



University of Cyprus – MSc Artificial Intelligence

# MAI644 – COMPUTER VISION

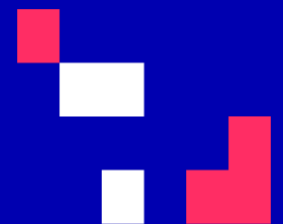
## Lecture 1: Introduction to Computer Vision

**Melinos Averkiou**

CYENS Centre of Excellence

University of Cyprus - Department of Computer Science

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# Today's Agenda

- Who we are
- Introduction to Computer Vision
  - What is Computer Vision
  - How hard is Computer Vision
  - Why is Computer Vision so hard
  - How to organize Computer Vision
  - Why study Computer Vision
  - Applications
- What we do

## Who we are

### Visual Computing Group at CYENS Centre of Excellence



**Melinos Averkiou**  
MRG Leader



**Yiangos Georgiou**  
Research Associate  
(DTP)



**Marios Loizou**  
Research Associate

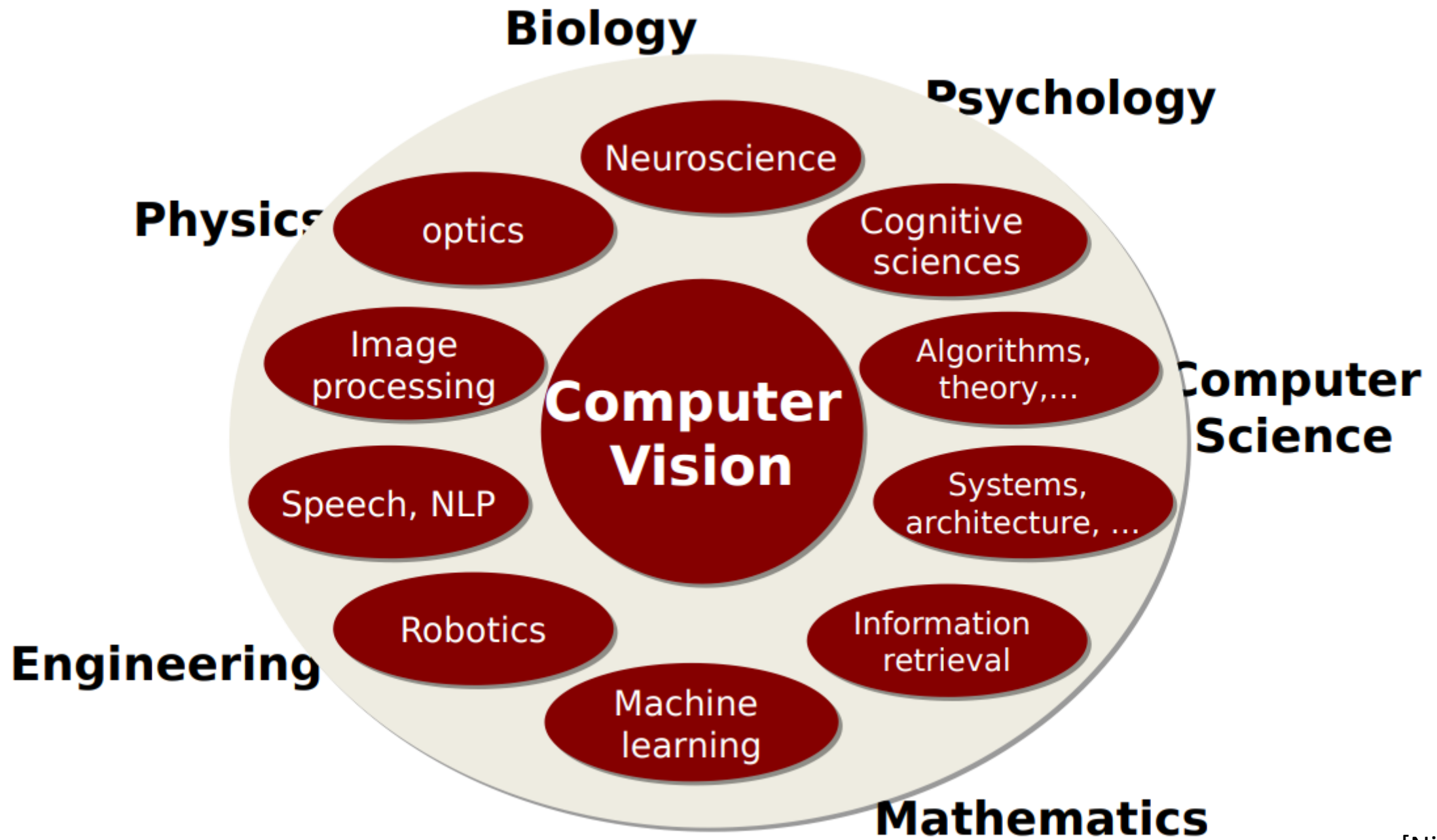


**Yeshwanth Kumar  
Adimoolam**  
Research Associate  
(DTP)

# Today's Agenda

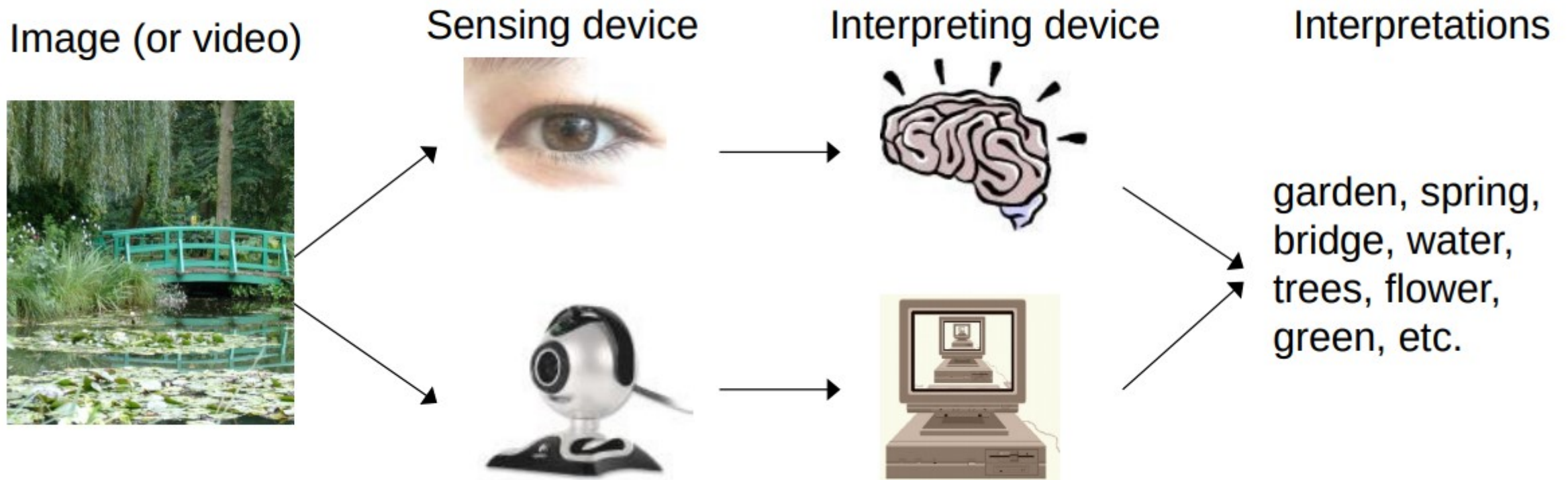
- Course Overview
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[Niebles]

# What is (Computer) Vision ?



[Niebles, Fergus]

# What is (Computer) Vision?

- *Vision* is about discovering from images
  - **what** is present in the scene, and
  - **where** it is
- In *Computer Vision* a **camera** (or several **cameras**) is linked to a computer
- The computer interprets **images** of a scene to obtain information
- Useful for tasks such as navigation, manipulation and recognition





# What is Computer Vision?

Computer Vision's **goal** is to obtain a high-level **understanding** of the world using images as input



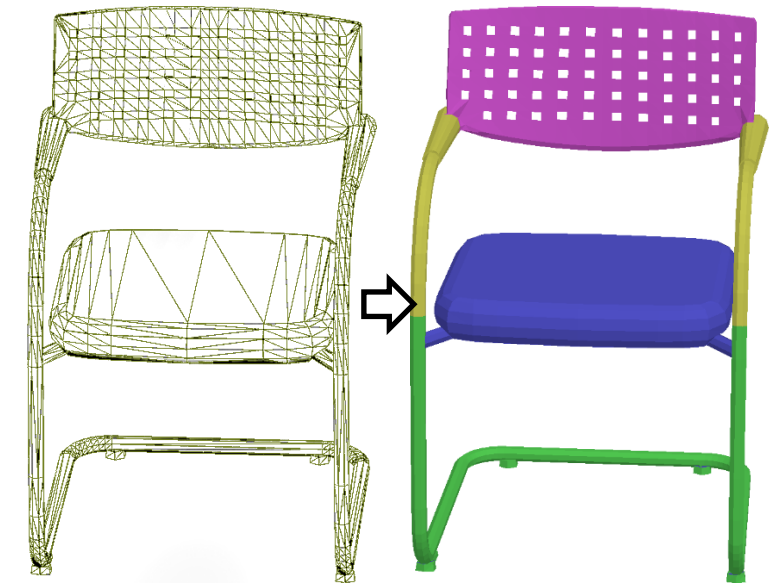
# Understand = Obtain Semantics & Geometry



3D Object layout  
Input: RGBD Image

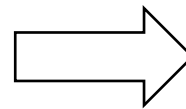


Building facade segmentation  
Input: RGB Image



Object semantic segmentation  
Input: 3D Mesh

## Understanding the world is hard for machines



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What we see

What the machine sees

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# How hard is Computer Vision ?

- The Summer Vision Project – MIT AI Memo 100, 1966
  - ‘Solve vision in a summer project’ - almost an [urban legend](#)
    - Basic foreground/background segmentation,
    - Analyse scenes with simple non-overlapping objects,
    - Extend the system to more complex objects.



MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
PROJECT MAC

Artificial Intelligence Group  
Vision Memo. No. 100.

July 7, 1966

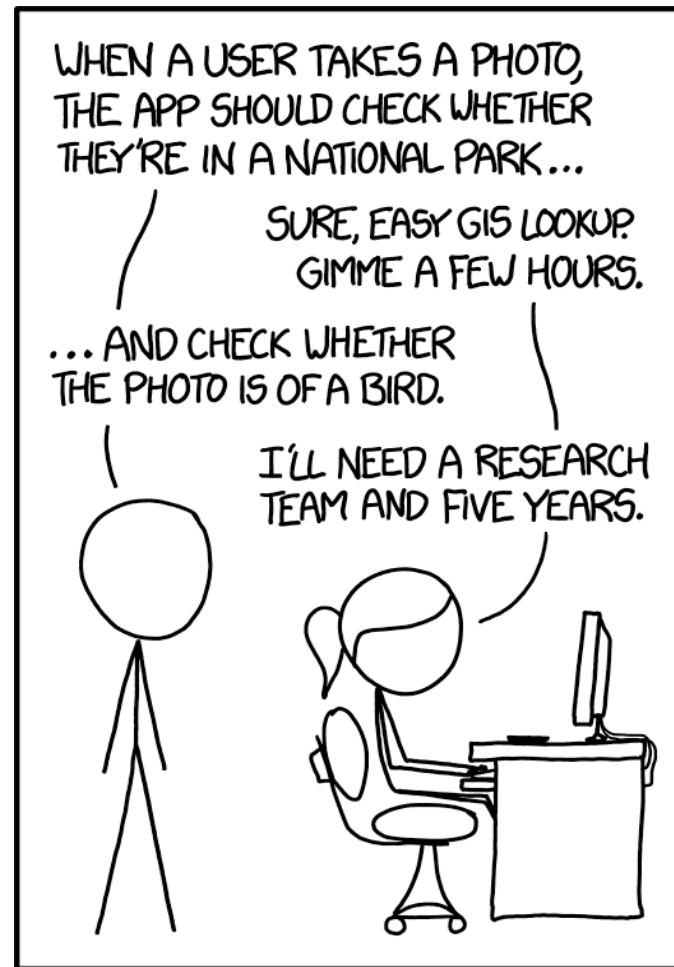
THE SUMMER VISION PROJECT

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".



# How hard is Computer Vision ?



[XKCD](#)

IN CS, IT CAN BE HARD TO EXPLAIN THE DIFFERENCE BETWEEN THE EASY AND THE VIRTUALLY IMPOSSIBLE.

# How hard is Computer Vision ?

**PARK or BIRD**

Want to know if your photo is from a U.S. national park? Want to know if it contains a bird? Just drag it into the box to the left, and we'll tell you. We'll use the GPS embedded in your photo (if it's there) to see whether it's from a park, and we'll use our super-cool computer vision skills to try to see whether it's a bird (which is a hard problem, but we do a pretty good job at it).

To try it out, just drag any photo from your desktop into the upload box, or try dragging any of our example images. We'll give you your answers below!

Want to know more about PARK or BIRD, including why the heck we did this? Just [click here for more info](#) → ⓘ

**PARK? YES**  
Hey, yeah! I went to Bryce Canyon once!

**BIRD? NO**  
Beautiful clouds, but I don't see any birds flying up there.

EXAMPLE PHOTOS

Photo credits

[Flickr 'solved' it](#)

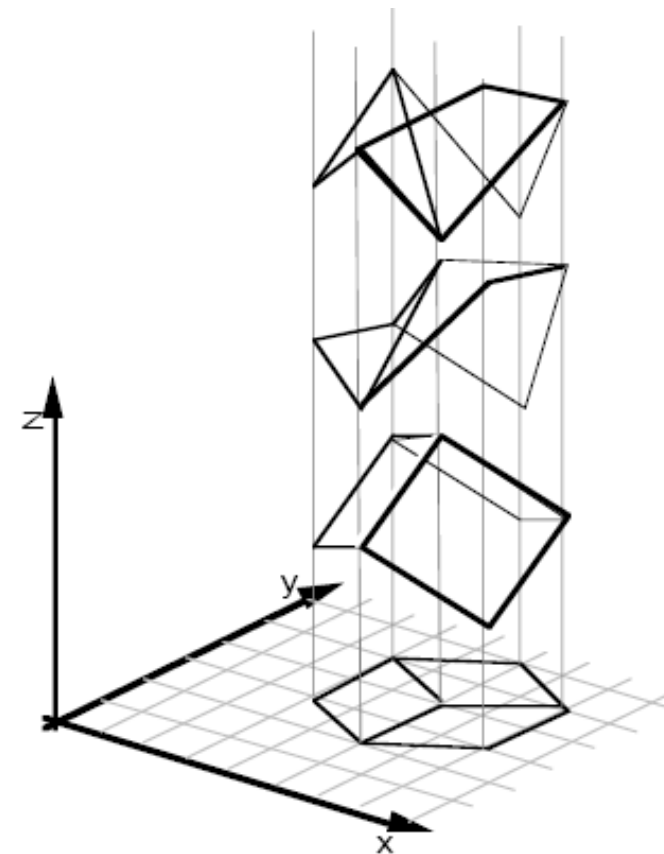


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# Why is Computer Vision so hard?

Because it is an ill-posed problem



[Sinha and Adelson 1993]

## Challenge 1: viewpoint variation



Madonna della Pietà,  
Michelangelo Buonarroti, 1498-99



[Fei Fei, Fergus & Torralba]

## Challenge 2: illumination



[S. Ullman]

## Challenge 3: occlusion



The Blank Signature,  
Rene Magritte, 1965

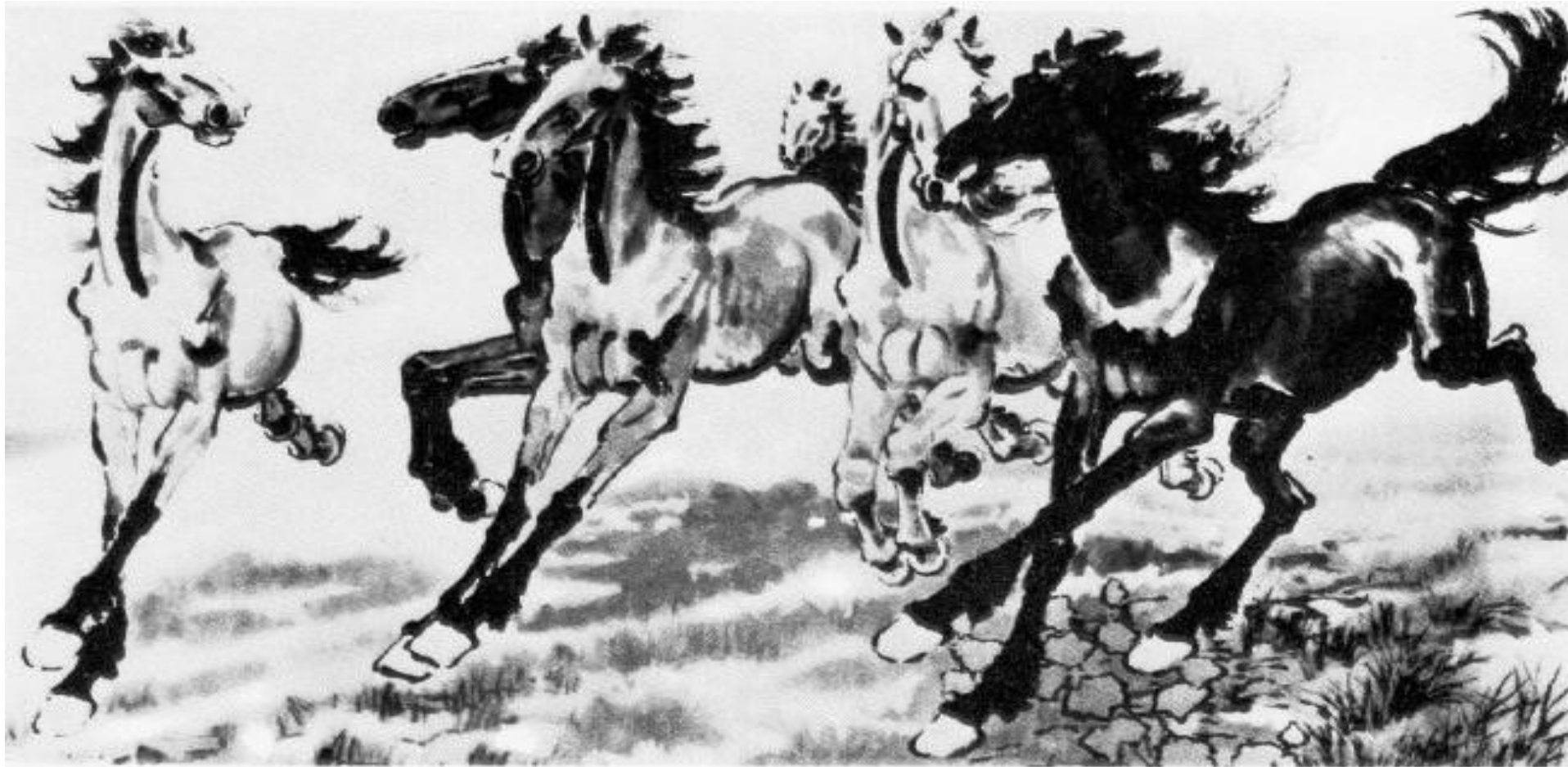
[Fei Fei, Fergus &  
Torralba]

## Challenge 4: scale



[Fei Fei, Fergus & Torralba]

## Challenge 5: deformation



Six Galloping Horses,  
Xu Beihong, 1942

[Fei Fei, Fergus & Torralba]

## Challenge 6: background clutter



The Maiden,  
Gustav Klimt, 1913

[Fei Fei, Fergus &  
Torralba]

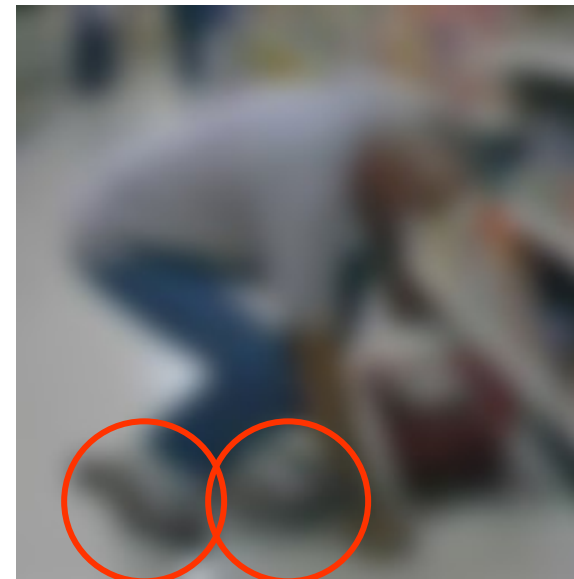
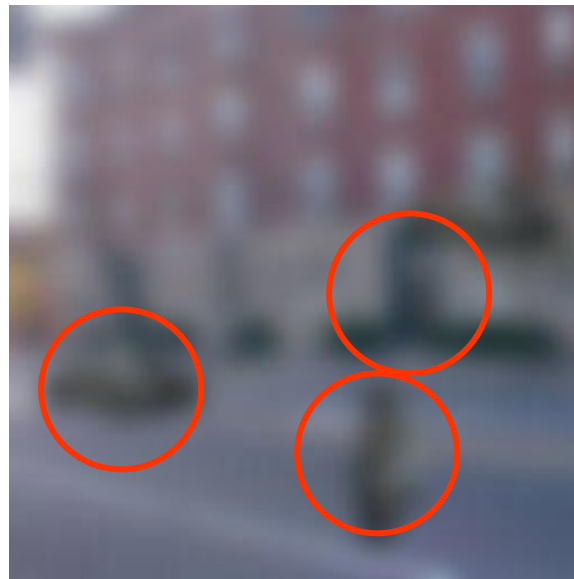
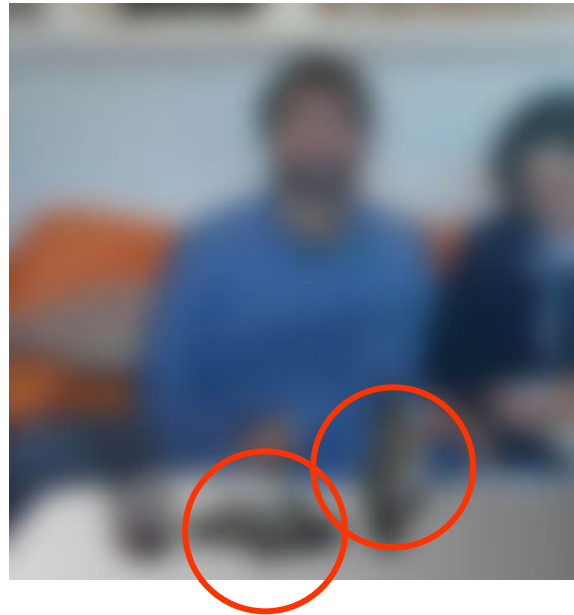
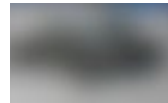


## Challenge 7: object intra-class variation



[Fei Fei, Fergus & Torralba]

## Challenge 8: local ambiguity



[Fei Fei, Fergus & Torralba]

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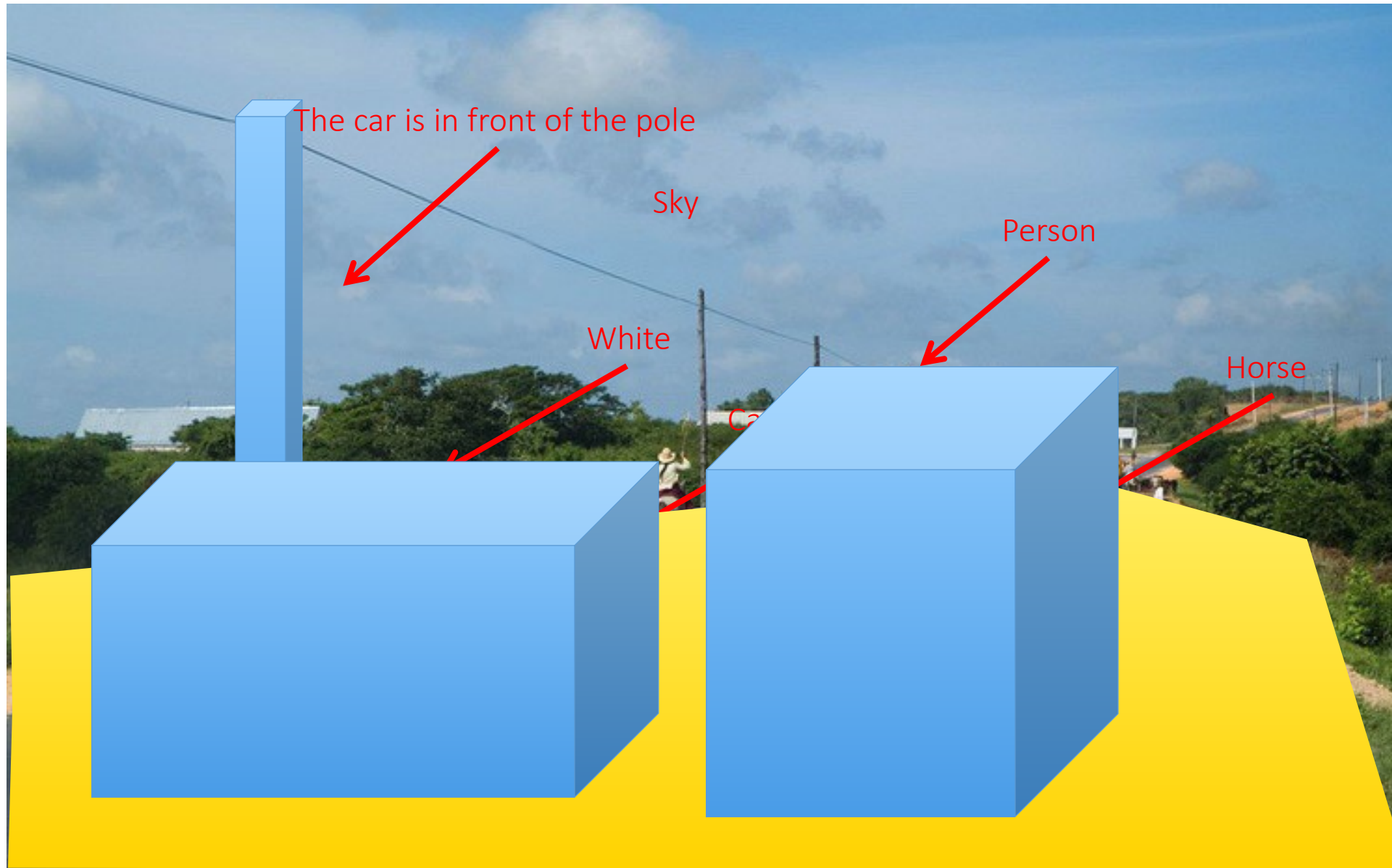


# How to organize Computer Vision ?

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[Shapiro]





[Shapiro]

# How to organize Computer Vision ?

- Low Level Vision
  - Measurements
  - Enhancements
  - Region segmentation
  - Features
- Mid Level Vision
  - Reconstruction
  - Depth
  - Motion Estimation
- High Level Vision
  - Category detection
  - Activity recognition
  - Deep understanding



[Shapiro]

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[Shapiro]

# Low-Level: Exposure

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[Redmon]



# Low-Level: Edges

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[Redmon]

# Low-Level: Segmentation (color)

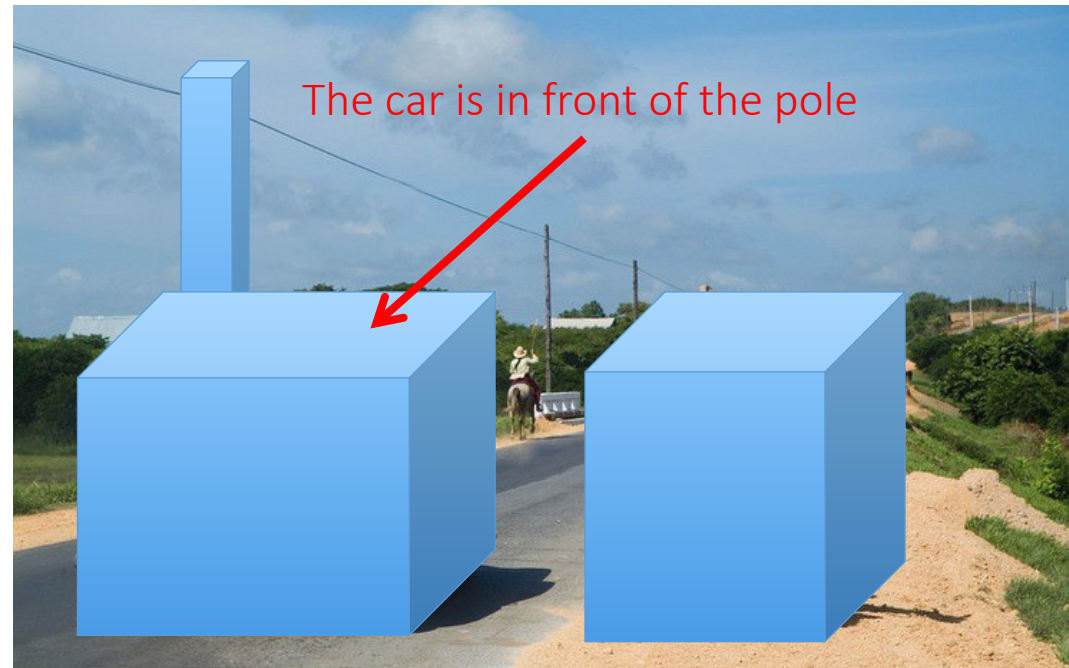
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[Redmon]

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[Shapiro]

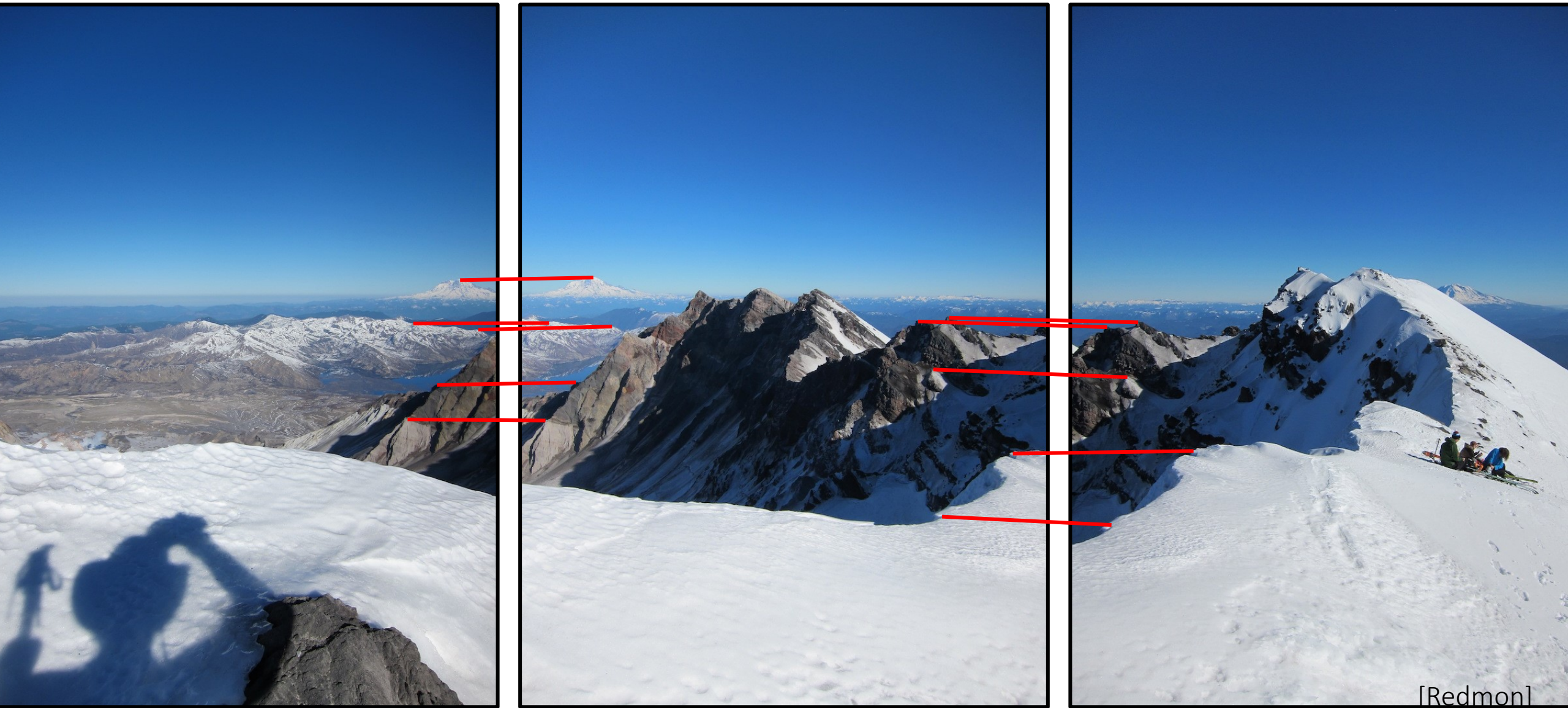
# Mid-Level: Panorama Stitching

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[Redmon]

## Mid-Level: Panorama Stitching



# Mid-Level: Panorama Stitching

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[Redmon]

# Mid-Level: Multi-View Stereo

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[Redmon]

# Mid-Level: Multi-View Stereo



[Redmon]



# Mid-Level: Multi-View Stereo

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[Building Rome in a Day,  
Agarwal et al., ICCV 2009]

The Colosseum, 2,106 images, 819,242 points

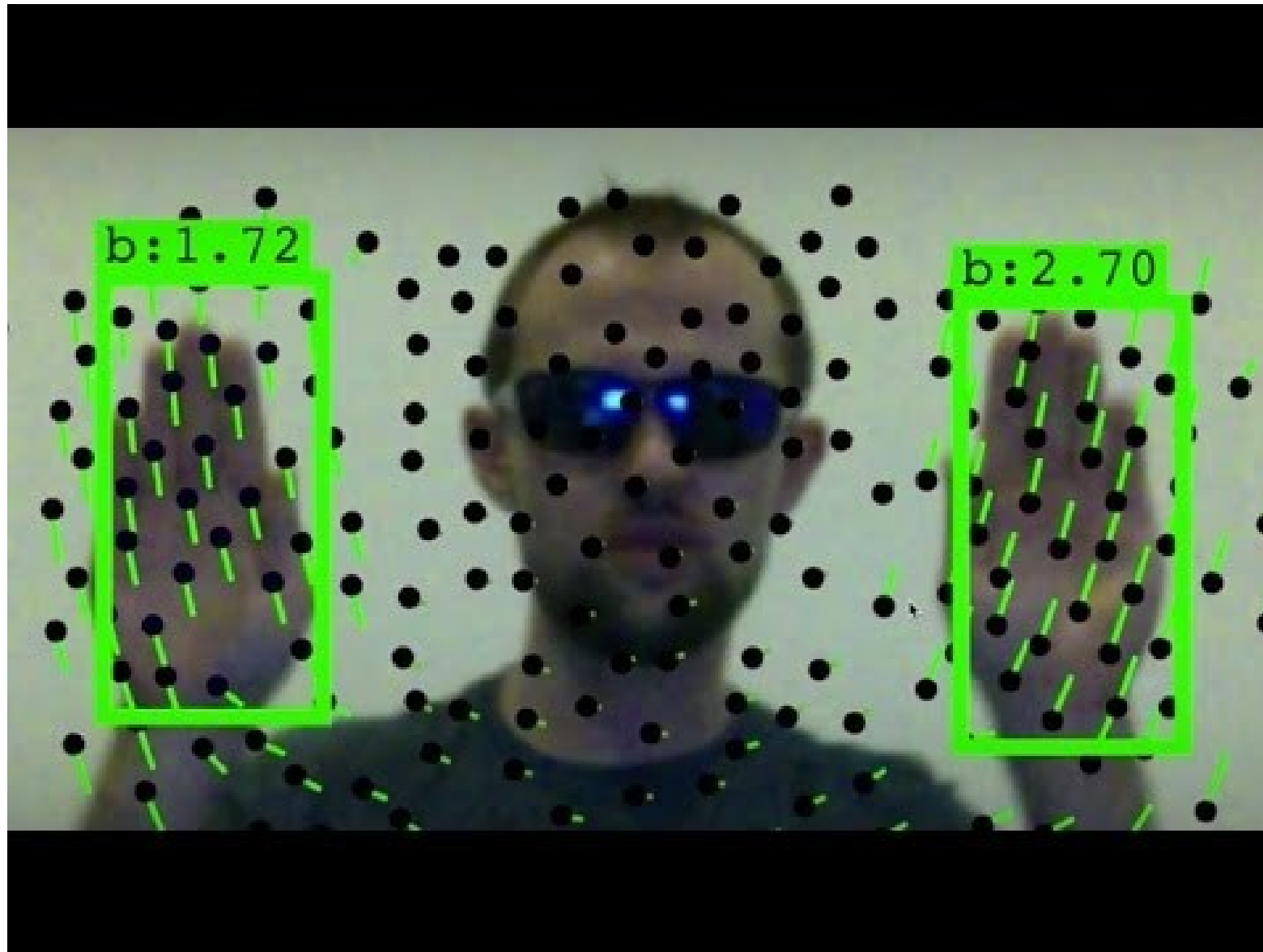
# Mid-Level: Optical Flow

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[Redmon]

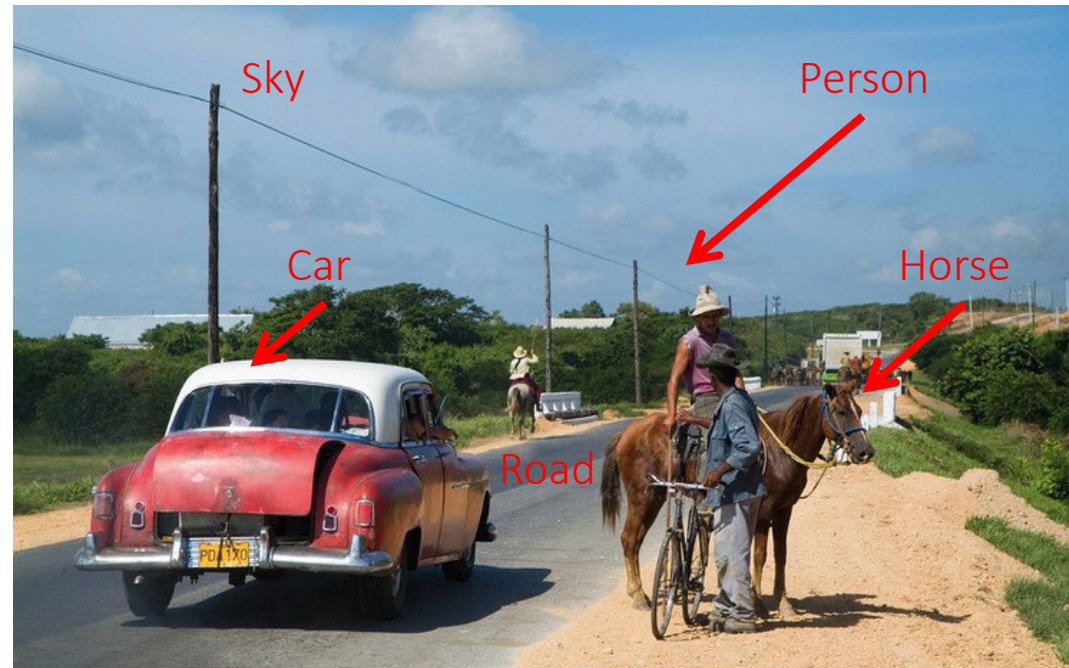
# Mid-Level: Optical Flow



[Redmon]

# How to organize Computer Vision ?

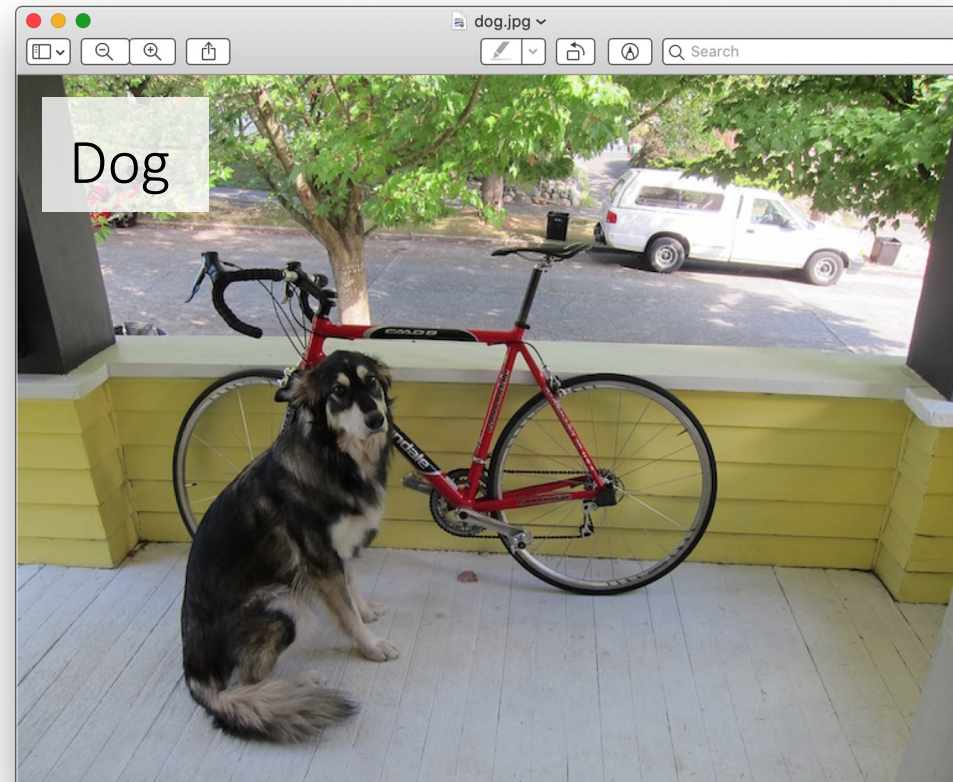
- Low Level Vision
  - Measurements
  - Enhancements
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[Shapiro]

# High-Level: Classification

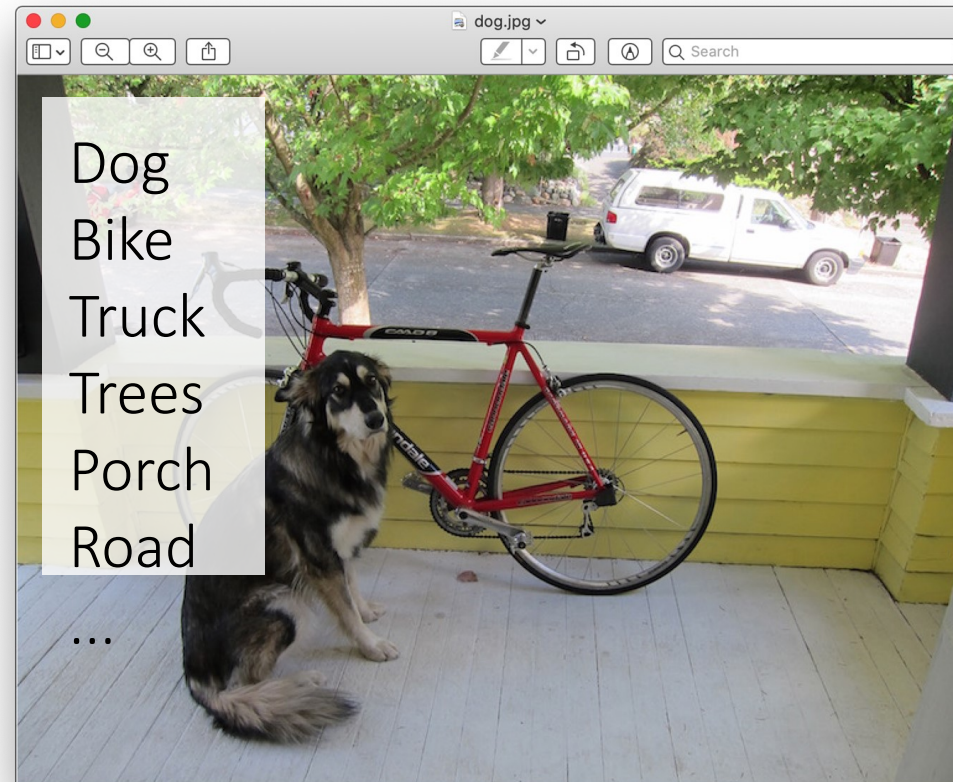
- What is in the image?



[Redmon]

# High-Level: Tagging

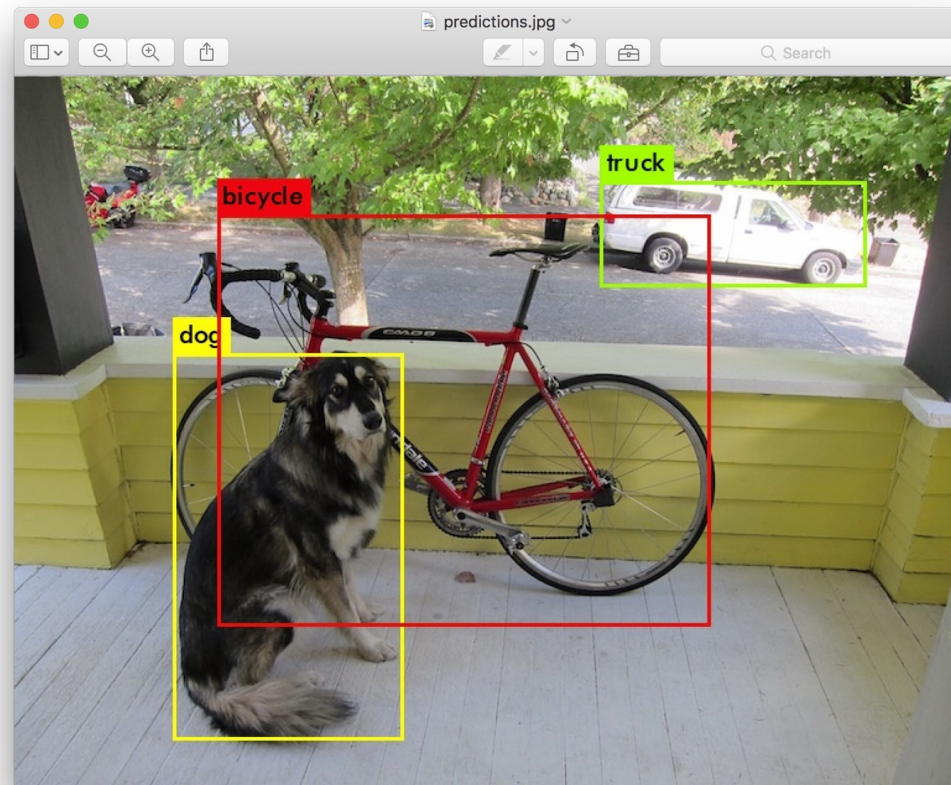
- What are ALL the things in the image?



[Redmon]

# High-Level: Detection

- What are ALL the things in the image?
- Where are they?



[Redmon]

# High-Level: Semantic Segmentation



[Redmon]



# High-Level: Instance Segmentation



<http://www.youtube.com/watch?v=OOT3UIXZztE>

[Redmon]

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# Why study Computer Vision?

- *Match (or beat) human vision*
  - central to Artificial Intelligence, countless applications
- Understand human vision → neuroscience
- Do research with huge impact
- Get a job in the industry
- Timing is perfect: AI revolution – big data, faster hardware, deep learning

# Do research with huge impact

Google Scholar

Top publications

Categories ▾

Publication
1. Nature
2. The New England Journal of Medicine
3. Science
4. The Lancet
5. IEEE/CVF Conference on Computer Vision and Pattern Recognition
6. Advanced Materials
7. Nature Communications
8. Cell
9. Chemical Reviews
10. Chemical Society reviews
11. Journal of the American Chemical Society
12. Angewandte Chemie
13. Proceedings of the National Academy of Sciences
14. JAMA
15. Nucleic Acids Research

Google Scholar

Top publications

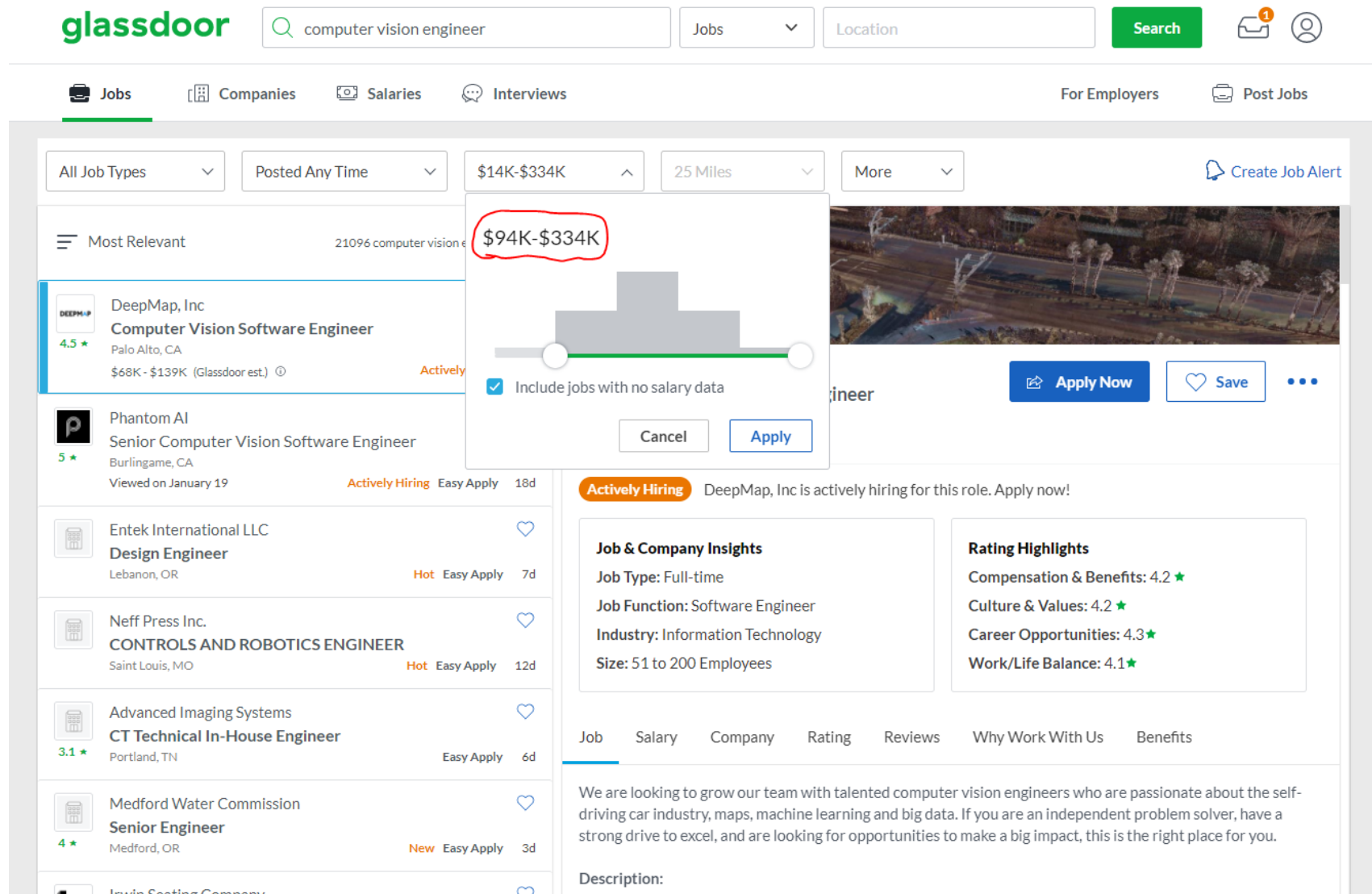
Categories ▾ English ▾

Publication	<u>h5-index</u>	<u>h5-median</u>
1. Nature	414	607
2. The New England Journal of Medicine	410	704
3. Science	391	564
4. IEEE/CVF Conference on Computer Vision and Pattern Recognition	356	583
5. The Lancet	345	600
6. Advanced Materials	294	406
7. Cell	288	459
8. Nature Communications	287	389
9. Chemical Reviews	270	434
10. International Conference on Learning Representations	253	470
11. JAMA	253	446
12. Neural Information Processing Systems	245	422
13. Proceedings of the National Academy of Sciences	245	337
14. Journal of the American Chemical Society	245	330
15. Angewandte Chemie	235	314

2021

2022

# Get a job in the industry



The screenshot shows a Glassdoor search for 'computer vision engineer' with filters for salary (\$14K-\$334K) and location (25 Miles). A salary range overlay is set to '\$94K-\$334K'. The job list includes:

- DeepMap, Inc**: Computer Vision Software Engineer, Palo Alto, CA, \$68K - \$139K (Glassdoor est.)
- Phantom AI**: Senior Computer Vision Software Engineer, Burlingame, CA
- Entek International LLC**: Design Engineer, Lebanon, OR
- Neff Press Inc.**: CONTROLS AND ROBOTICS ENGINEER, Saint Louis, MO
- Advanced Imaging Systems**: CT Technical In-House Engineer, Portland, TN
- Medford Water Commission**: Senior Engineer, Medford, OR

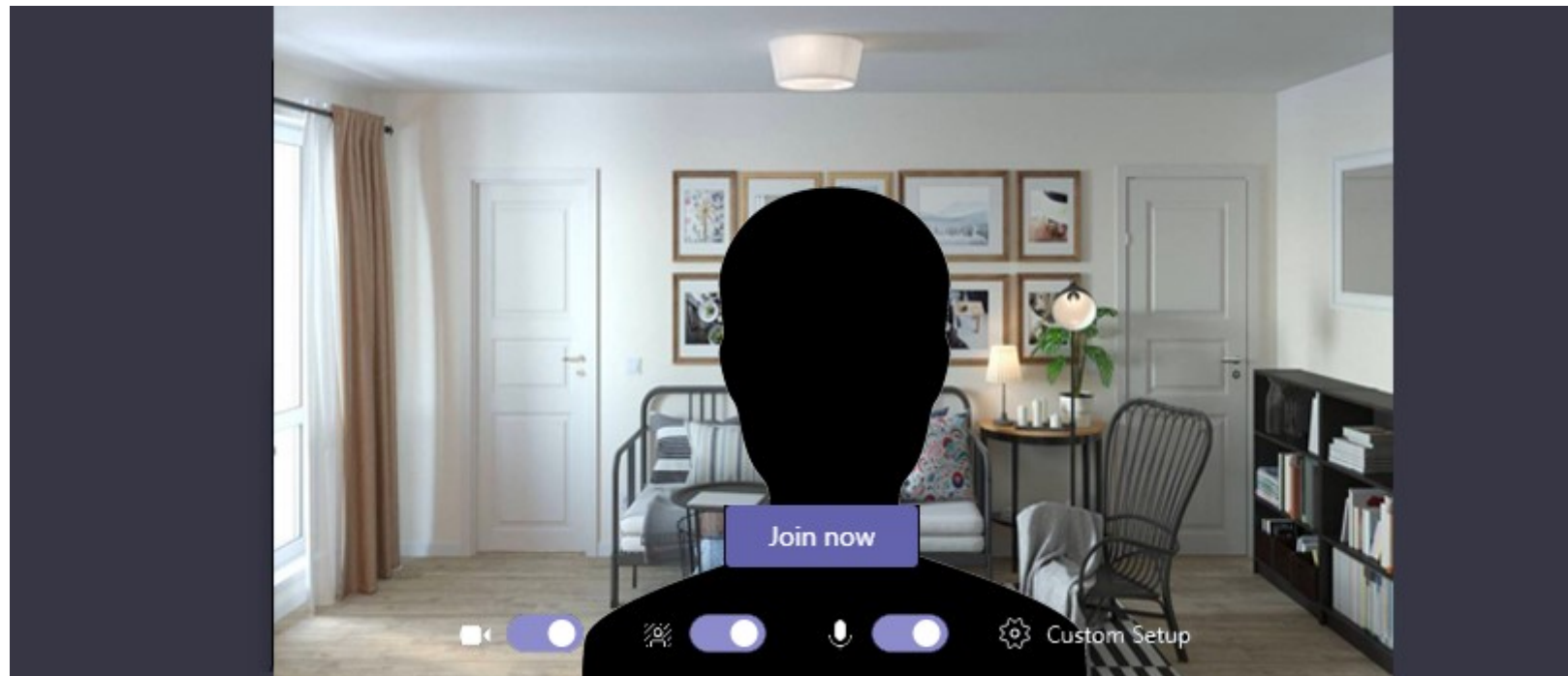
The job details for DeepMap, Inc are expanded, showing 'Job & Company Insights' (Job Type: Full-time, Job Function: Software Engineer, Industry: Information Technology, Size: 51 to 200 Employees) and 'Rating Highlights' (Compensation & Benefits: 4.2, Culture & Values: 4.2, Career Opportunities: 4.3, Work/Life Balance: 4.1).

# Today's Agenda

- Course Overview
- Introduction to Computer Vision
  - What is Computer Vision
  - How hard is Computer Vision
  - Why is Computer Vision so hard
  - How to organize Computer Vision
  - Why study Computer Vision
  - Applications
- What we do



# Segmentation and Matting



## 3D Maps

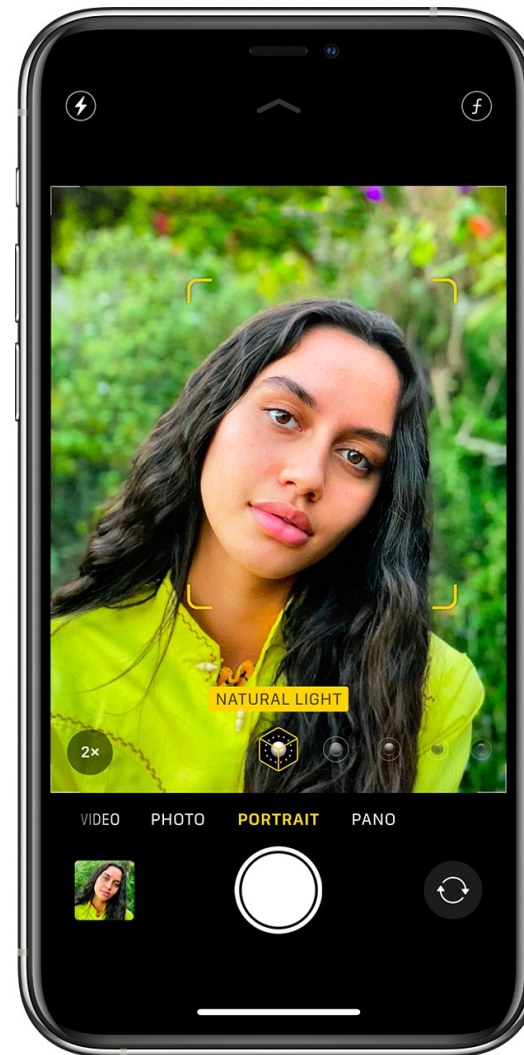


Apple Maps

[Seitz, Szeliski]



# Computational photography



Portrait mode  
simulating wider aperture

[Seitz, Szeliski]

# Even wider aperture...



[How scientists captured the first image of a black hole, 2019](#)

[Seitz, Szeliski]

## 3D photos

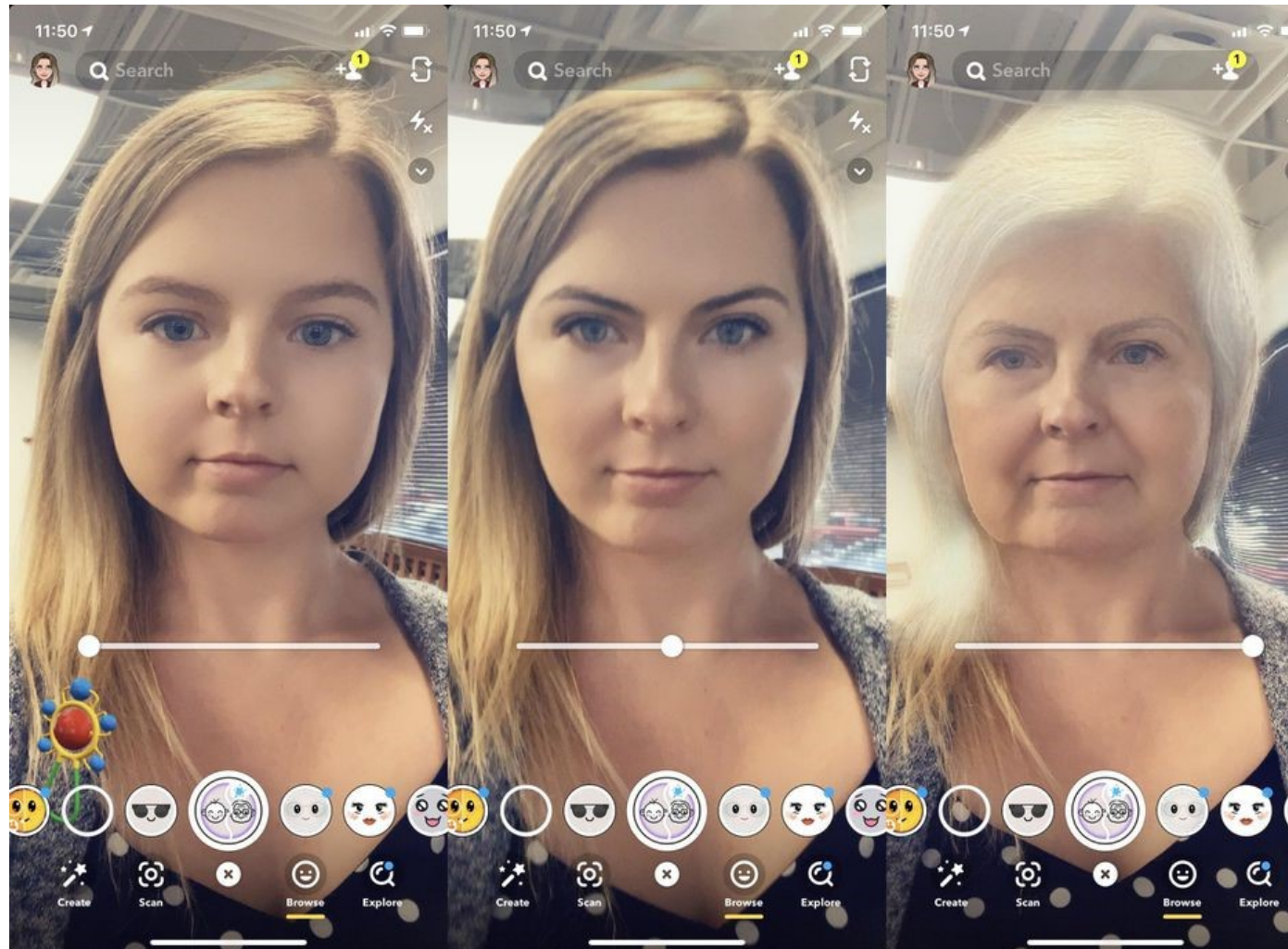


### [3D Photos on Facebook](#)

Estimate depth from photo to create animation

[Seitz, Szeliski]

# Age Simulation

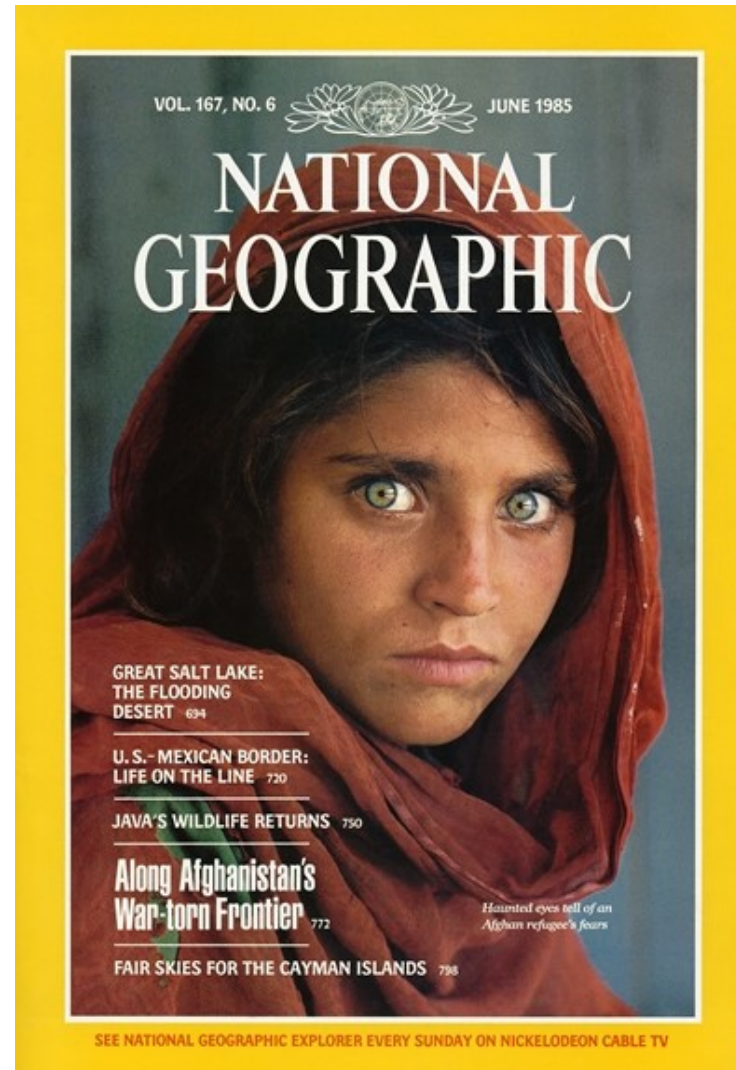


From [CNET](#)

Snapchat Time Machine

[Seitz, Szeliski]

# Face recognition



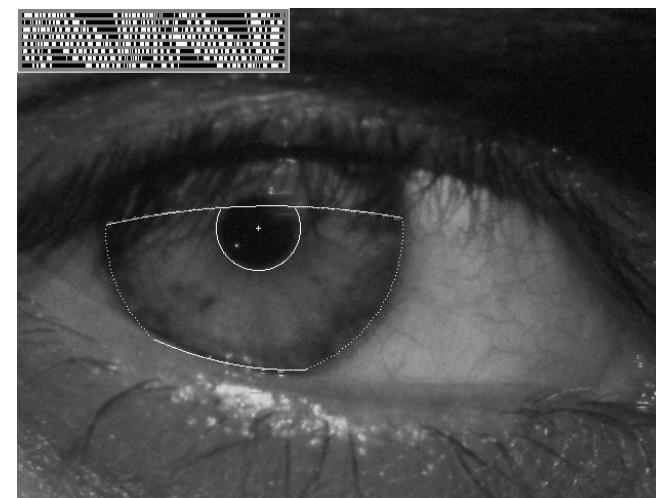
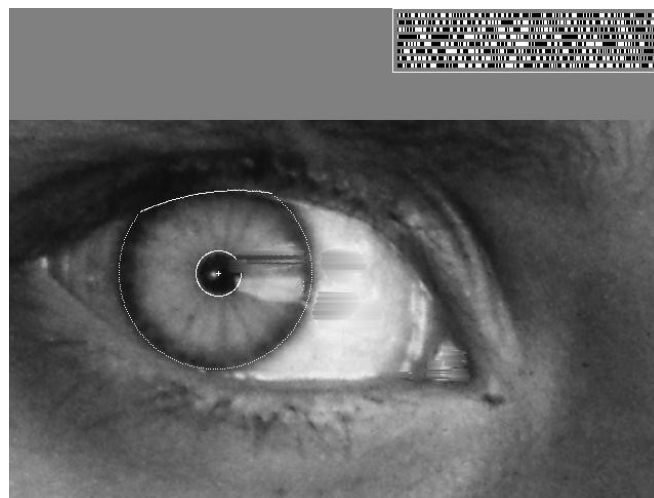
Who is she?

[Seitz, Szeliski]

# Vision-based biometrics

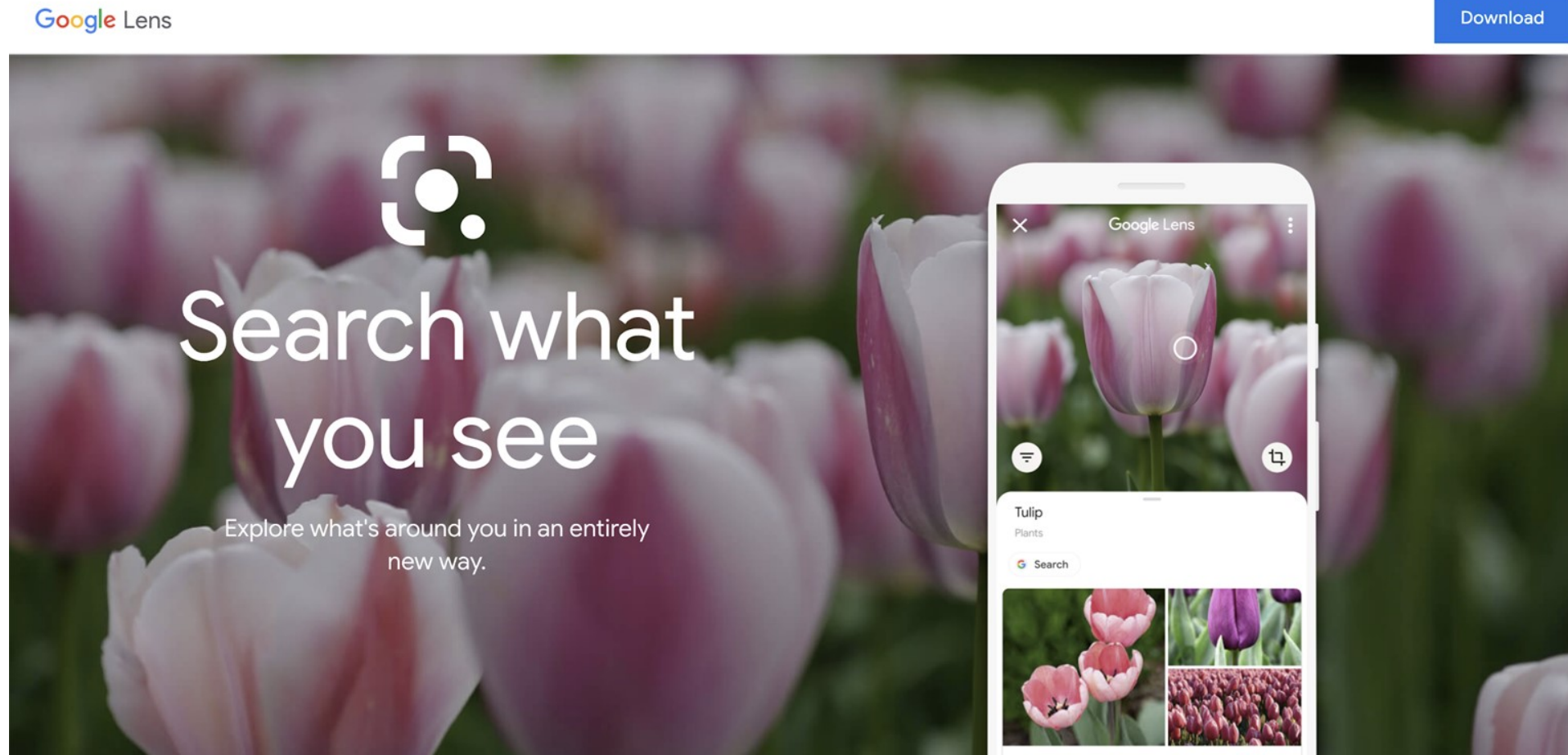


*“How the Afghan Girl was Identified by Her Iris Patterns”* Read the [story](#)



[Seitz, Szeliski]

# Object recognition



[Seitz, Szeliski]

# Special effects: shape capture

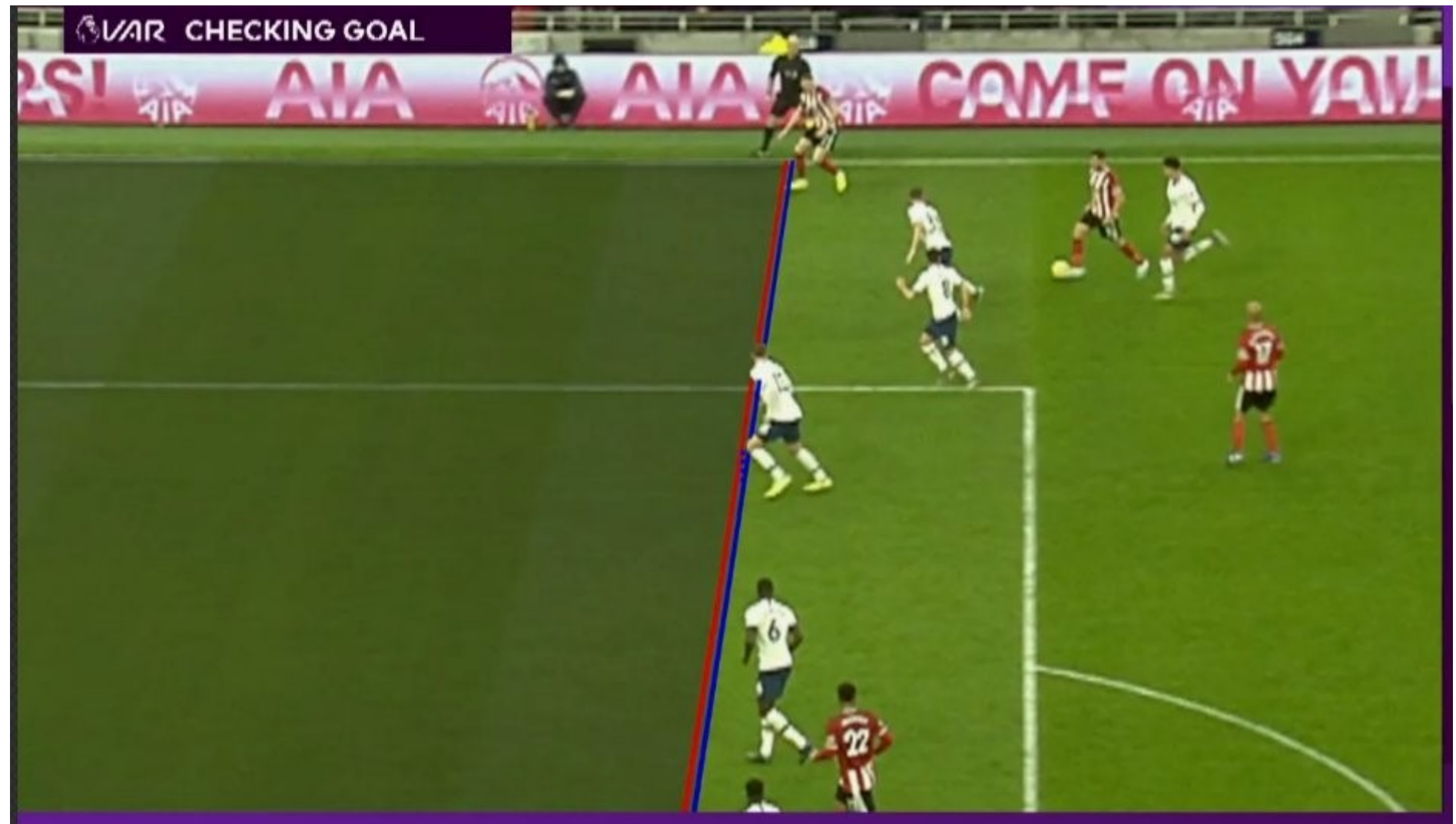


*The Matrix* movies, ESC Entertainment, XYZRGB, NRC

[Seitz, Szeliski]



## Sports - VAR





## Games



Microsoft's XBox Kinect

[Seitz, Szeliski]



## Virtual Reality - Metaverse



Oculus Quest, Beat Saber

[Seitz, Szeliski]

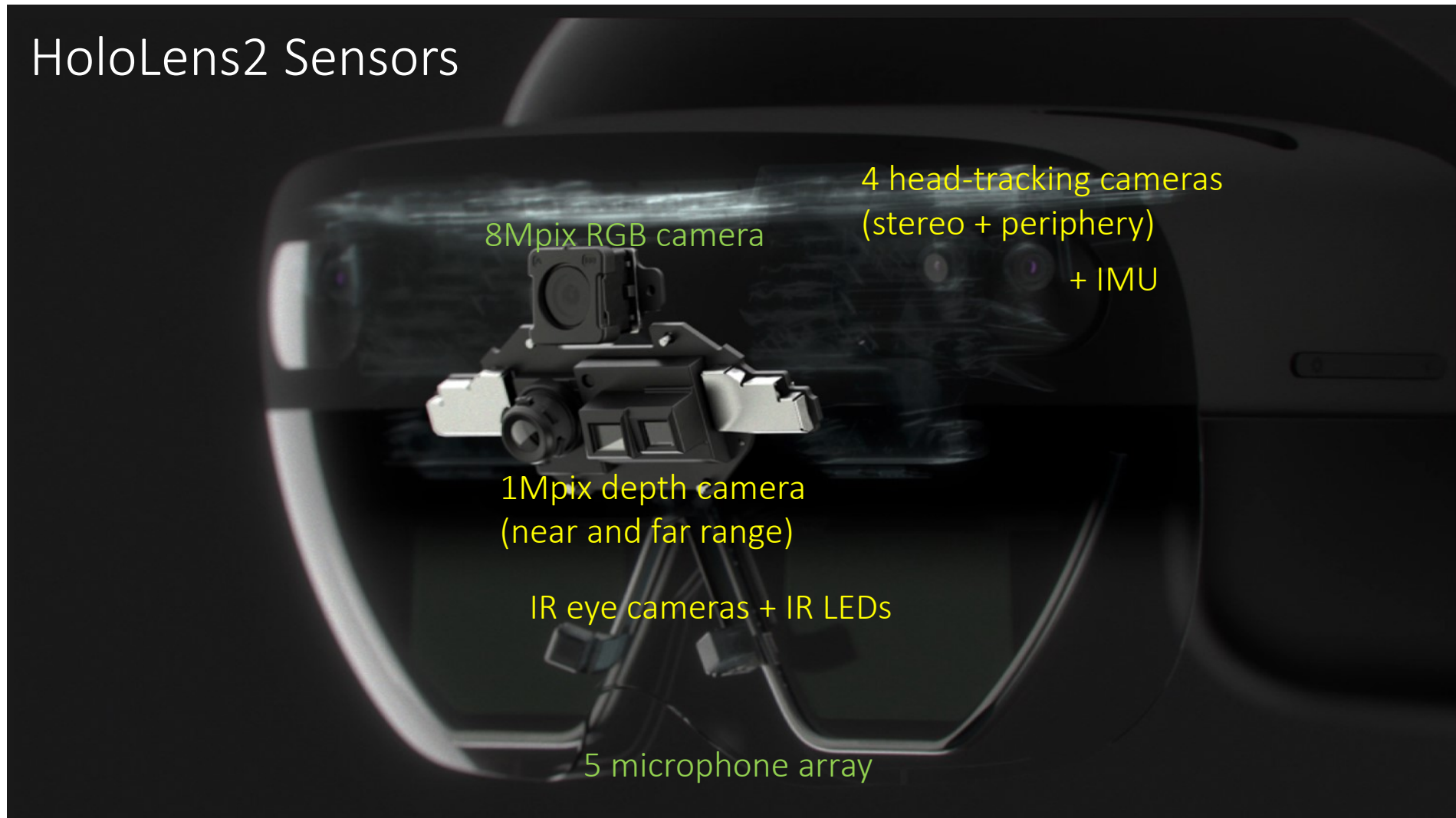
# Augmented Reality - Metaverse



Microsoft Hololens 2

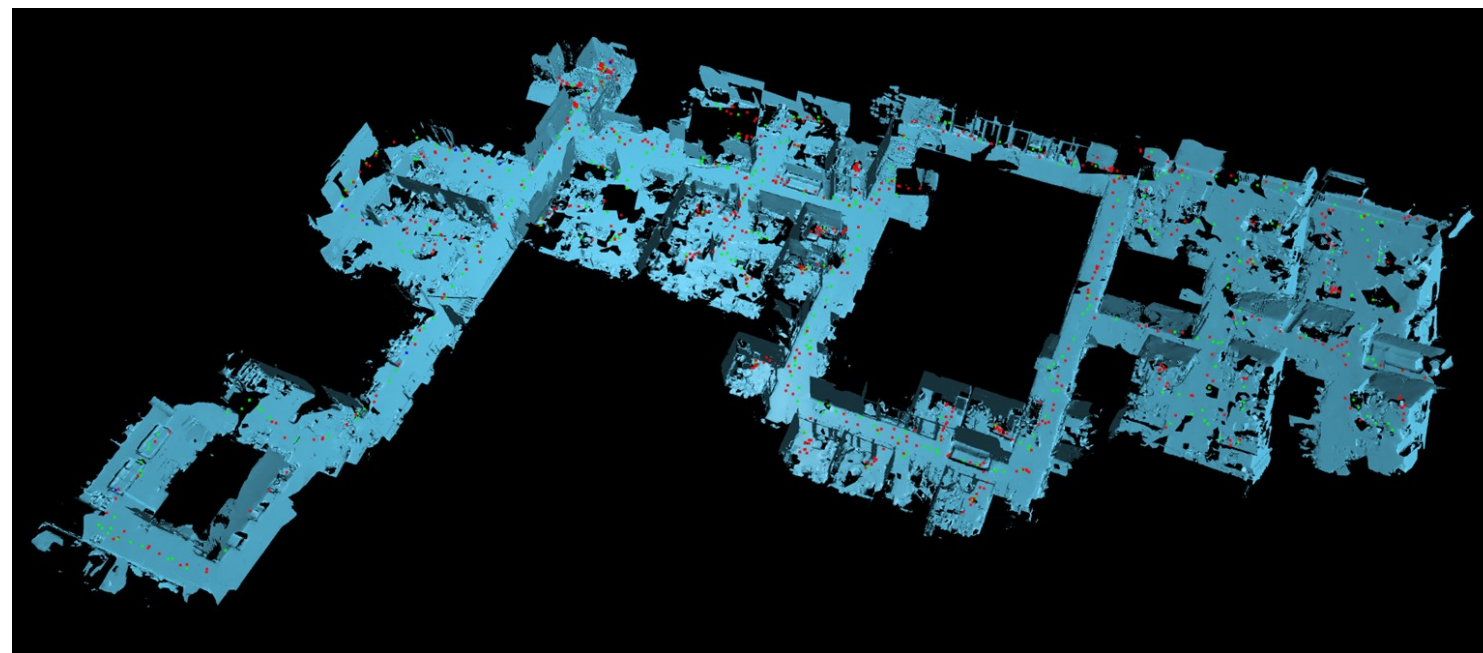
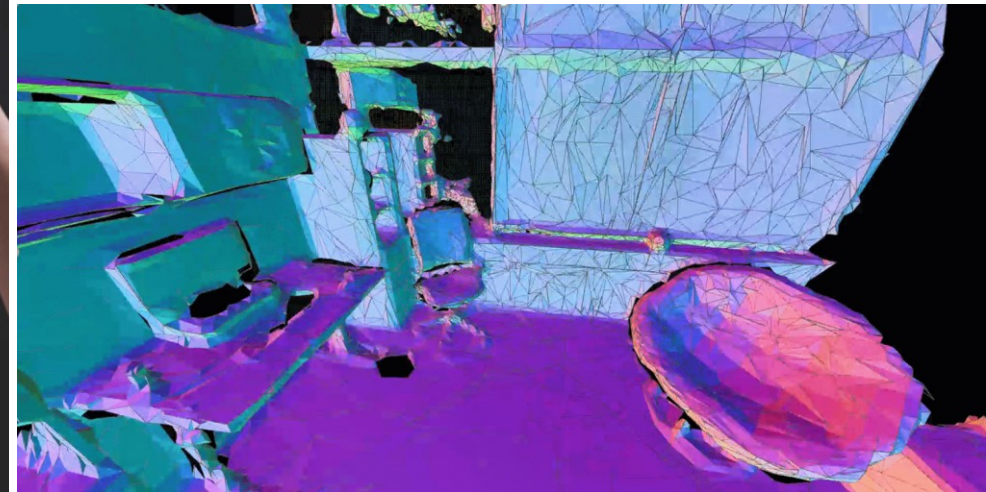
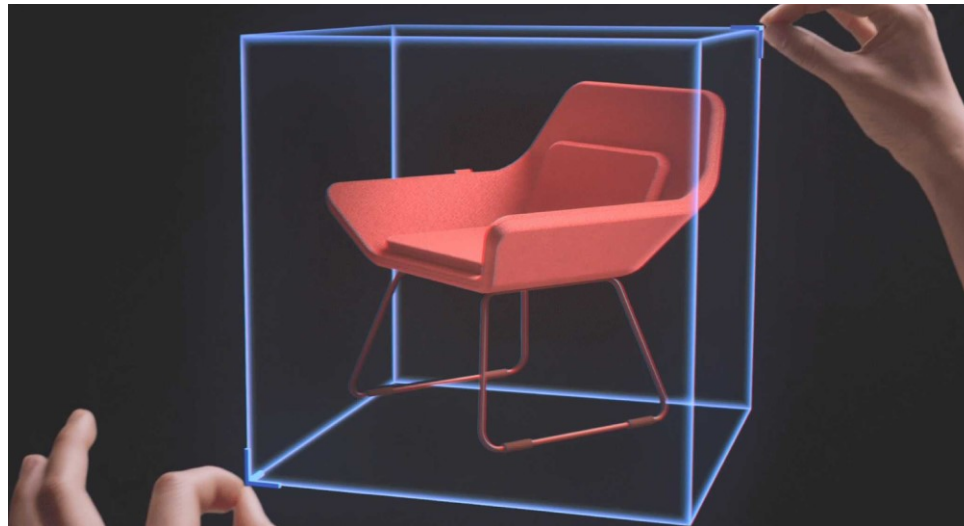
[Seitz, Szeliski]

# Augmented Reality - Metaverse



[Seitz, Szeliski]

# Augmented Reality



[Seitz, Szeliski]

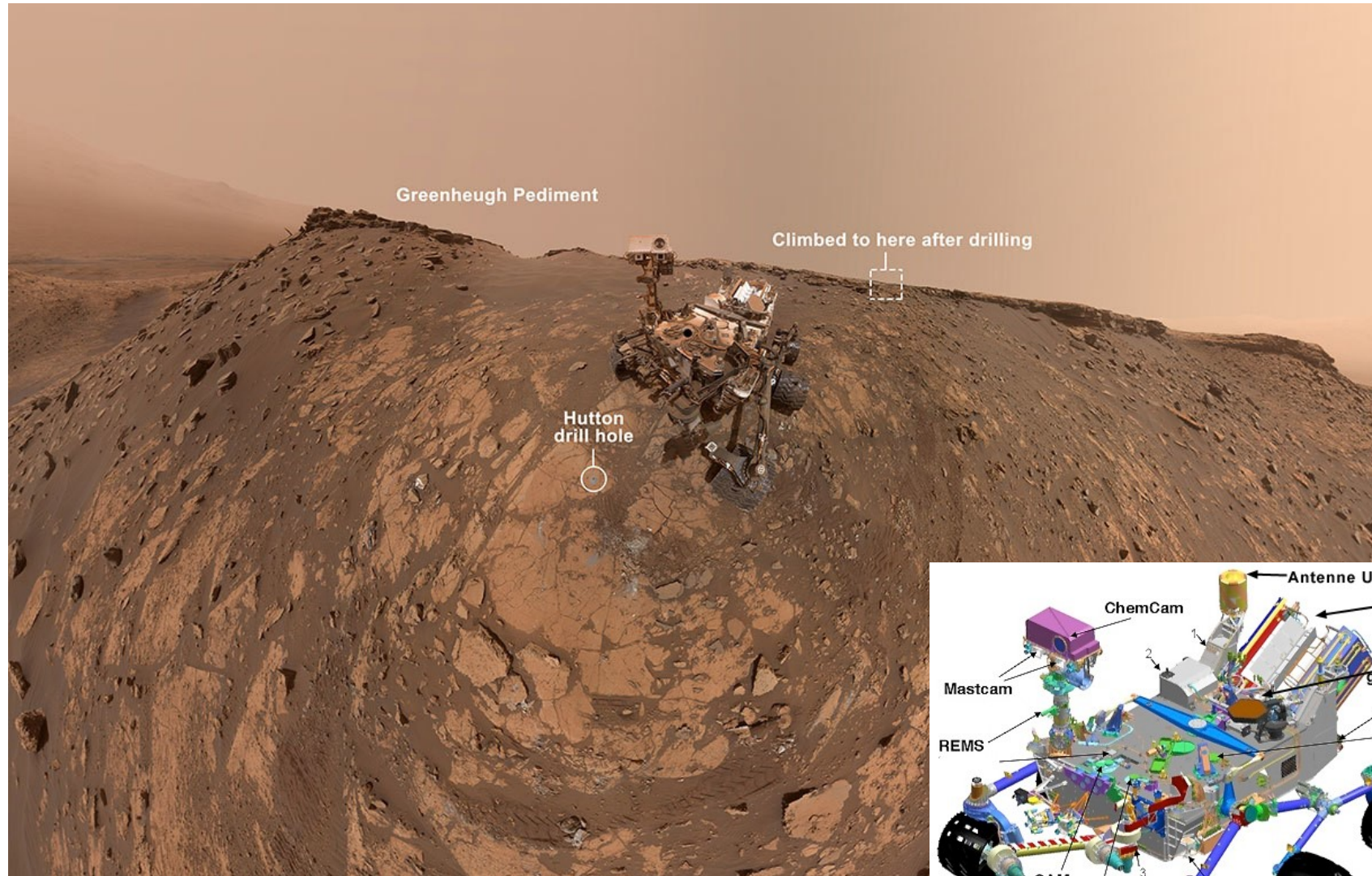
## Phone-based AR



<http://www.youtube.com/watch?v=0Pj-jzy6ESE>

[Seitz, Szeliski]

# Robotics



NASA's Mars Curiosity Rover (self portrait)  
[https://en.wikipedia.org/wiki/Curiosity\\_\(rover\)](https://en.wikipedia.org/wiki/Curiosity_(rover))

[Seitz, Szeliski]



# Smart cars



The screenshot displays the Mobileye website with the following content:

- Navigation tabs: **manufacturer products** (selected) and **consumer products**.
- Header: **Our Vision. Your Safety.**
- Central image: A top-down view of a car with three camera fields of view highlighted: **rear looking camera**, **side looking camera**, and **forward looking camera**.
- News section:
  - > **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 section:
  - > **Mobileye at Equip Auto, Paris, France**
  - > **Mobileye at SEMA, Las Vegas, NV**
  - > [read more](#)
- Product highlights:
  - EyeQ Vision on a Chip**: Includes an image of the EyeQ chip and a [read more](#) link.
  - Vision Applications**: Includes an image of a pedestrian and text: "Road, Vehicle, Pedestrian Protection and more" with a [read more](#) link.
  - AWS Advance Warning System**: Includes an image of a circular display showing a car icon and "0.8" with a [read more](#) link.

## Mobileye

- Vision systems currently in high-end BMW, GM, Volvo models

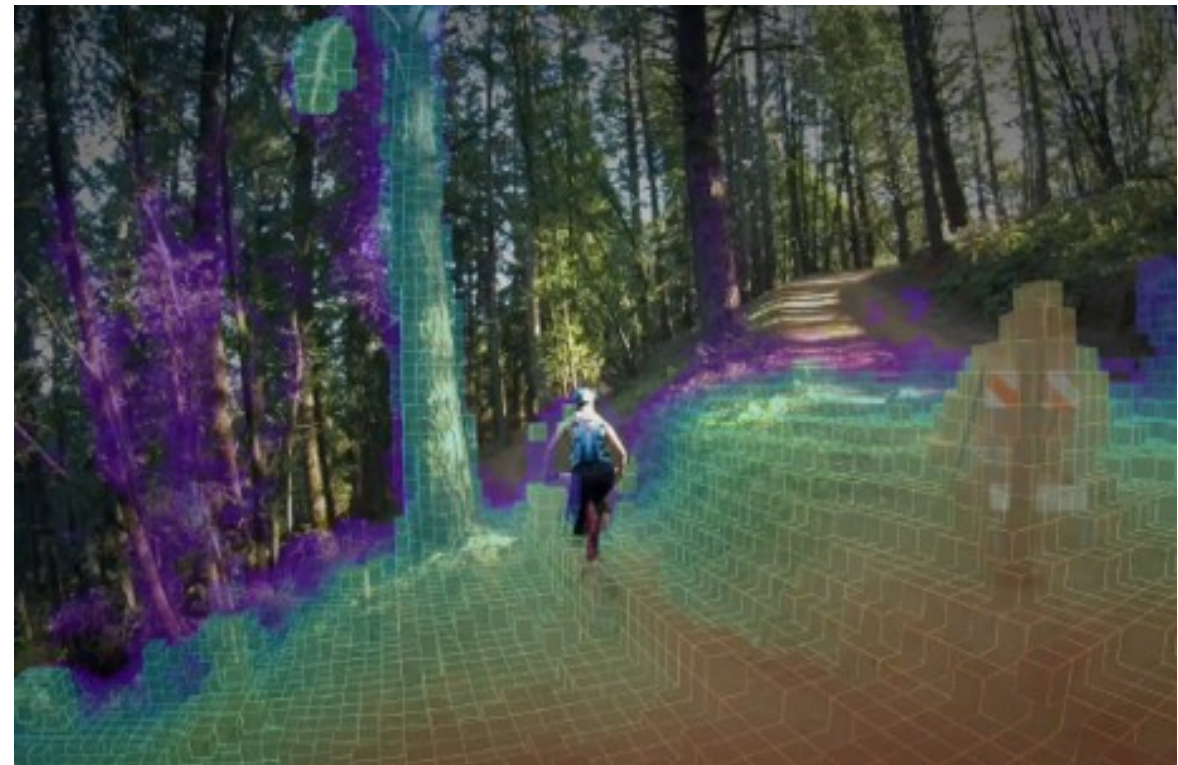
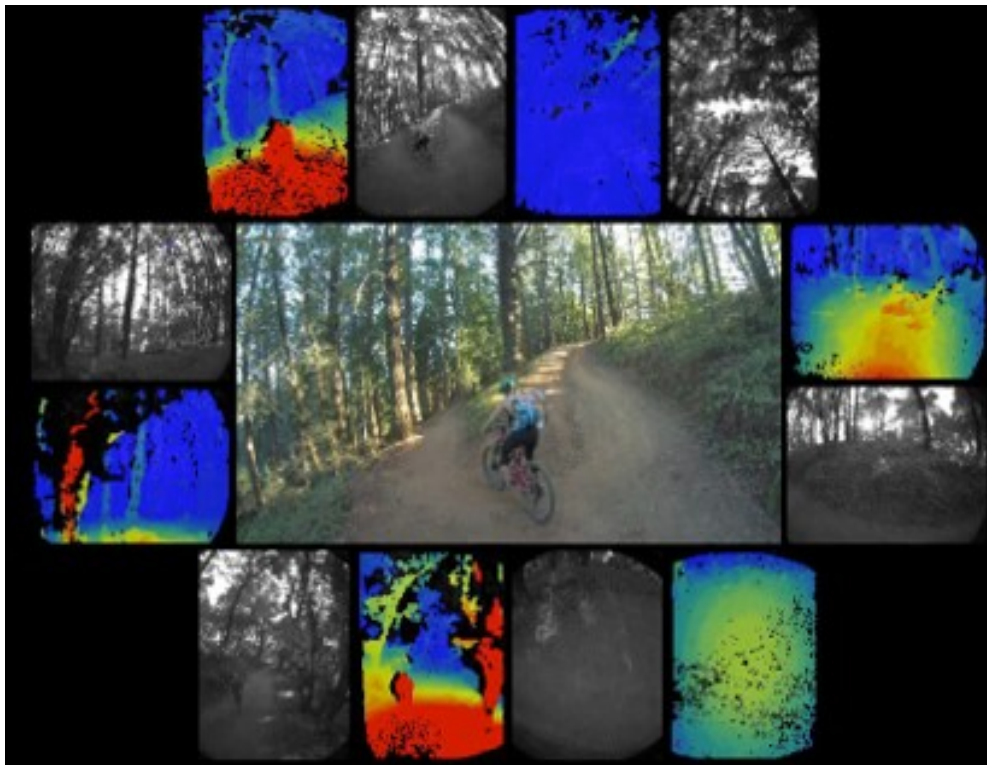
[Seitz, Szeliski]

# Self-driving cars



<https://waymo.com/tech/>

## Drones



<https://www.skydio.com/>

[Seitz, Szeliski]

# Research: Yolo



<http://www.youtube.com/watch?v=MPU2HistivI>

[Seitz, Szeliski]

# Research: StyleGan



[http://www.youtube.com/watch?v=BIZg\\_PPuj\\_0](http://www.youtube.com/watch?v=BIZg_PPuj_0)

[Seitz, Szeliski]

# Today's Agenda

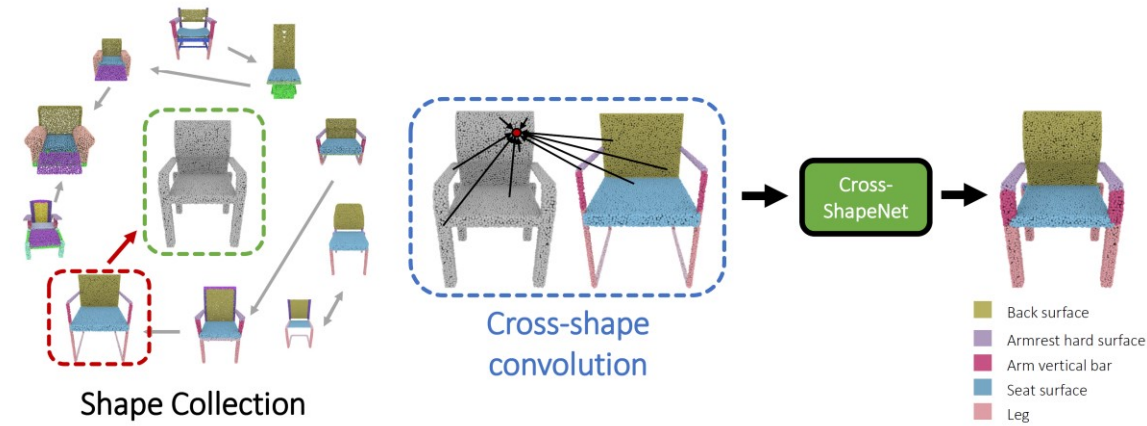
- Who are we?
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# 3D Shape Understanding

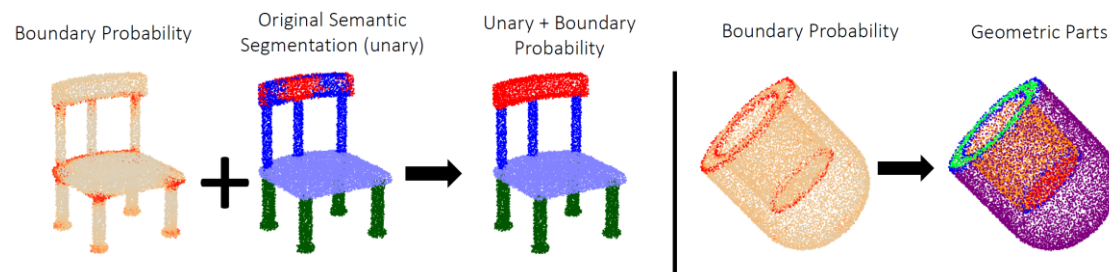
## 3D Building Semantic Understanding



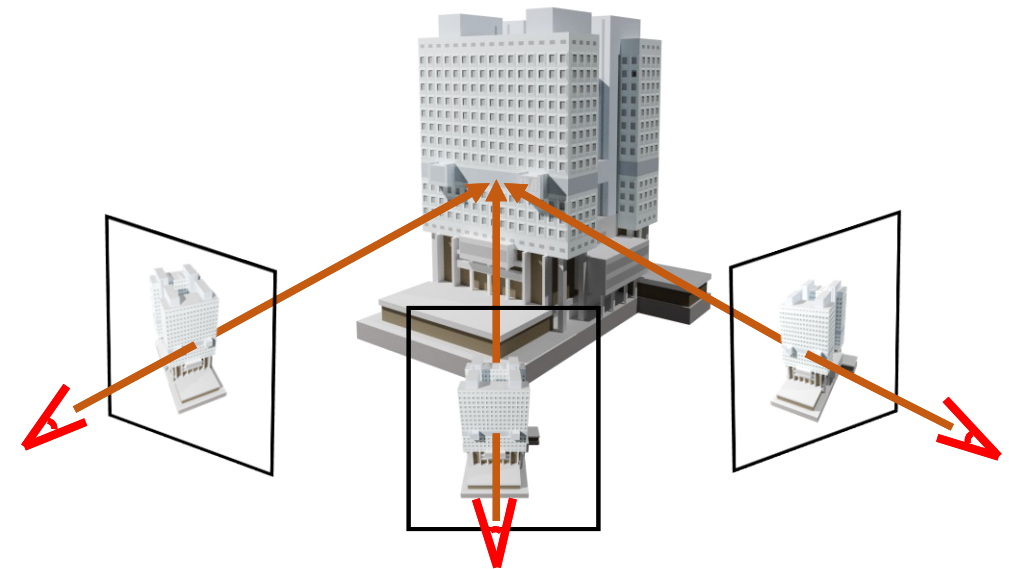
## Cross-shape semantic segmentation



## Geometric/Semantic Decomposition



## Neural 3D Reconstruction



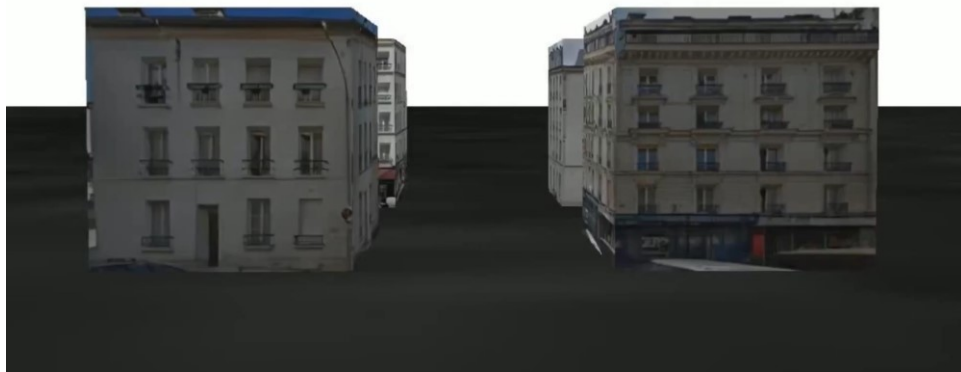
# Texture Generation for 3D Data

## Single-View Guided Façade Synthesis



Reference Façade Images

3D Scene Renderings



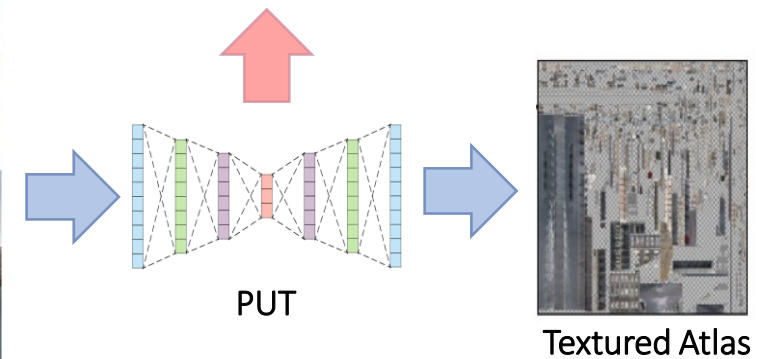
Interactive Texturing

## Projective Urban Texturing



Street Level Panoramic Images

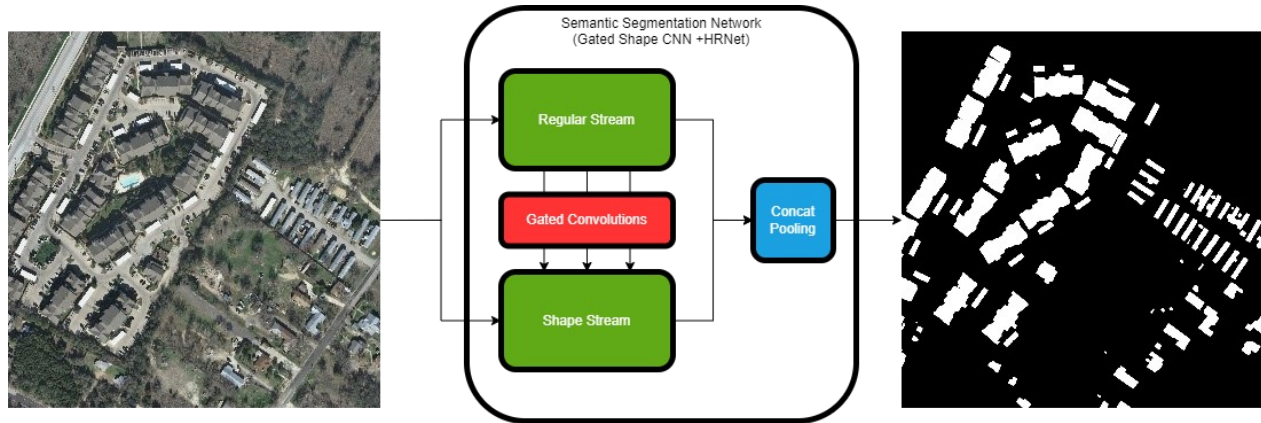
Textured 3D Geometry



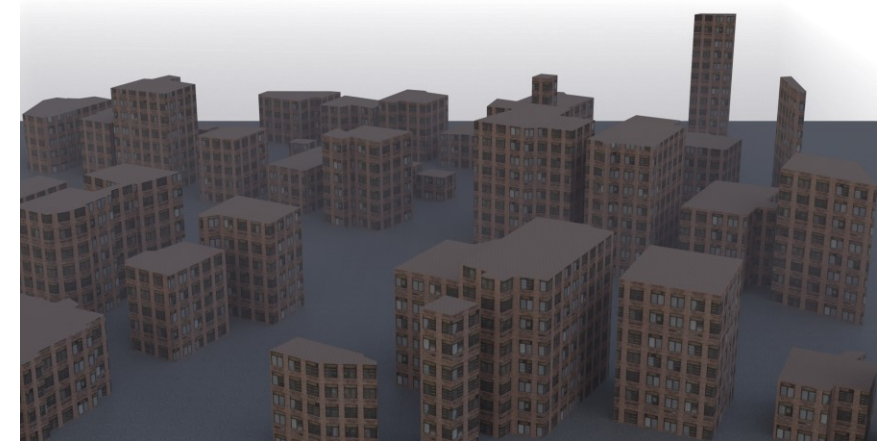


# Urban Semantic Understanding from Remote Sensing Data Sources

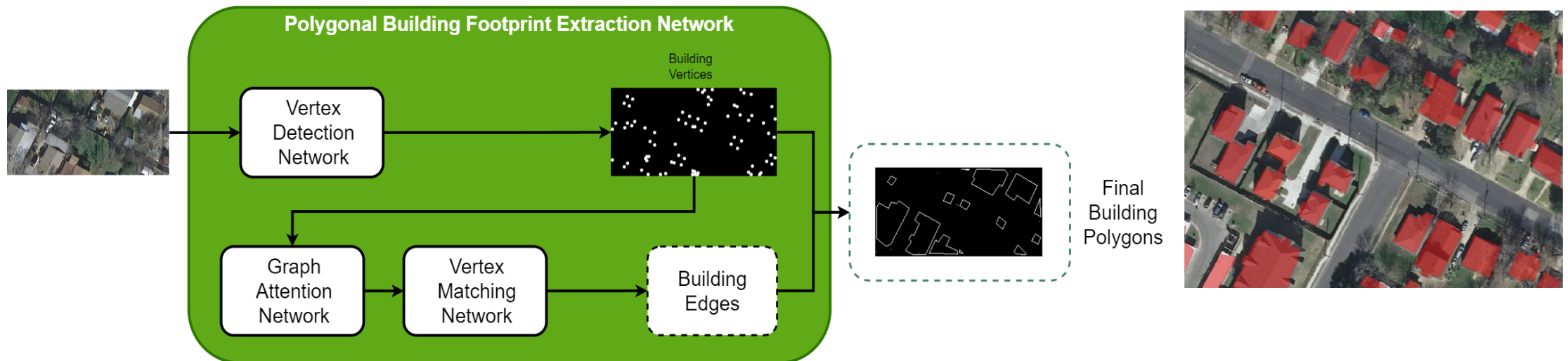
## Semantic Segmentation of Buildings



## Urban 3D Reconstruction



## Building Footprint Extraction



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Intelligence 4 Careers in Europe



**CYENS**  
CENTRE OF EXCELLENCE



# Thank you.

