

CSCE 4603

Fundamentals of Computer Vision

Dr. Mahmoud Khalil

Fall 2019

Course Team

- Instructor: Dr. Mahmoud Khalil
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- TA Eng. Mohamed Magdy
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Text Books

- Rafael C. Gonzalez and Richard E. Woods, **Digital Image Processing**, 4th Edition, Pearson Education, Inc. 2018., ISBN: 978-9353062989
- Richard Szeliski, **Computer Vision Algorithms and Applications**, Springer, 2011 (available online for free at: <http://szeliski.org/Book/>), ISBN: 978-1848829343
- Rafael C. Gonzalez , Richard E. Woods and Steven L. Eddins, **Digital Image Processing Using Matlab**, Second edition,, Pearson Education, Inc. 2009., ISBN: 978-0070702622
- **OpenCV**: <https://opencv.org/>

Grading Scheme

- Assignments: 20%
- Midterm Exams (2): 40%
- Final Exam: 20%
- Project: 20%

General Policies

- More than 6 absence days without an official excuse will result you an “F” in this course.
- Any plagiarism case will result you 0 in the corresponding component and possibly an “F” in this course.
- Late Assignments will NOT be accepted.
- An assignment is an individual effort while the project can be done individually or in groups of up to 3 students (with individual tasks validation).

Course Contents

Image acquisition, image transformations, gray level operations, histogram equalization, spatial filtering, edge detection, line and circle detection, generalized Hough transform, connected components labelling. Haar features, object detection with Adaboost, applications: face detection, open CV programming.

Visual Sciences

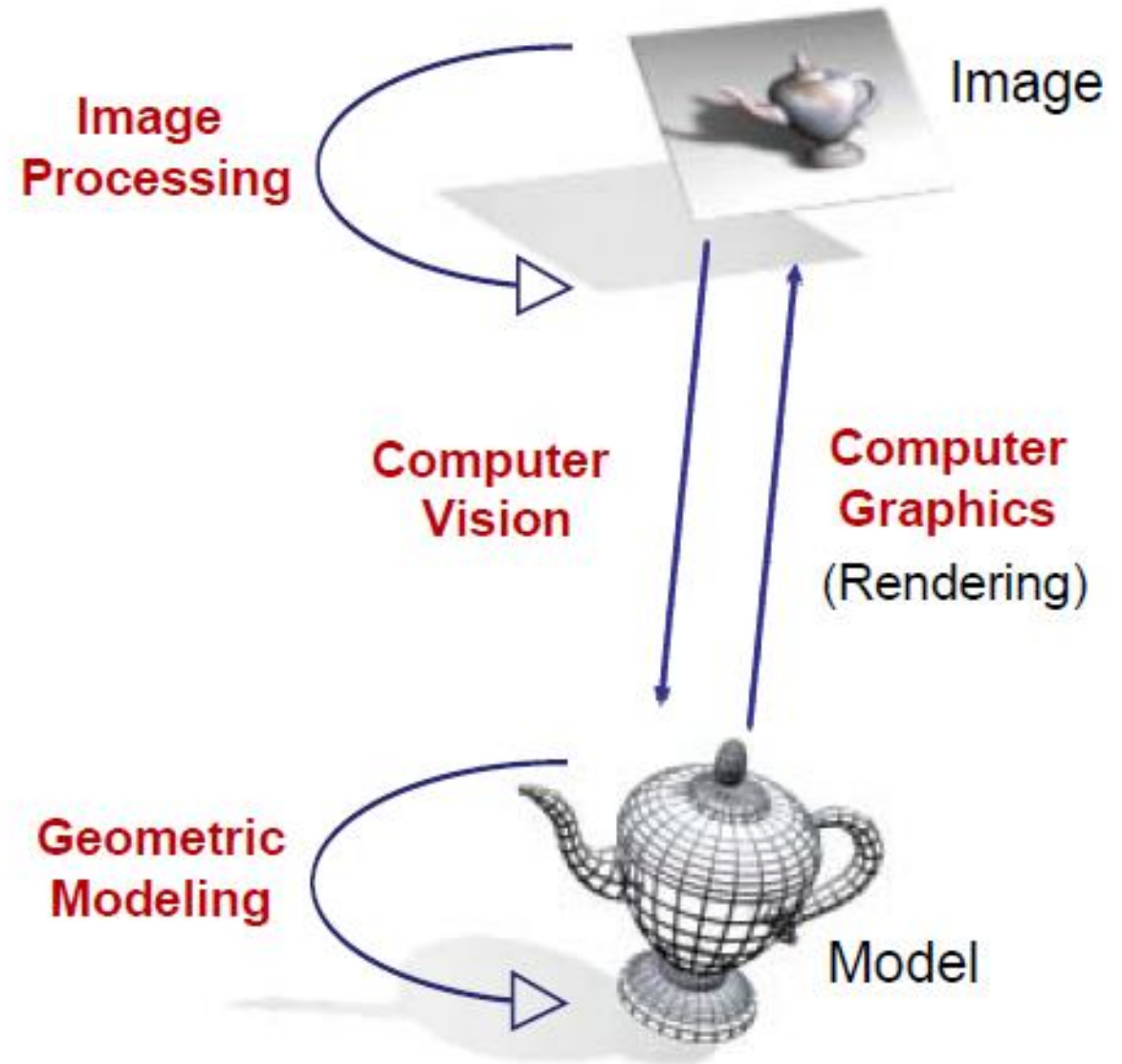
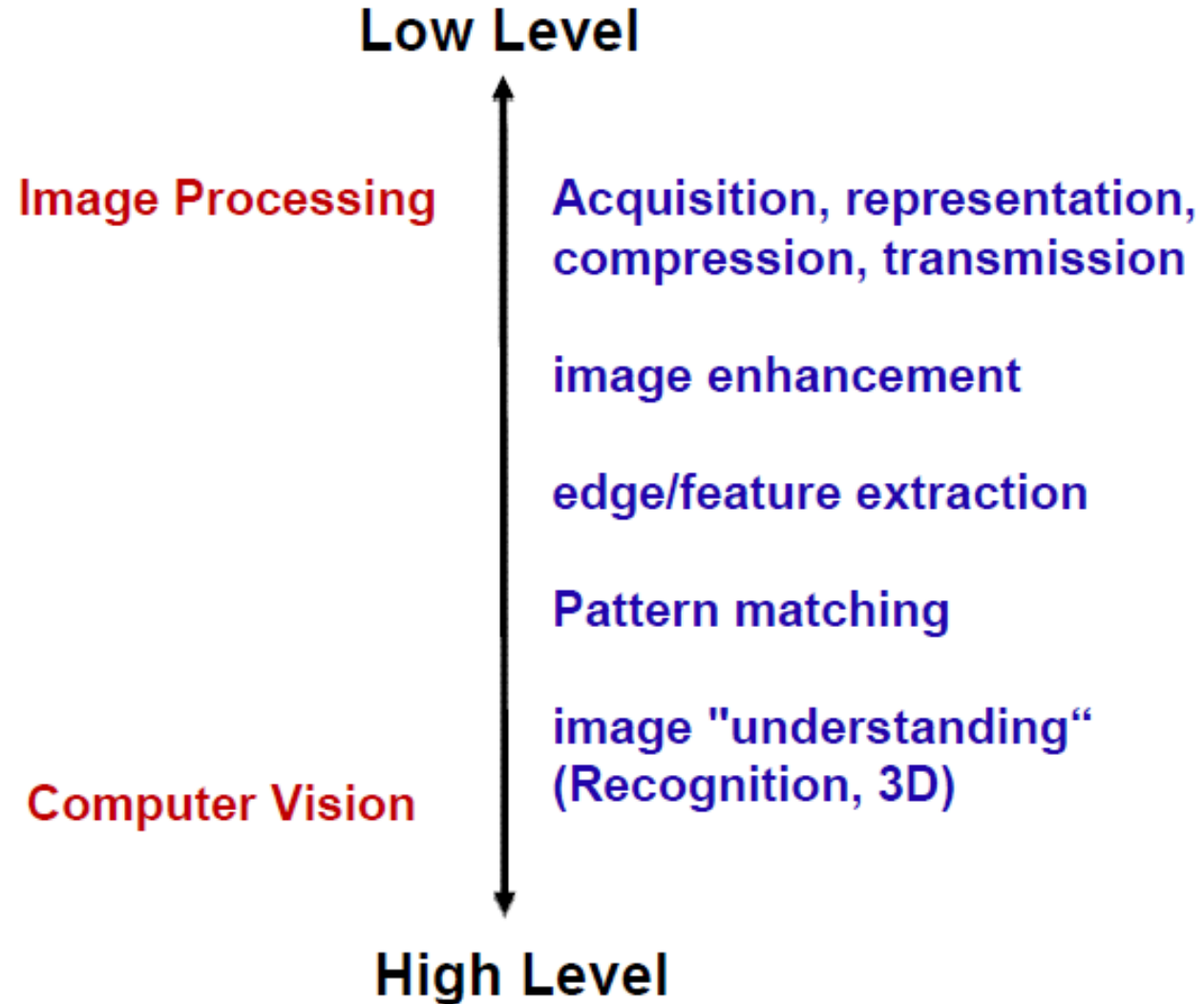


Image Processing - Computer Vision



Course Outlines

FIGURE 1.23
Fundamental
steps in digital
image processing.

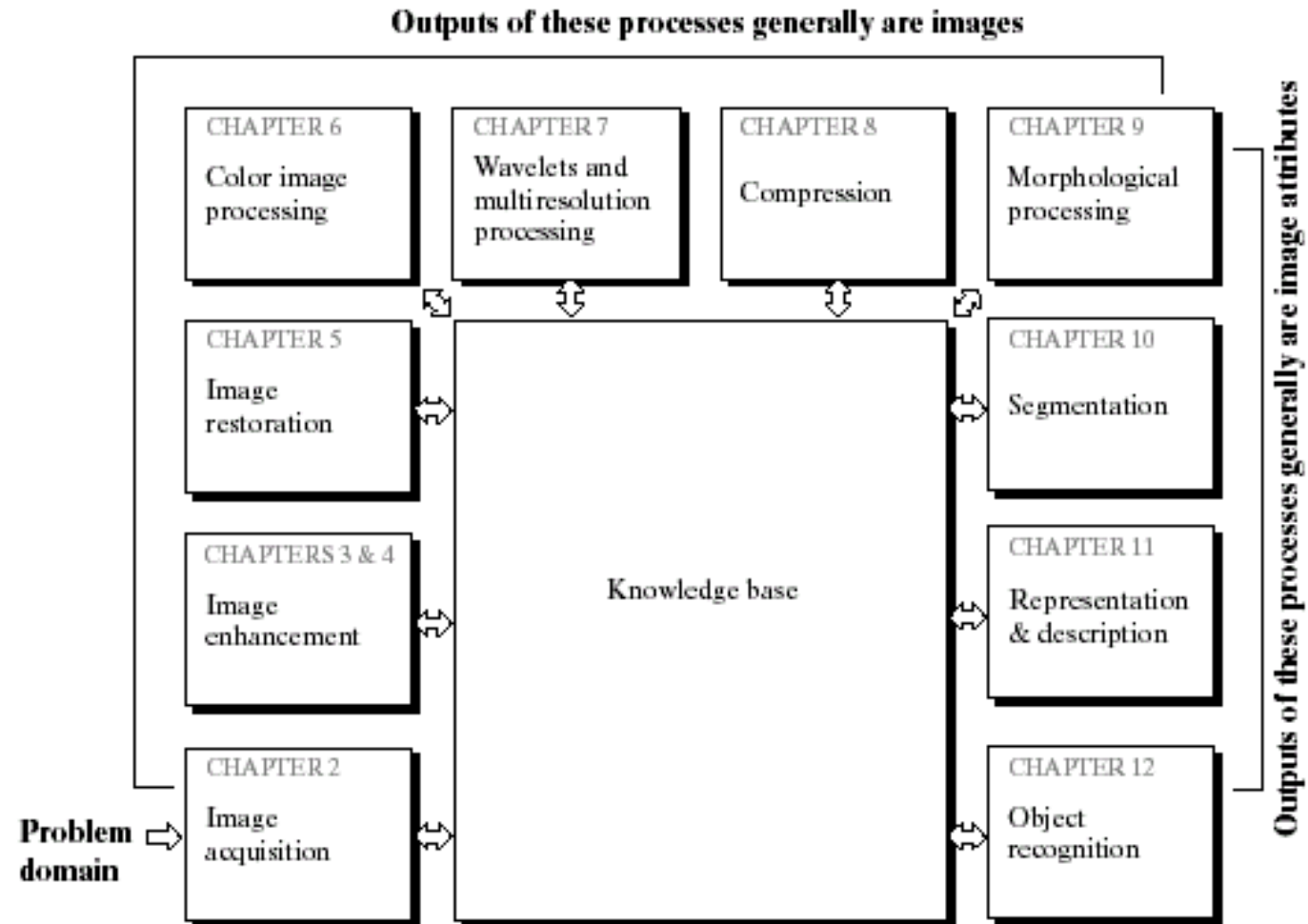


Image Enhancement

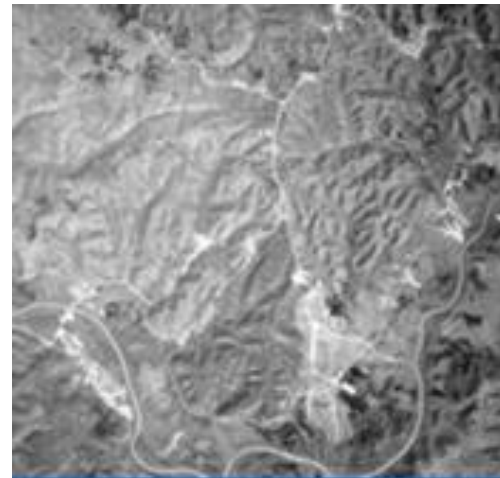
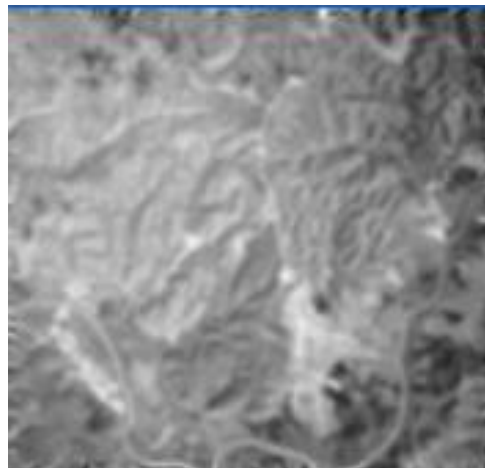
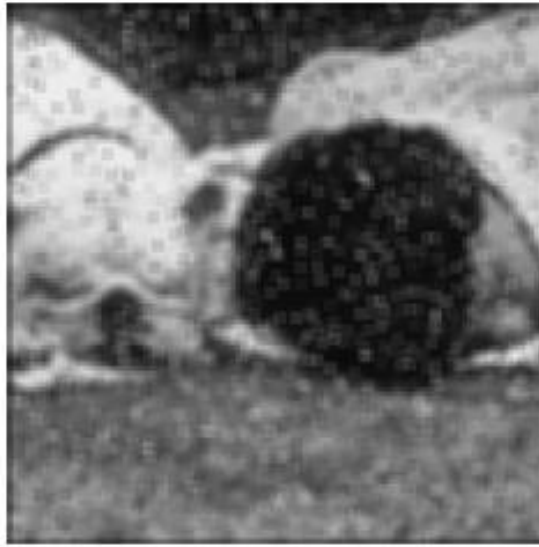


Image Denoising

Salt & Pepper
Noise



3 X 3 Average

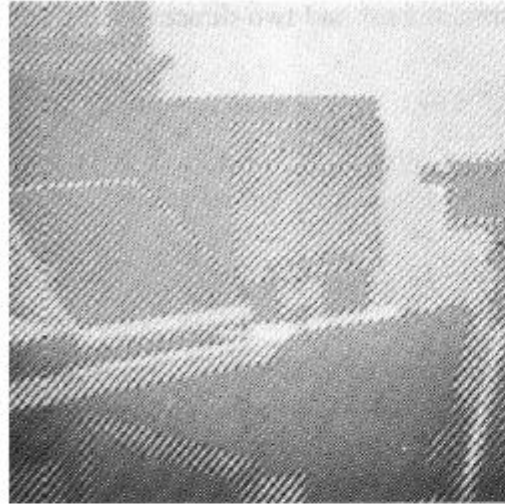


Median

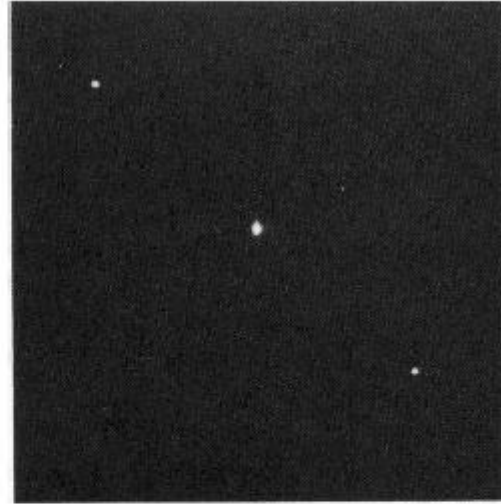


Image Enhancement - Frequency Domain

Original Noisy image



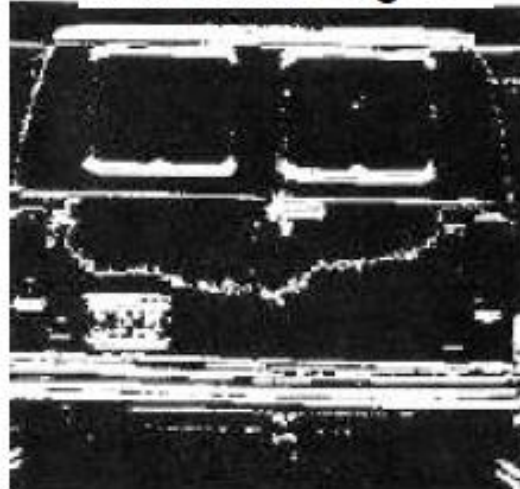
Fourier Spectrum



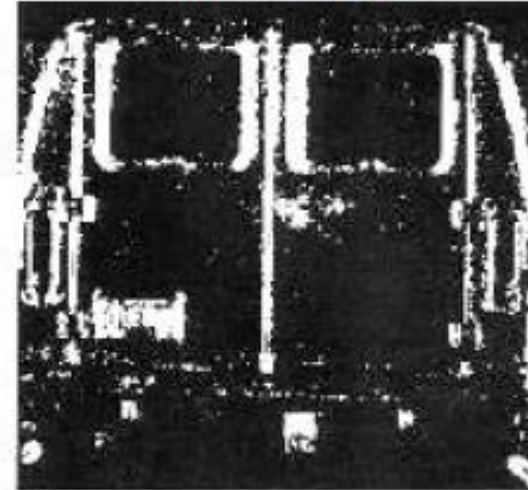
Edge Detection



Horizontal Edges



Vertical Edges



Linked Edges

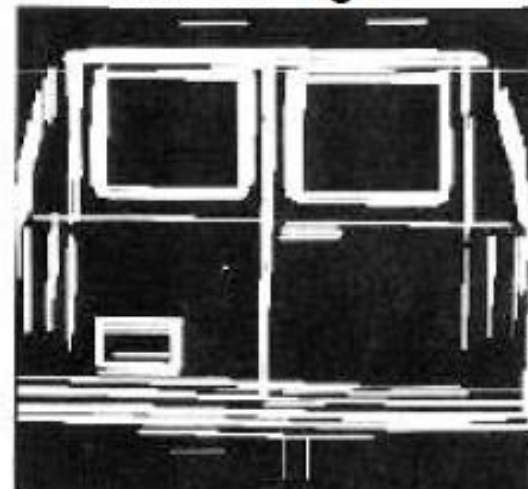
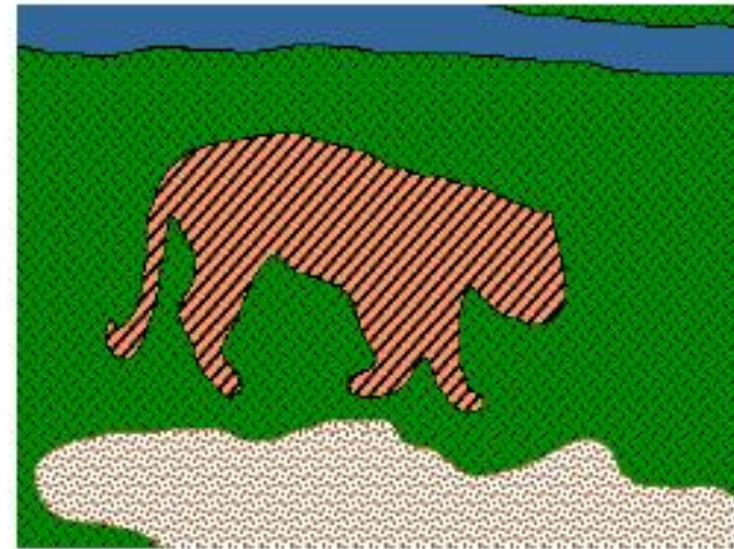


Image Segmentation

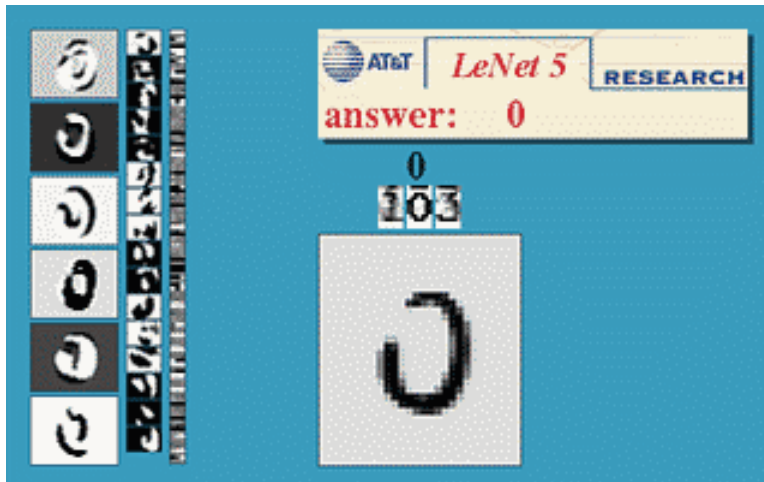
Goal: identify groups of pixels that go together



Optical character recognition (OCR)

Technology to convert scanned docs to text

- If you have a scanner, it probably came with OCR software



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



License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Face detection

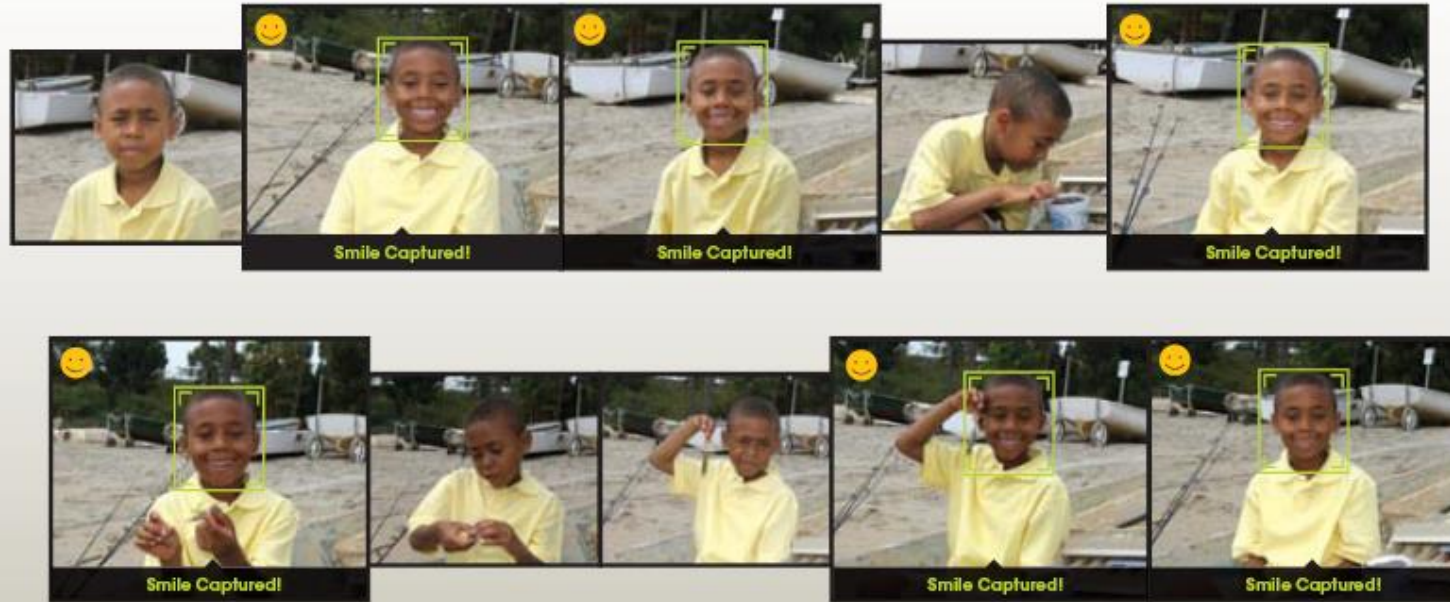


- Many new digital cameras now detect faces
 - Canon, Sony, Fuji, ...

Smile detection

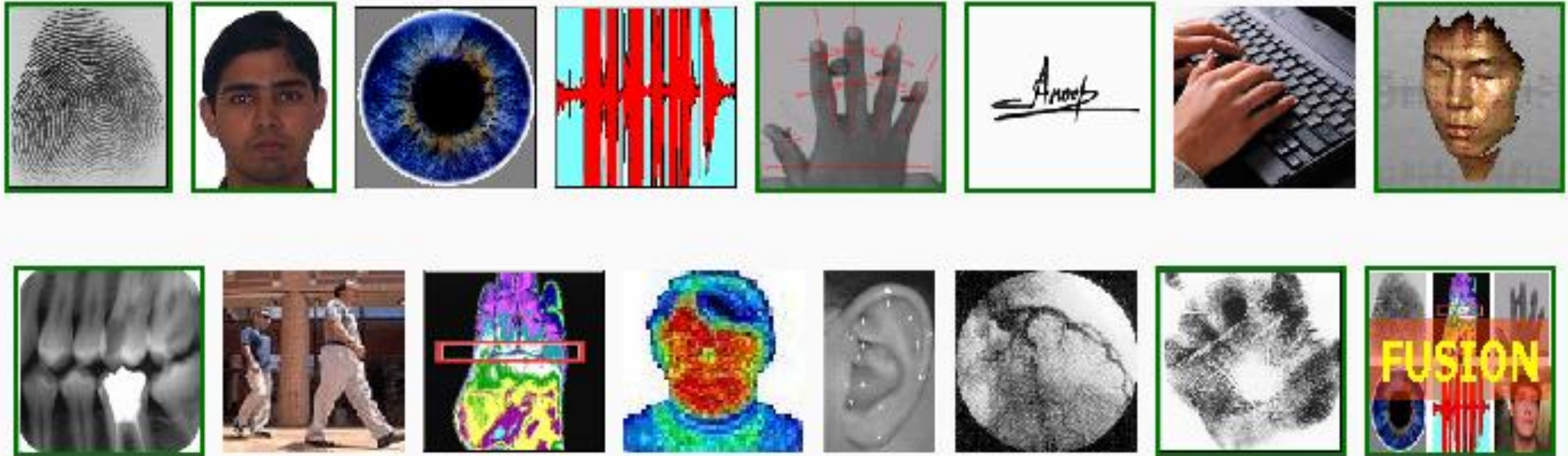
The Smile Shutter flow

Imagine a camera smart enough to catch every smile! In Smile Shutter Mode, your Cyber-shot® camera can automatically trip the shutter at just the right instant to catch the perfect expression.



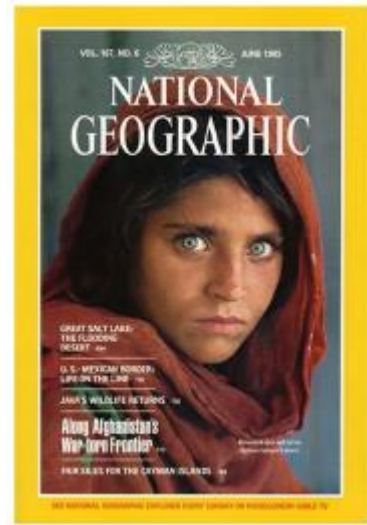
[Sony Cyber-shot® T70 Digital Still Camera](#)

Biometrics



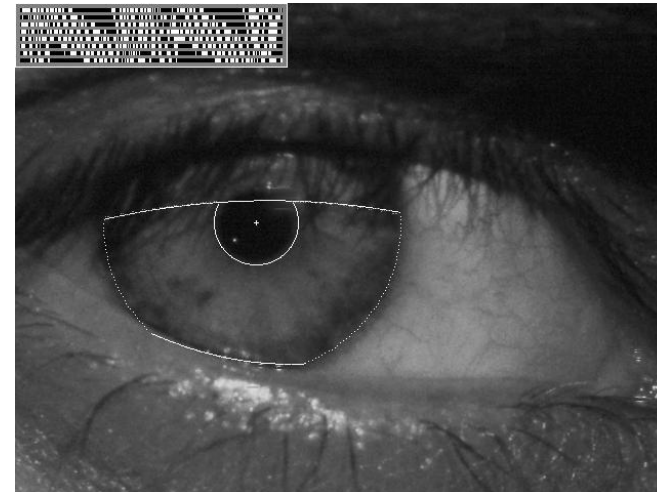
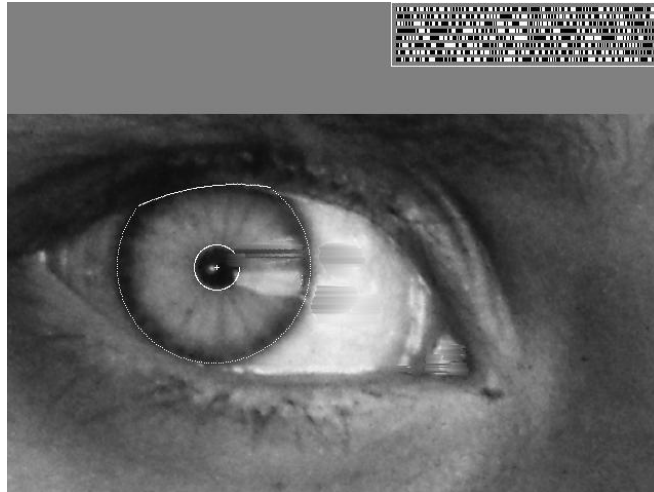
Adapted from Anil Jain, Michigan State

Vision-based biometrics



"How the Afghan Girl was Identified by Her Iris Patterns"

Read the [story](#)
[wikipedia](#)



Login without a password...



Fingerprint scanners on many new laptops, other devices



Face recognition systems now beginning to appear more widely
<http://www.sensiblevision.com/>

Object recognition (in mobile phones)



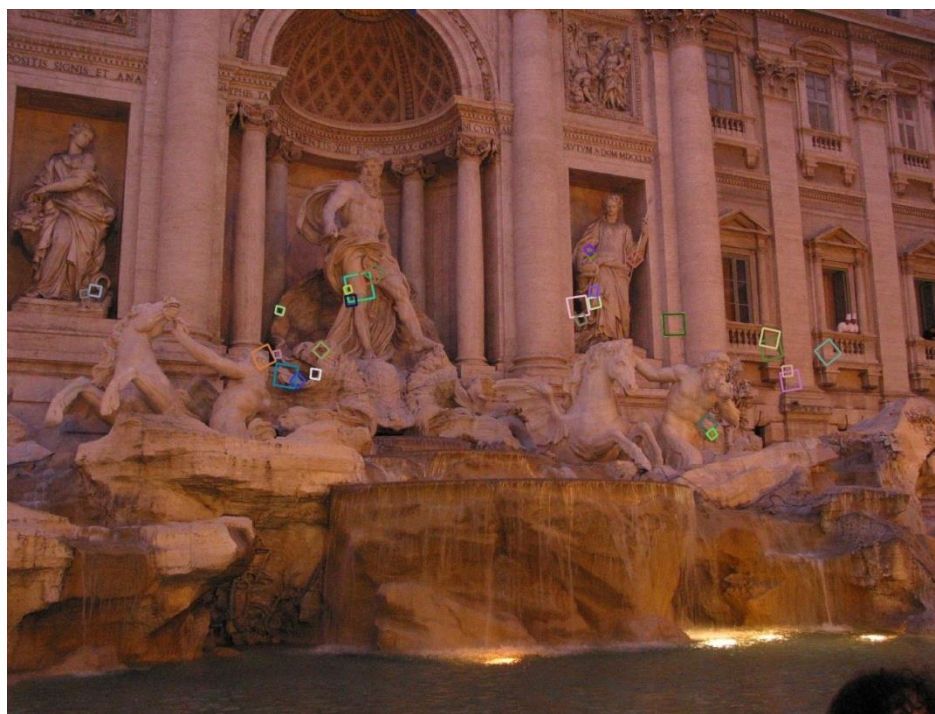
Point & Find, Google Goggles

Building a Panorama



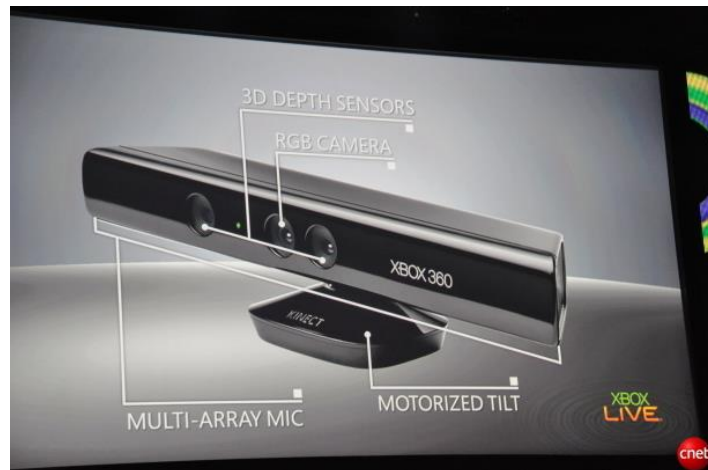
Feature descriptors

- Extraordinarily robust matching technique
 - Can handle changes in viewpoint
 - Up to about 60 degree out of plane rotation
 - Can handle significant changes in illumination
 - Sometimes even day vs. night (below)
 - Fast and efficient—can run in real time

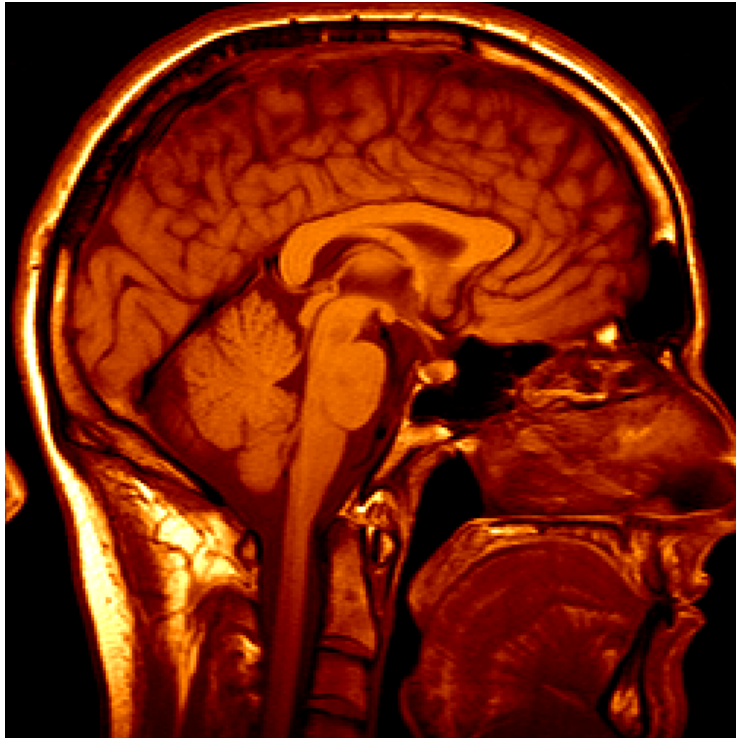


Interactive Games: Kinect

- Object Recognition:
<http://www.youtube.com/watch?feature=iv&v=fQ59dXOo63o>
- Mario: <http://www.youtube.com/watch?v=8CTJL5IUjHg>
- 3D: <http://www.youtube.com/watch?v=7QrnwoO1-8A>
- Robot: <http://www.youtube.com/watch?v=w8BmgtMKFbY>



Medical imaging



3D imaging
MRI, CT



Image guided surgery
[Grimson et al., MIT](#)

Smart cars

The screenshot displays the Mobileye website with a top navigation bar containing 'manufacturer products' and 'consumer products'. The main header reads 'Our Vision. Your Safety.' Below this, a top-down view of a car is shown with yellow cones representing the fields of view for its cameras: 'rear looking camera', 'side looking camera', and 'forward looking camera'. The bottom section features three columns: 'EyeQ Vision on a Chip' with an image of the chip and a 'read more' link; 'Vision Applications' showing a pedestrian on a crosswalk with the text 'Road, Vehicle, Pedestrian Protection and more' and a 'read more' link; and 'AWS Advance Warning System' with a circular display showing a car icon and the number '0.8' and a 'read more' link. On the right side, there are two vertical panels: 'News' with two headlines about Volvo's collision warning system and a 'read more' link, and 'Events' with two headlines about Mobileye at Equip Auto in Paris and at SEMA in Las Vegas, along with a 'read more' link.

manufacturer products consumer products

Our Vision. Your Safety.

rear looking camera

side looking camera

forward looking camera

EyeQ Vision on a Chip

Vision Applications

Road, Vehicle, Pedestrian Protection and more

AWS Advance Warning System

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

- <https://www.mobileye.com/>
- Vision systems currently in high-end BMW, GM, Volvo models

Google cars

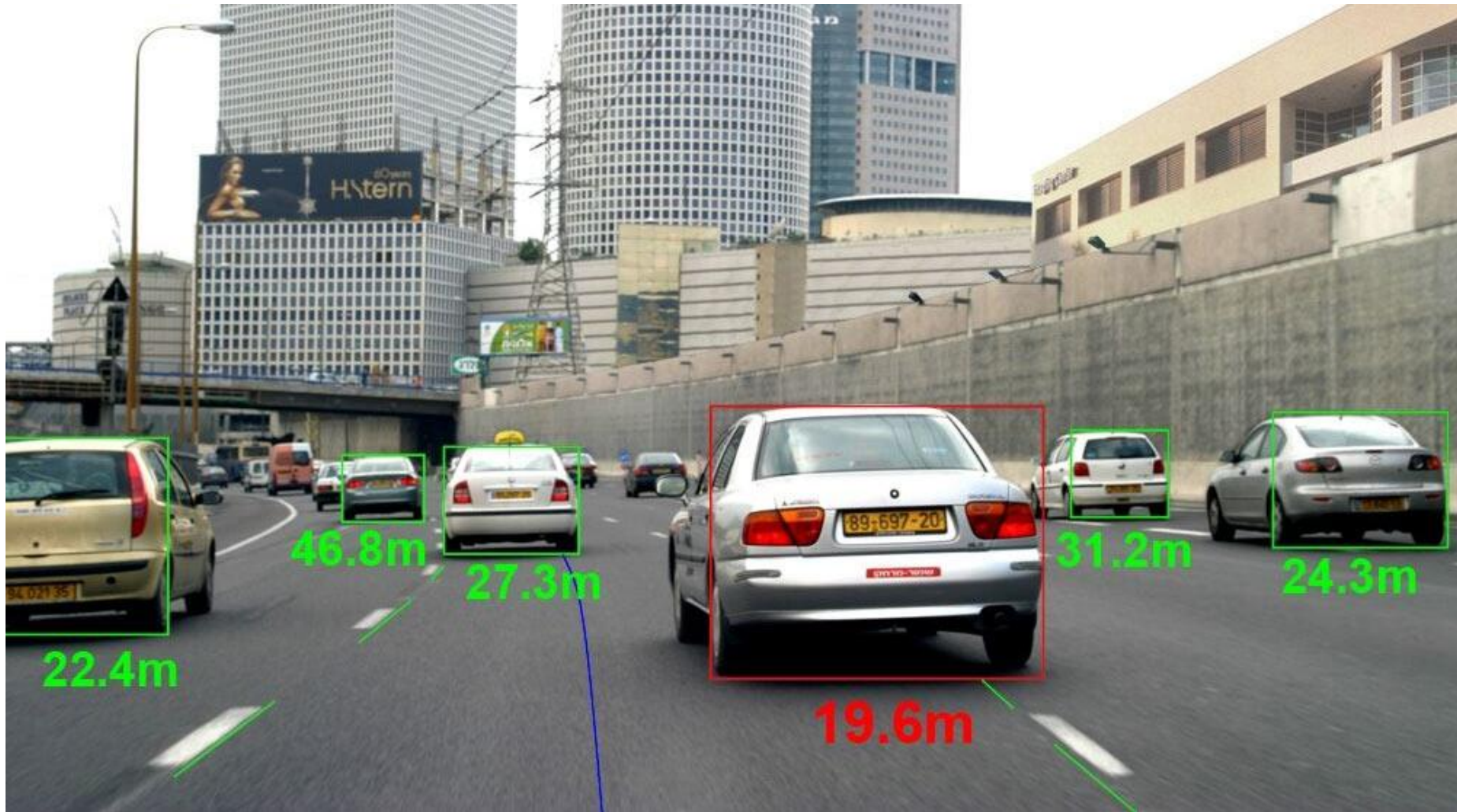


<http://www.nytimes.com/2010/10/10/science/10google.html?ref=artificialintelligence>

AutoCars - Uber bought CMU's lab



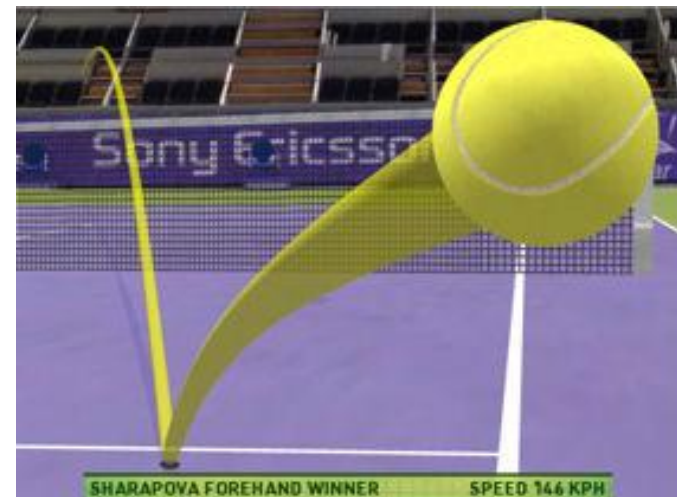
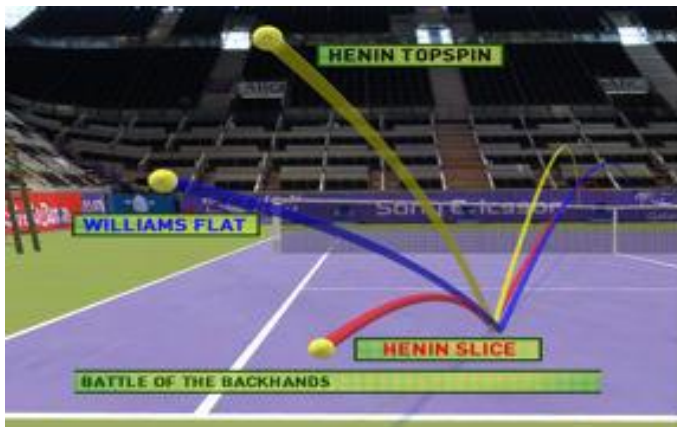
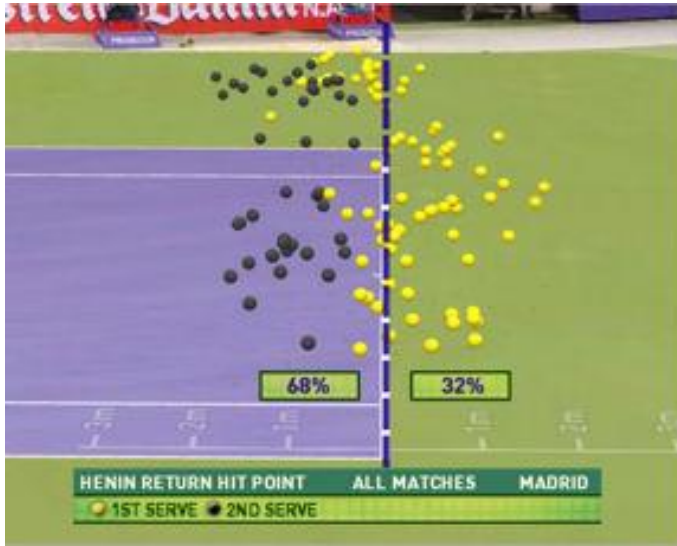
Car Detection and Depth Estimation



Vision as a Source of Semantic Information

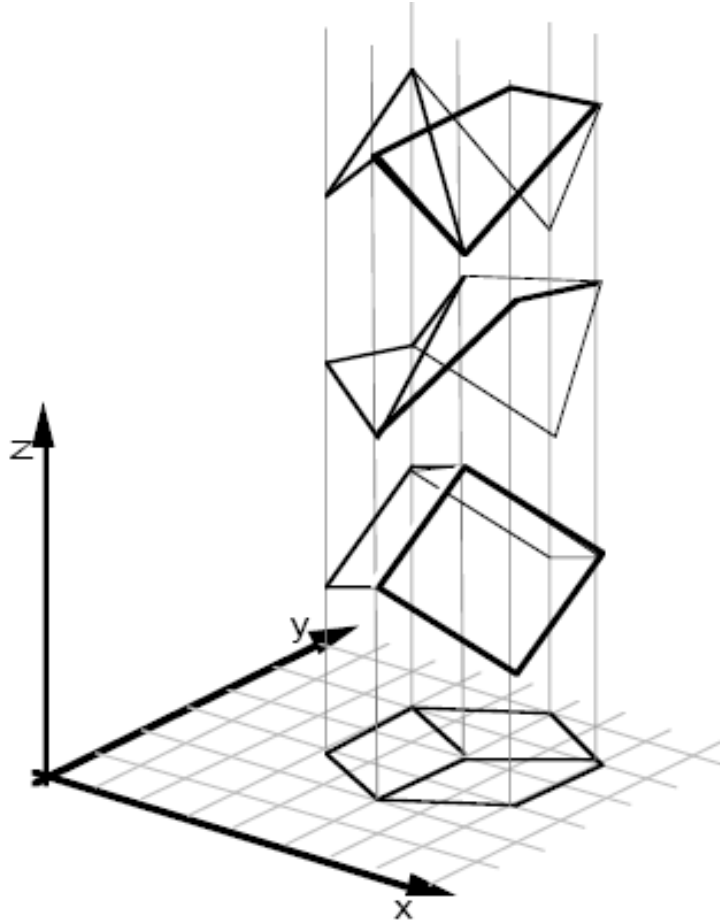


Sports video analysis



Tennis review system

Why is vision so hard?



[Sinha and Adelson 1993]

posed problem

Challenges 1: view point variation

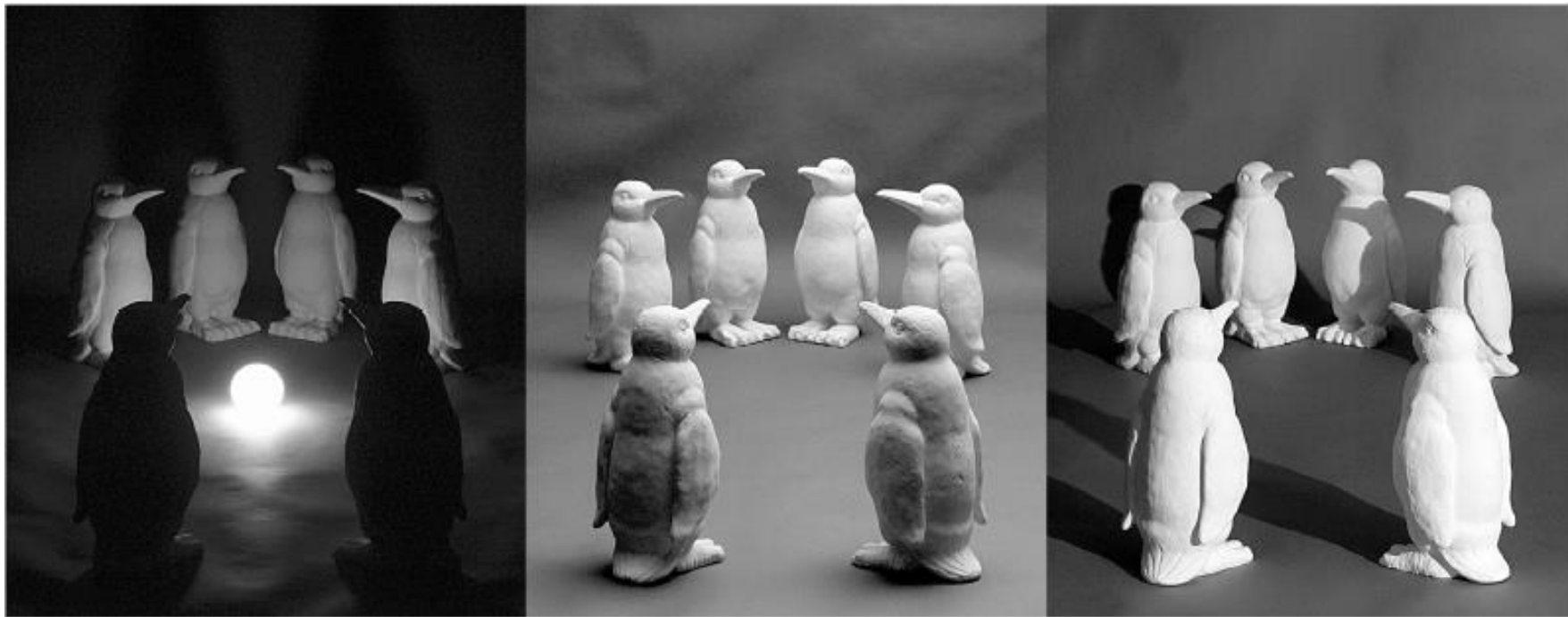


Michelangelo 1475-1564



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

Challenges 2: illumination

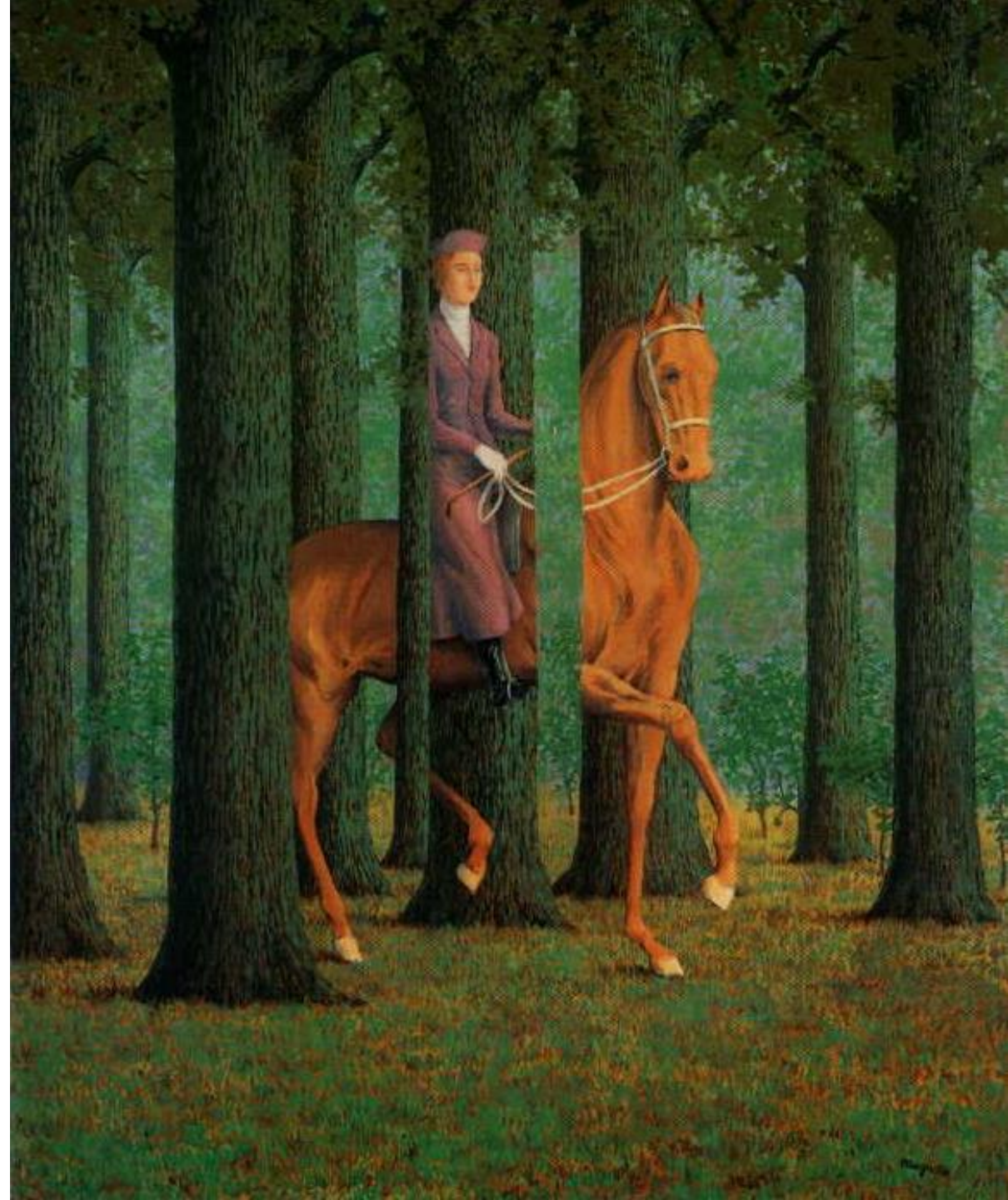


Adapted from Fei-Fei Li

Challenges 3: occlusion

Magritte, 1957

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

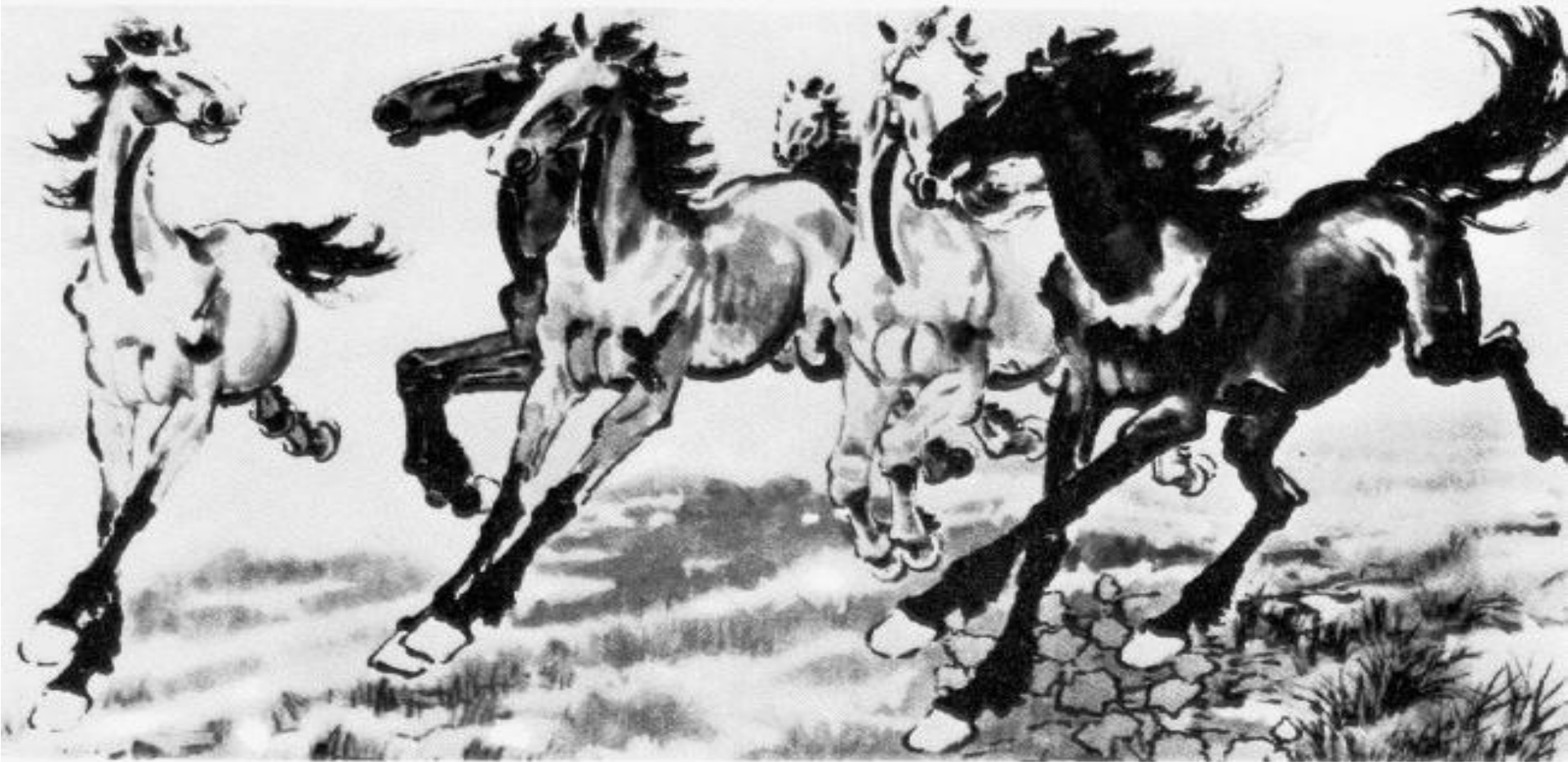


Challenges 4: scale



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

Challenges 5: deformation



Xu, Beihong 1943

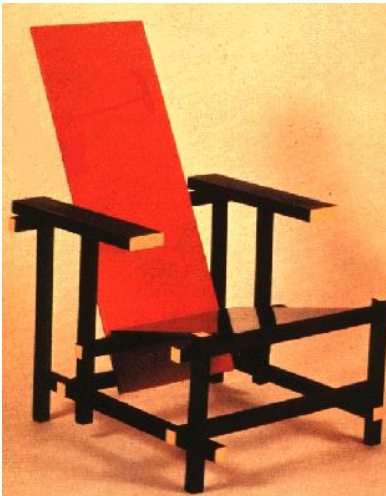
Adapted from L. Fei-Fei, R. Fergus, A. Torralba

Challenges 6: background clutter



Adapted from Fei-Fei Li

Challenges 7: intra-class variation



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

What do computers see?

47	49	51	47	41	41	41	38	42	54	66	66	58	56	53	48	43	43	45	47	50	47	47	47
45	44	39	38	37	48	67	95	138	151	156	157	165	157	125	79	36	38	47	48	48	43	38	36
43	35	31	45	64	109	155	179	178	160	142	132	146	187	195	170	133	86	45	46	51	41	36	32
33	24	24	47	88	149	135	136	160	170	166	135	111	153	169	169	109	113	86	57	49	46	40	36
22	19	22	47	122	131	99	120	204	199	185	150	119	152	159	173	110	80	83	82	63	58	45	42
22	20	24	60	114	108	123	191	215	212	198	169	156	169	168	172	151	115	91	77	82	59	53	53
20	19	29	86	127	87	169	223	219	218	212	182	178	190	194	185	169	108	88	85	74	55	52	51
20	20	26	131	138	129	214	228	224	222	221	206	207	208	203	193	177	136	88	87	72	54	44	42
24	23	28	130	125	152	226	224	222	223	217	218	214	201	185	168	164	114	70	39	45	47	39	34
29	26	25	104	92	123	220	226	230	228	218	213	210	193	152	118	136	97	50	26	39	41	36	33
26	24	25	66	95	140	222	223	228	225	218	208	205	181	140	97	101	121	71	35	78	51	40	37
26	30	24	51	149	179	224	221	218	215	205	204	210	191	140	108	107	127	112	43	46	42	39	40
27	34	30	23	142	198	210	226	233	220	205	204	222	210	175	154	134	125	137	51	54	55	44	34
26	32	29	18	124	197	178	174	140	113	182	183	174	112	98	74	34	69	126	54	53	78	59	41
30	27	26	19	114	197	207	138	73	43	167	191	49	29	139	66	33	76	92	60	85	50	42	40
26	25	23	18	91	198	220	221	184	133	210	214	40	112	210	129	120	105	81	62	60	28	22	30
23	19	16	13	53	201	211	227	220	227	226	216	75	72	196	190	130	58	62	58	32	21	24	26
18	14	12	11	13	93	198	220	226	209	219	218	121	34	148	170	53	37	50	25	17	17	23	24
17	15	14	13	15	25	177	203	189	151	223	219	139	59	33	78	30	39	45	26	22	21	16	38
12	14	17	13	15	11	125	201	149	194	223	203	67	19	15	22	33	43	55	37	29	28	31	68
10	13	14	11	16	15	58	196	170	193	213	175	123	34	19	48	37	93	35	32	30	38	93	118
17	19	19	20	31	35	30	145	191	201	215	182	134	47	66	89	45	196	45	16	52	98	141	149
25	28	34	34	28	32	20	105	216	215	213	187	168	130	73	26	148	195	34	12	21	76	121	123
31	36	30	26	29	42	20	77	220	215	221	213	185	131	37	117	201	85	56	11	16	10	22	38
24	20	21	40	43	42	24	106	190	235	212	188	134	85	138	178	45	89	40	13	19	13	19	21
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32	36	46	39	40	27	10	157	250	230	190	156	172	216	250	135	149	50	9	18	16	12	13	18
38	38	38	45	40	29	10	140	240	244	151	50	30	118	229	255	187	11	16	26	20	18	25	29
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43	34	34	32	31	21	18	80	232	252	147	85	208	247	252	207	18	13	10	13	19	20	20	21
41	33	33	32	31	18	27	64	220	211	62	71	209	246	250	108	5	19	11	13	16	18	21	20
40	33	33	34	30	17	31	50	182	159	49	45	136	248	208	24	11	13	12	17	11	10	15	19

Stages of computer vision

- Low-level

image → image

- Mid-level

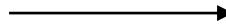
image → features / attributes

- 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

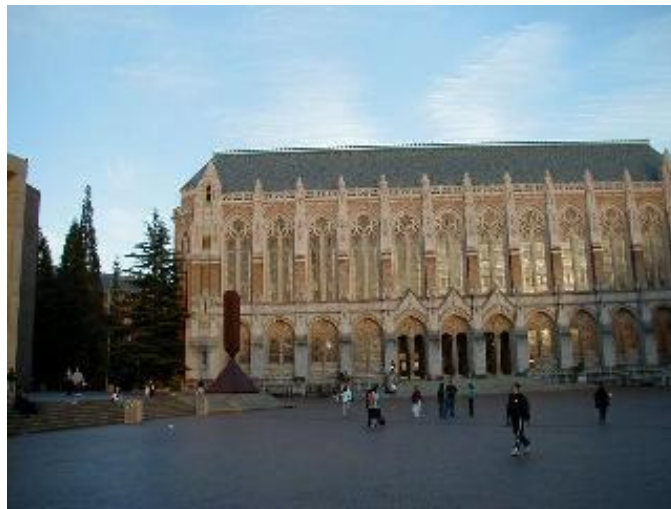
ORT
↓

data
structure



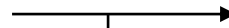
circular arcs and line segments

Mid-level

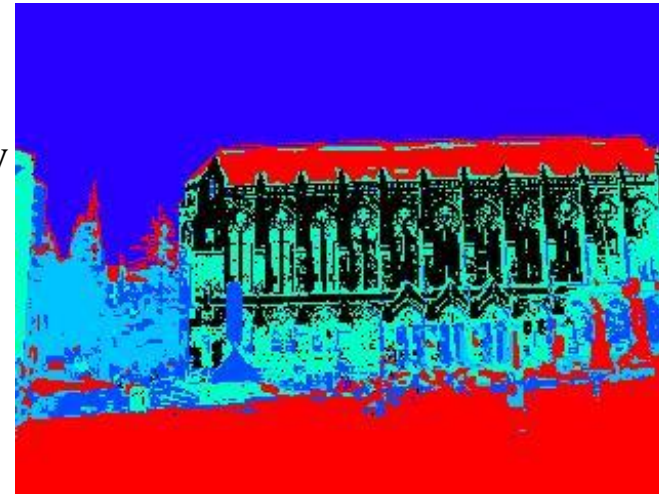


original color image

K-means
clustering
(followed by
connected
component
analysis)

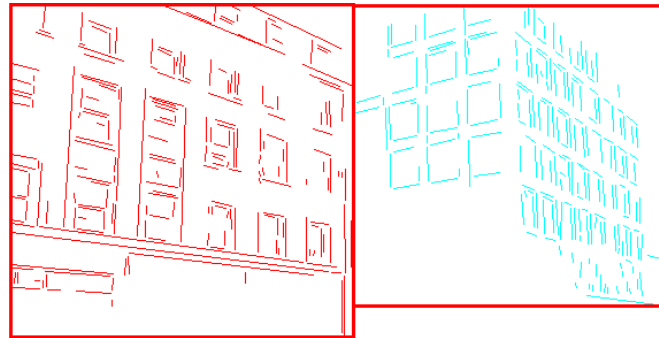


data
structure

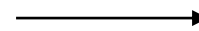


regions of homogeneous color

Low-level to high-level



low-level

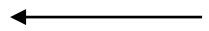


edge image

mid-level



consistent
line clusters



high-level

Visual recognition

Verification

Is this a car?



Visual recognition

Classification

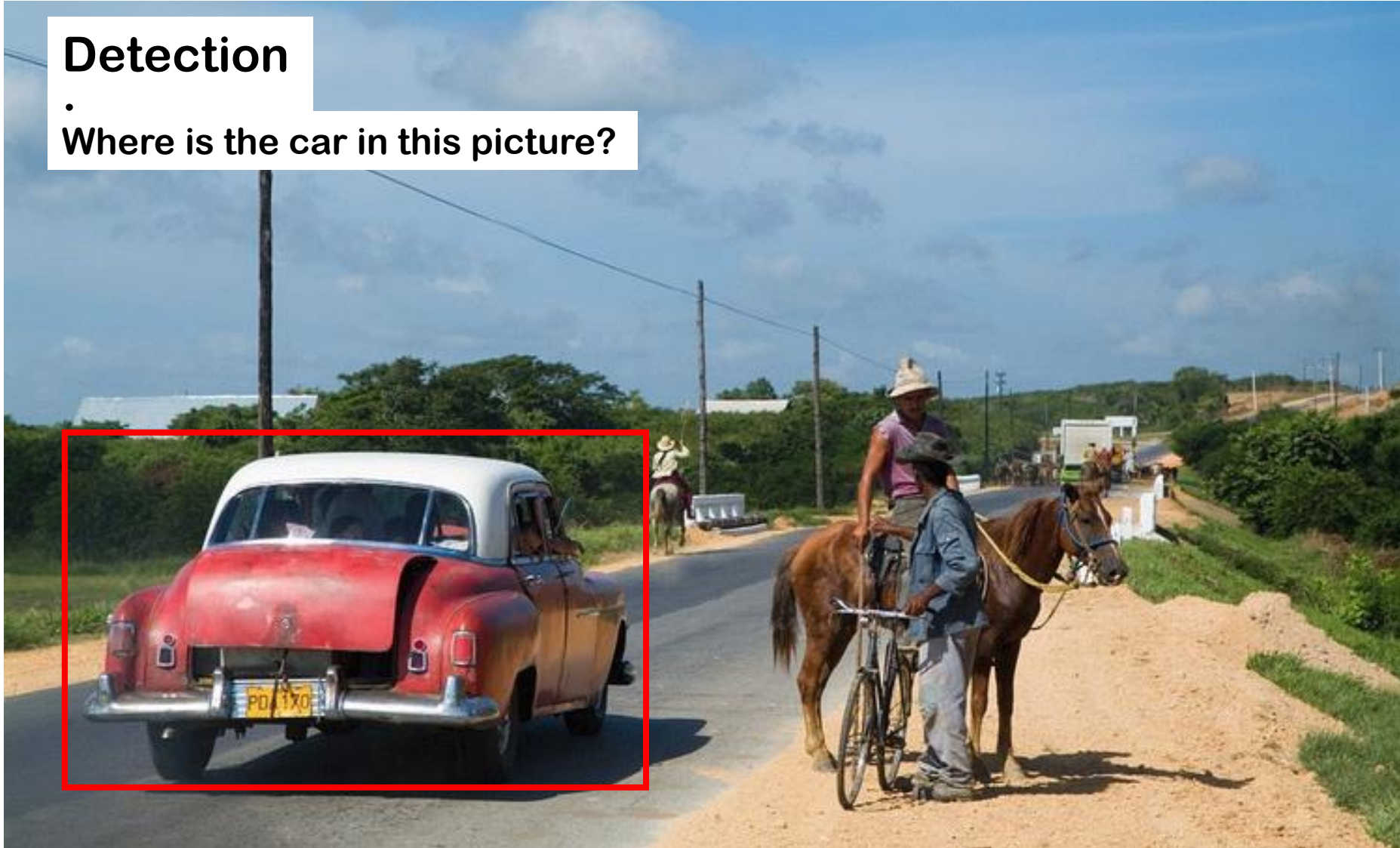
- Is there a car in this picture?



Visual recognition

Detection

- Where is the car in this picture?



Visual recognition

Pose Estimation:



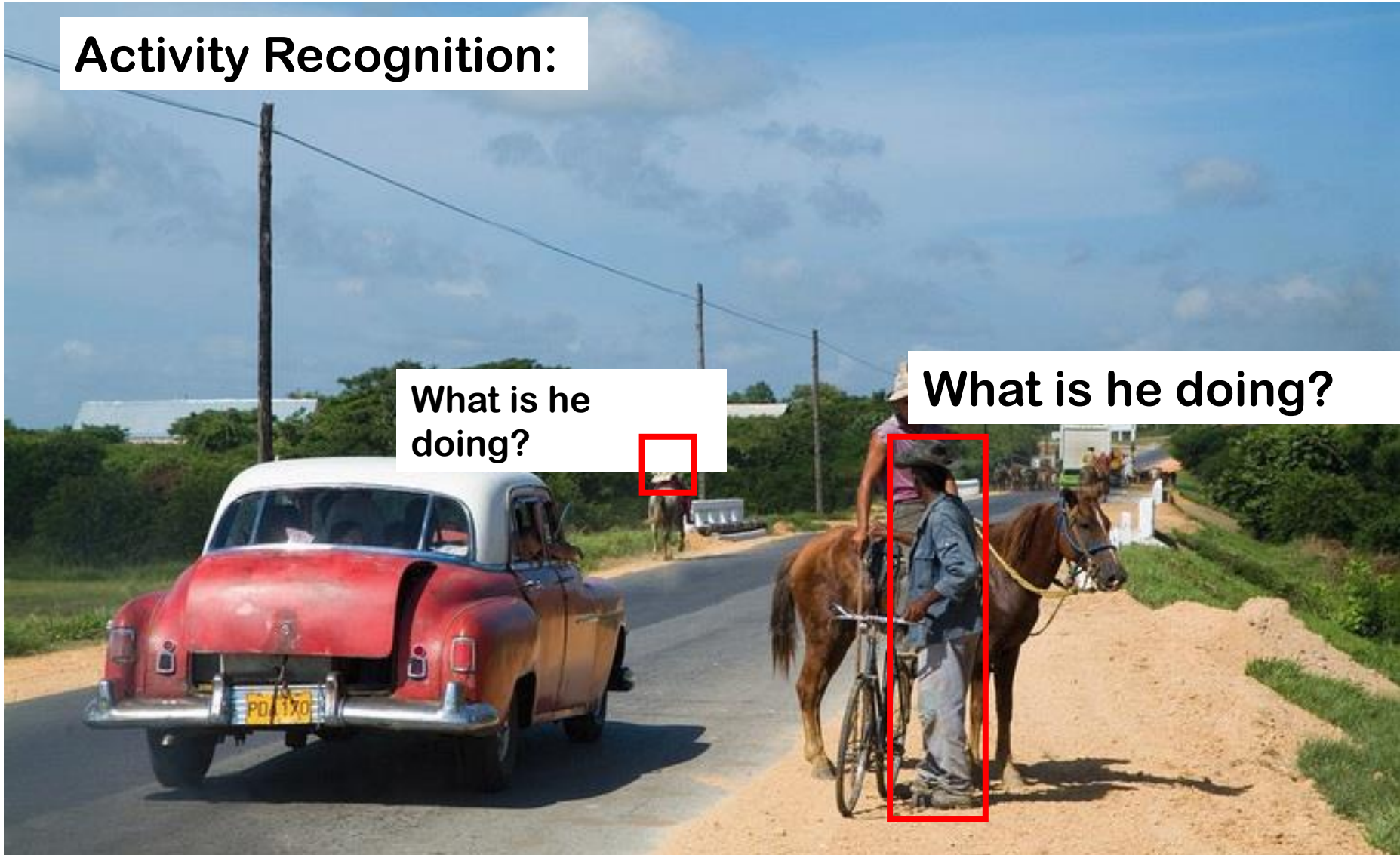
Visual recognition

Activity Recognition:

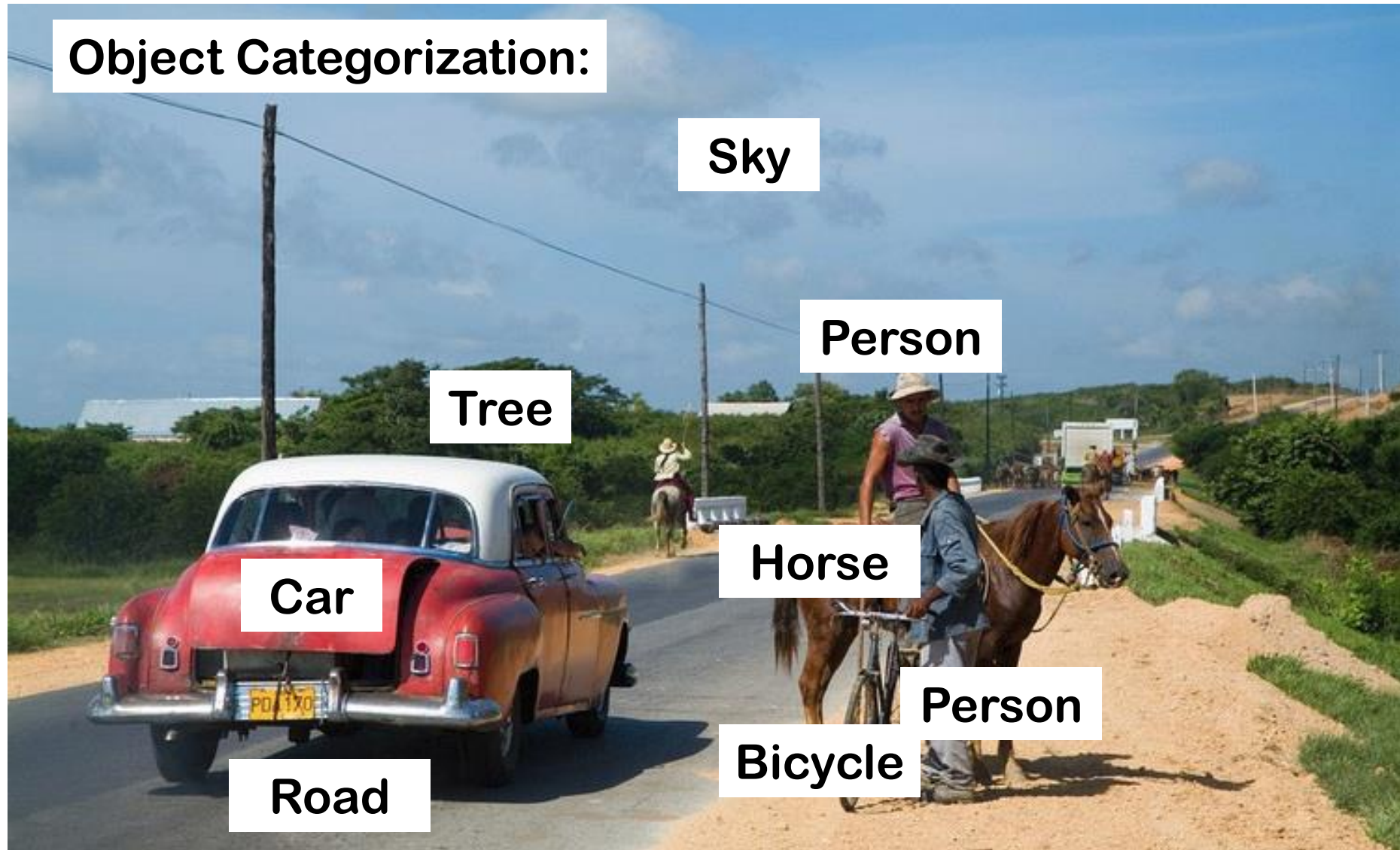
What is he
doing?



What is he
doing?



Visual recognition



Visual recognition

