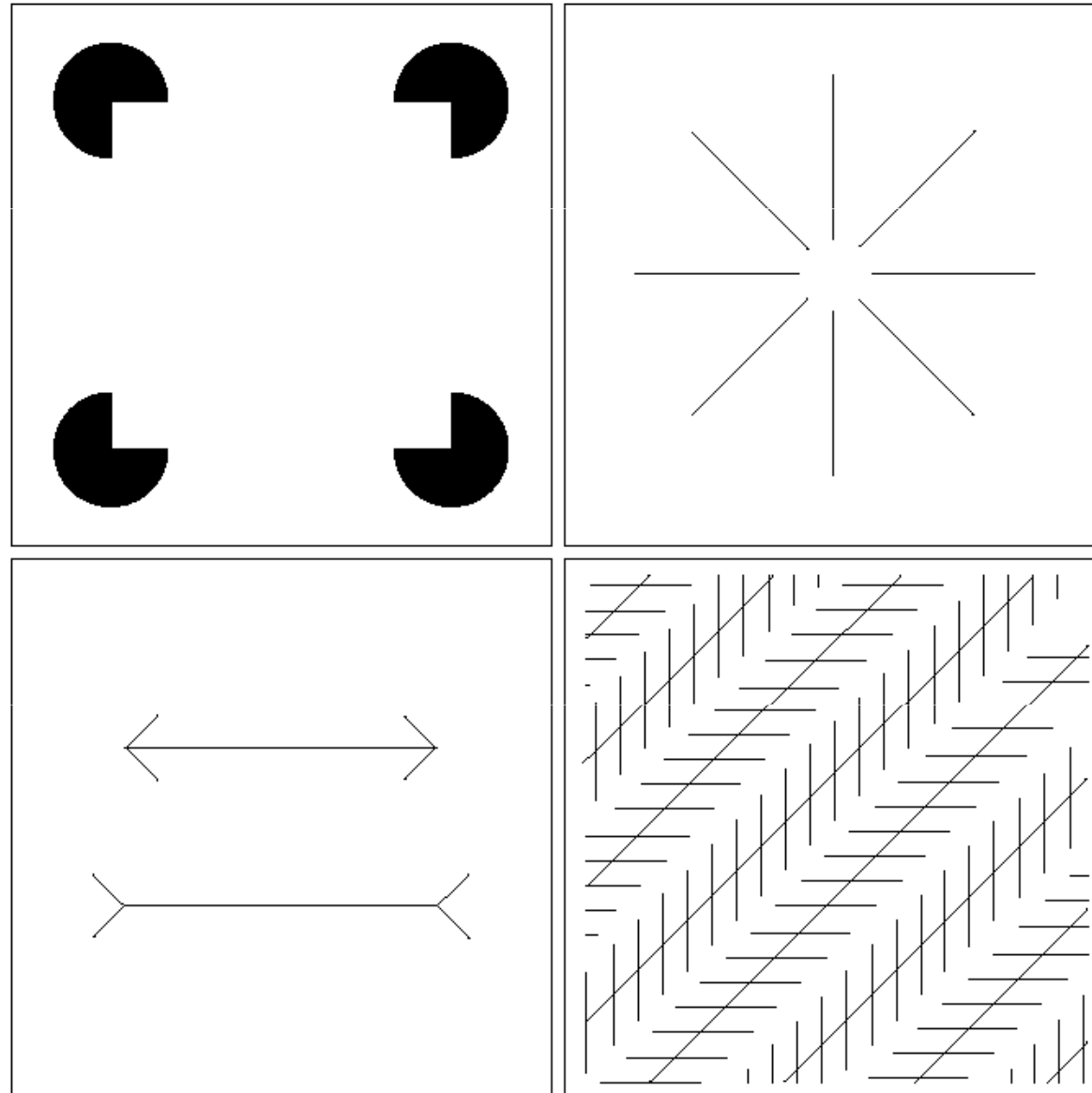


Subjective
contours

Perception and grouping

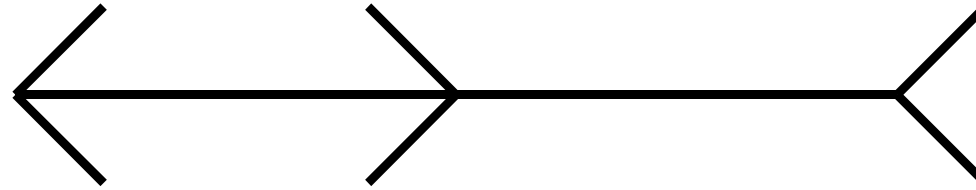
a b
c d

FIGURE 2.9 Some well-known optical illusions.

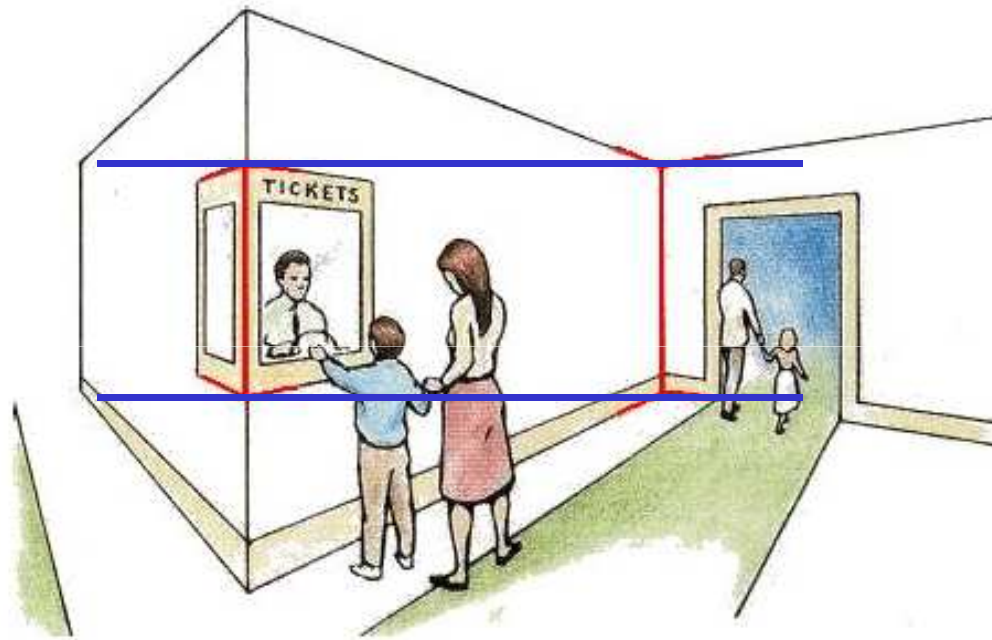


Adapted from Gonzales and Woods

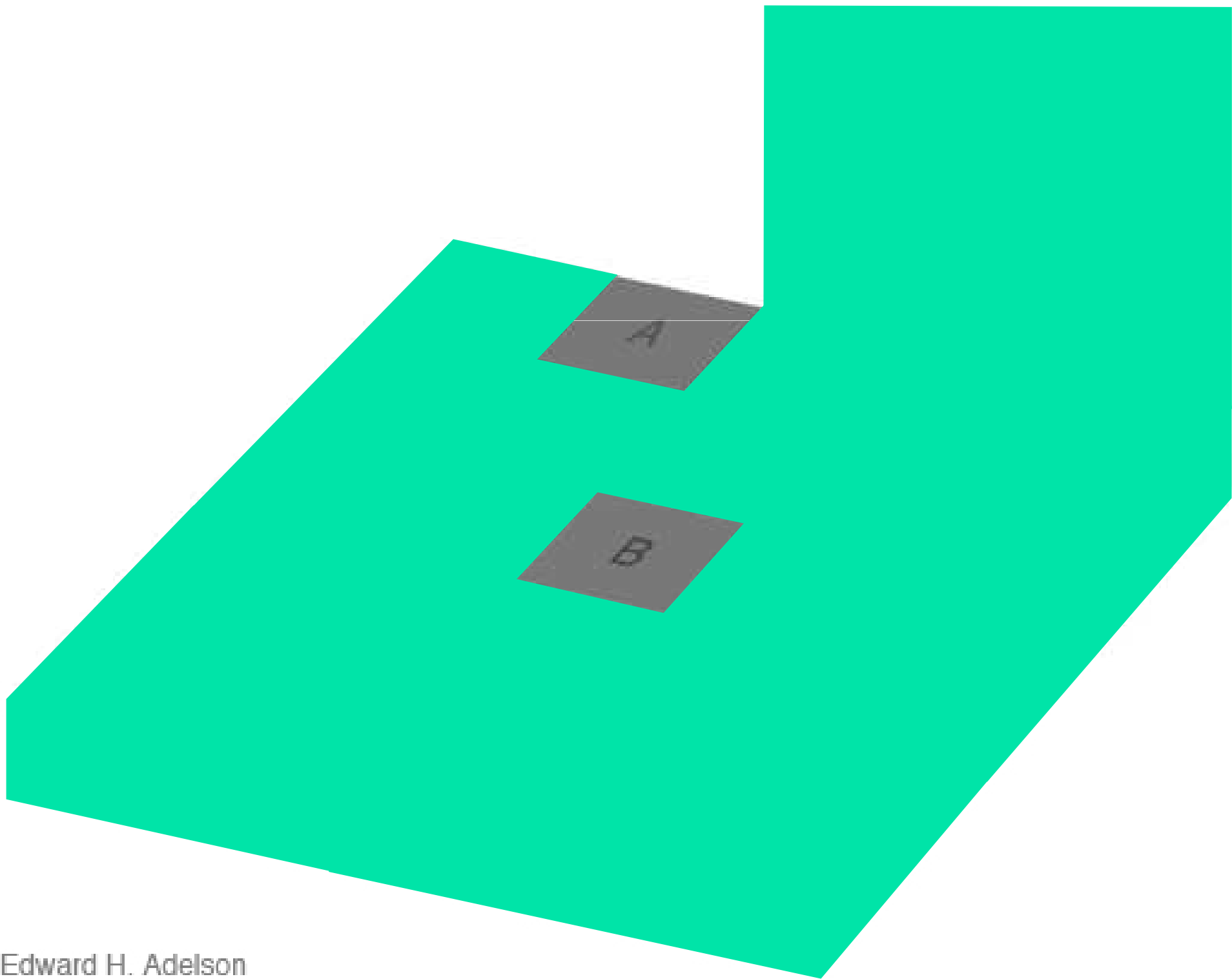
Perception and grouping

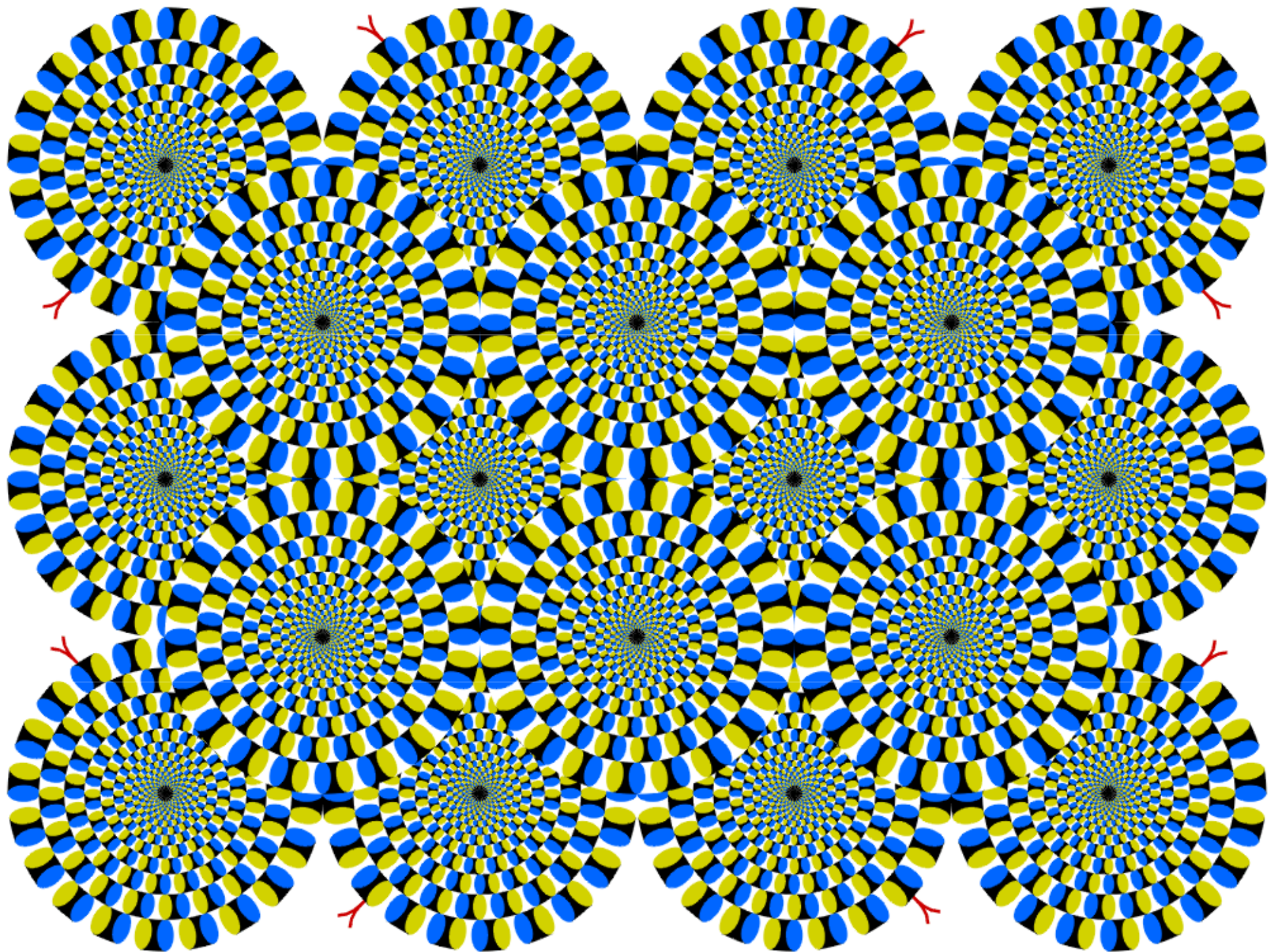


Müller-Lyer Illusion



Adapted from Alyosha Efros, Carnegie Mellon





Perception and grouping

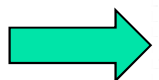


Occlusion

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

I. Rock, The Logic of Perception, 1983.

Adapted from Michael Black, Brown University



60

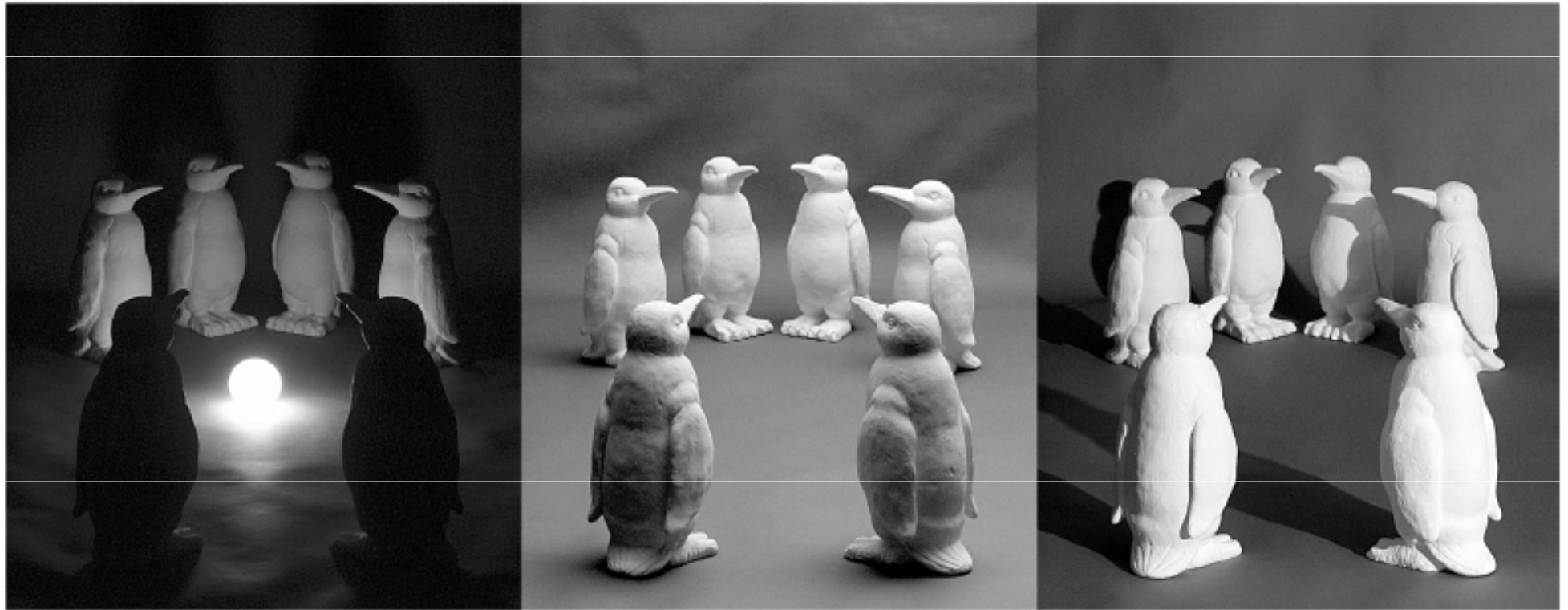
Challenges 1: view point variation



Michelangelo 1475-1564

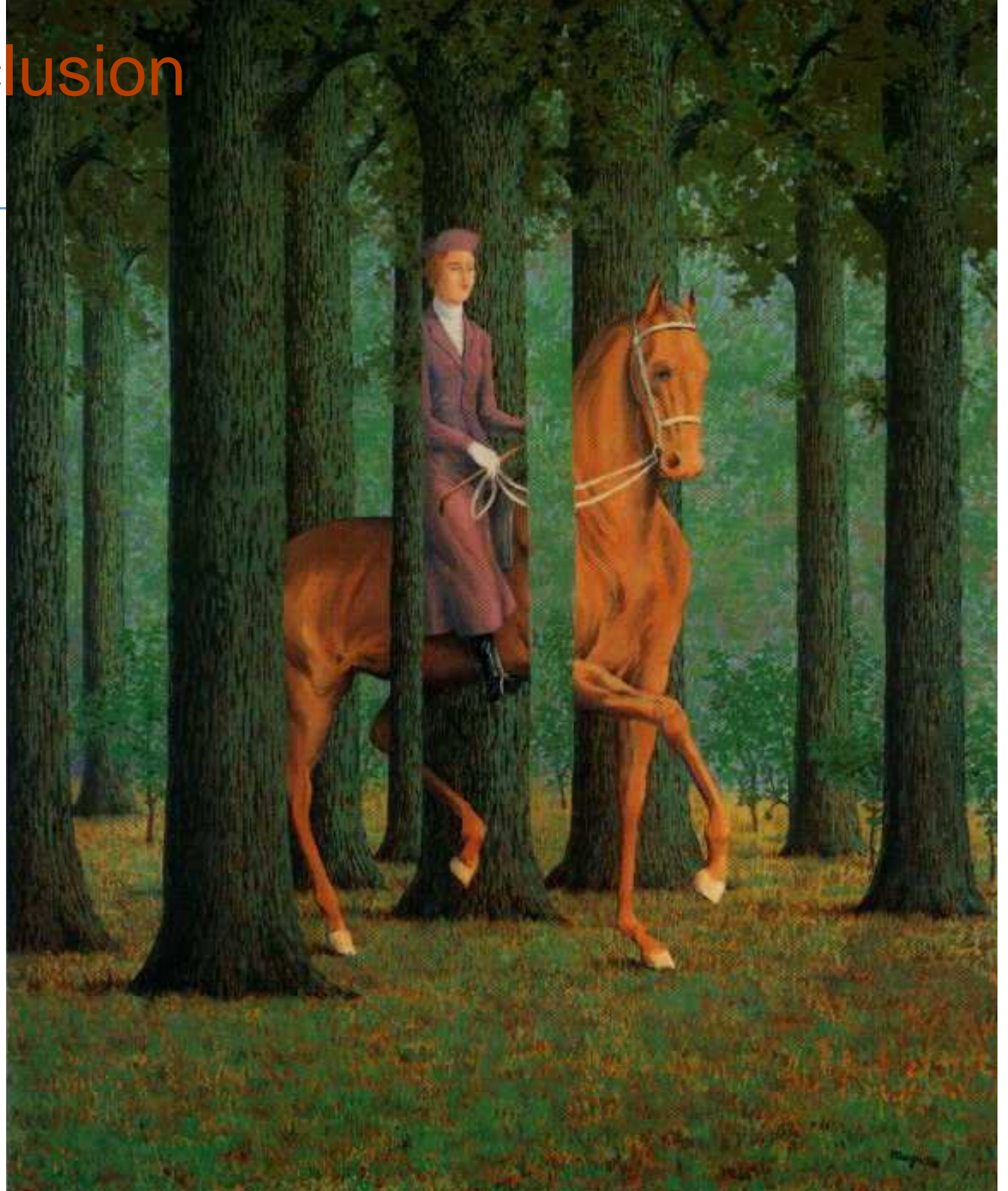


Challenges 2: illumination



Challenges 3: occlusion

Magritte, 1957



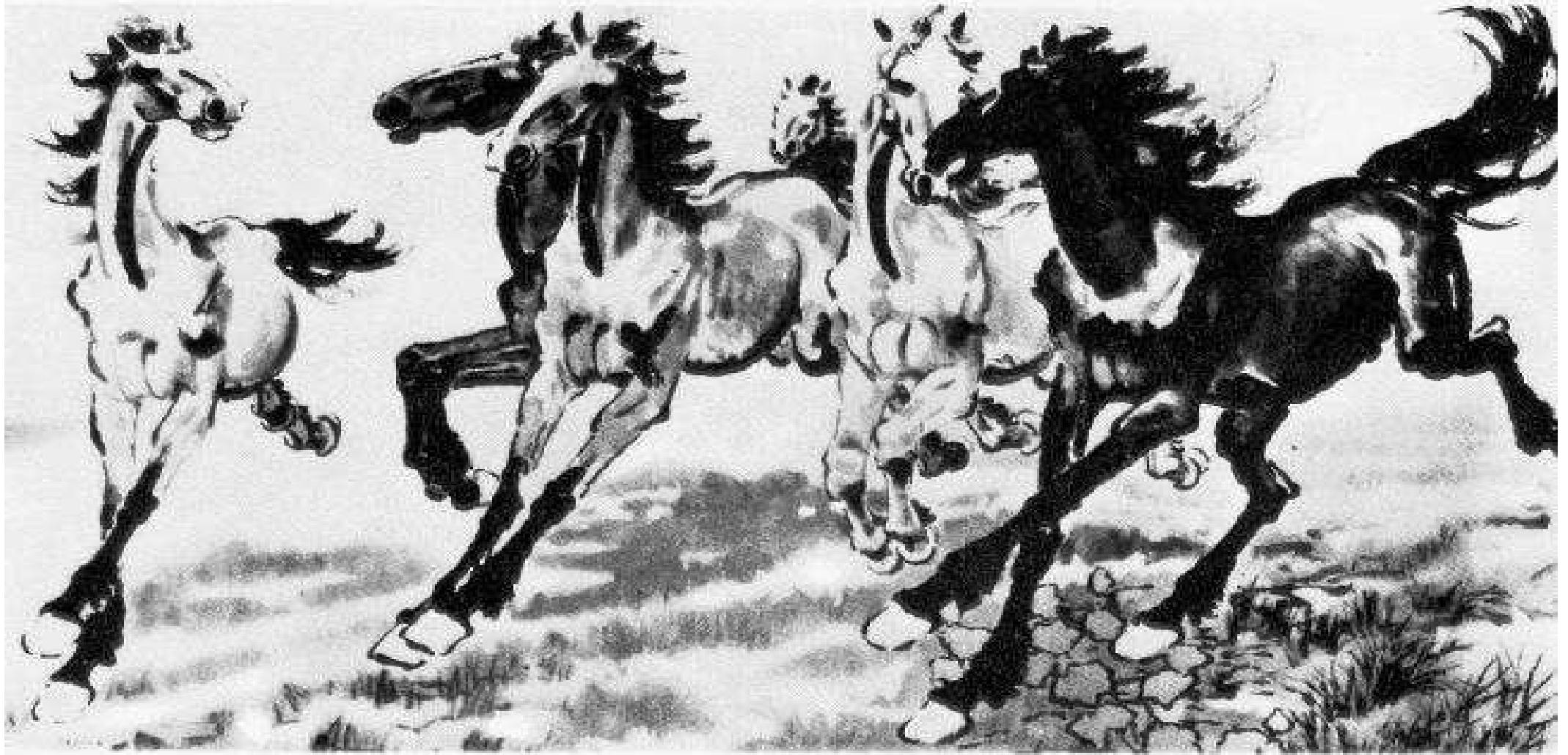
Adapted from L. Fei-Fei,
R. Fergus, A. Torralba

CS 484, Fall 2012

Challenges 4: scale



Challenges 5: deformation



Xu, Beihong 1943

Challenges 6: background clutter



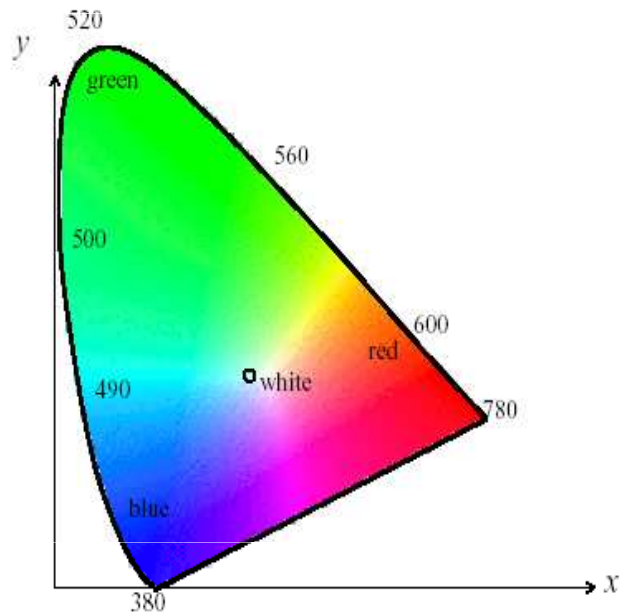
Challenges 7: intra-class variation



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



Color, texture, and proximity



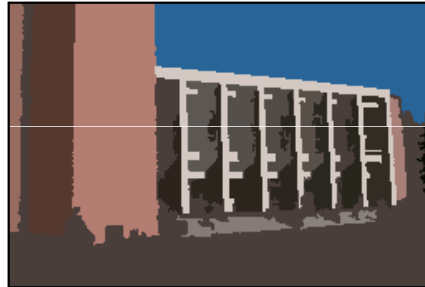
Adapted from Fei-Fei Li

Segmentation

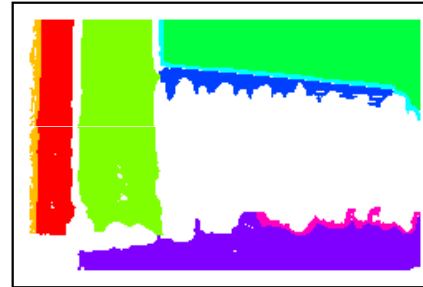
Original Images



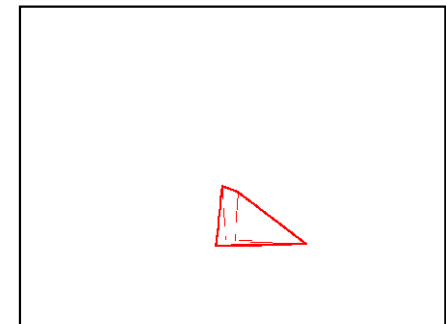
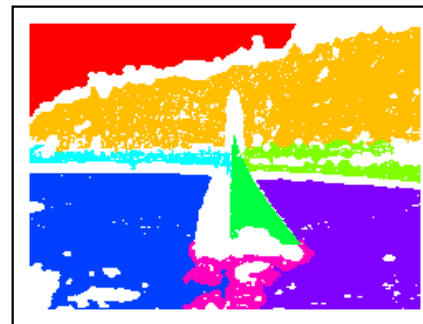
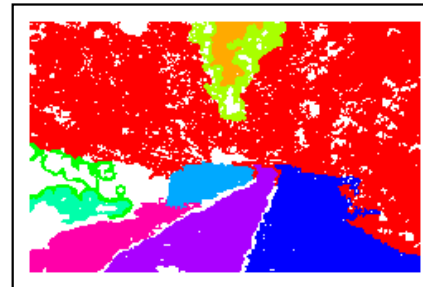
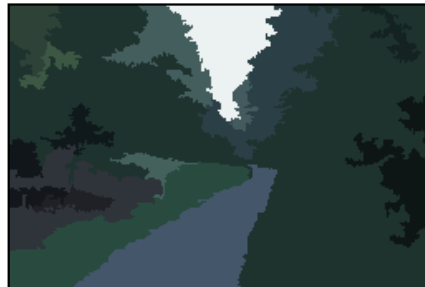
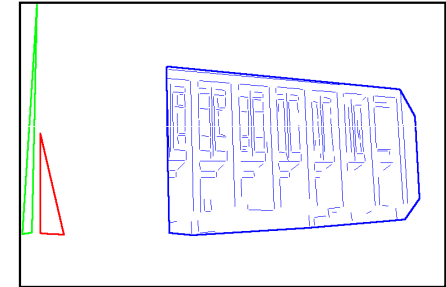
Color Regions



Texture Regions

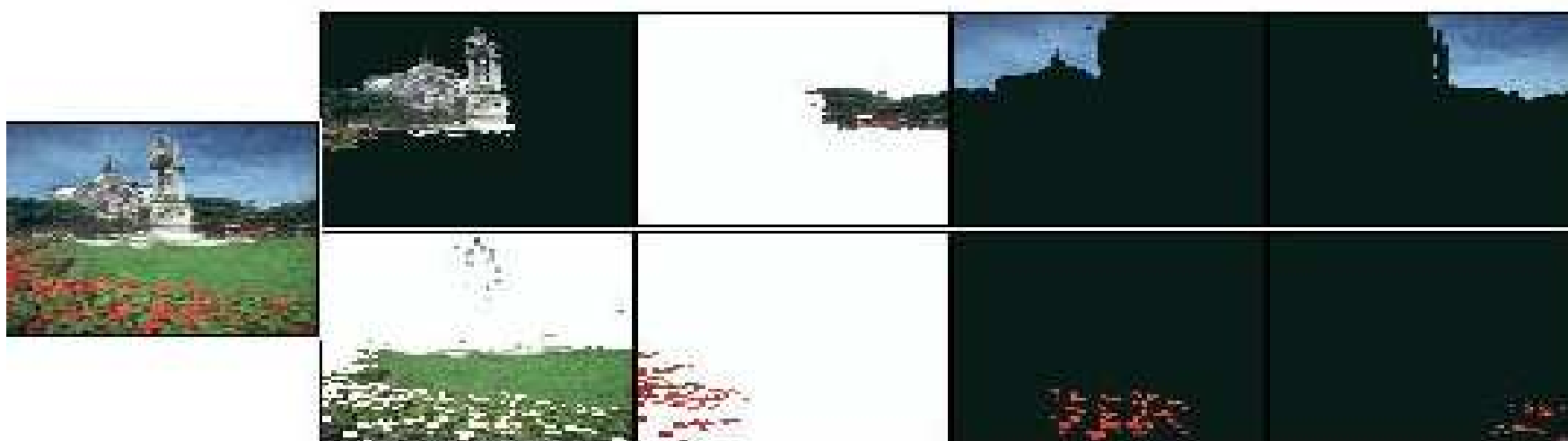
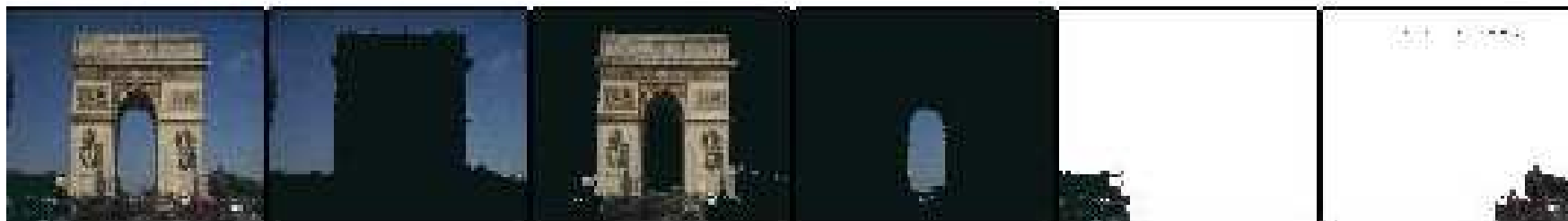


Line Clusters

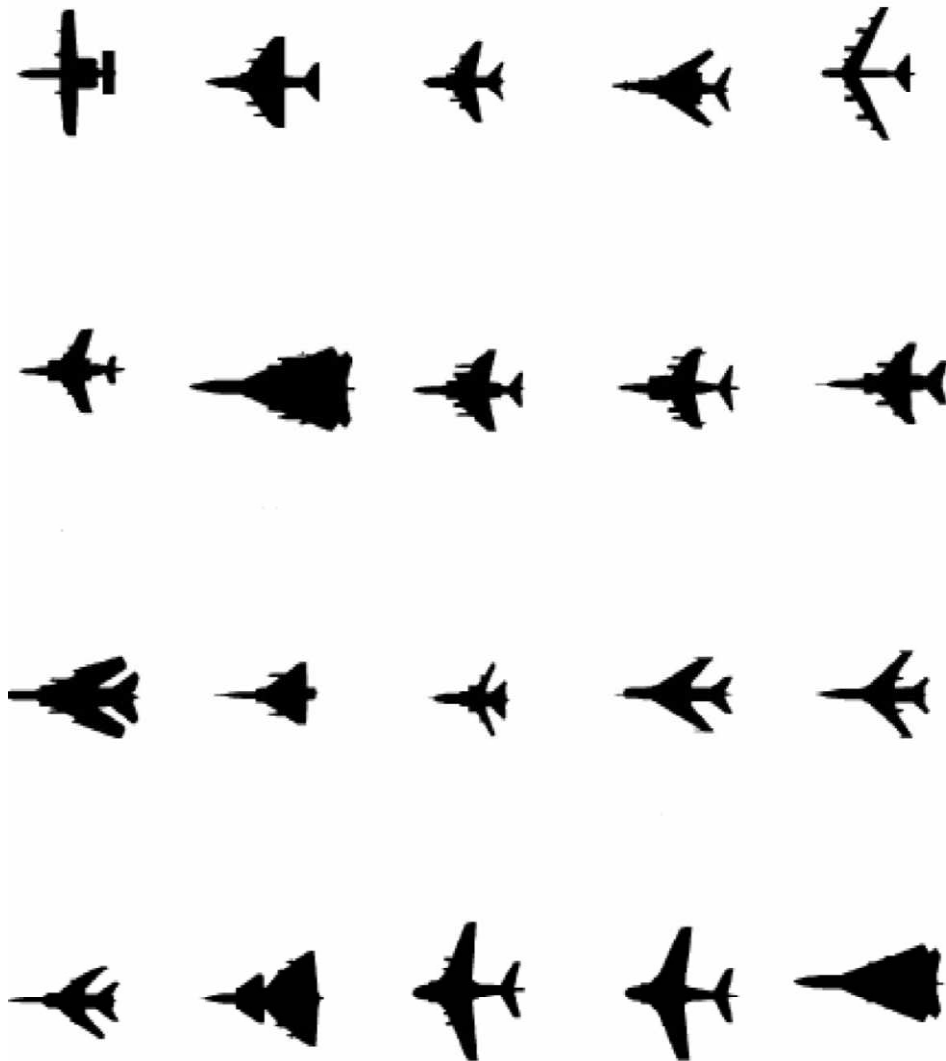


Adapted from Linda Shapiro, U of Washington

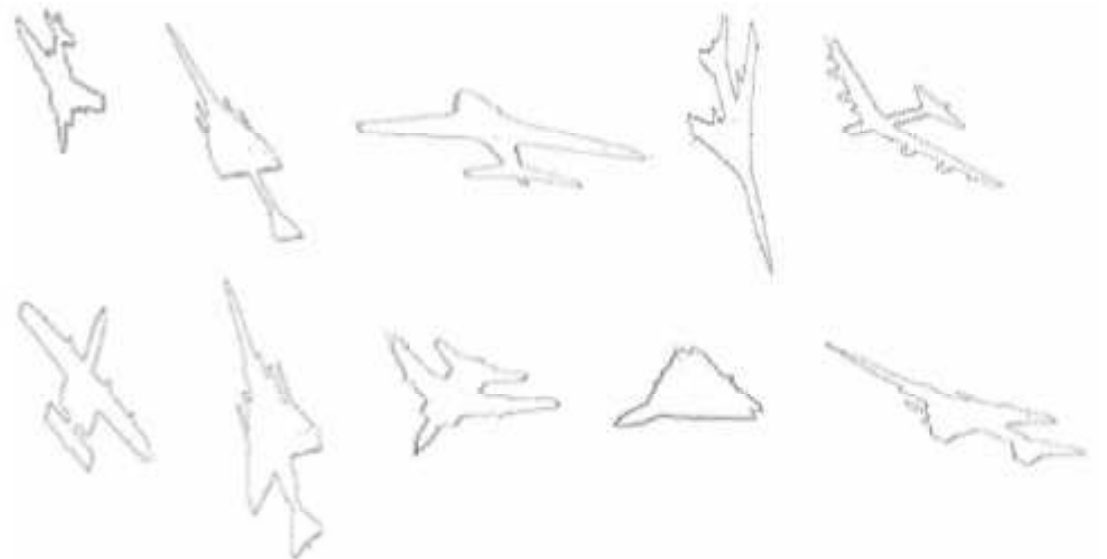
Segmentation



Shape



Model database



Recognized objects

Adapted from Enis Cetin, Bilkent University

Motion



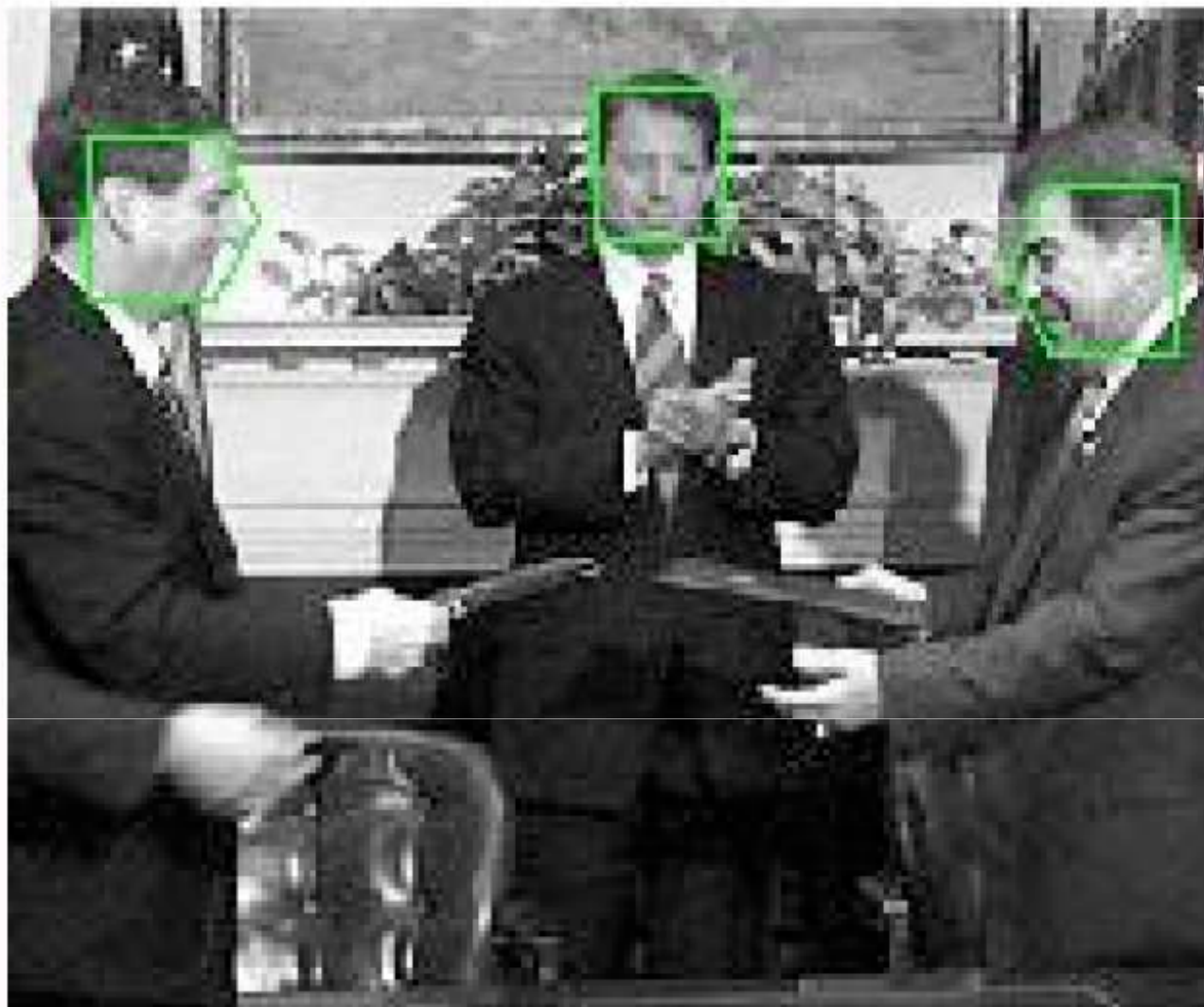
Adapted from Michael Black, Brown University

Detection



Adapted from David Forsyth, UC Berkeley

Detection

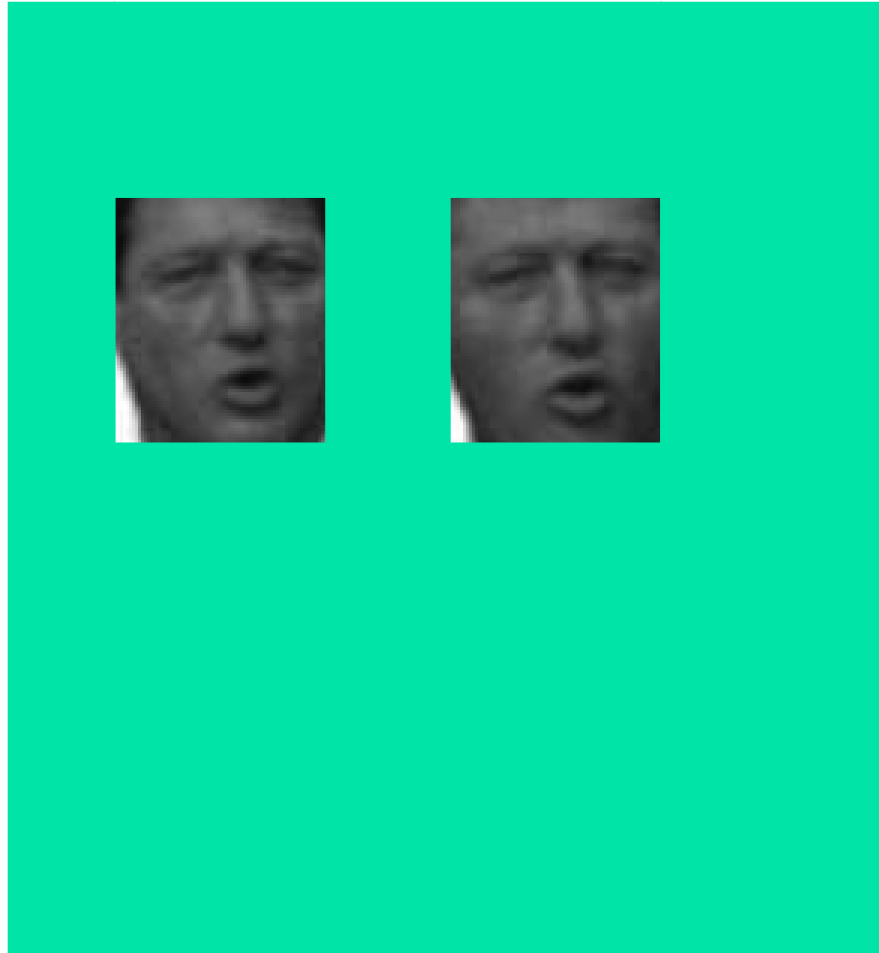


Adapted from David Forsyth, UC Berkeley

Detection

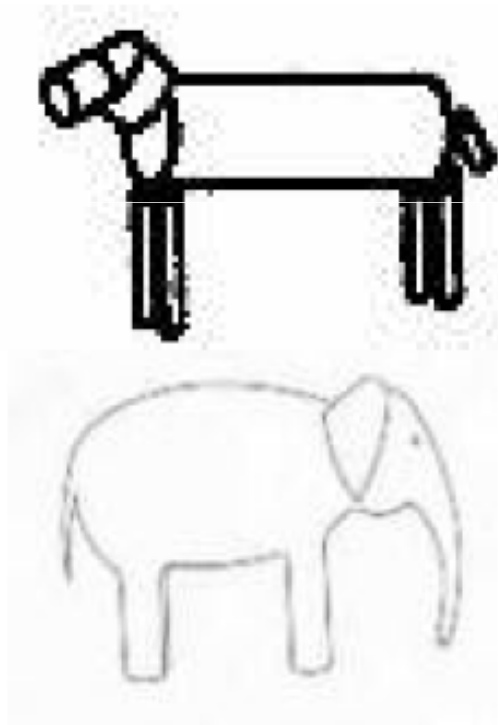
What are our
“models”?

How good
are they?

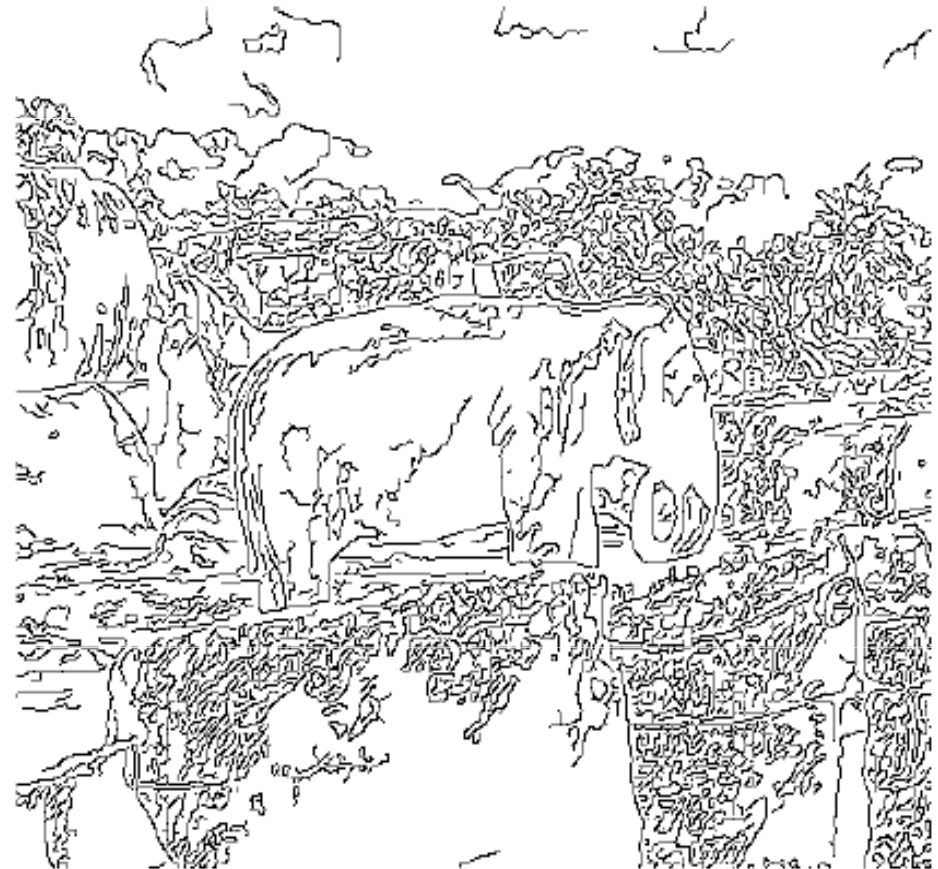


Adapted from Michael Black, Brown University

Recognition

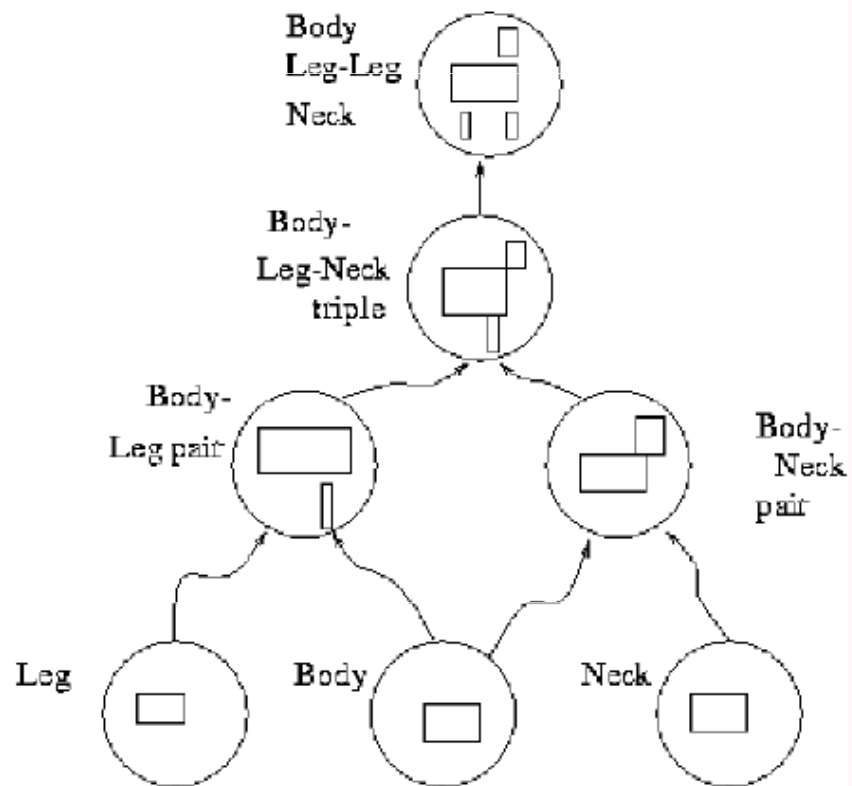


Match “model” to
measurements?



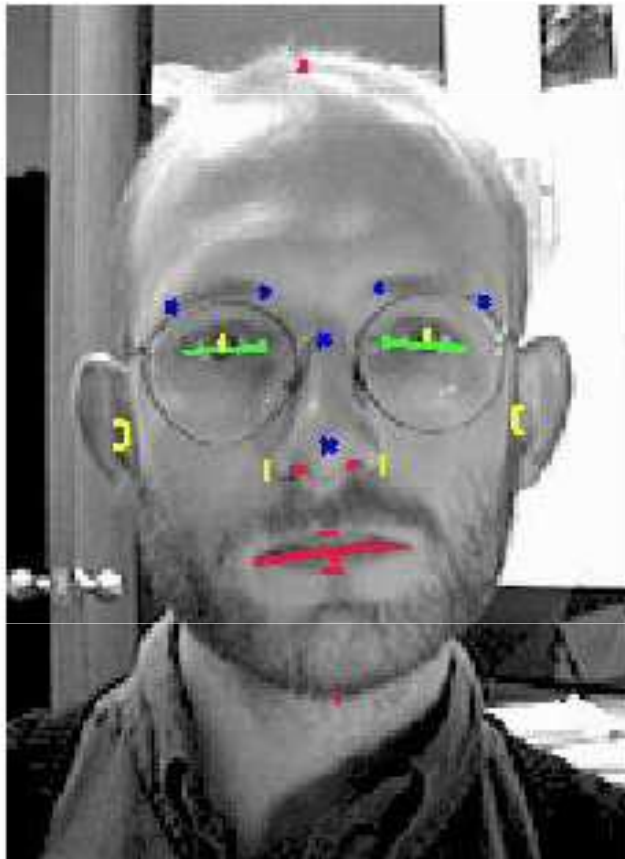
Adapted from Michael Black, Brown University

Recognition

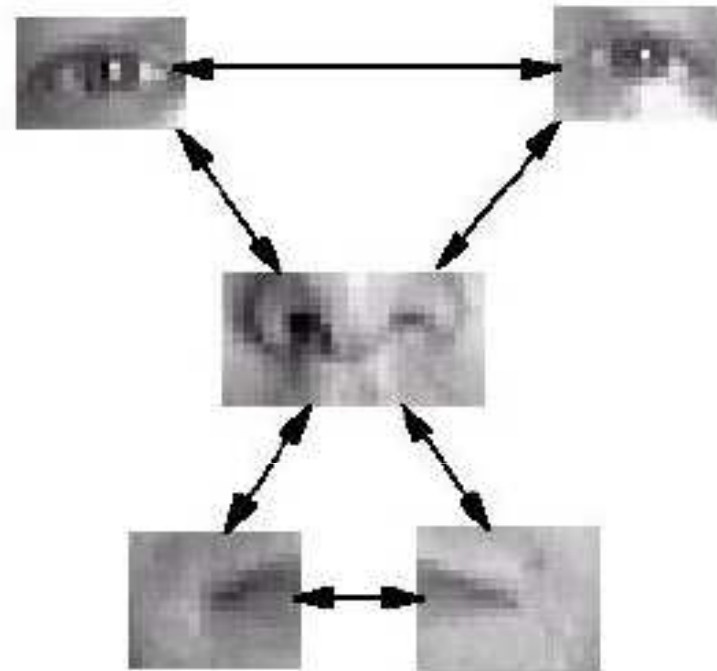


Adapted from David Forsyth, UC Berkeley

Parts and relations



Patch Model



<http://www.research.ibm.com/ecvg/biom/facereco.html>

Adapted from Michael Black, Brown University

Parts and relations



How flexible are the spatial relations of the parts?

Adapted from Michael Black, Brown University

Context



Adapted from Antonio Torralba, MIT

Context



Adapted from Antonio Torralba, MIT

Context



Adapted from Derek Hoiem, CMU

Context



Adapted from
Derek Hoiem, CMU

Stages of computer vision

- Low-level

image → 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



original image

Canny



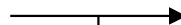
edge image

Mid-level



edge image

ORT



data
structure



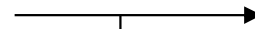
circular arcs and line segments

Mid-level

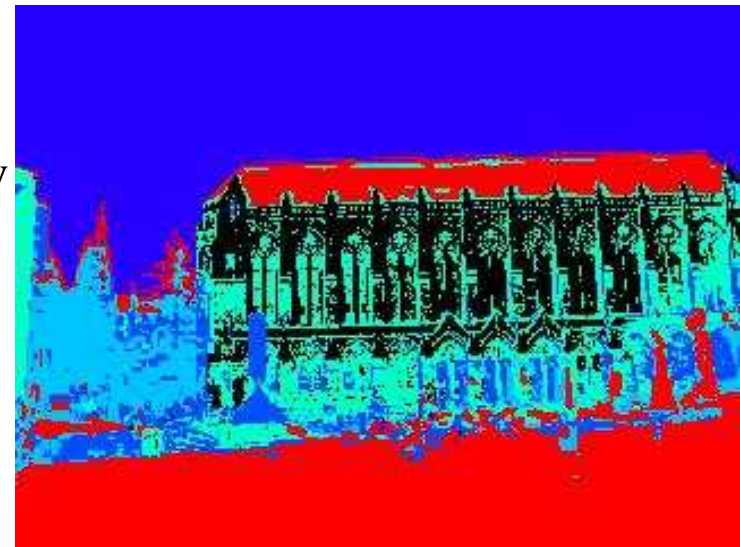


original color image

K-means
clustering
(followed by
connected
component
analysis)



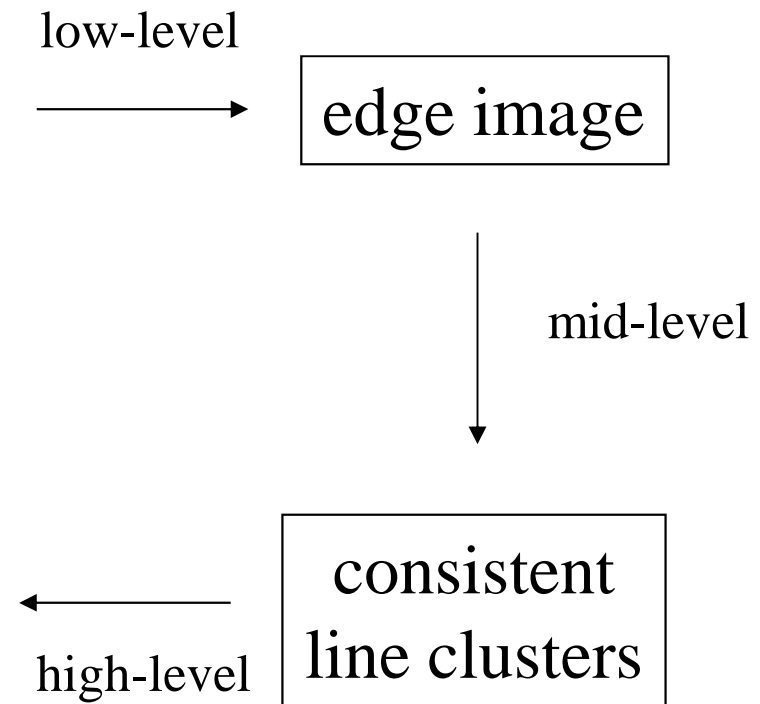
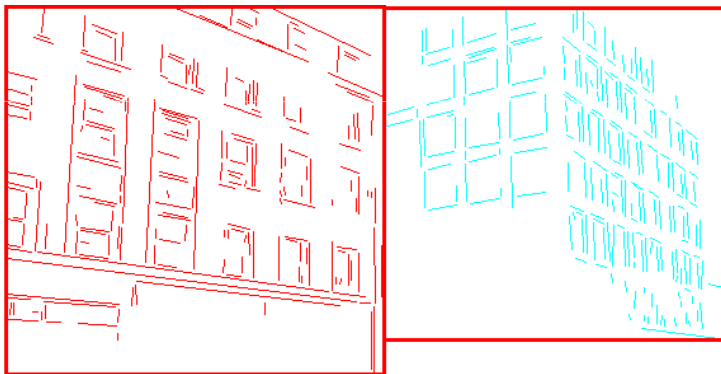
data
structure



regions of homogeneous color

Adapted from Linda Shapiro, U of Washington

Low-level to high-level



Adapted from Linda Shapiro, U of Washington