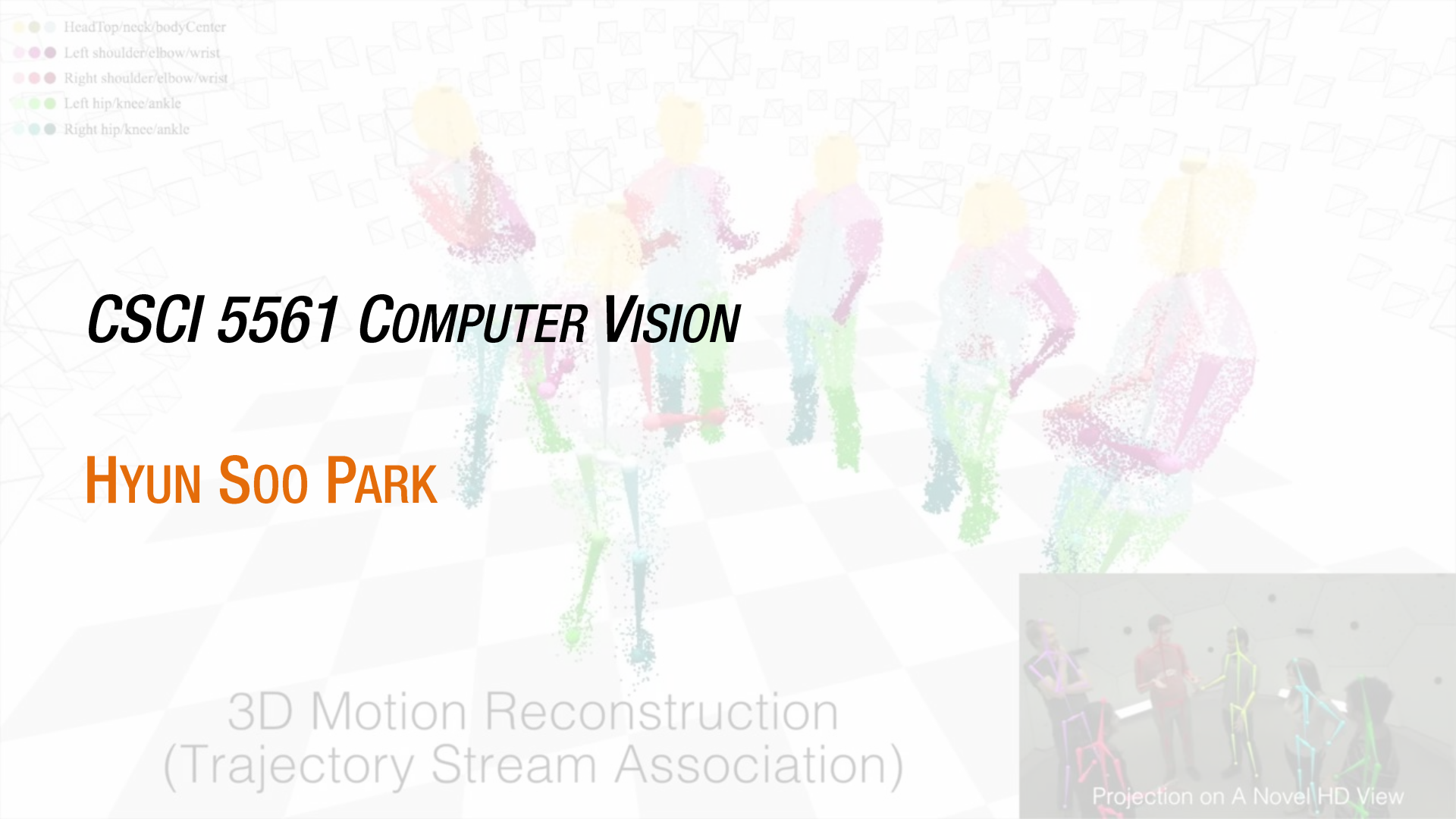

CSCI 5561 Computer Vision

Hyun Soo Park

What This Image Can Tell Us About The Scene?

What This Image Can Tell Us About The Scene?

- Rainy day
- Street market
- People / role
- Interaction
- Car/fruit/shelter
- Distance
- Height of the cameraman

What This Image Can Tell Us About The Scene?

- Rainy day
- Street market
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Computer Vision

Def) computationally understanding the scene/image.

Cf) image processing

What This Image Can Tell Us About The Scene?

- Rainy day
- Street market
- People / role
- Interaction
- Car/fruit/shelter
- Distance
- Height of the cameraman

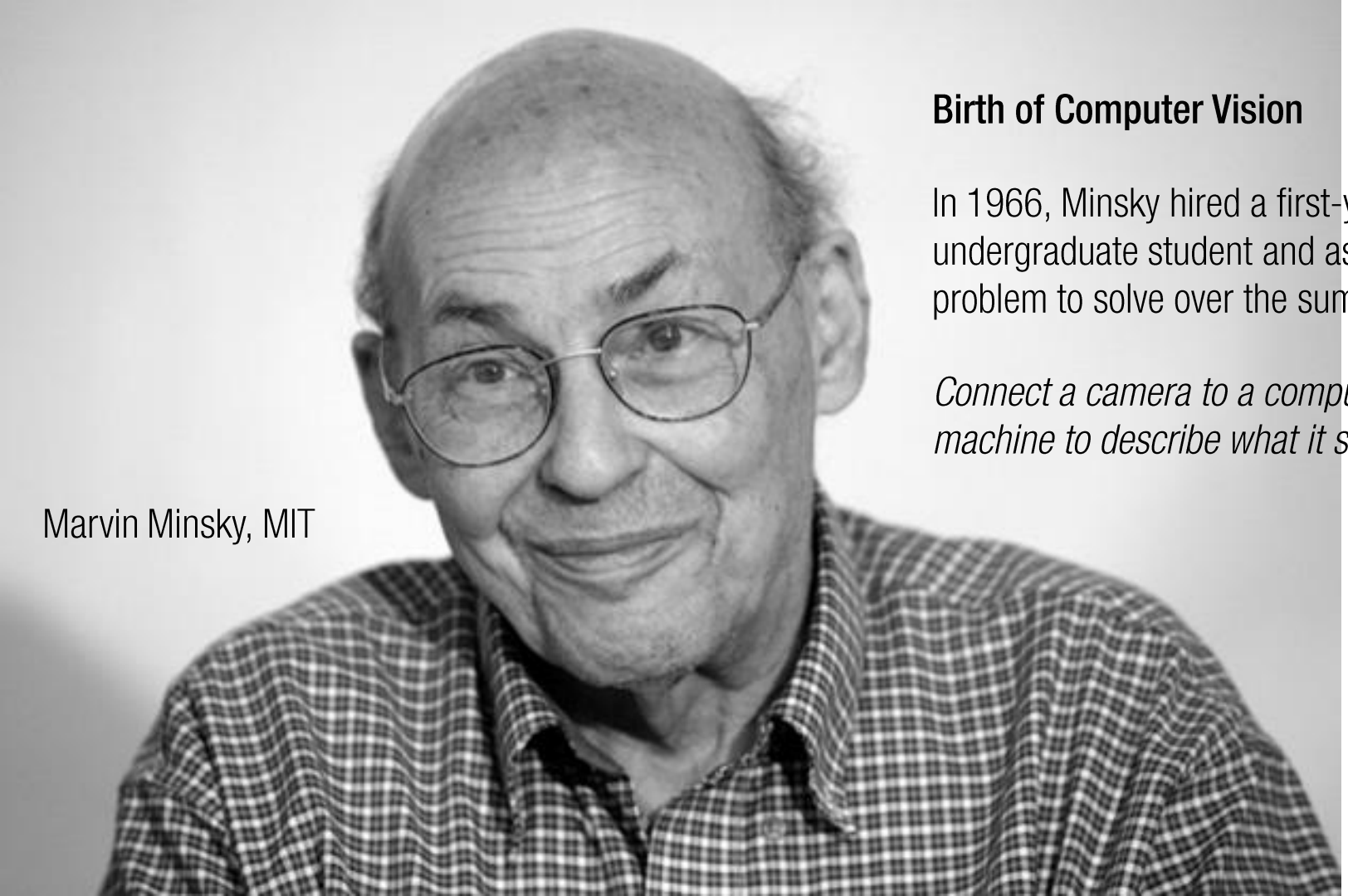
Computer Vision

Def) computationally understanding the scene/image.

Cf) image processing

Extremely difficult

# of pixels: 8.2M



Marvin Minsky, MIT

Birth of Computer Vision

In 1966, Minsky hired a first-year undergraduate student and assigned him a problem to solve over the summer:

Connect a camera to a computer and get the machine to describe what it sees.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

Artificial Intelligence Group July 7, 1966
Vision Memo. No. 100.

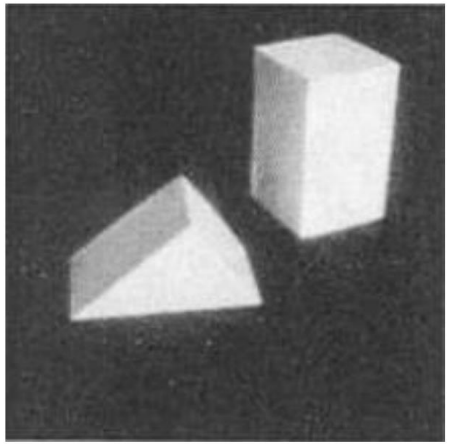
THE SUMMER VISION PROJECT

Seymour Papert

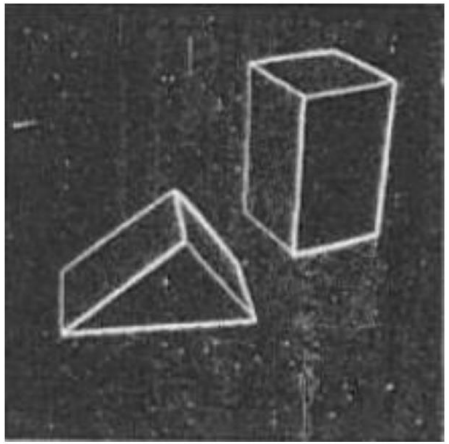
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the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

1960's: interpretation of synthetic worlds

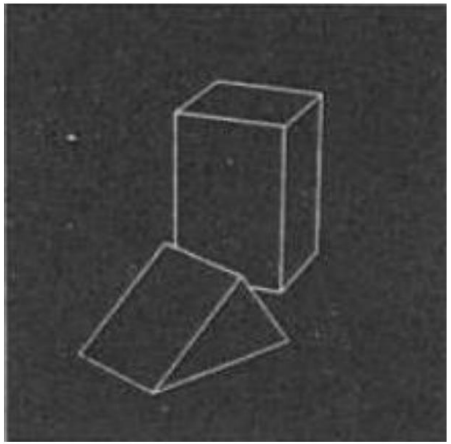
Larry Roberts
"Father of Computer Vision"



Input image



2x2 gradient operator

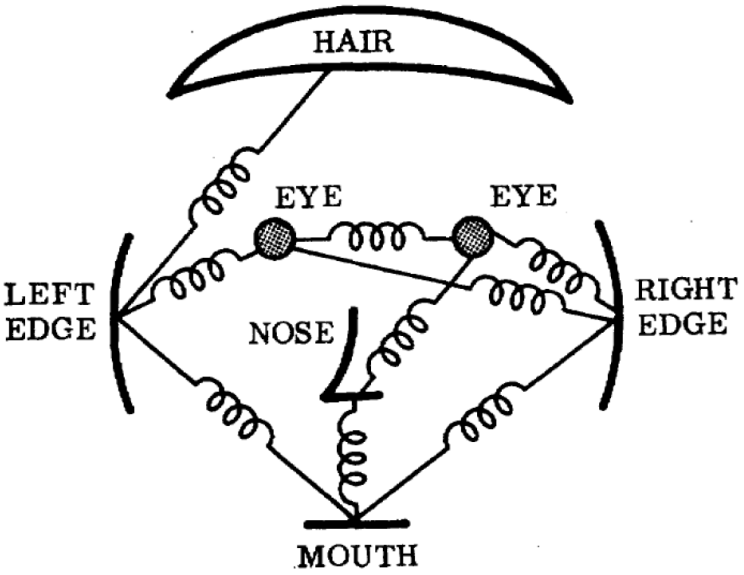


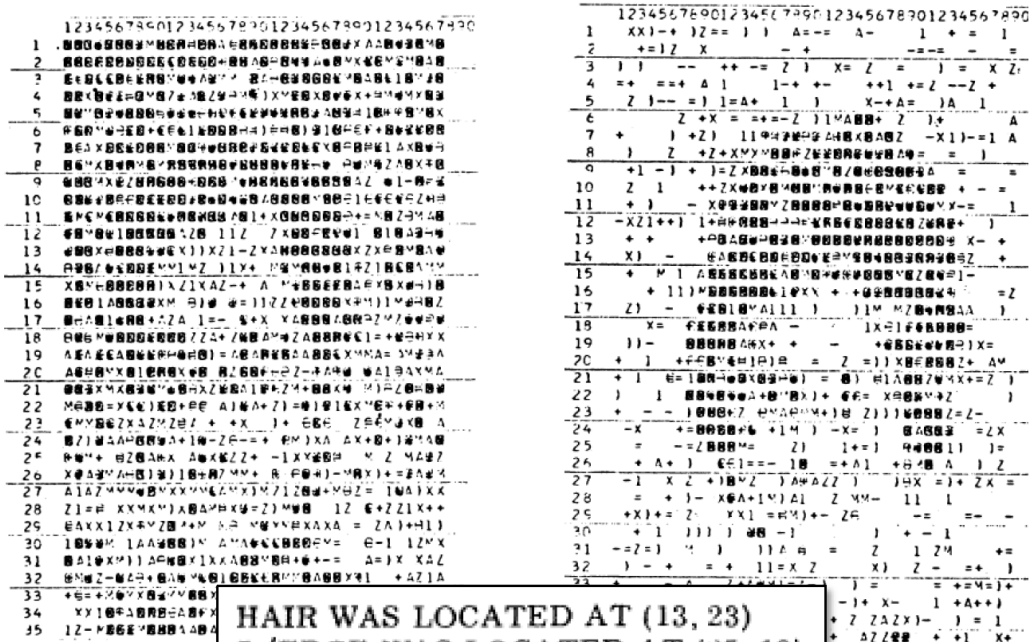
computed 3D model
rendered from new viewpoint

Larry Roberts PhD Thesis, MIT, 1963,
Machine Perception of Three-Dimensional Solids

Slide credit: Steve Seitz

1970's: some progress on interpreting selected images

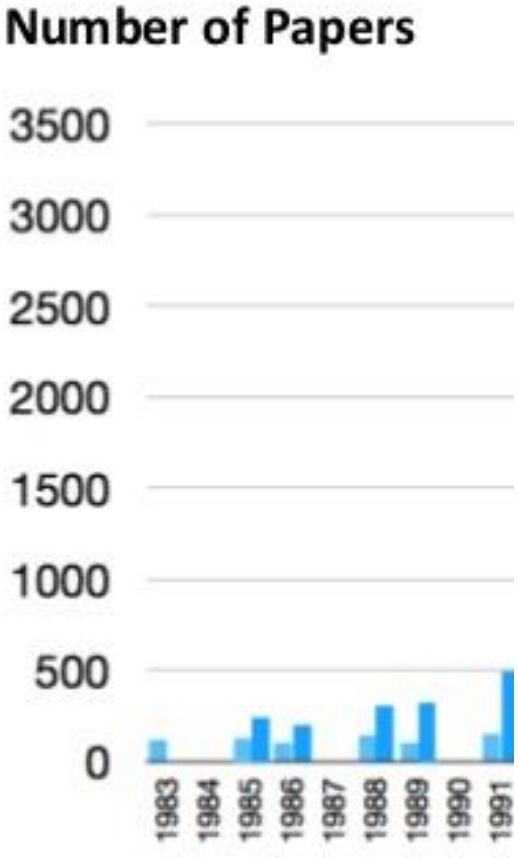




HAIR WAS LOCATED AT (13, 23)
L/EDGE WAS LOCATED AT (25, 13)
R/EDGE WAS LOCATED AT (25, 28)
L/EYE WAS LOCATED AT (22, 16)
R/EYE WAS LOCATED AT (22, 23)
NOSE WAS LOCATED AT (27, 20)
MOUTH WAS LOCATED AT (29, 19)

The representation and matching of pictorial structures
Fischler and Elschlager, 1973

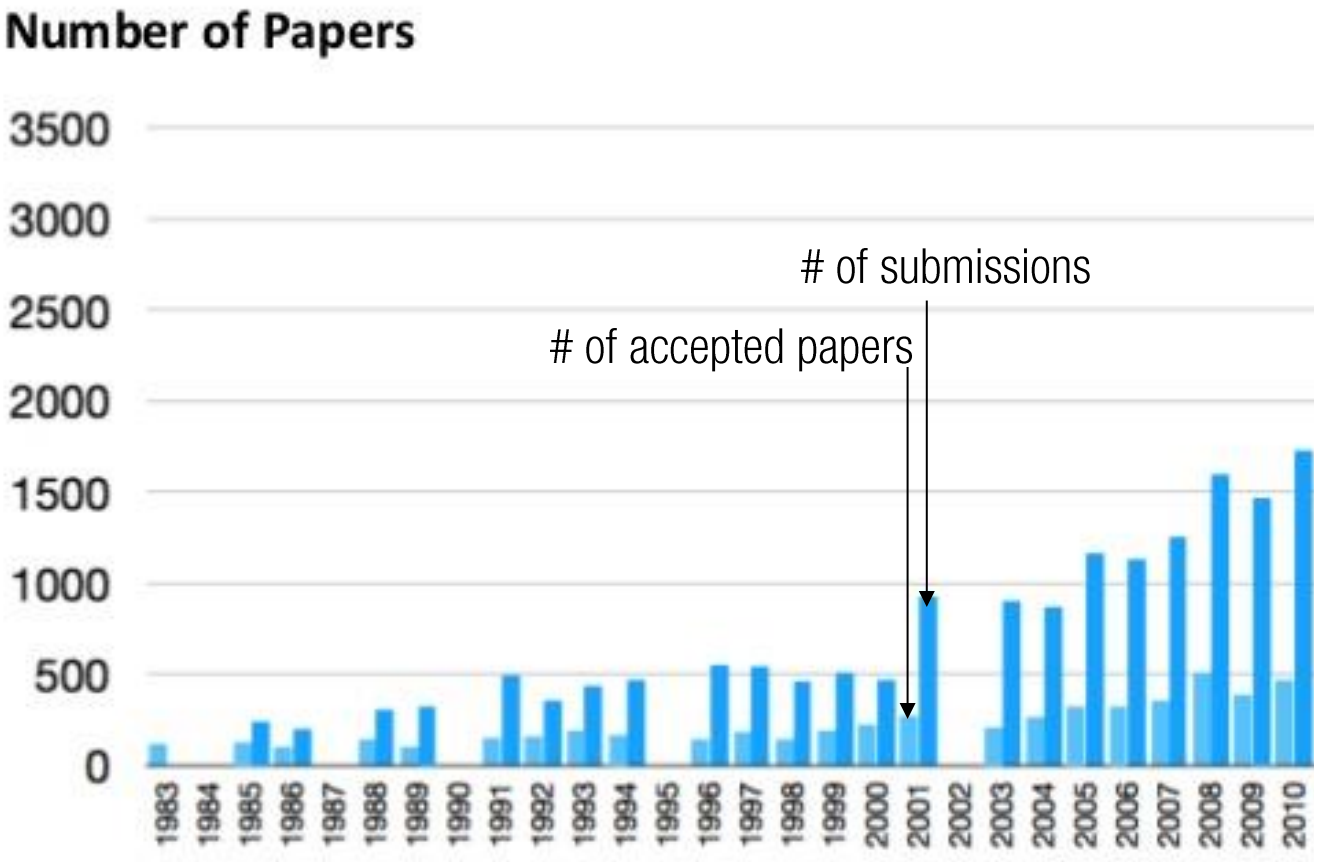
Conference on Computer Vision and Pattern Recognition



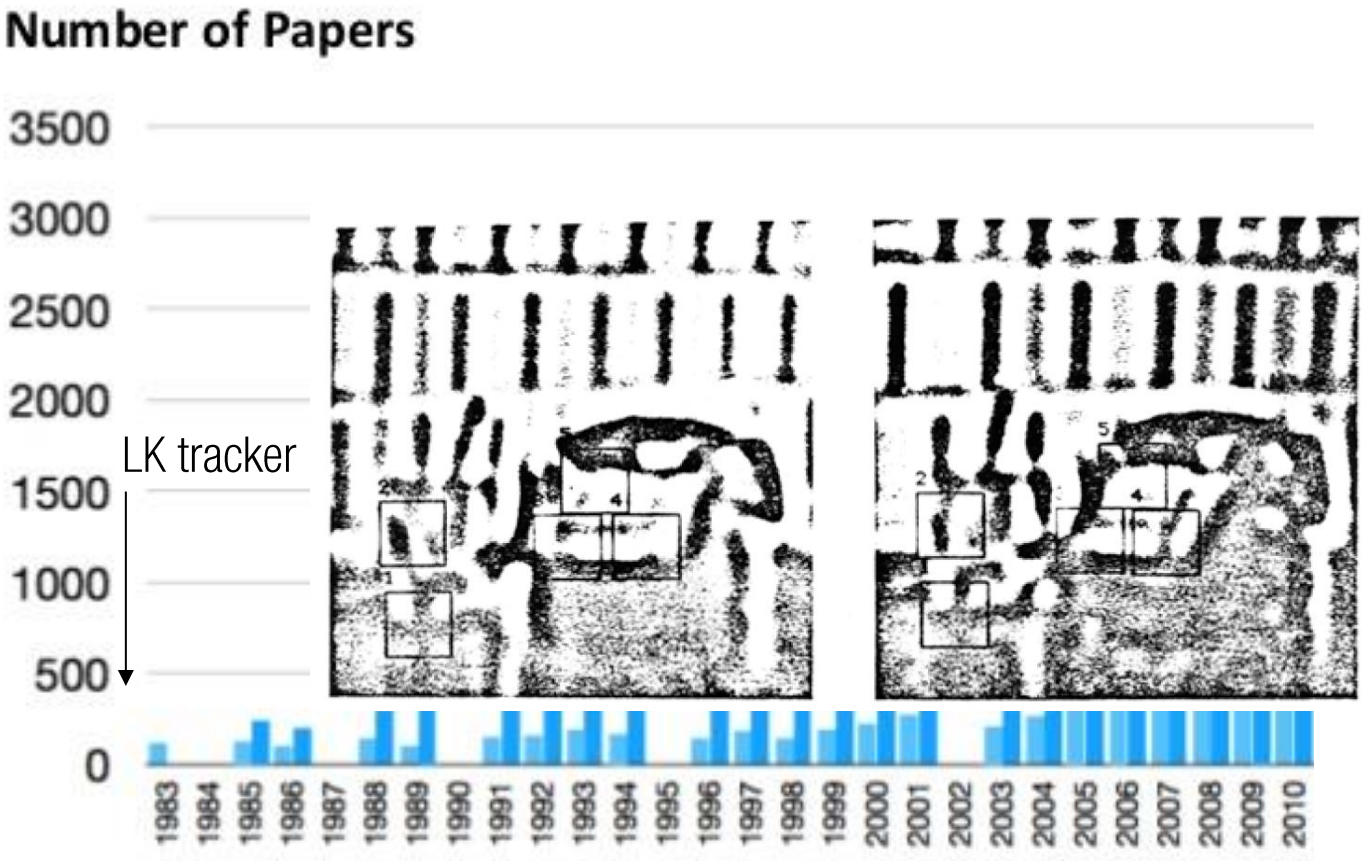
Takeo Kanade, CMU

Dana Ballard, U of Rochester

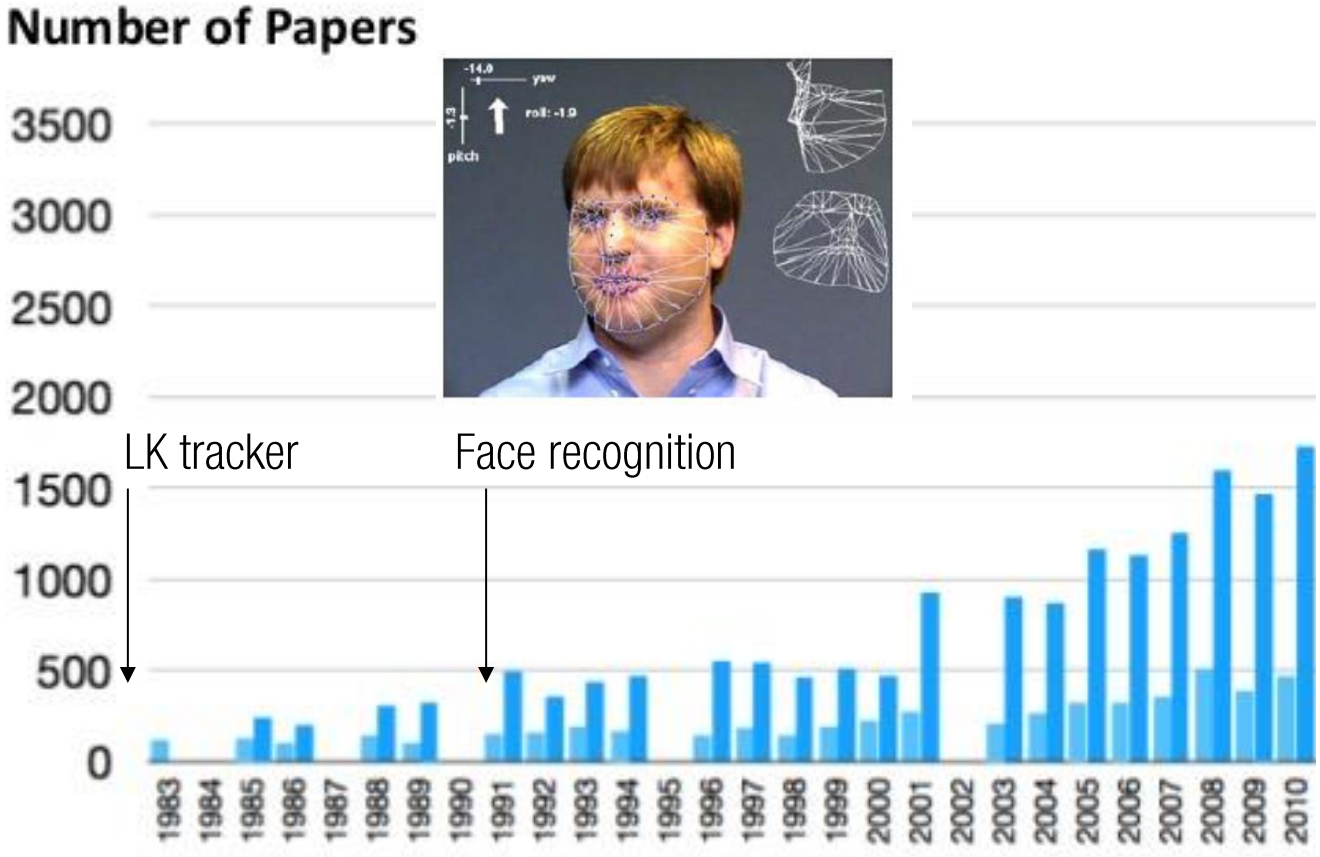
Conference on Computer Vision and Pattern Recognition



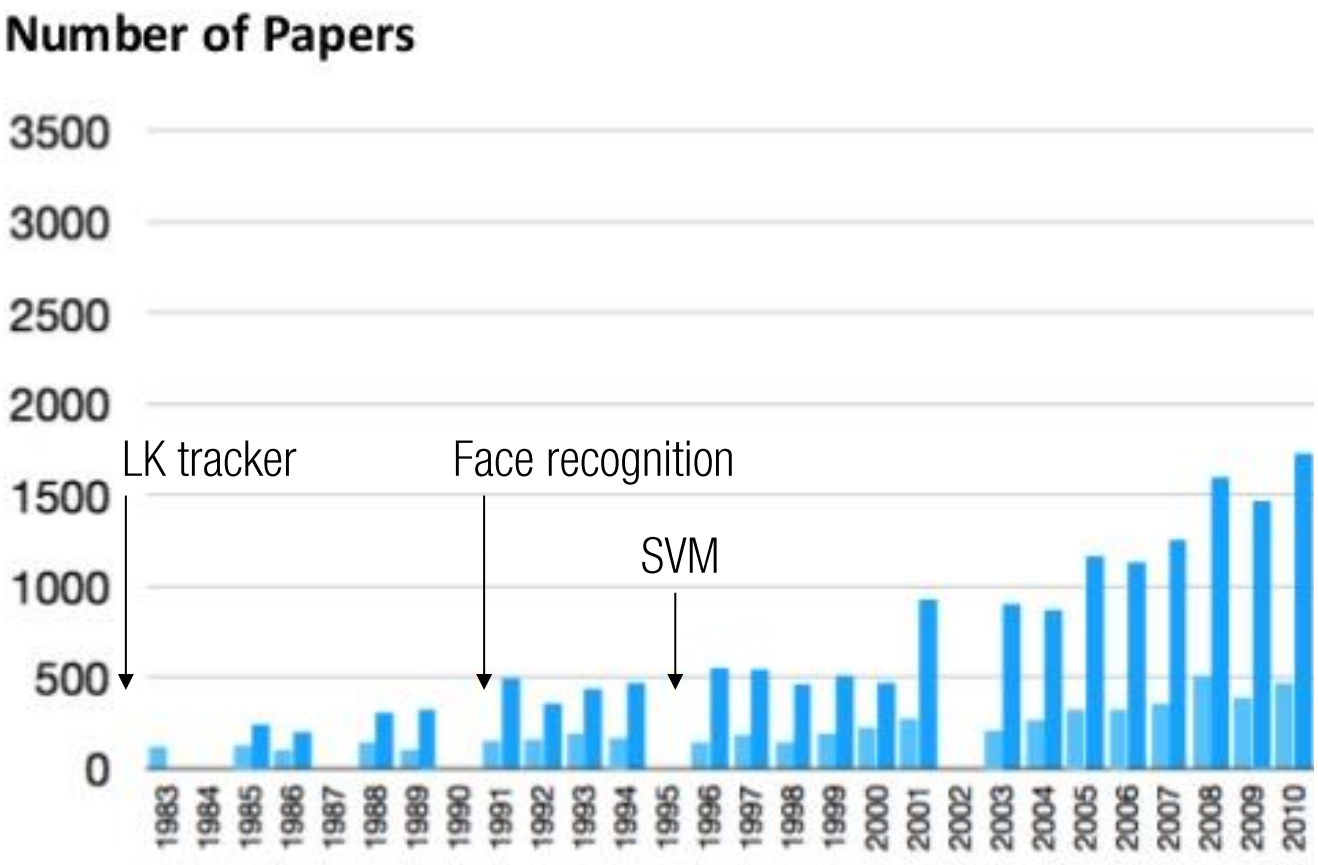
Conference on Computer Vision and Pattern Recognition



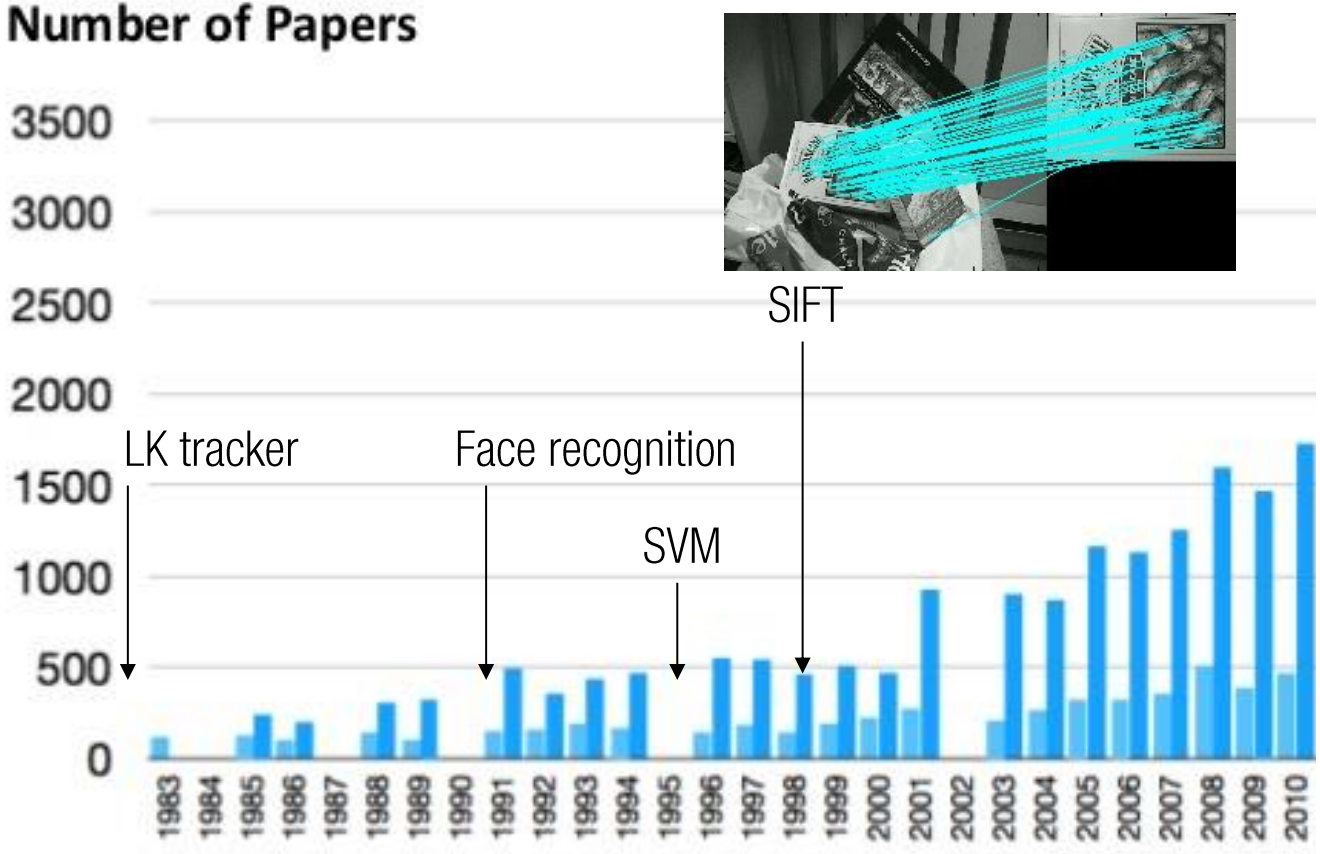
Conference on Computer Vision and Pattern Recognition



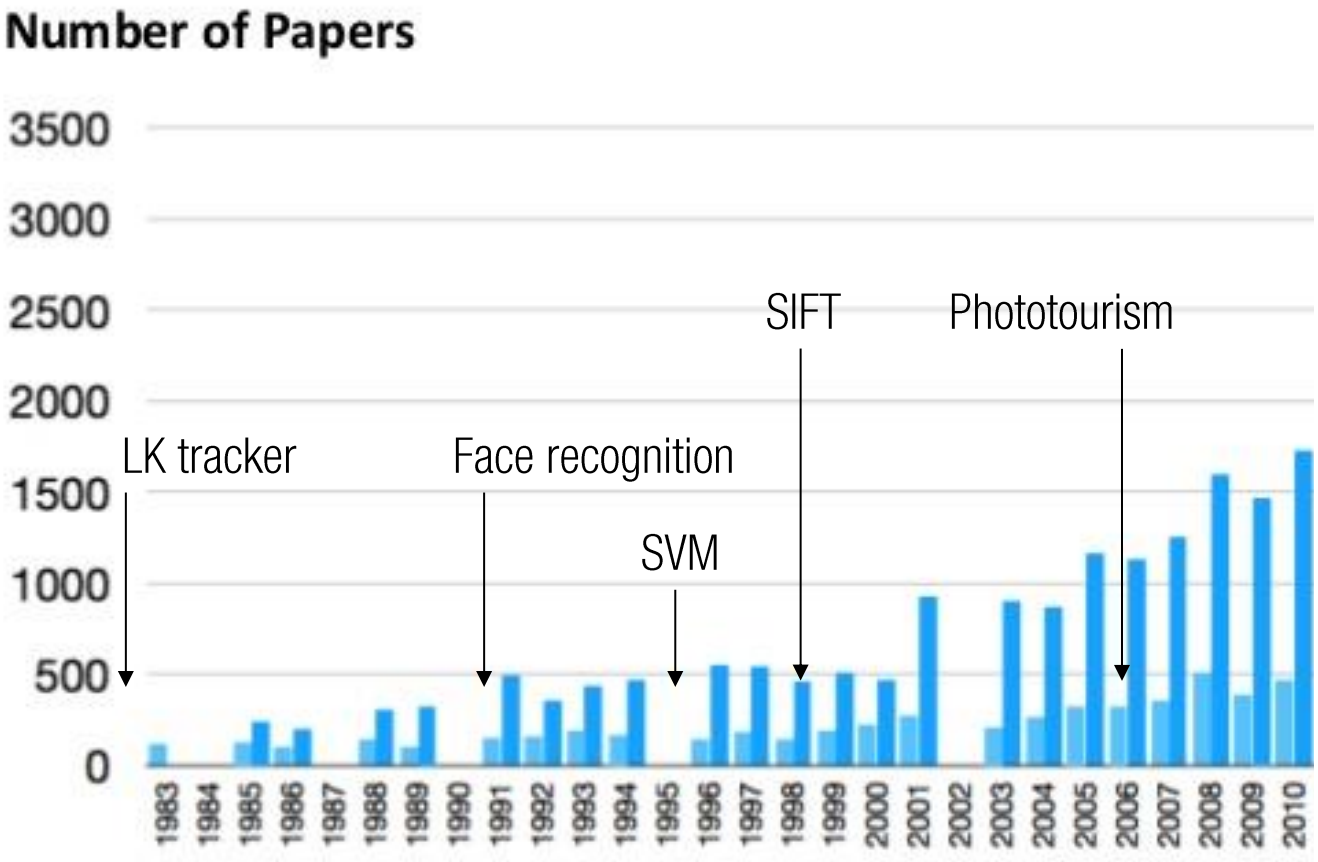
Conference on Computer Vision and Pattern Recognition



Conference on Computer Vision and Pattern Recognition

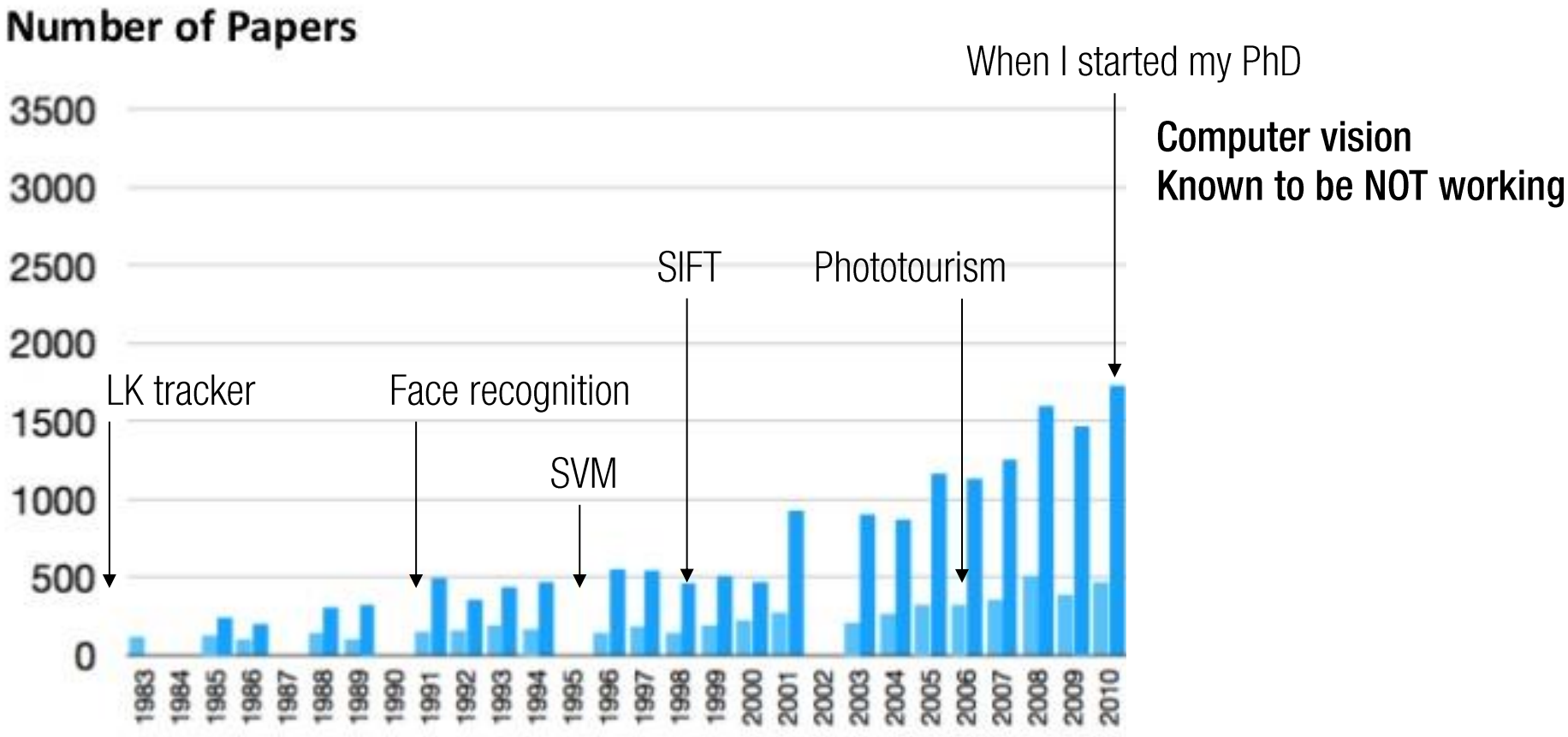


Conference on Computer Vision and Pattern Recognition

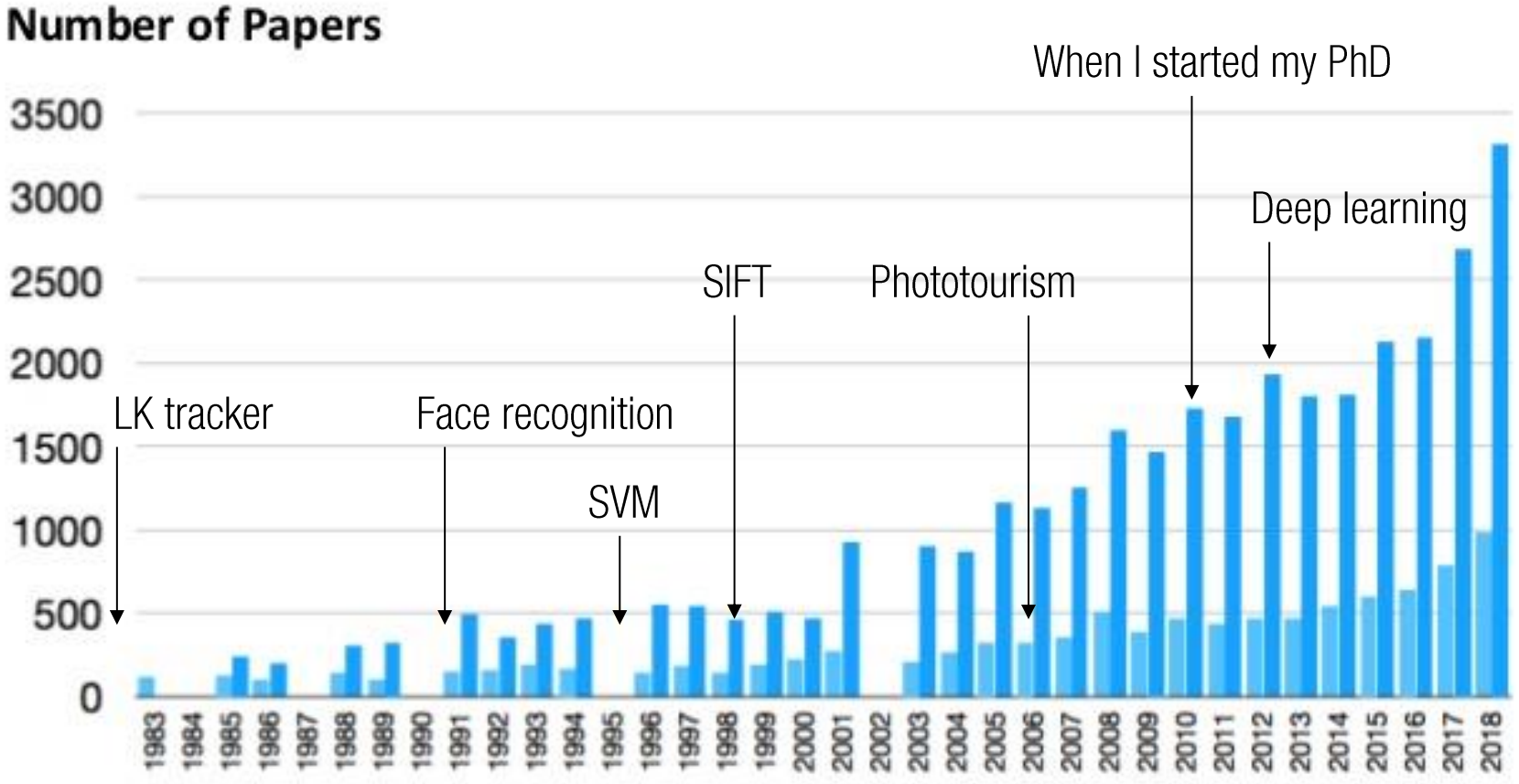



Conf
Num
350
300
250
200
150
100
50

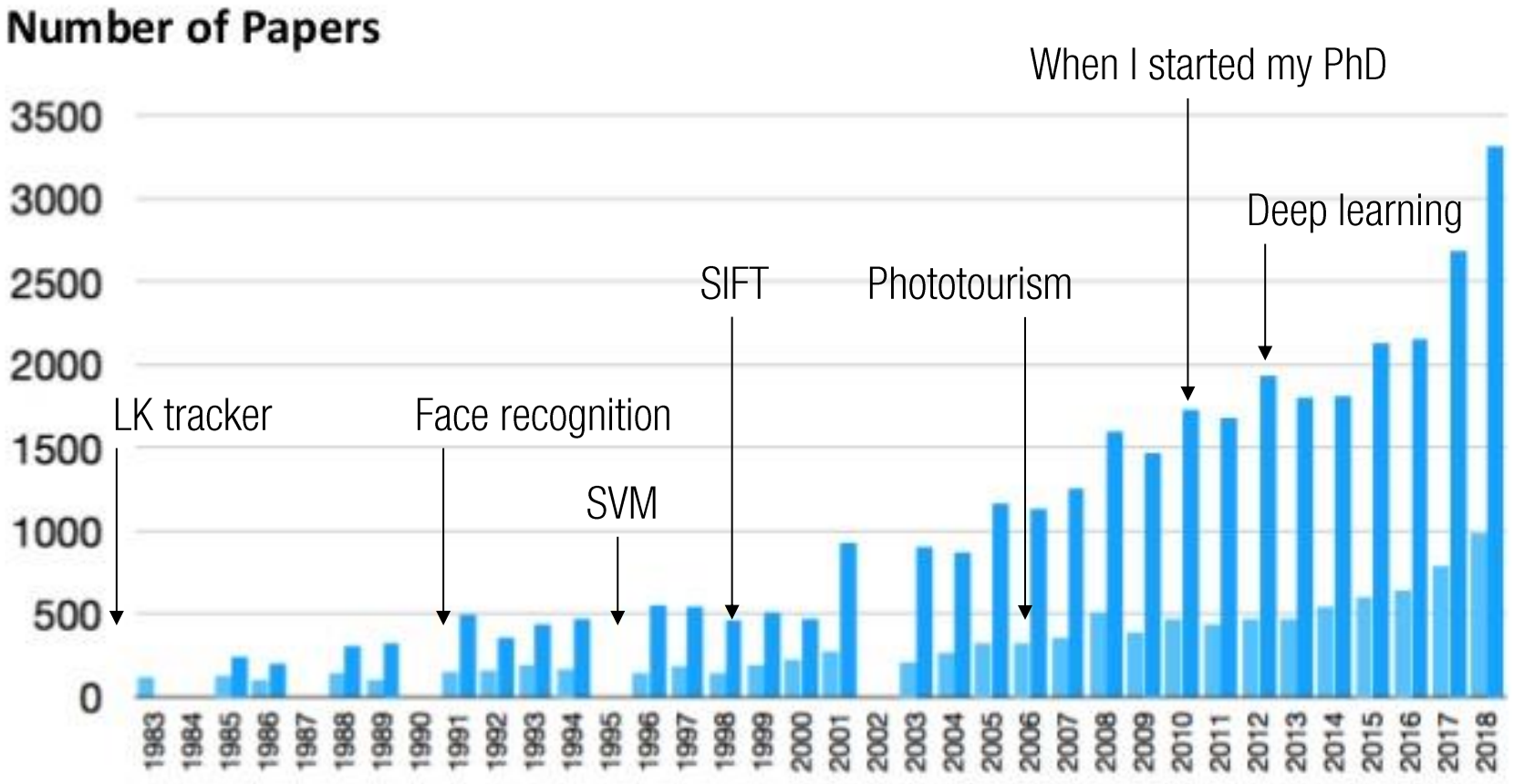
Conference on Computer Vision and Pattern Recognition



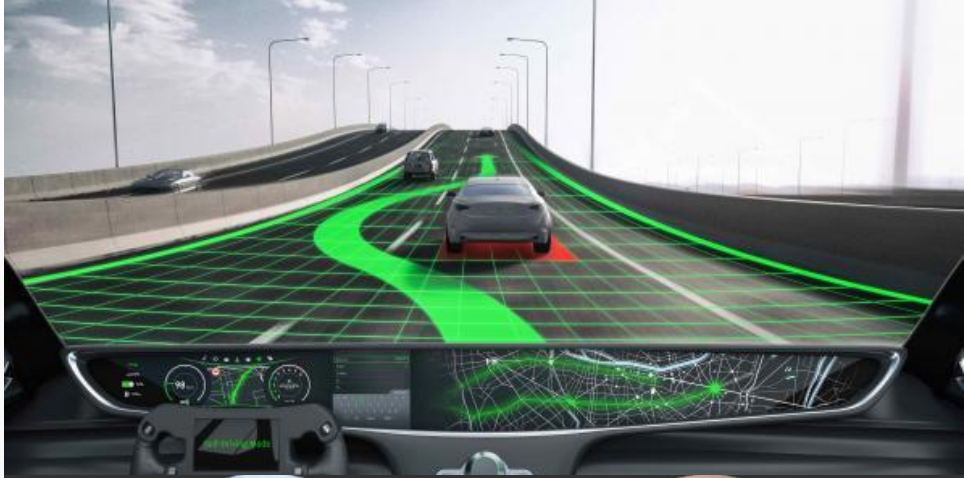
Conference on Computer Vision and Pattern Recognition



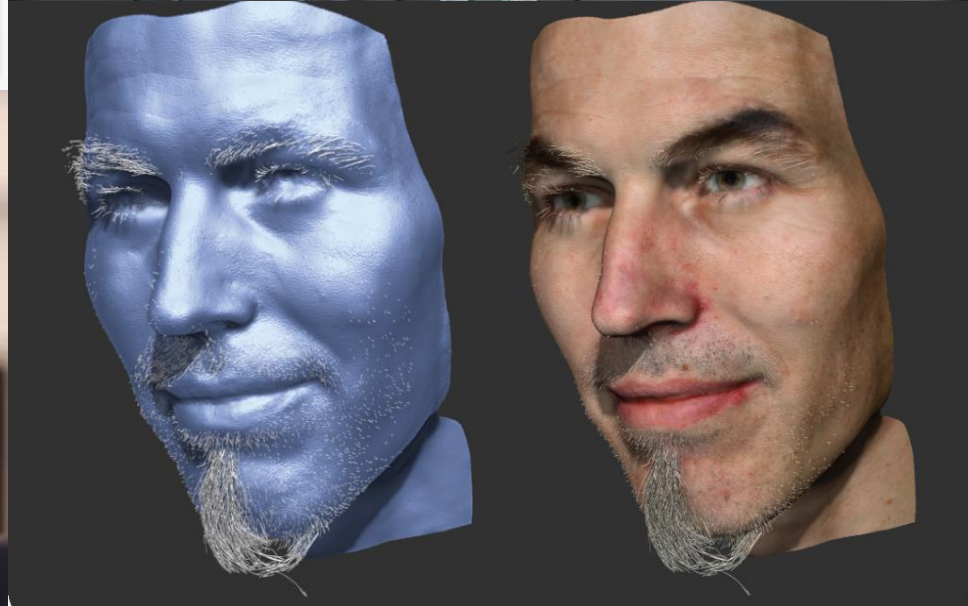
Conference on Computer Vision and Pattern Recognition




3:08
SEND TO




BBC
NEWS

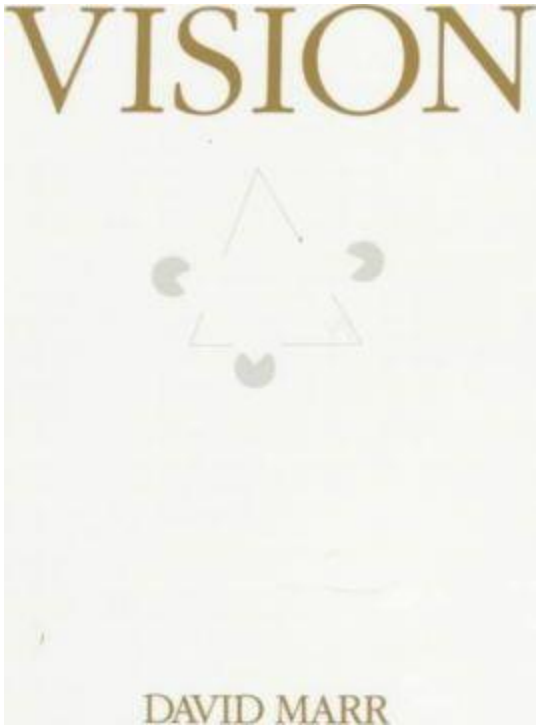


CVPR sponsor (2018)

How to Make a Computer to Understand an Image?

Marr's Vision

David Marr (1945-1980)



1982

Three Levels of Visual Perception

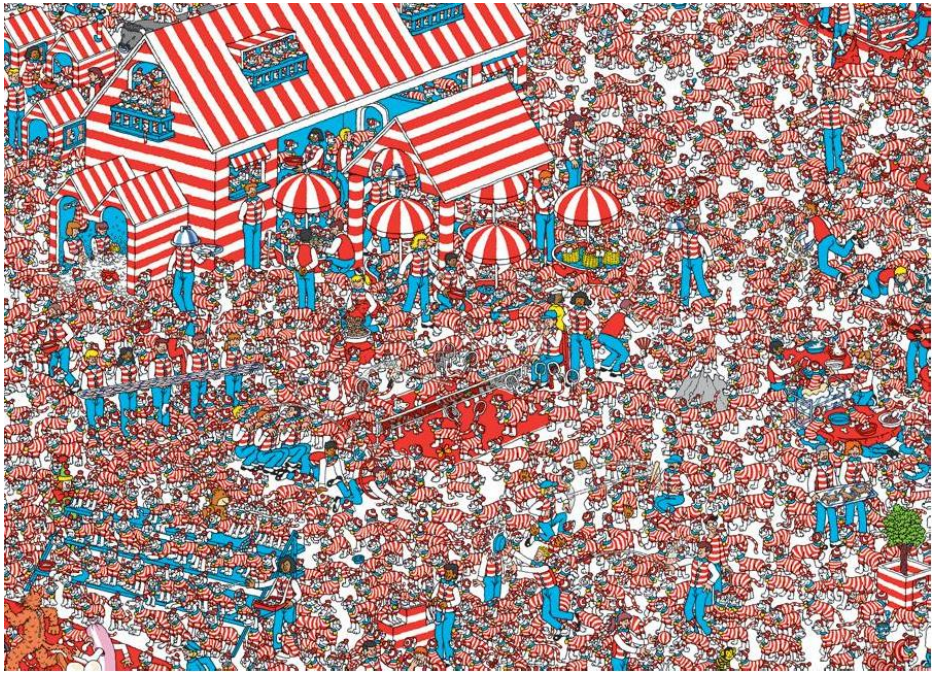
David Marr (1945-1980)

Three Levels of Visual Perception

David Marr (1945-1980)

1. Computational

e.g., what is the goal of the computation?



How to computationally find Waldo?

Three Levels of Visual Perception

David Marr (1945-1980)

1. Computational

e.g., what is the goal of the computation?

How to formulate the objective:

$$\underset{p}{\text{minimize}} \sum_{\mathbf{x}} \Big(J(w(\mathbf{x}; p)) - T(\mathbf{x}) \Big)^2$$

Three Levels of Visual Perception

David Marr (1945-1980)

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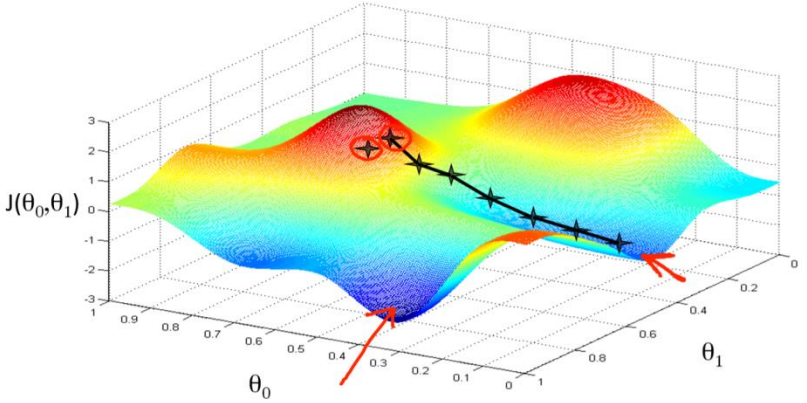
How to formulate the objective:

$$\underset{p}{\text{minimize}} \sum_{\mathbf{x}} \Big(J\left(w(\mathbf{x}; p)\right) - T(\mathbf{x}) \Big)^2$$

How to achieve the objective:

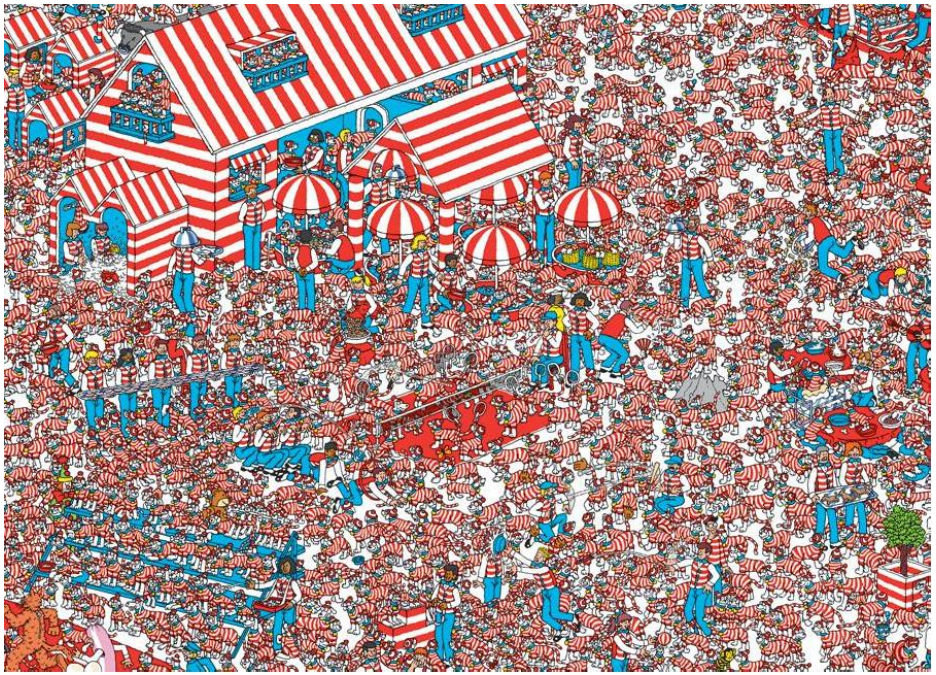


Three Levels of Visual Perception

David Marr (1945-1980)

2. Algorithmic

e.g., what representation can implement the computation?



How to represent the image?

Three Levels of Visual Perception

David Marr (1945-1980)

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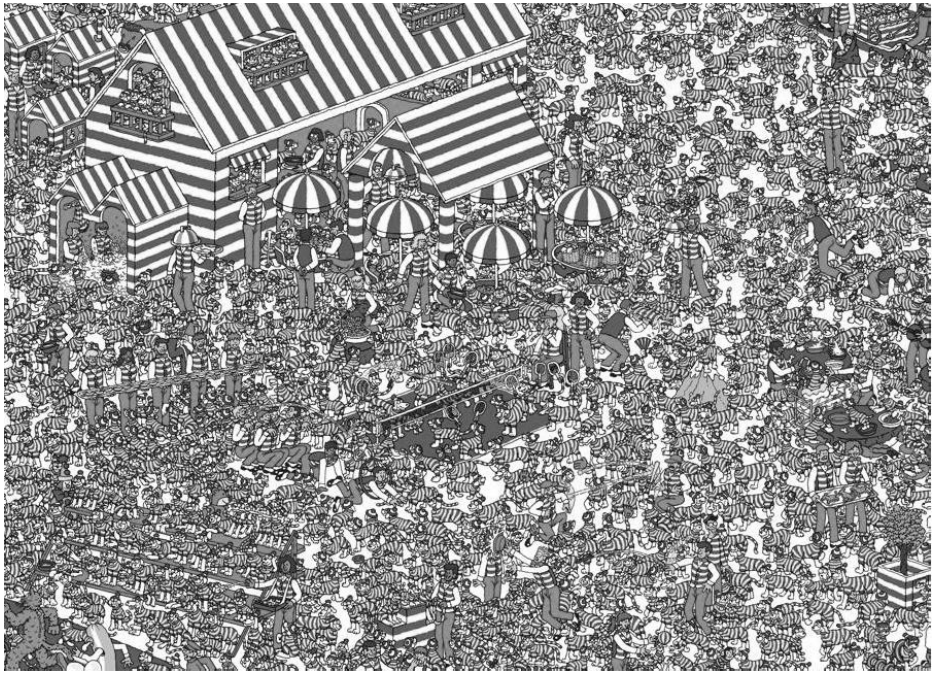
e.g., what representation can implement the computation?



How to represent the image?

Three Levels of Visual Perception

David Marr (1945-1980)

2. Algorithmic

e.g., what representation can implement the computation?

78	99	108	106	117	117	149	205	206	169	109	118	147	150	155	217	222	233
78	98	106	104	116	115	148	205	206	169	109	118	147	150	155	217	222	233
78	103	113	111	121	120	151	207	208	170	108	117	146	149	154	217	223	233
74	145	176	170	164	158	183	226	229	178	93	103	134	136	143	224	233	239
62	147	184	177	169	161	187	227	230	178	90	101	133	134	142	225	234	240
159	165	168	167	165	158	187	236	239	188	101	111	135	136	143	225	234	240
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235	152	114	119	159	171	196	243	245	196	113	123	130	128	137	229	238	243
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155	112	92	91	171	200	212	240	245	187	86	98	110	109	118	223	234	239
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192	160	146	149	134	129	110	73	70	110	171	173	241	250	246	222	219	232
201	171	157	160	143	139	117	76	73	110	165	166	237	247	243	226	223	235
151	136	130	132	113	108	90	57	54	105	190	186	232	238	233	202	196	218

255	255	245	215
223	222	213	197
111	109	123	145
114	112	125	145
222	222	226	233
253	252	254	255
248	248	250	254
246	246	248	251
246	246	247	249
245	245	248	251
245	244	248	253
245	243	248	254
249	248	248	246
254	255	248	235
253	253	248	238

How to represent the image?

Three Levels of Visual Perception

David Marr (1945-1980)

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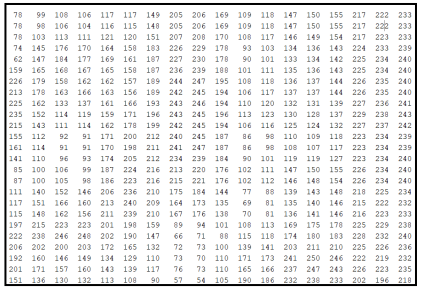
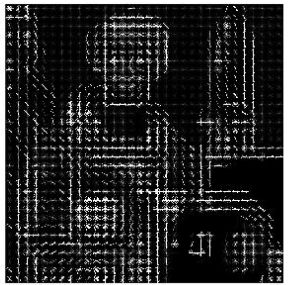
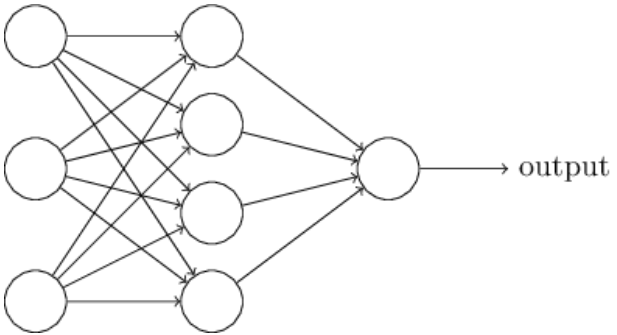
e.g., what representation can implement the computation?

How to represent the image?





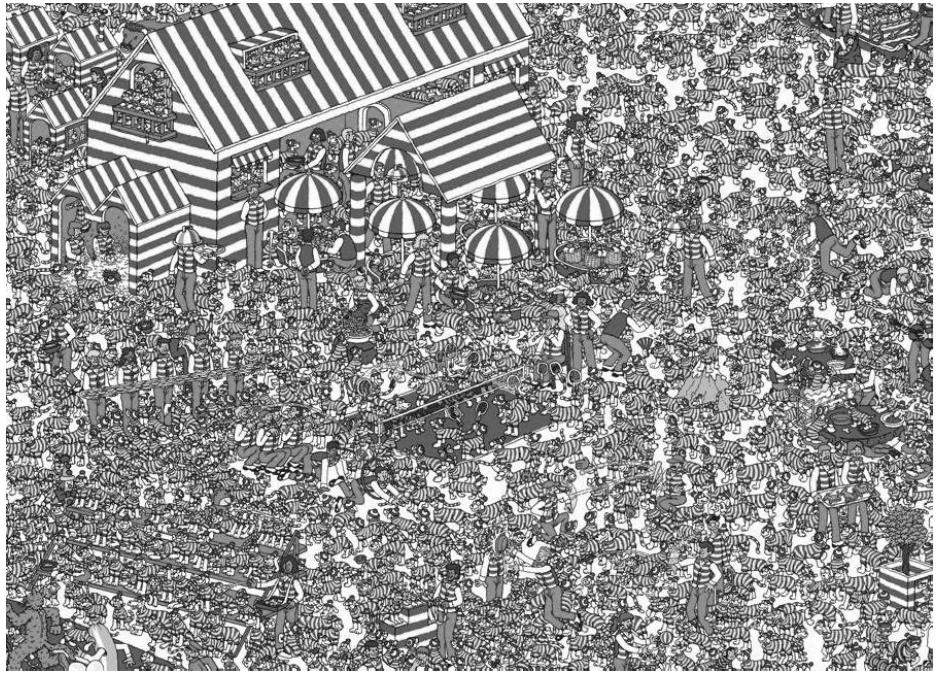


Three Levels of Visual Perception

David Marr (1945-1980)

3. Implementational

e.g., how hardware can carry out such computation?



Three Levels of Visual Perception

David Marr (1945-1980)

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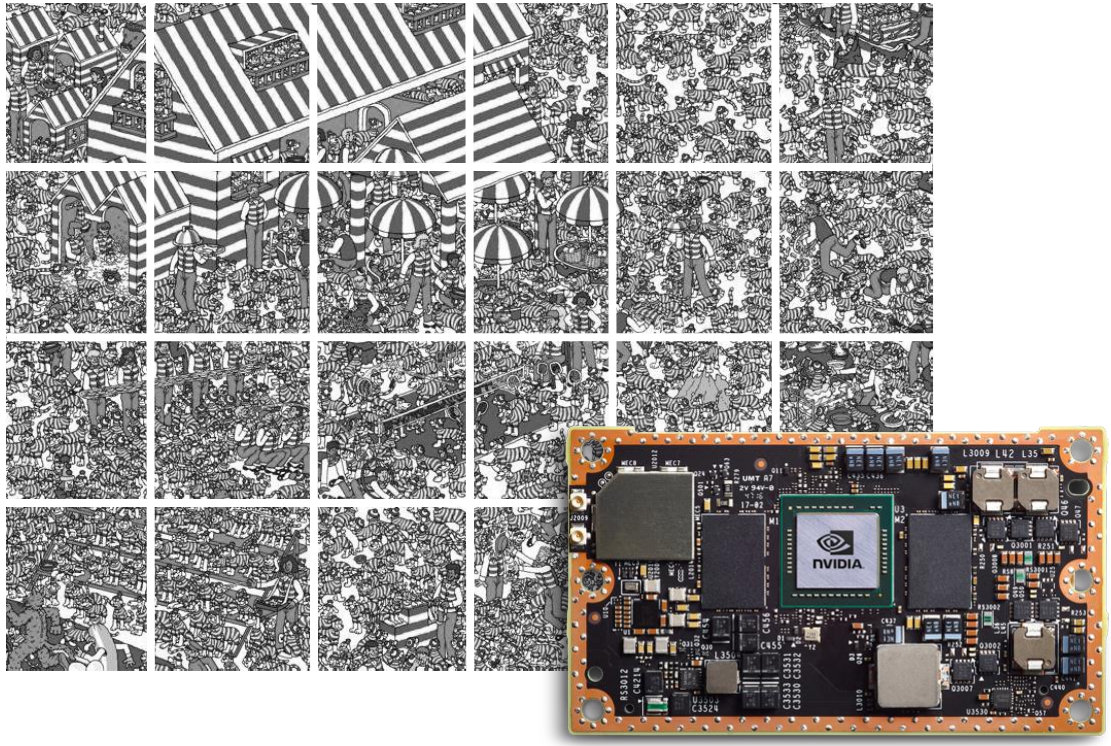

Three Levels of Visual Perception

David Marr (1945-1980)

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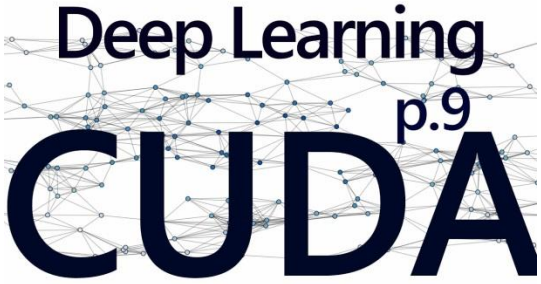
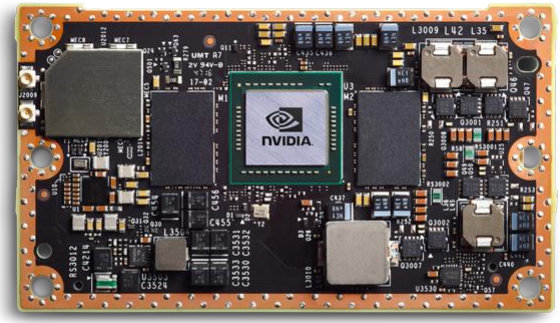


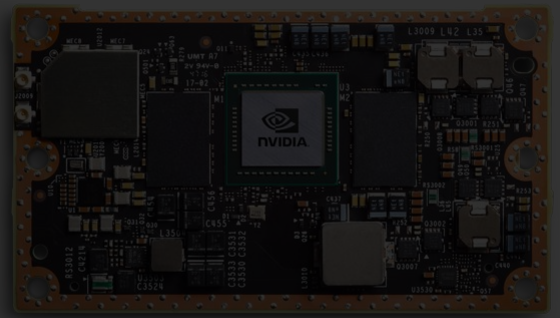


Three Levels of Visual Perception

David Marr (1945-1980)

3. **Implementational**
   e.g., how hardware can carry out such computation?

Beyond the Scope of This Course.



What Will Be Covered?

Basics and 4 Rs of Computer Vision

BASICS

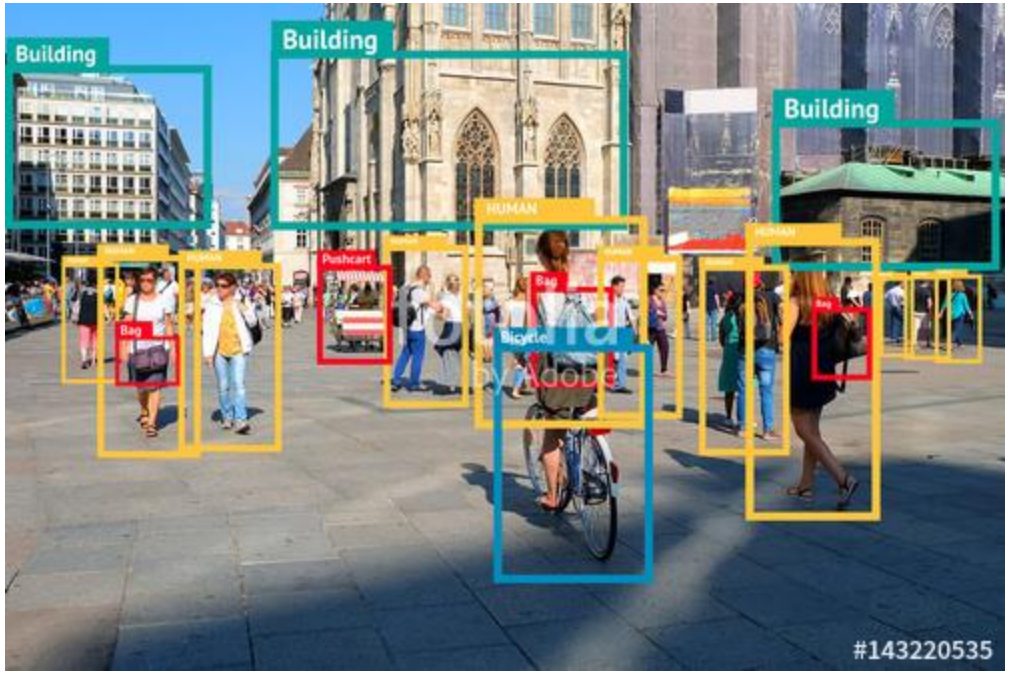
Image formation
Image convolution/filtering
Feature representation

4 Rs: Registration

Optical flow
Image alignment
Tracking

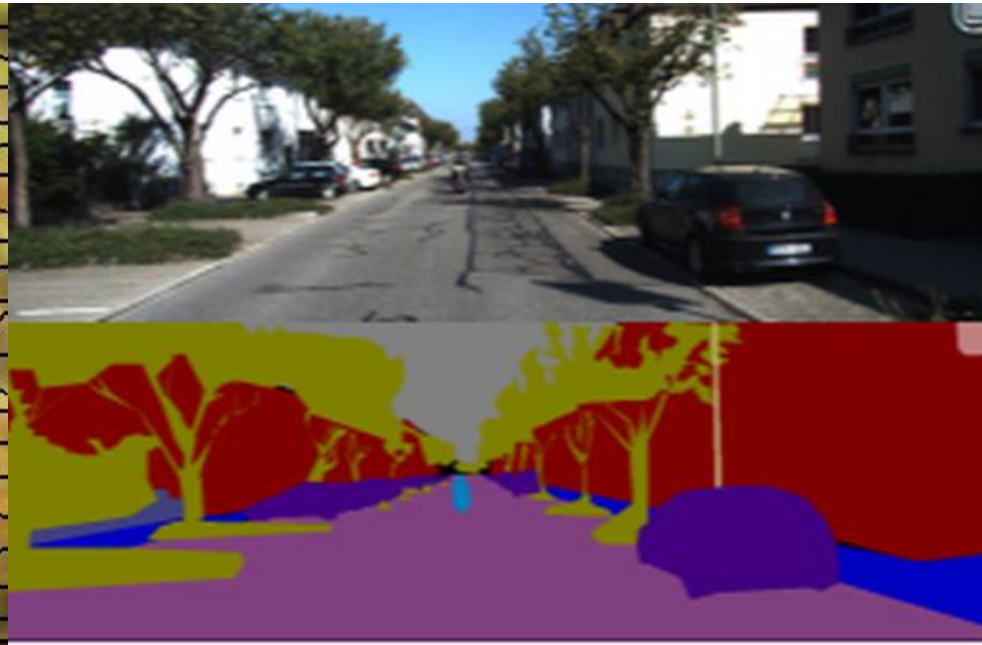
4 Rs: Recognition

Bag of feature
Template matching
Object proposal
Convolutional neural network



4 Rs: Reorganization

Graph cuts
Superpixel
Semantic segmentation



4 Rs: Reconstruction

Camera geometry
Epipolar geometry
Stereo

What Will Not Be Covered?

What Will Not Be Covered?

- Basic Machine Learning knowledge
- MATLAB / Python programming
- Linear algebra / Calculus

What Will Not Be Covered?

- Basic Machine Learning knowledge
- MATLAB / Python programming
- Linear algebra / Calculus

Tips:

1. Drop this course if you are not fluent on these materials---you will be embrassed if you ask these even during office hours.
2. Drop this course if you are not confident on mathematical programming, e.g., translating math concept to code.
3. Drop this course if you are not confortable on debugging and the usage of debugging tools.
4. Study by yourself and read relevant materials (e.g., book, wikipedia, coursera).

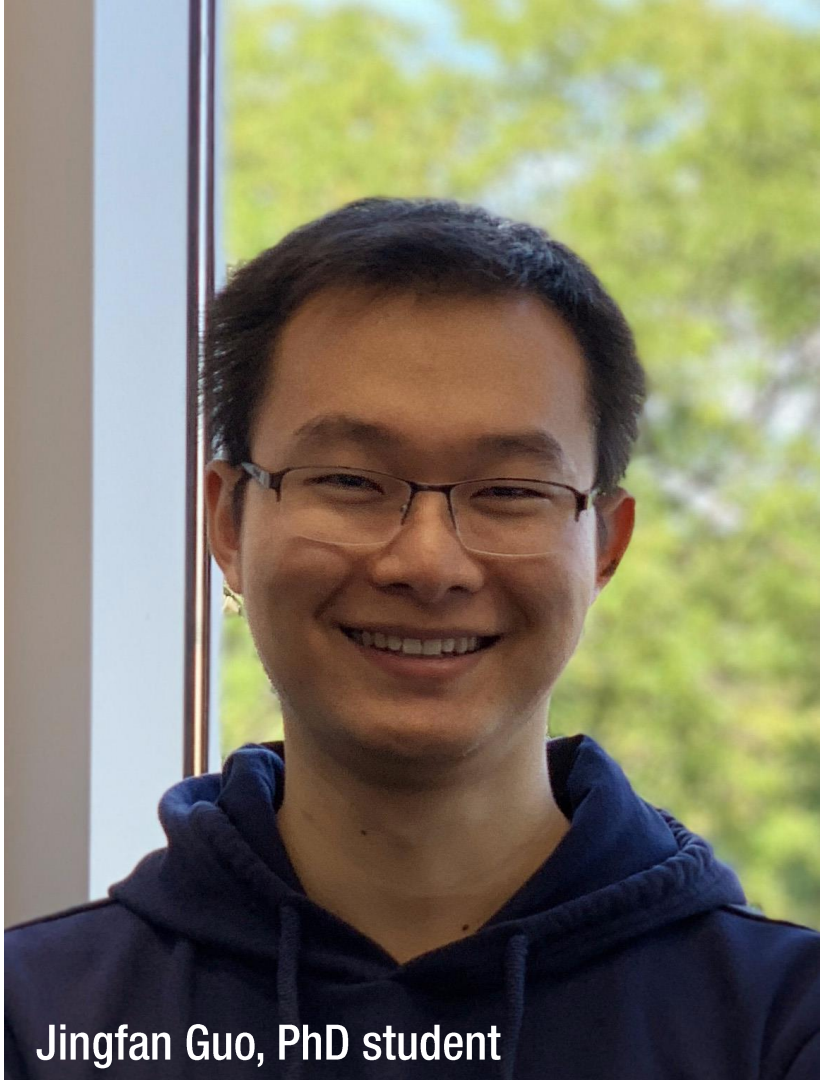
EVALUATION

- 5 programming assignments (15% each)
  - Late submission: 20% off from each extra late day
- 1 final written exam (25%): May 1st during the lecture time

No make-up assignment and exam

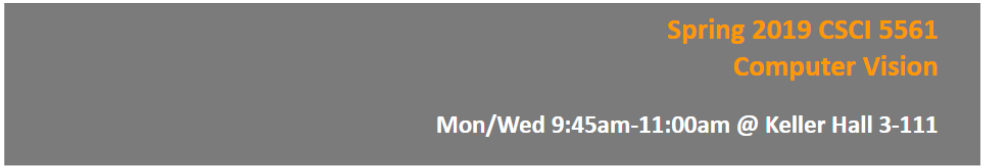
Office Hour

- Hyun Soo Park: MW 4-5pm @ Shepherd 261
- Jingfan Guo: TTh 4-5pm @ Shpherd 234



COURSE WEBSITE

https://www-users.cs.umn.edu/~hspark/csci5561/csci5561.html



Information

Syllabus

Instructor: Hyun Soo Park (hspark at umn.edu)
Office hour: Mon/Wed 4:00pm-5:00pm (Shepherd Laboratory 261)

TA: Jingfan Guo (guo00109 at umn.edu)
Office hour: Tue/Thr 4:00pm-5:00pm (Shepherd Laboratory 234)

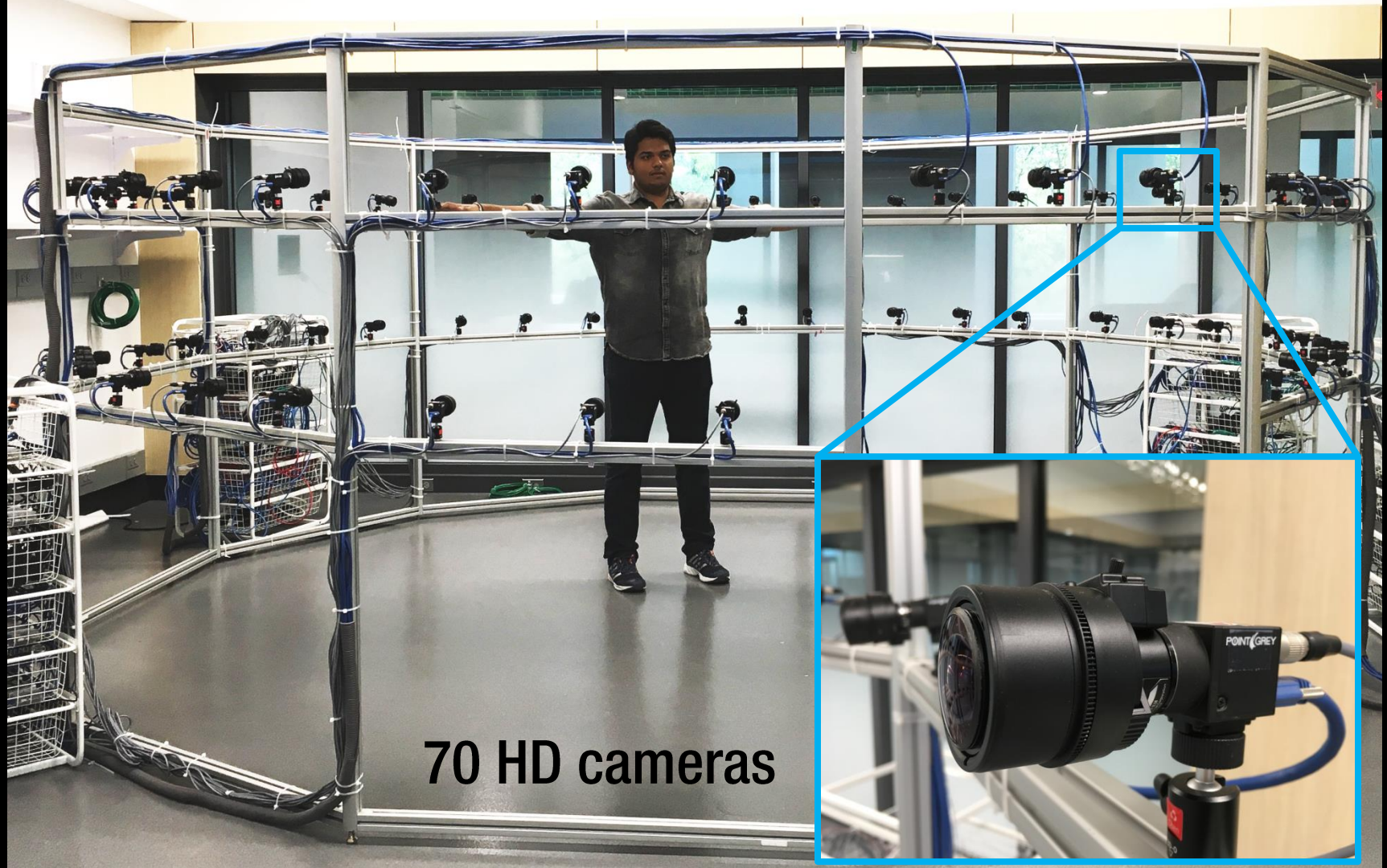
While only 5511 is listed as a prerequisite, **I will assume that all students are fluent on the following subjects** (we don't have time to cover in the lectures):
+ MATLAB/Python usage for image handling
+ Linear algebra
+ Calculus
+ Machine learning

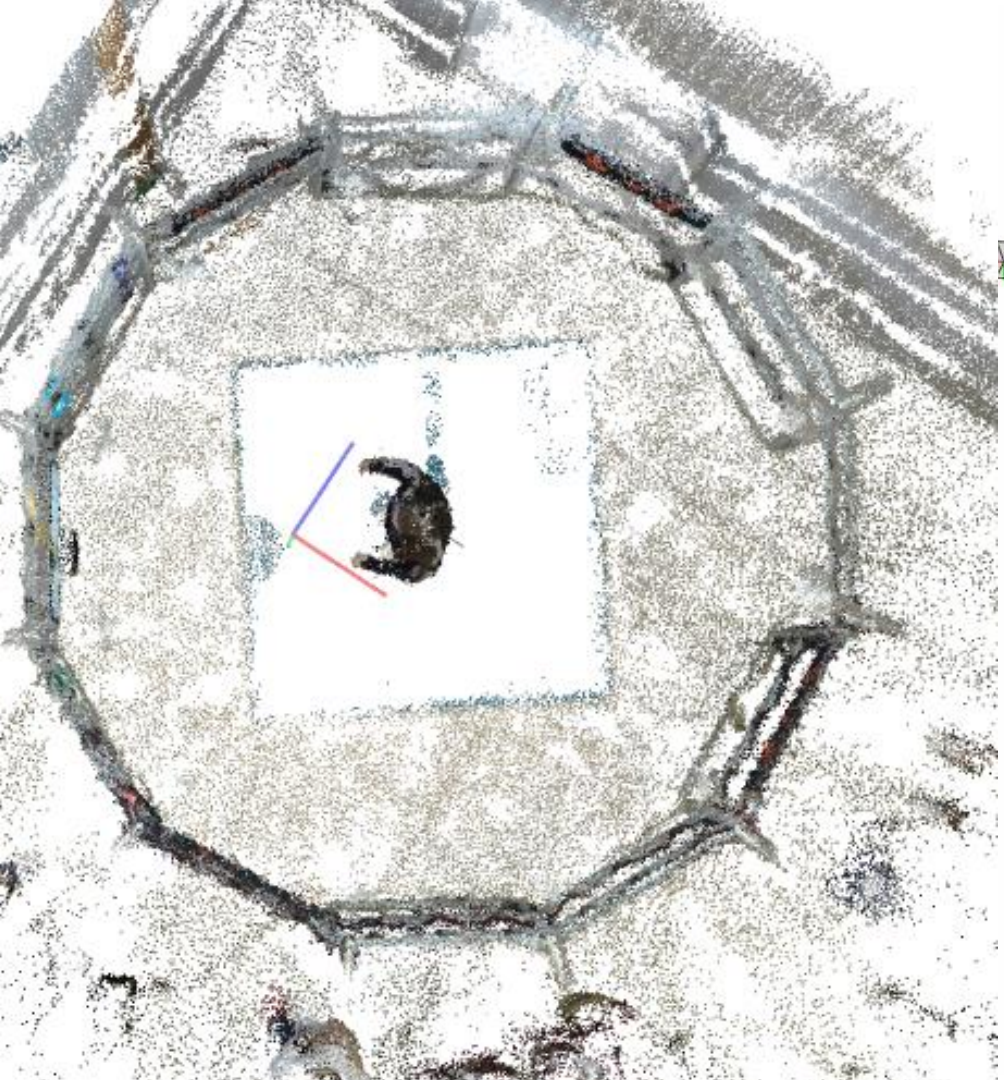
Textbook: Not required but the following books will be frequently referred:
+ "Computer Vision: Algorithms and Applications", Richard Szeliski
+ "Computer Vision: A Modern Approach", David A. Forsyth and Jean Ponce

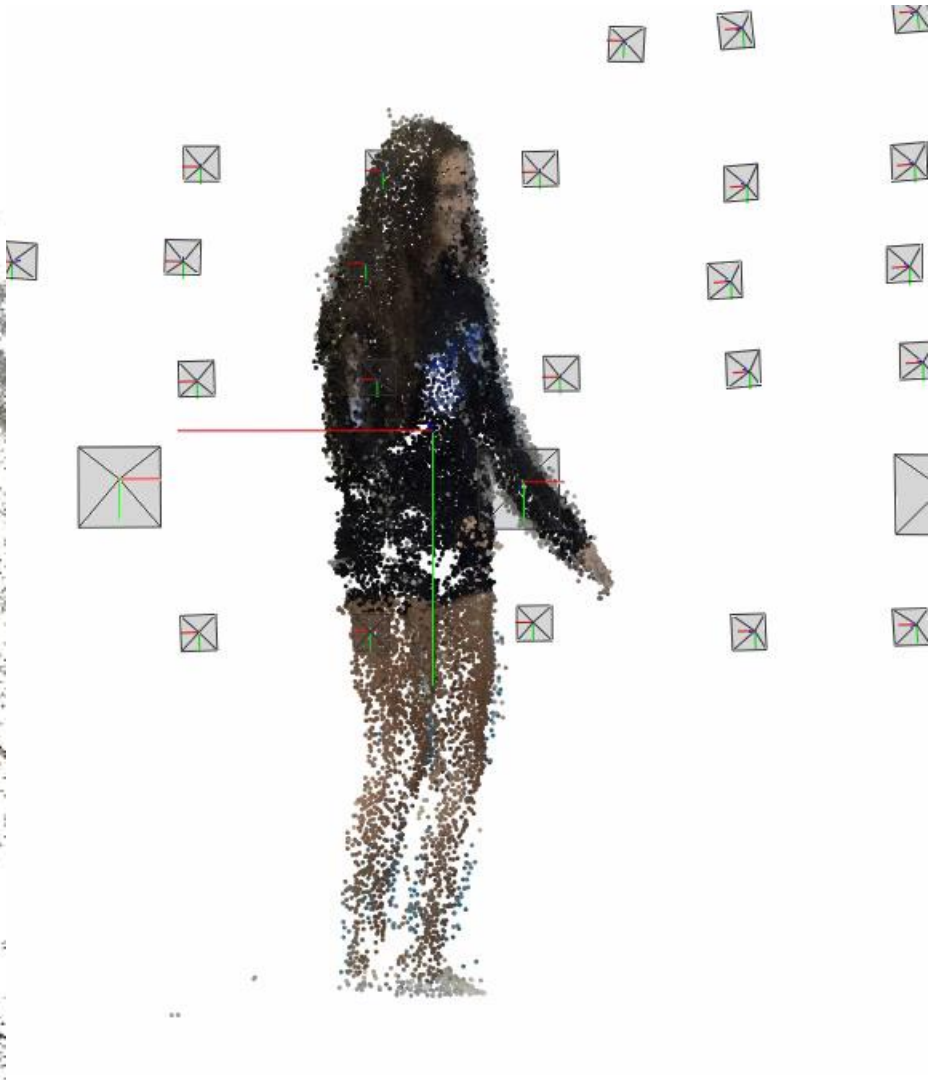
Topics:
+ Visual representation
  - Image formation
  - Image transformation
  - Image filtering/convolution
  - Image feature

- Syllabus
- Schedule
- Lecture slide

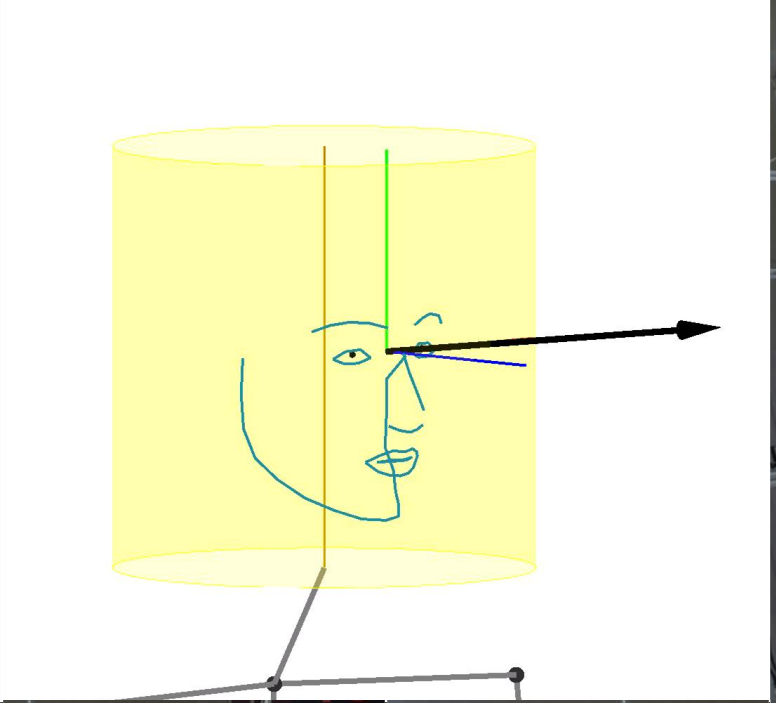
Who am I?

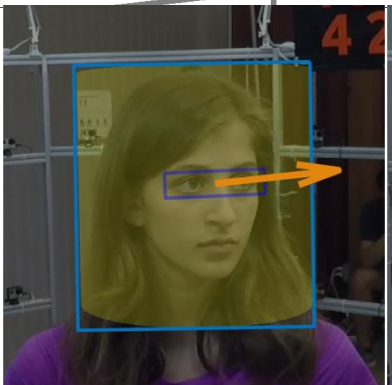

70 HD cameras
POINT GREY

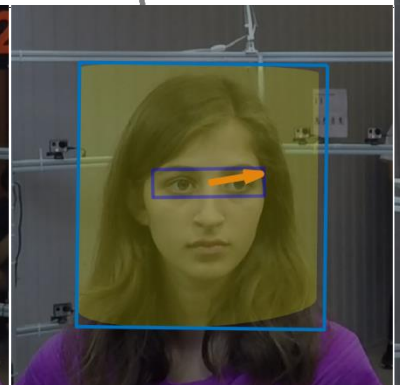


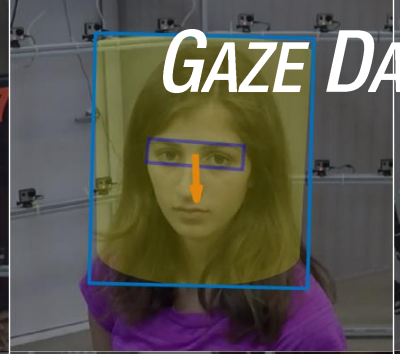


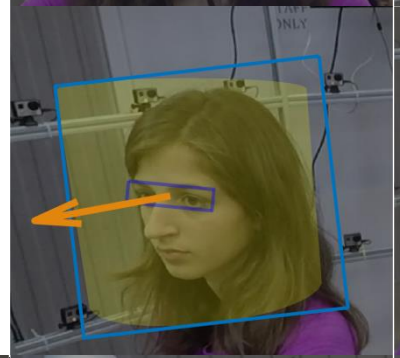
GAZE DATA CAPTURE

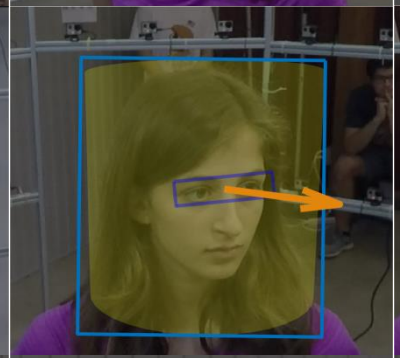


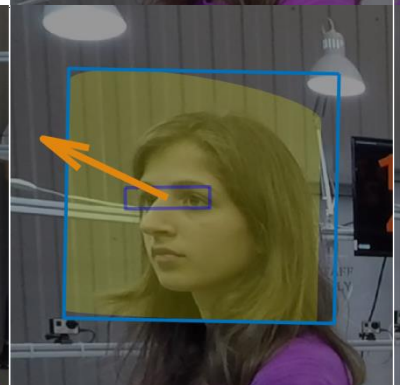


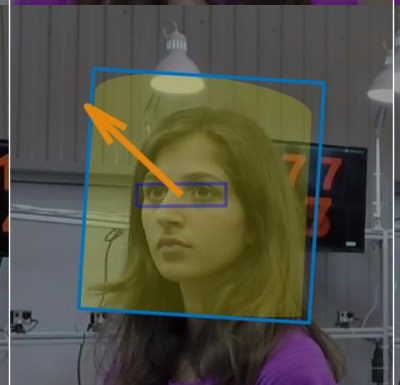


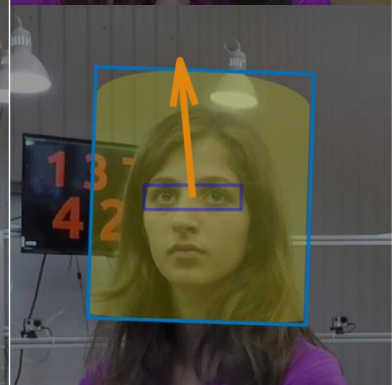








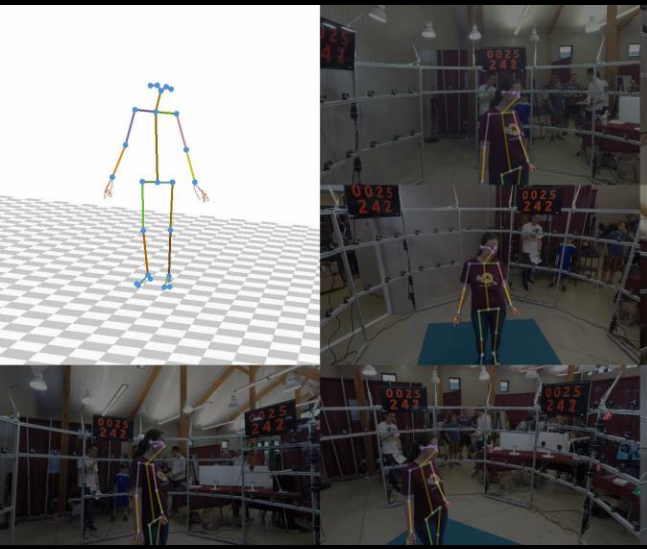




Face Data Capture

Body Data Capture

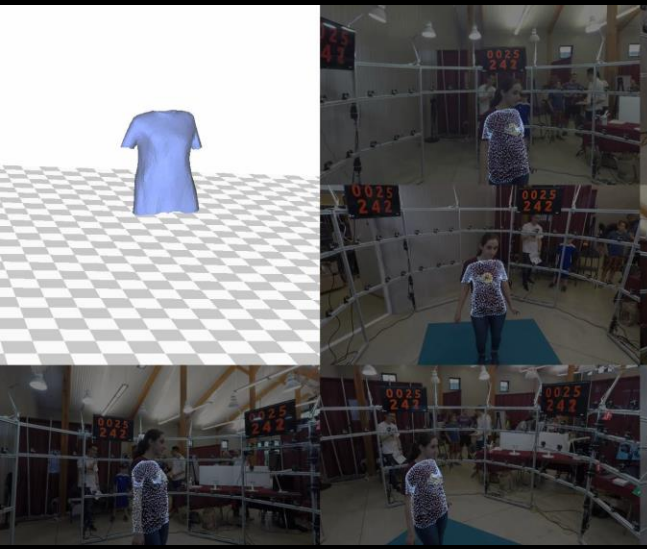
Body Data Capture



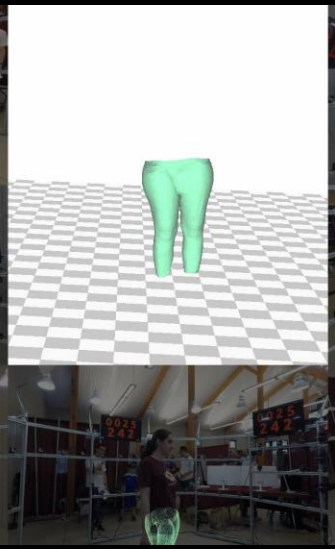
Skeleton

Body skin

Cloth Data Capture

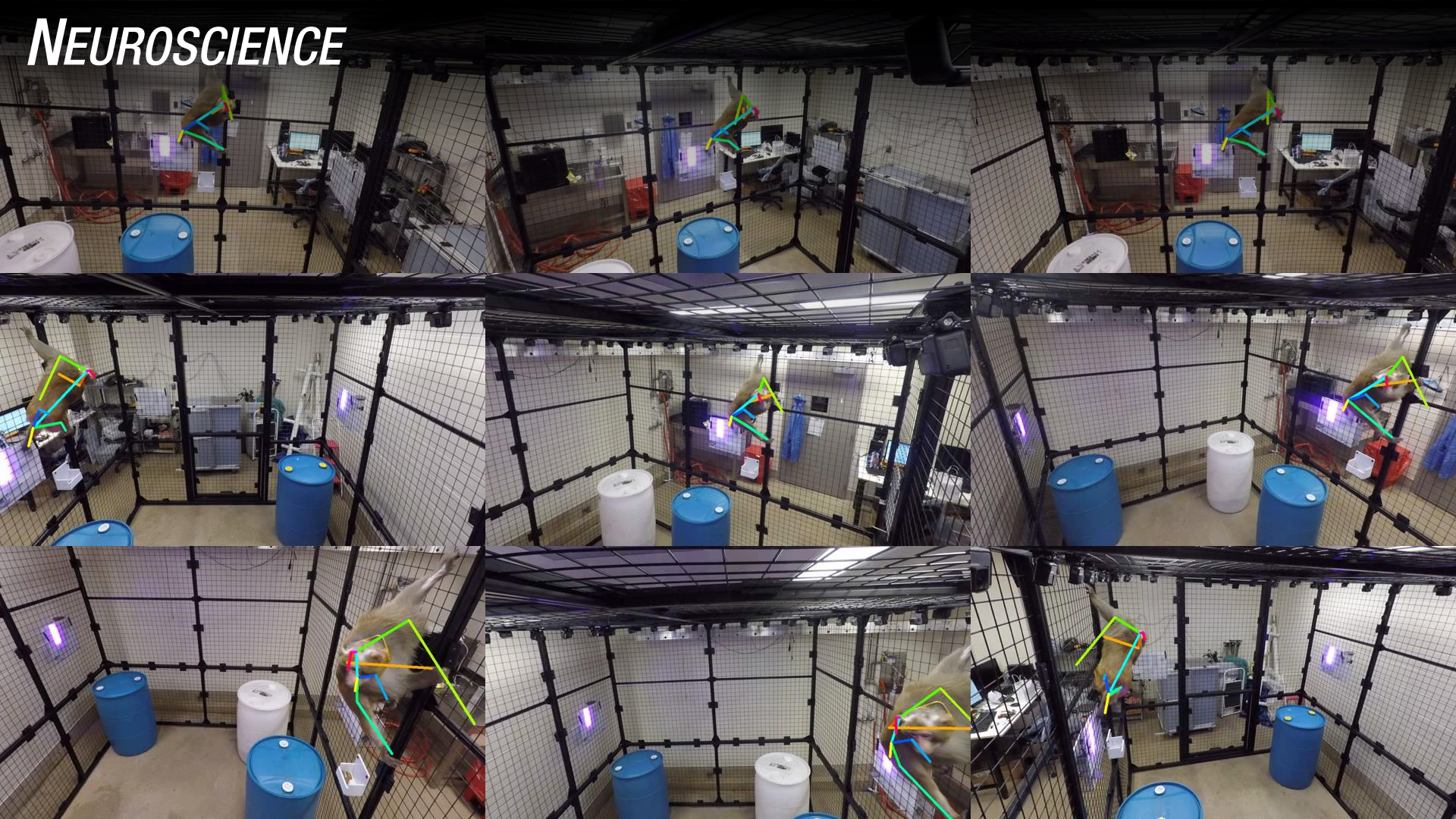


Top



Pants

NEUROSCIENCE



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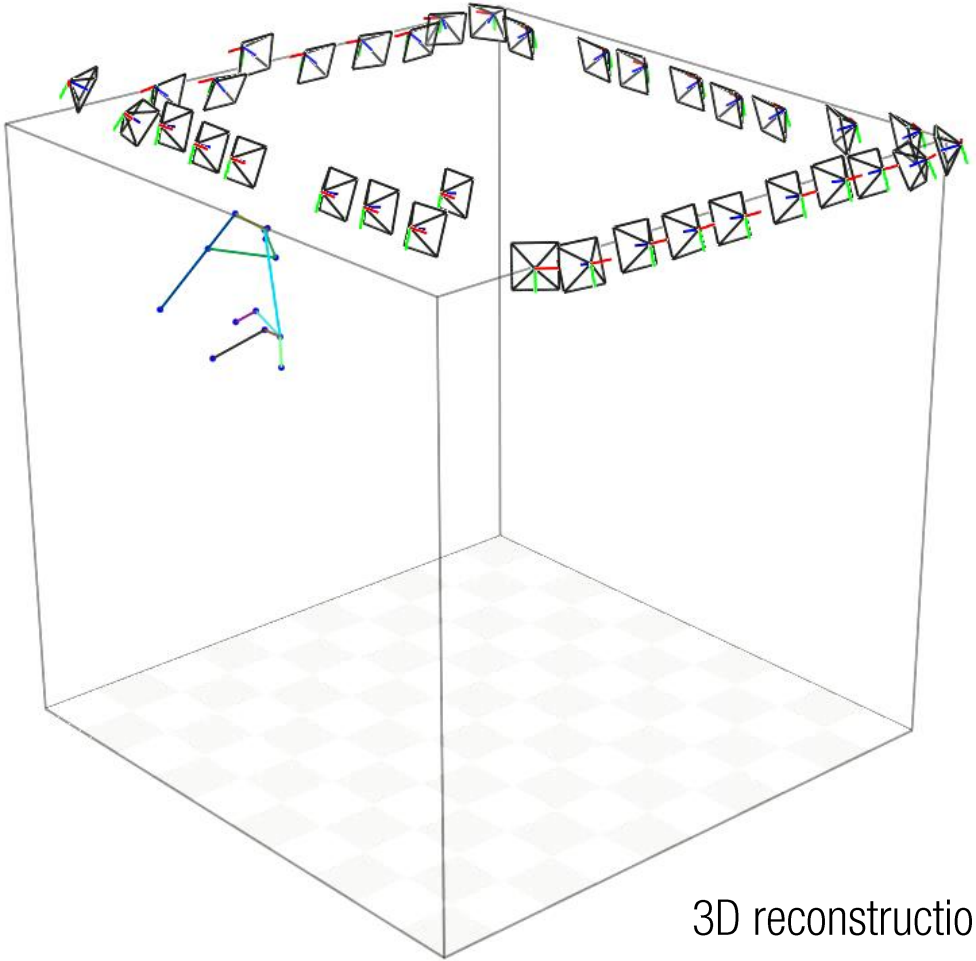
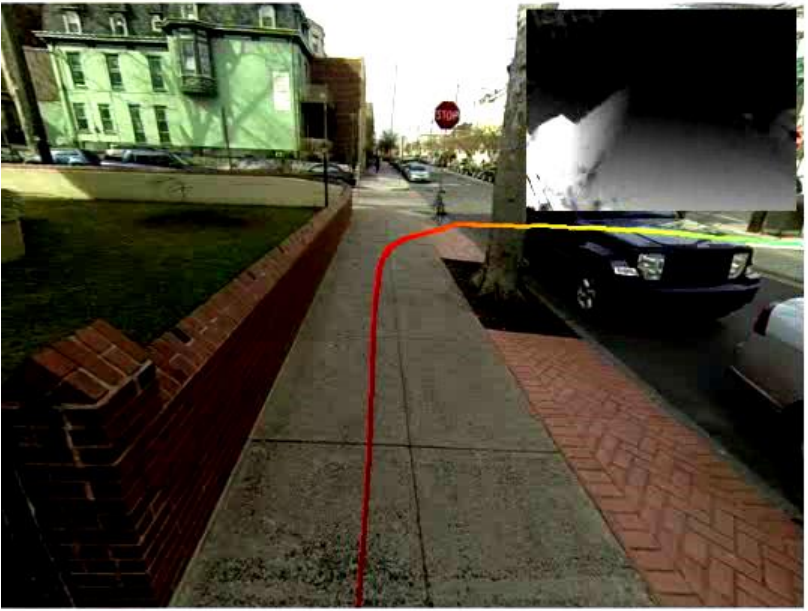
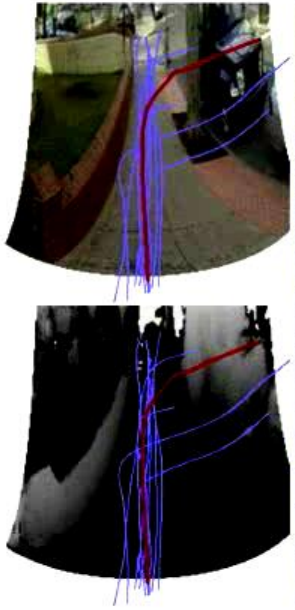


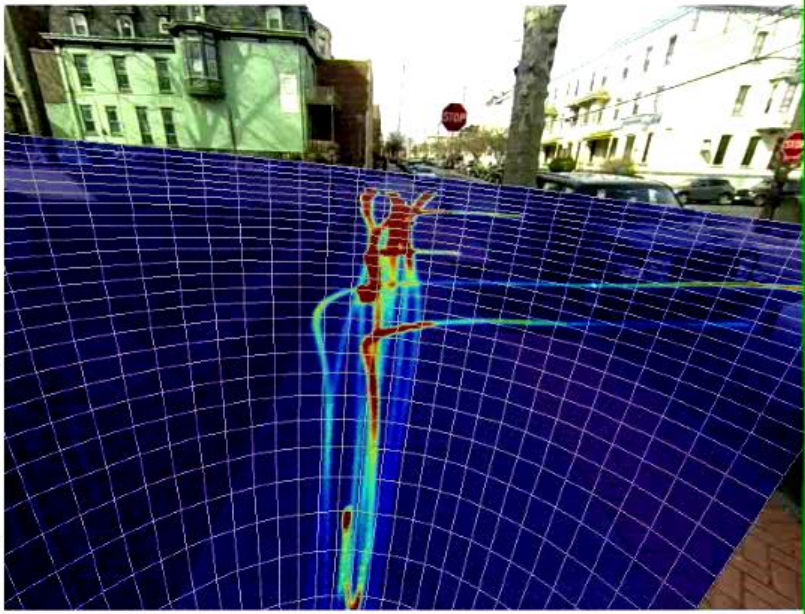
3D reconstruction of monkey movement



Ground truth



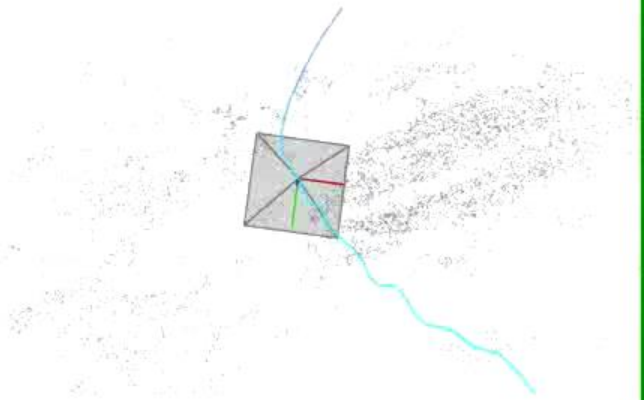
EgoRetinal map



Predicted trajectories

SENSORIMOTOR SKILL LEARNING

https://www.youtube.com/watch?v=aVJ45wlUE88



3D reconstruction