Computer Vision 1

Introduction

Dr. Martin Oswald, Dr. Dimitris Tzionas, Dr. Arun Mukundan,
(m.r.oswald, d.tzionas, a.mukundan)@uva.nl → Please always CC Arun and your TA

PhD TAs: Alvaro Budria, Dimitrije Antić, Georgios Paschalidis, Yue Li,

MSc TAs: Adrian Sauter, Alisia Baielli, Andro Erdelez, Devin Pereira, Koen Veldhorst, Konstantinos Zafeirakis, Marom Sverdlov, Matei Nastase, Meher Changlani, Michał Mazuryk, Oliver van Erven, Teo Stereciu, Udit Thakur, Viktória Pravdová, Wojciech Trejter, Wojciech Kosiuk

University of Amsterdam

computer vision lab

Today's Agenda

Part 1:

- Introduction
- Motivation
- Challenges
- Brief History
- Applications

--- Break ---

Part 2:

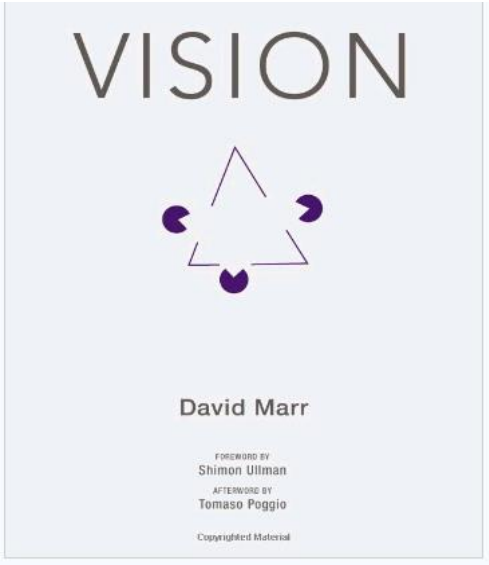
- Course Structure
- Q&A

What is Computer Vision?

What is Vision?

Is “*to know what is where, by looking*”

David Marr (1945–1980)

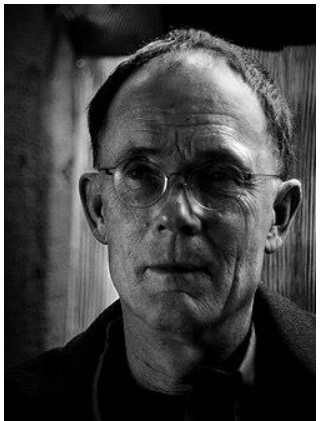


What is Vision?

"We see in order to move;

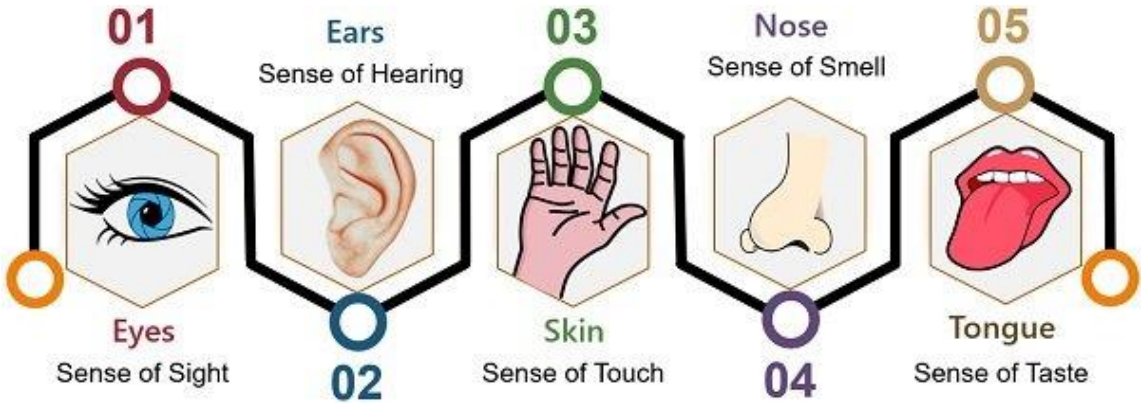
we move in order to see"

William Gibson



Why is Vision important?

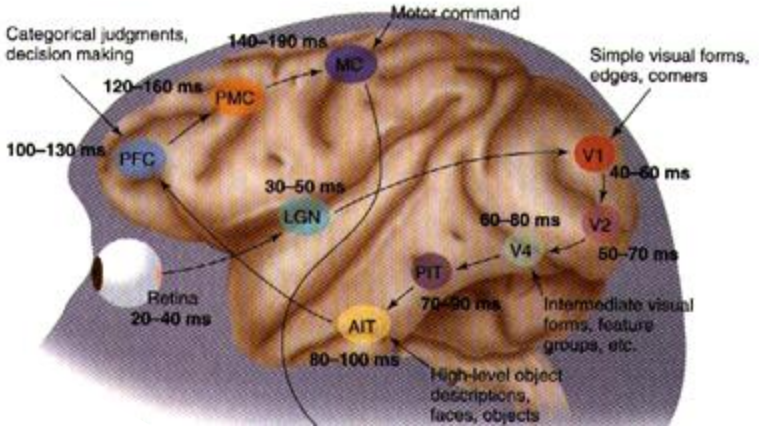
Vision is the ‘primary’ human sense for perception



Human visual system

Vision is the ‘most powerful’ of our senses

Around **1/3 of our brain** is devoted to processing signals from our eyes



[Thorpe et. al.]

The Visual Cortex alone has around 4-6 billion neurons

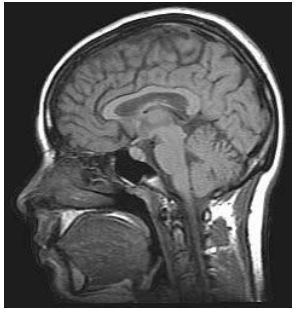
What is Computer Vision?

Computer Vision concerns building **artificial** vision systems that obtain useful information from **image data**.

The image data can take many forms, e.g.:

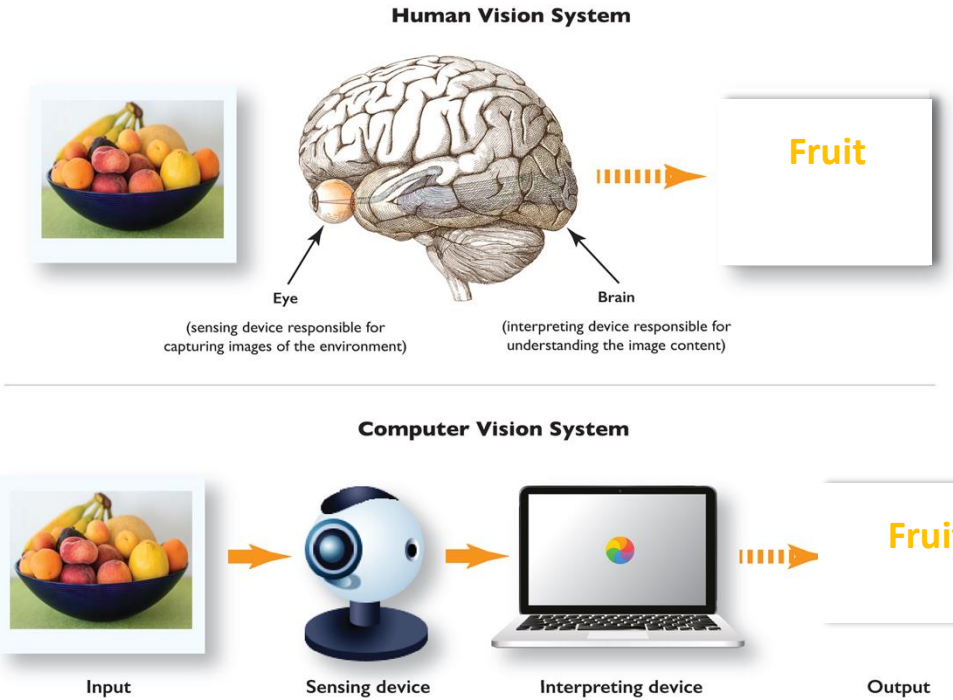
color images, depth images, video sequences,

multiple views from multiple cameras, multi-dimensional medical scans



Computer Vision

- Enable computers to ‘see’ & ‘understand’ images
- For humans & animals this seems ‘effortless’
- But for computers this has proven to be challenging



Mohamed Elgendy, Deep Learning for Vision Systems, 2020

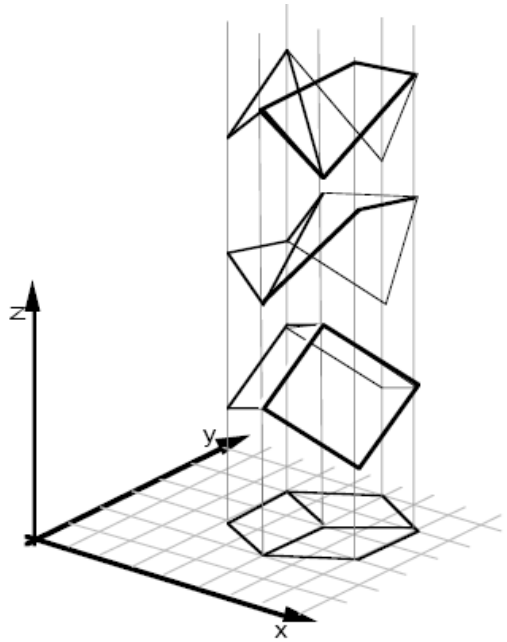
Challenges

Challenges – Projection Ambiguities

Ill-posed problem

Many 3D shapes project on the same 2D shape

We cannot recover 3D from 2D shapes (we miss 1D)



[Sinha and Adelson, 1993]

Challenges – Scale Ambiguities

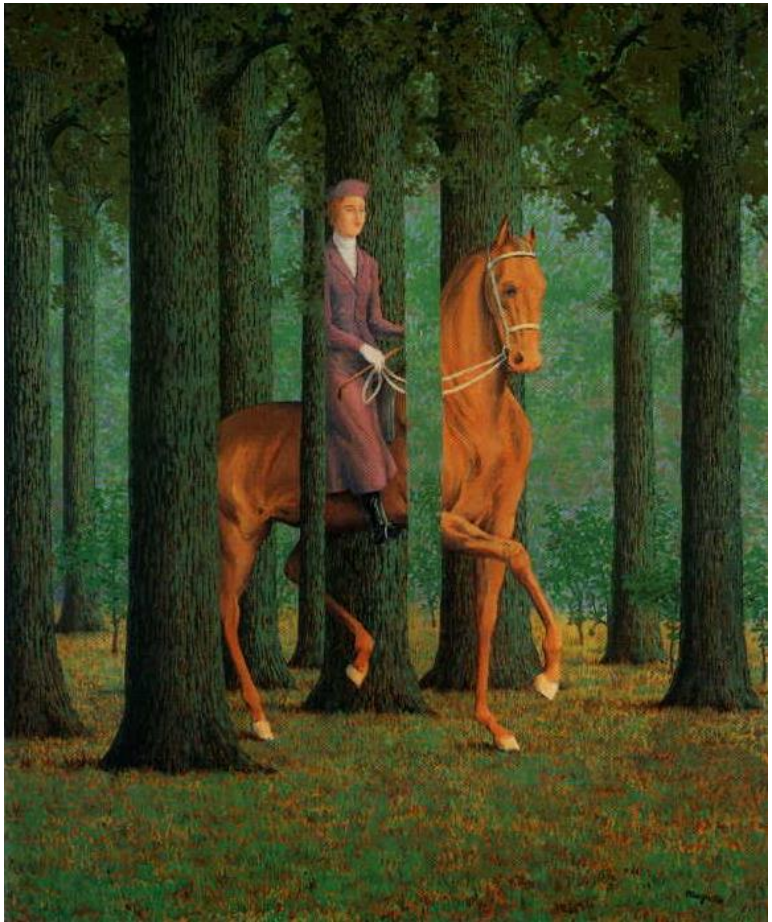
Example by Fei Fei, Fergus & Torralba

https://richardwiseman.com

Challenges – Single Viewpoint

https://x.com/CSProfKGD/status/1724847975191523701

Challenges – Occlusion



Magritte
1957

slide by Fei Fei,
Fergus & Torralba

Challenges – Viewpoint Variations

Slide by Fei Fei, Fergus & Torralba

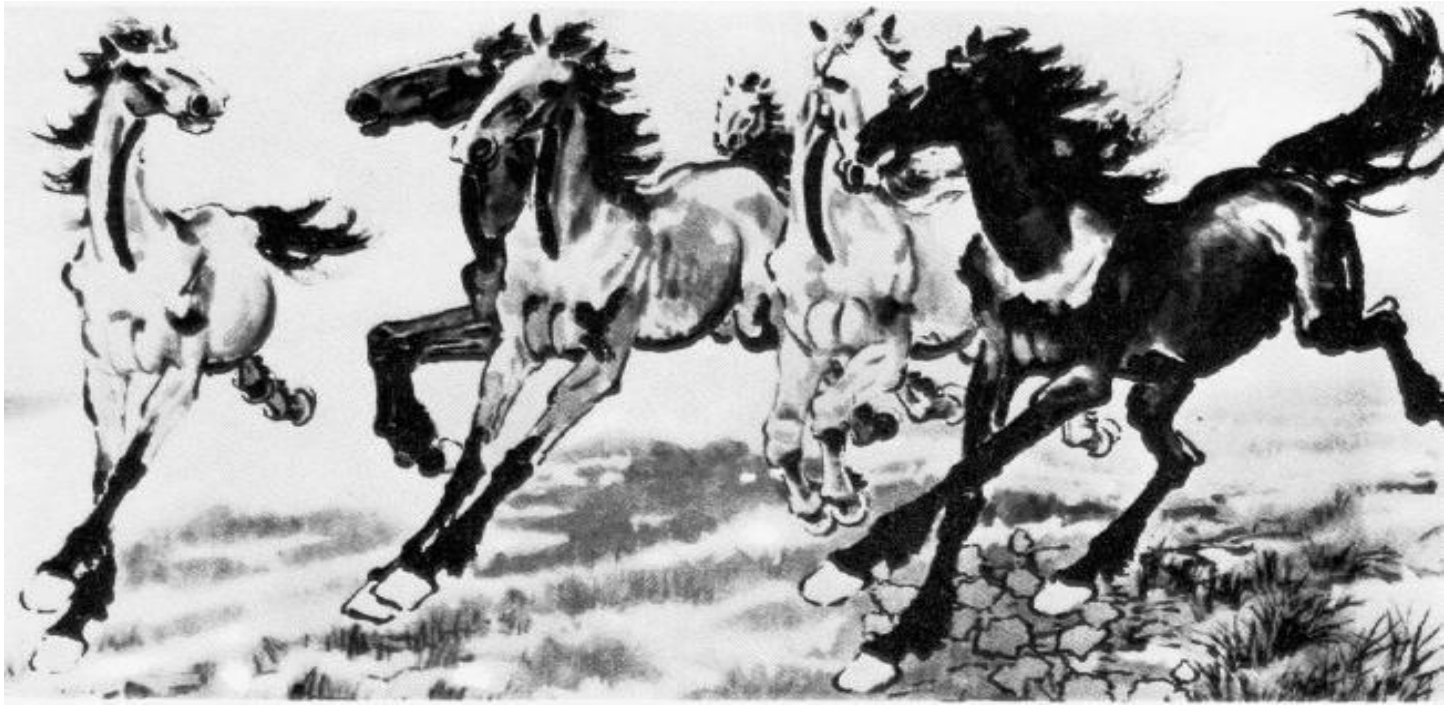
Michelangelo 1475-1564

Challenges – Illumination Conditions

Slide credit:
S. Ullman

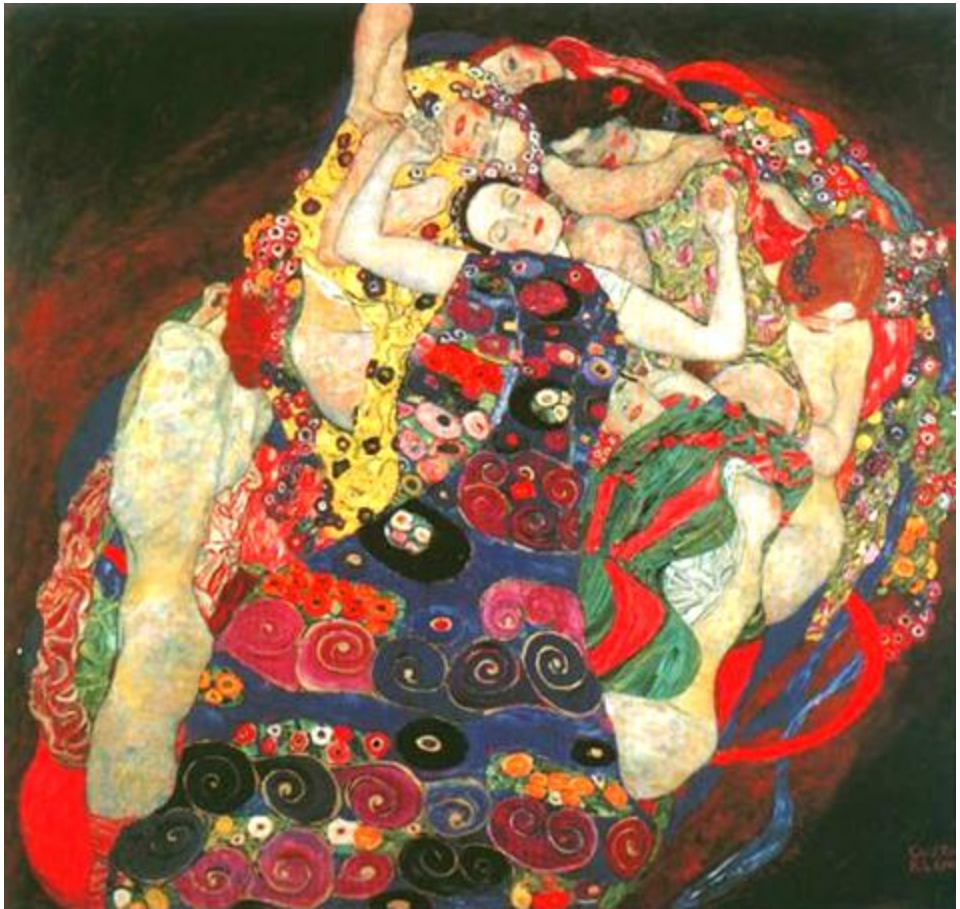
Challenges – Appearance Similarity & 1 View

Challenges – Deformable Shapes



Xu, Beihong 1943

Challenges – Background Clutter

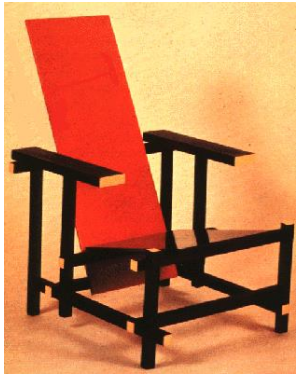


Klimt
1913

slide by Fei Fei,
Fergus & Torralba

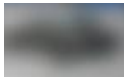
Challenges – Intra-class Shape Variance

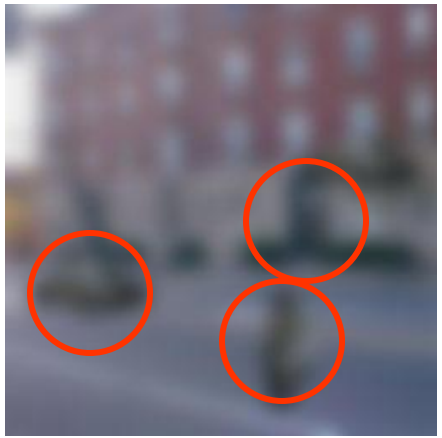


slide by Fei Fei, Fergus & Torralba

Challenges – Local Similarities





slide by Fei Fei,
Fergus & Torralba

Challenges – Depth Estimation

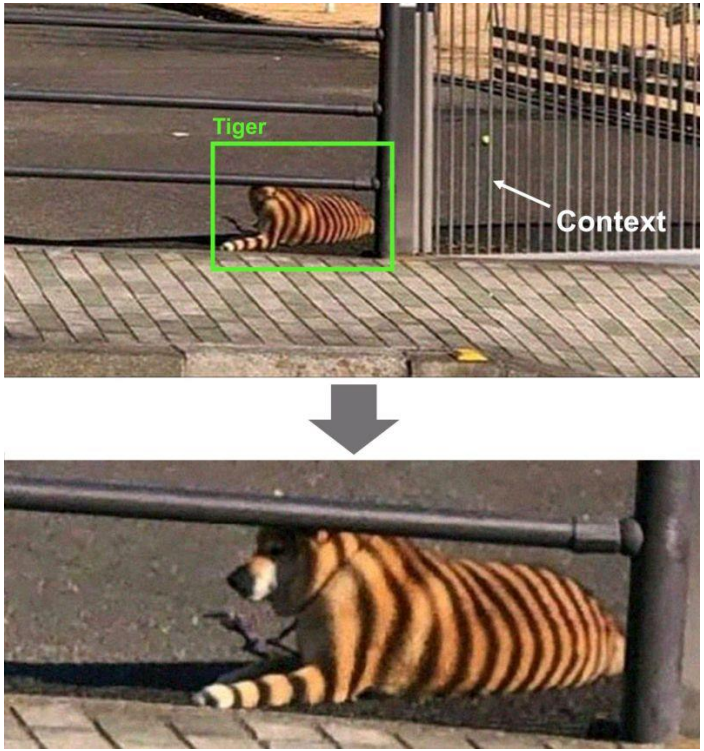
Slide Credit:
Alyosha Efros

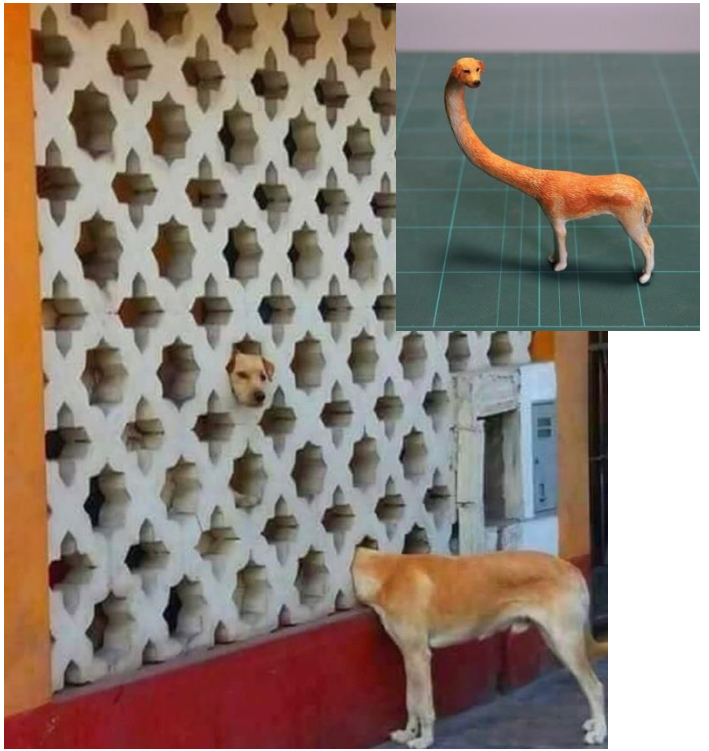
Challenges – Depth Estimation

[Marc Rober, YouTube]

https://x.com/gunsnrosesgirl3/status/1762749341209399750

Challenges in Scene Understanding

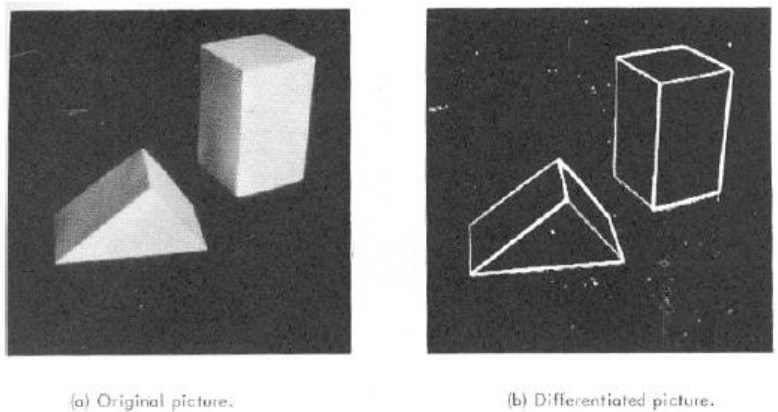




How to learn 3D **spatial context**
& **disentangle** various scene **factors**?

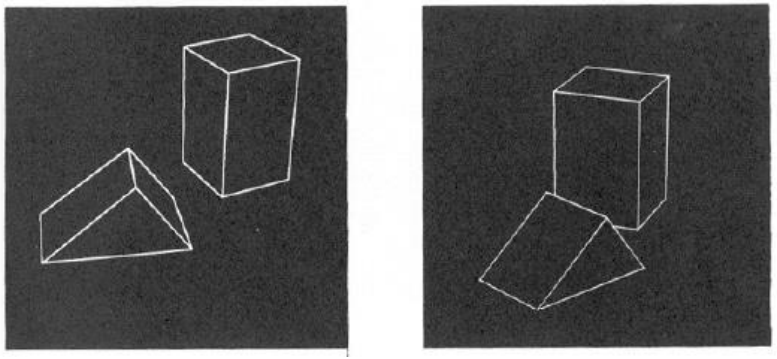
Brief History

Origins



(a) Original picture.

(b) Differentiated picture.



L.G. Roberts,

'*Machine Perception of Three Dimensional Solids*'

PhD thesis

MIT, 1963

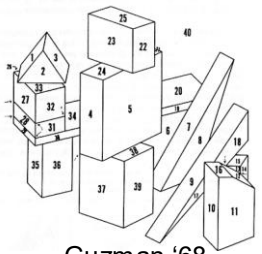
An (overly) optimistic start

- In 1966, Prof. Marvin Minsky at MIT asked his undergraduate student Gerald Jay Sussman to: spend 3 months in the summer to link a camera to a computer & get the computer to ‘describe what it saw’

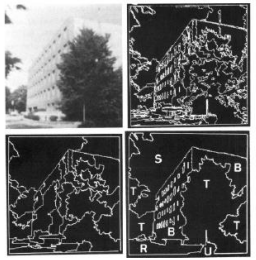
- In ~2026 (~60y later), we know that this problem is *significantly* more challenging

Brief History

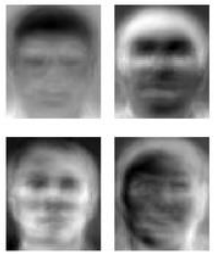
- **1963:** Robert's thesis
- **1966:** Minsky assigns computer vision as an undergrad summer project
- **1960s:** Interpretation of synthetic worlds
- **1970s:** Some progress on interpreting selected images
- **1980s:** ANNs come and go; shift toward geometry and increased mathematical rigor, Marrs book published (after he died).
- **1990s:** Face recognition; Statistical analysis
- **2000s:** Broader recognition; Large annotated datasets available; video processing starts; Vision & graphics; HCI; Internet vision, etc
- **2012:** Kinect, big-data, Google Car, …
- **2013~:** Deep learning, Image-Net, …
- **2020~:** Transformer, Vision+Language, Diffusion model …



Guzman '68

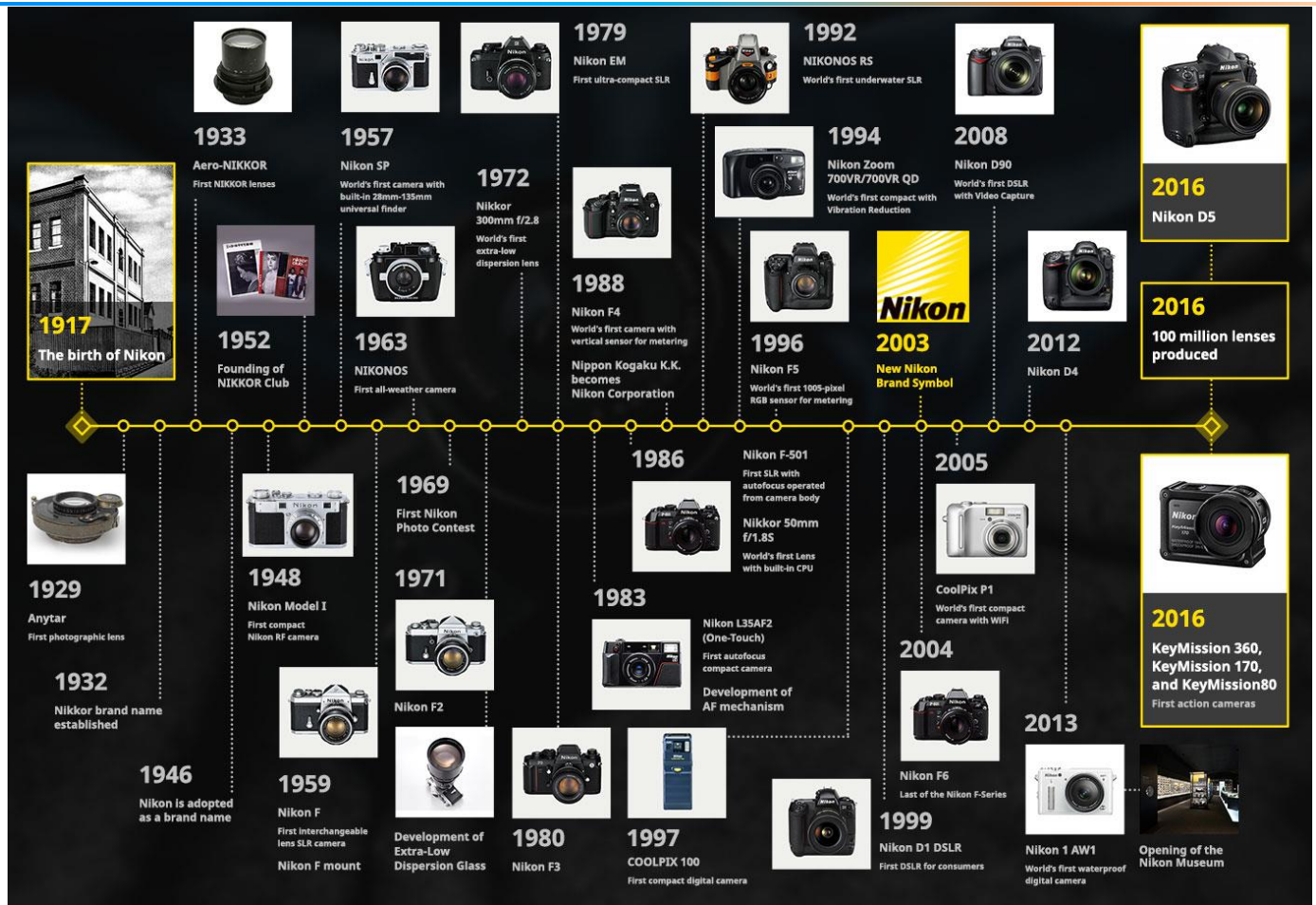


Ohta Kanade '78



Turk and Pentland '91

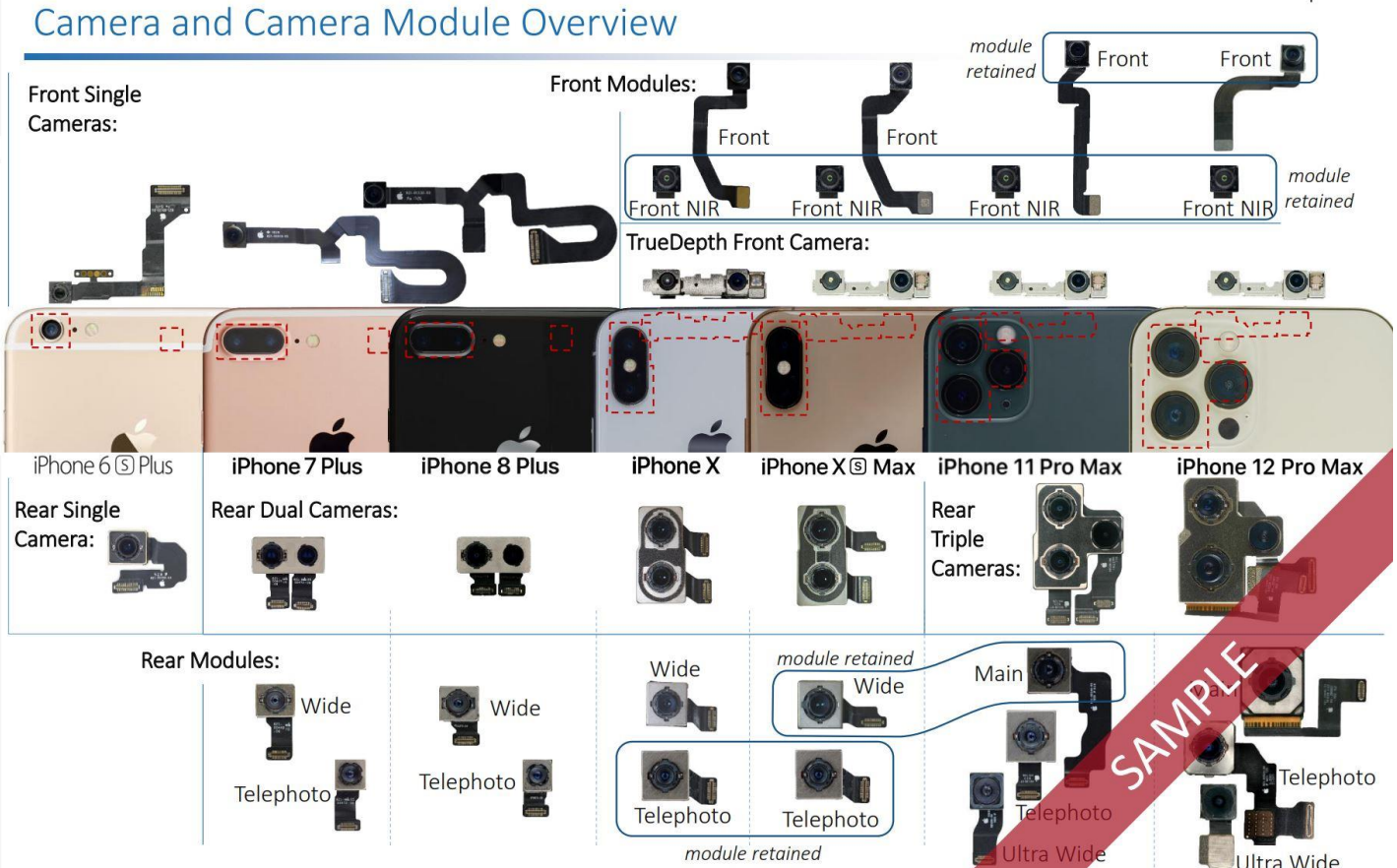
Camera Evolution (Nikon)



https://nikonrumors.com/2017/09/21/nikons-100-years-of-imaging-excellence-brief-history-of-nikon.aspx

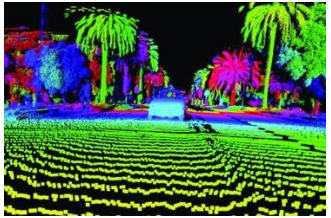
Camera Evolution

Cameras and camera modules are to scale for comparison.

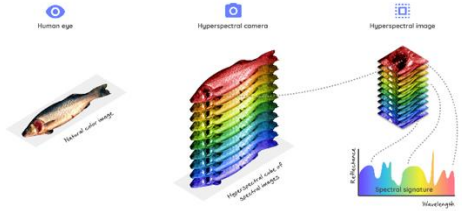


http://image-sensors-world.blogspot.com/2021/07/apple-iphone-cameras-evolution.html

Many other vision sensors

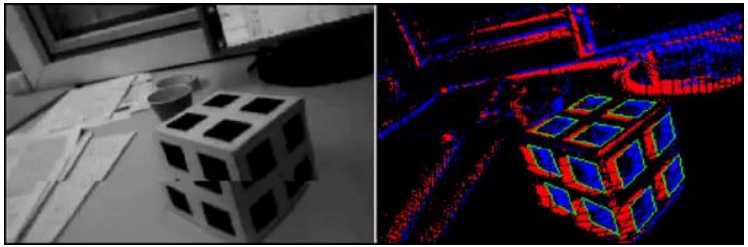


Lidar



Hyperspectral

Infra Red



Event camera

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

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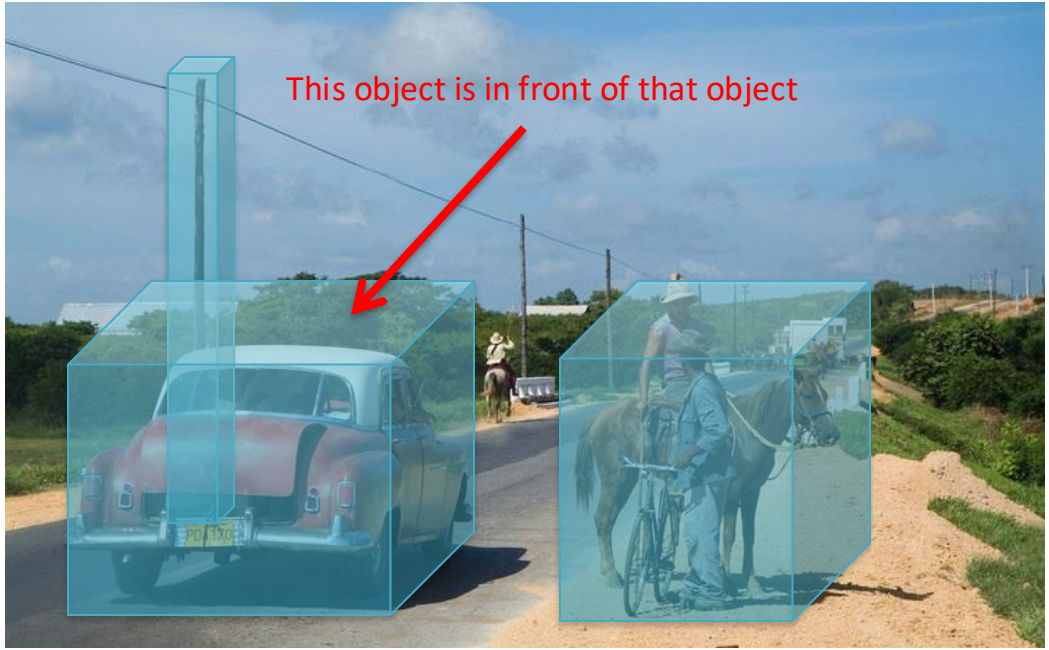

Computer Vision

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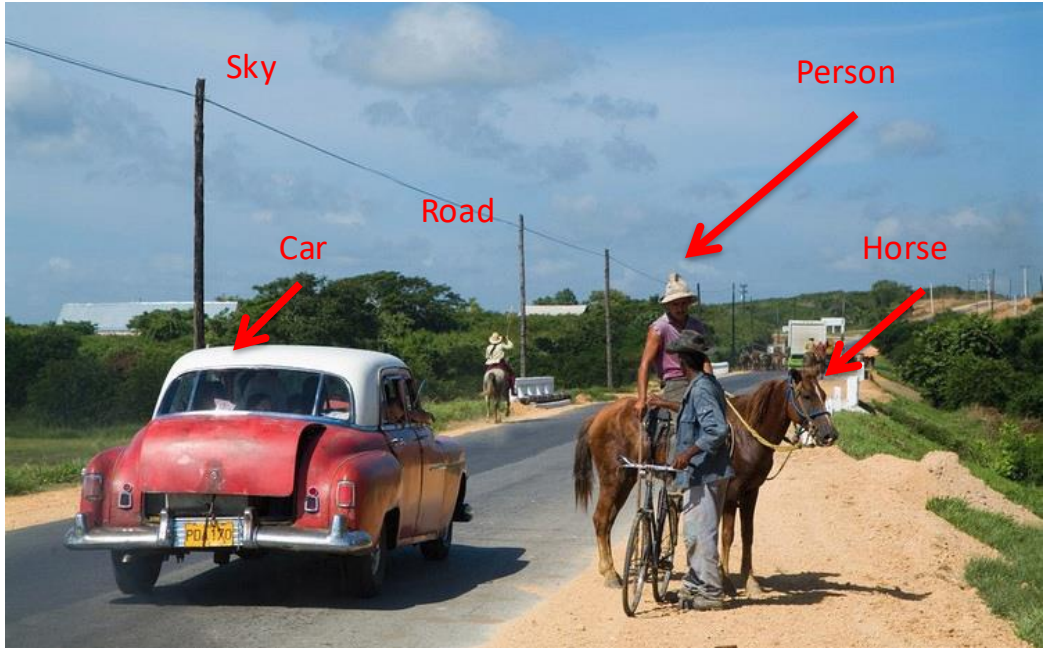


Applications

Panorama Stitching

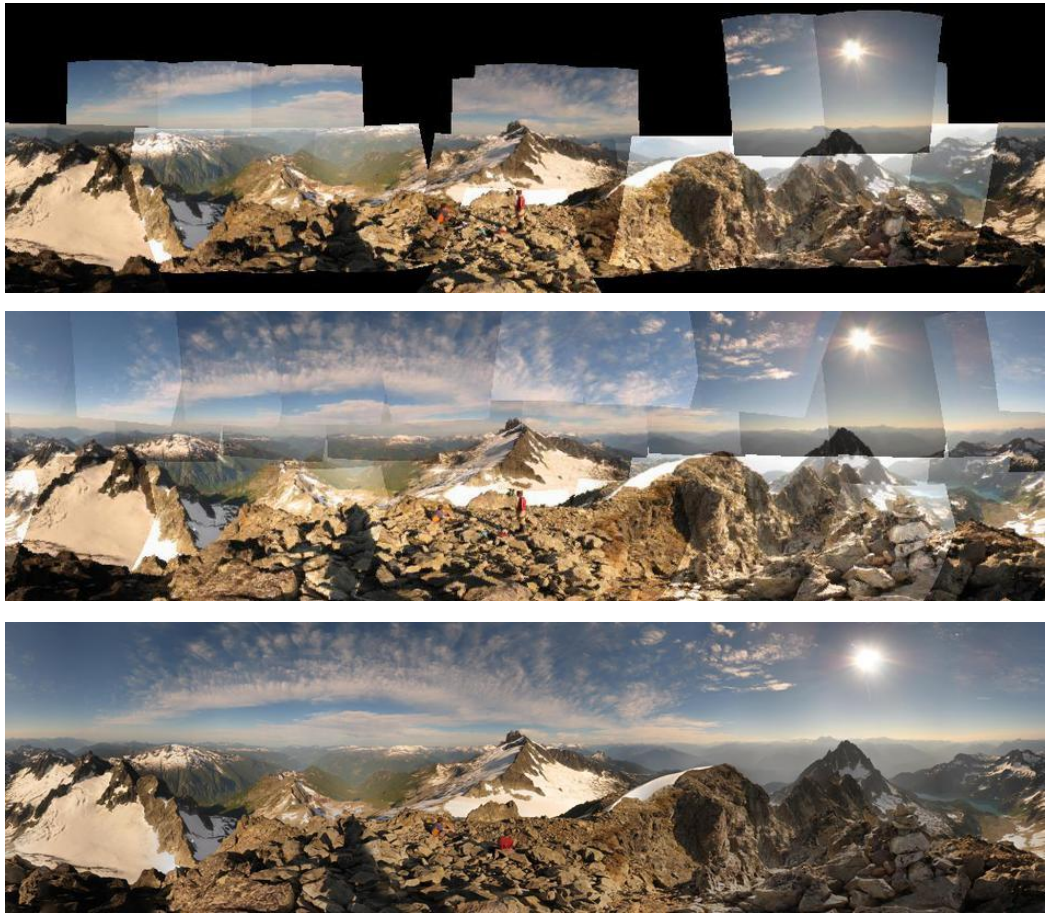
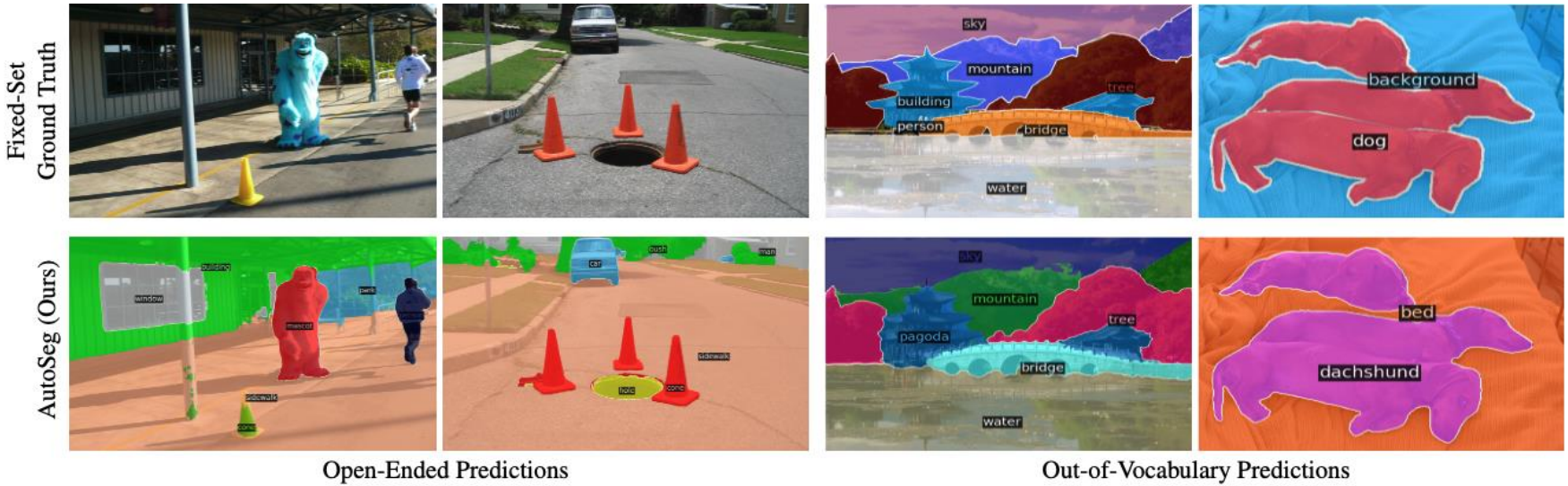


Image Segmentation

SAM
https://segment-anything.com
[Kirillov et al., ICCV'23]

Image Segmentation



[Auto-Vocabulary Semantic Segmentation]

Osman Ulger · Maksymilian Kulicki · Yuki Asano · Martin R. Oswald

ICCV 2025

Image Segmentation – Language + Vision

[Kerr et al., LERF: Language Embedded Radiance Fields, ICCV'23]

Image Inpainting – ‘Magic Eraser’

https://advimman.github.io/lama-project
[Suvorov et al., WACV’22]

Video Inpainting – ‘Magic Eraser’

https://github.com/gaomingqi/Track-Anything
[Yang et al., arXiv:2304.11968]

Point Tracking

https://omnimotion.github.io
[Wang et al., ICCV'23]

Depth Estimation from Color Image

https://marigoldmonodepth.github.io

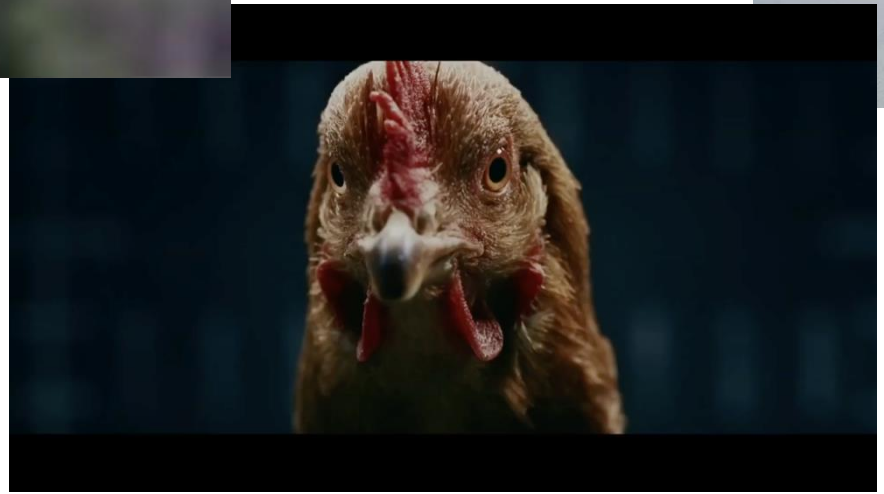
[Ke et al., CVPR'24]

Autonomous Driving

[Tesla AI, 2022]

Optical Stabilization

[Ed Ricker, Wind Hover Test, https://www.youtube.com/watch?v=nriY21MInxI]



[Mercedes-Benz commercial, https://www.youtube.com/watch?v=nLwML2PagbY]

3D Humans from a Single Image

Expressive Body Capture: 3D Hands, Face, and Body from a Single Image

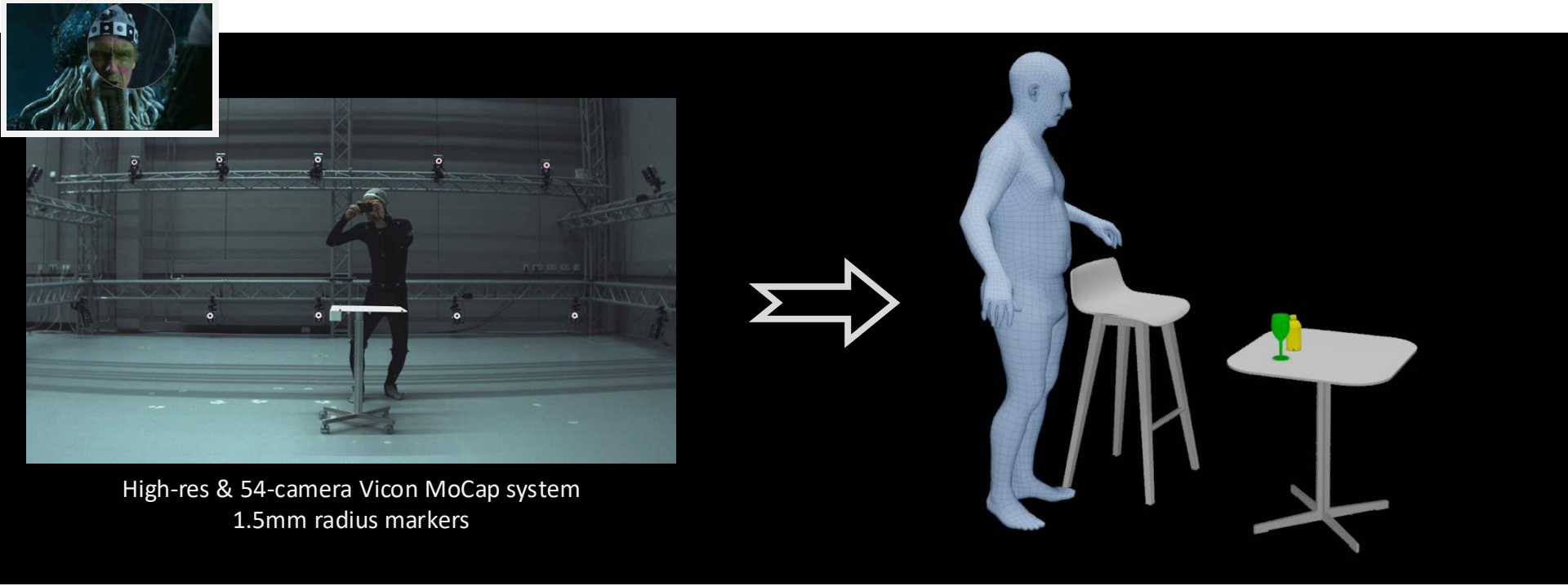
G. Pavlakos* · V. Choutas* · N. Ghorbani · T. Bolkart · A. A. A. Osman · D. Tzionas · M. J. Black

CVPR 2019

Motion/Shape Capture – Avatars & Relighting

Source: S. Seitz

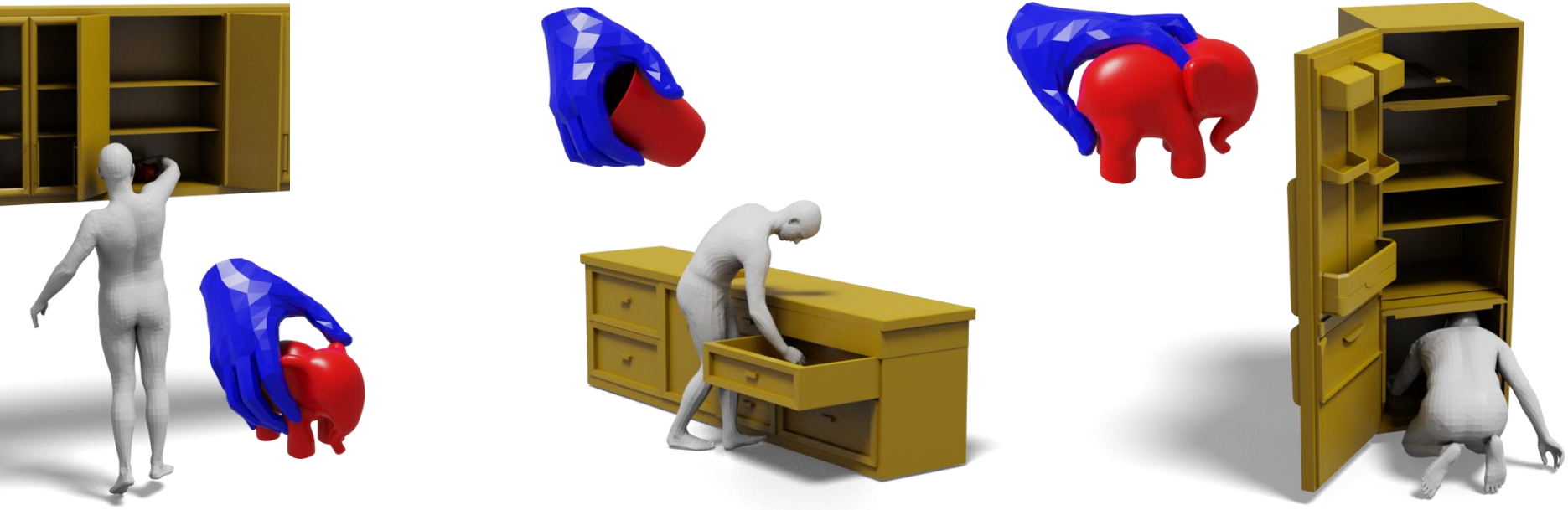
Motion Capture – Movies, Datasets, AR/VR



High-res & 54-camera Vicon MoCap system
1.5mm radius markers

GRAB: A Dataset of Whole-Body Human Grasping of Objects
Omid Taheri · N. Ghorbani, M. J. Black, D. Tzionas
ECCV 2020

Populate Scenes – Synthesized Humans



3D Whole-body Grasp Synthesis with Directional Controllability

Georgios Paschalidis · Romana Wilschut · Dimitrije Antić · O. Taheri · D. Tzionas

3DV 2025

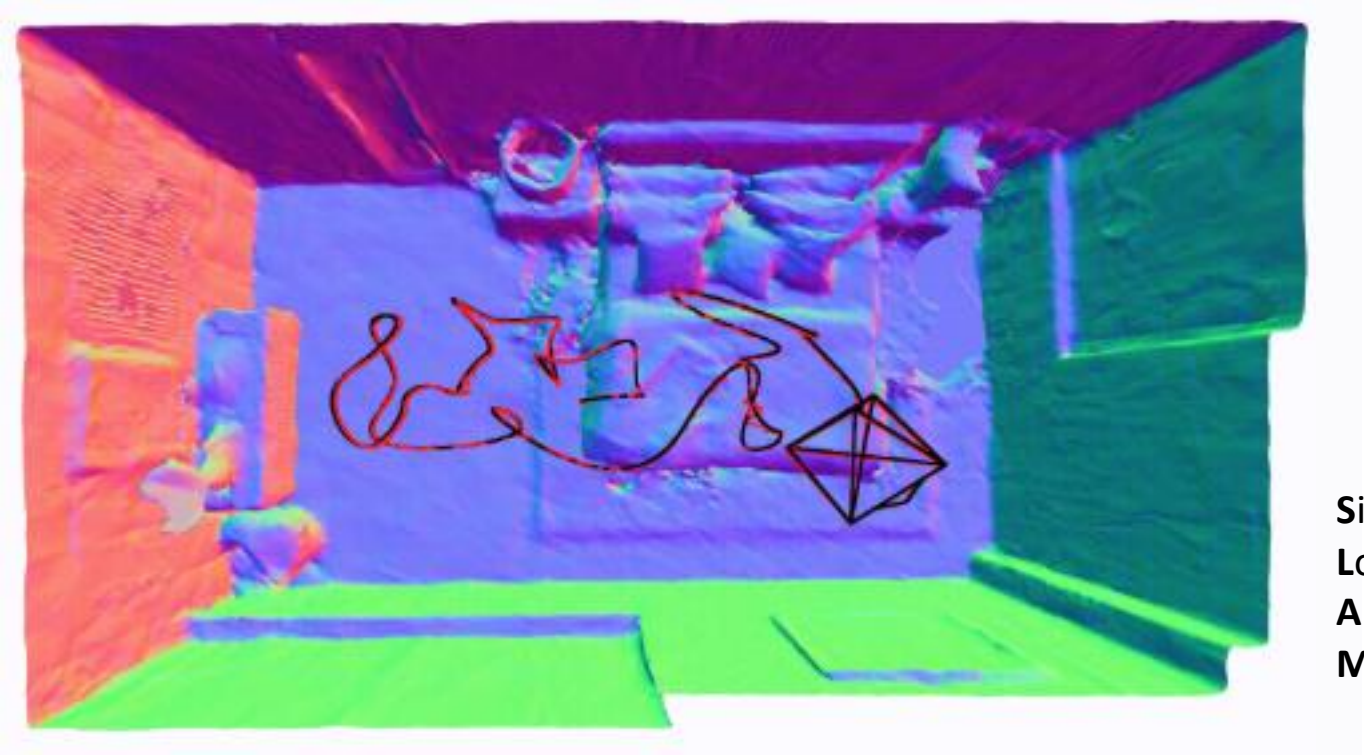
3D Humans from a Single Video

Resolving 3D Human Pose Ambiguities with 3D Scene Constraints
Mohammed Hassan, V. Choutas, D. Tzionas and M. J. Black
ICCV 2019

Populate Scenes – Synthesized Humans

[Populating 3D Scenes by Learning Human-Scene Interaction]
Mohammed Hassan, P. Ghosh, J. Tesch, D. Tzionas and M. J. Black
CVPR 2021

3D Space Reconstruction (SLAM)



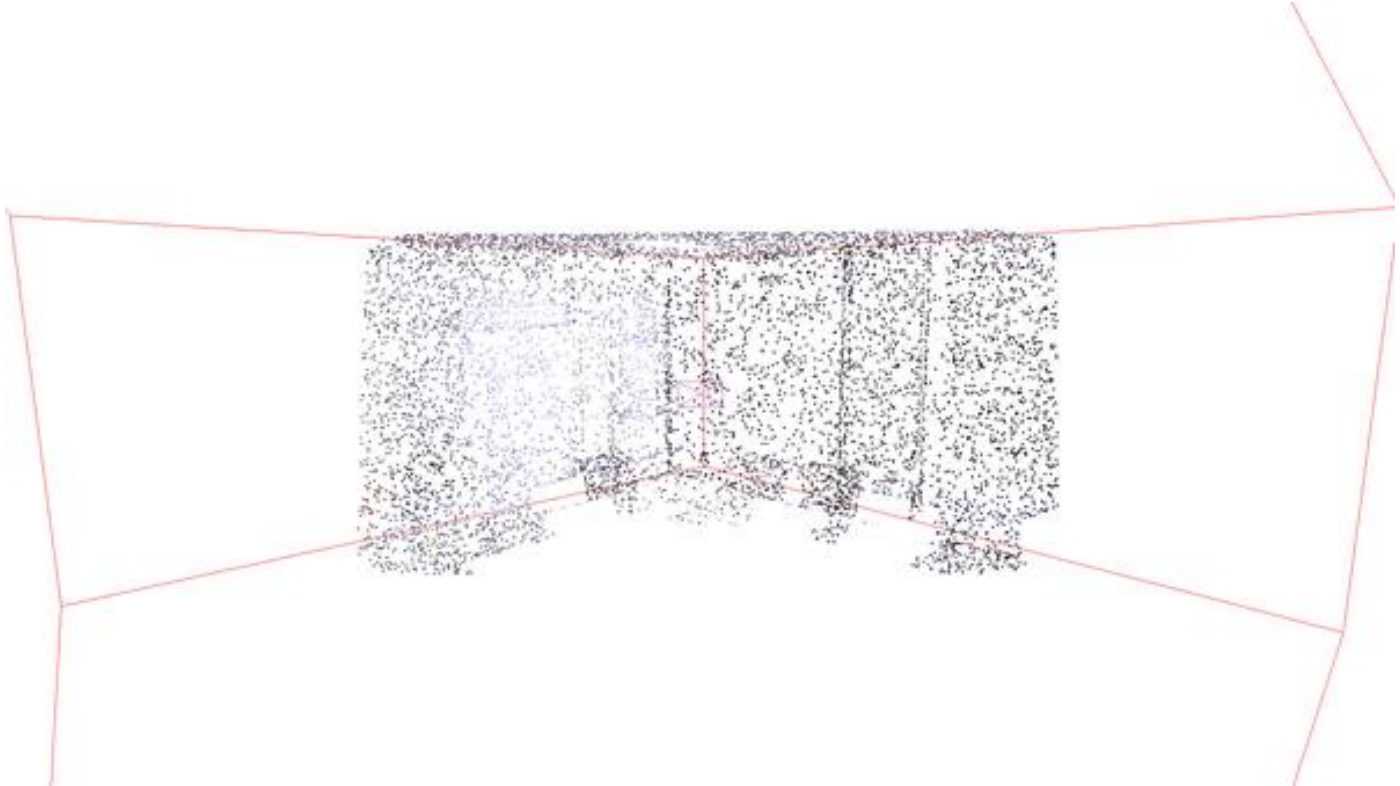
Simultaneous
Localization
And
Mapping

https://github.com/cvg/nice-slam

Z. Zhu* · S. Peng* · V. Larsson · W. Xu · H. B. Z. Cui · Martin R. Oswald · M. Pollefeys

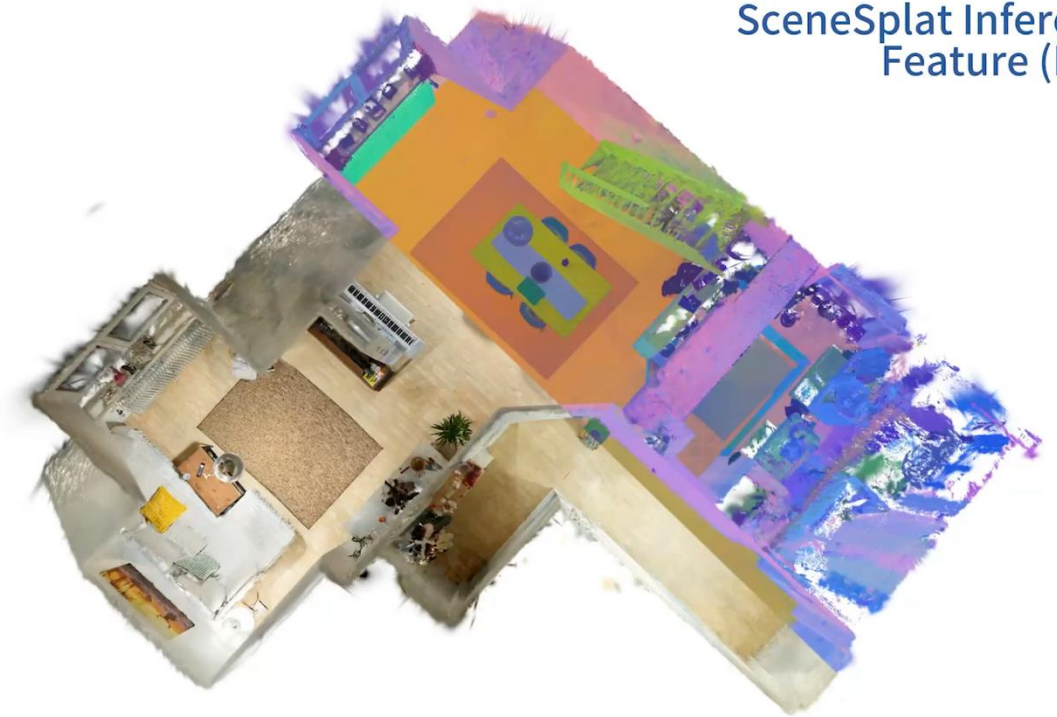
CVPR 2022

3D Space Reconstruction (SLAM)



Point-SLAM: Dense Neural Point Cloud-based SLAM
Erik Sandström* · Yue Li* · Luc Van Gool · Martin R. Oswald
ICCV 2023

3D Space Understanding (Vision + Language)



SceneSplat: Gaussian Splatting-based Scene Understanding with Vision-Language Pretraining

Yue Li* · Qi Ma* · … · T. Gevers · L. Van Gool · M. R. Oswald · D. P. Paudel

ICCV 2025

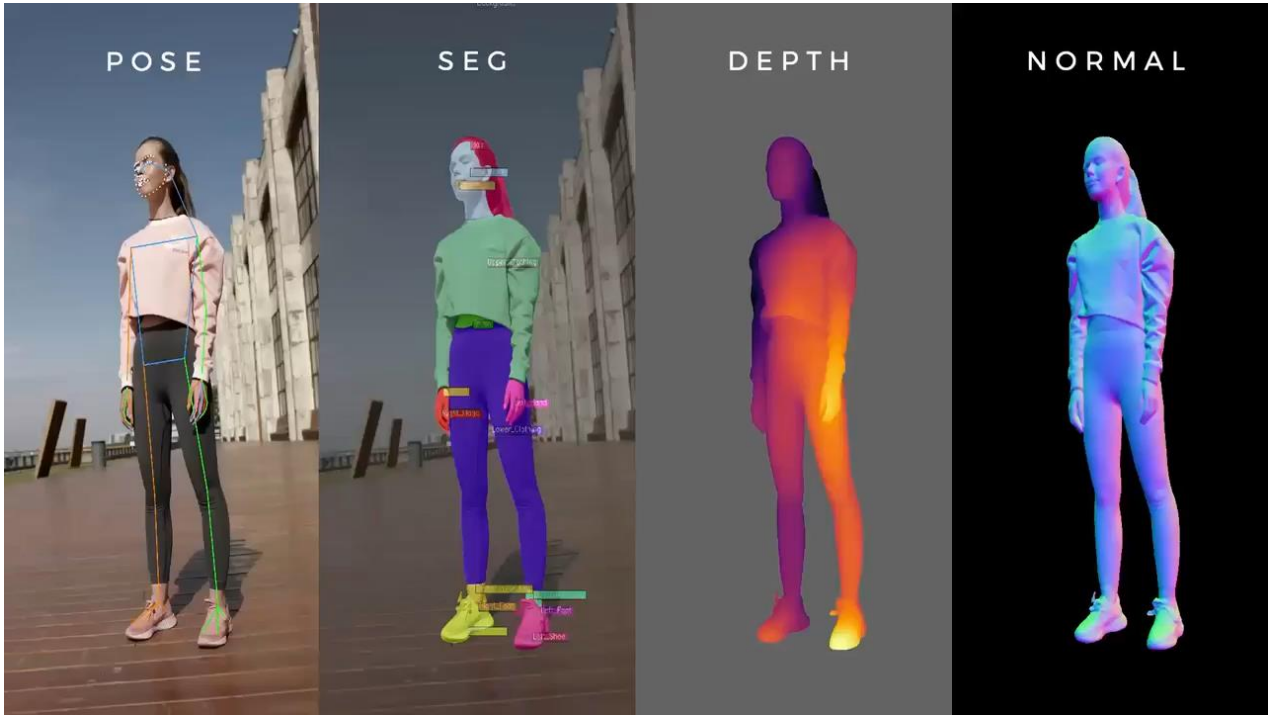
Foundational Models

DINOv3

https://github.com/facebookresearch/dinov3

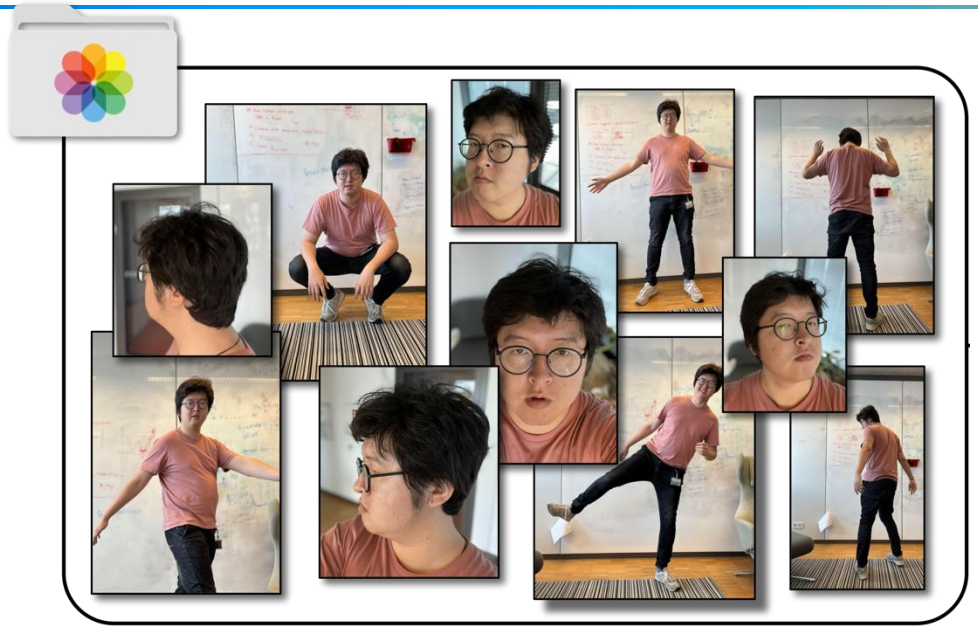
[Siméoni et al., arXiv:2508.10104, 2025]

Foundational Models → Humans



SAPIENS: Foundation for Human Vision Models
https://github.com/facebookresearch/sapiens
[Khirodkar et al., ECCV 2024]

3D Avatars – Personalized



Personal 'OOTD' Photo Album

Outfit Of The Day

Detailed 3D Human

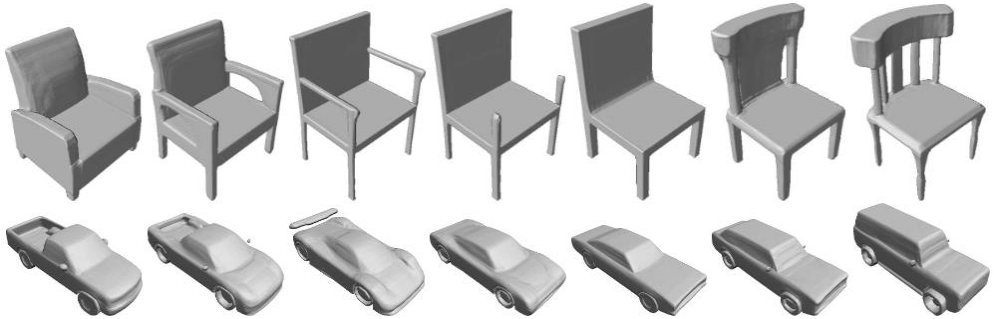
PuzzleAvatar

[PuzzleAvatar: Assembly of Avatar from Unconstrained Photo Collections]

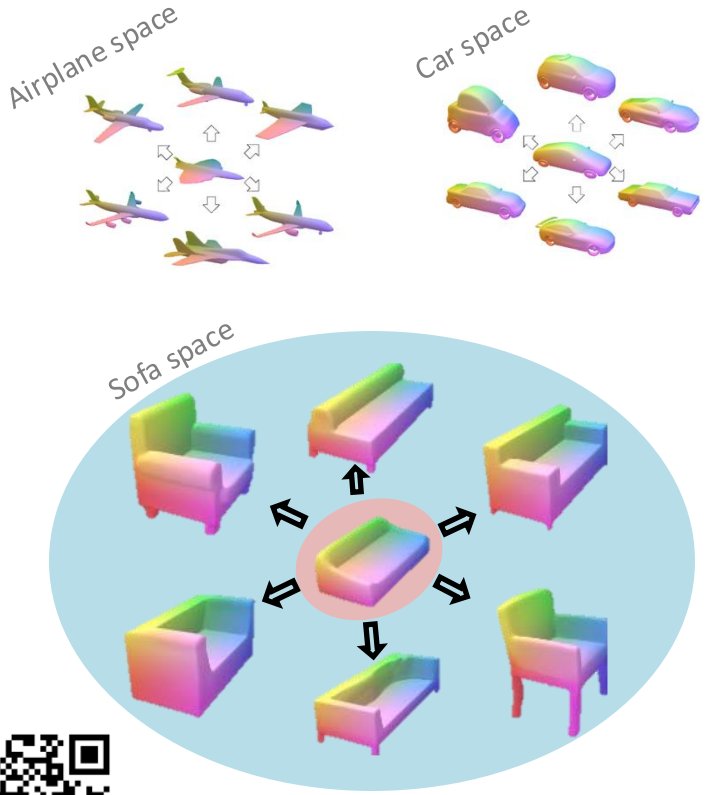
Yuliang Xiu · Y. Ye · Z. Liu · D. Tzionas · M. J. Black

SIGGRAPH, 2024

3D Object Shape Modelling



DeepSDF
[J.J.Park et al., CVPR]



Deep Implicit Templates (DIT)
[Zheng et al., CVPR 2021]

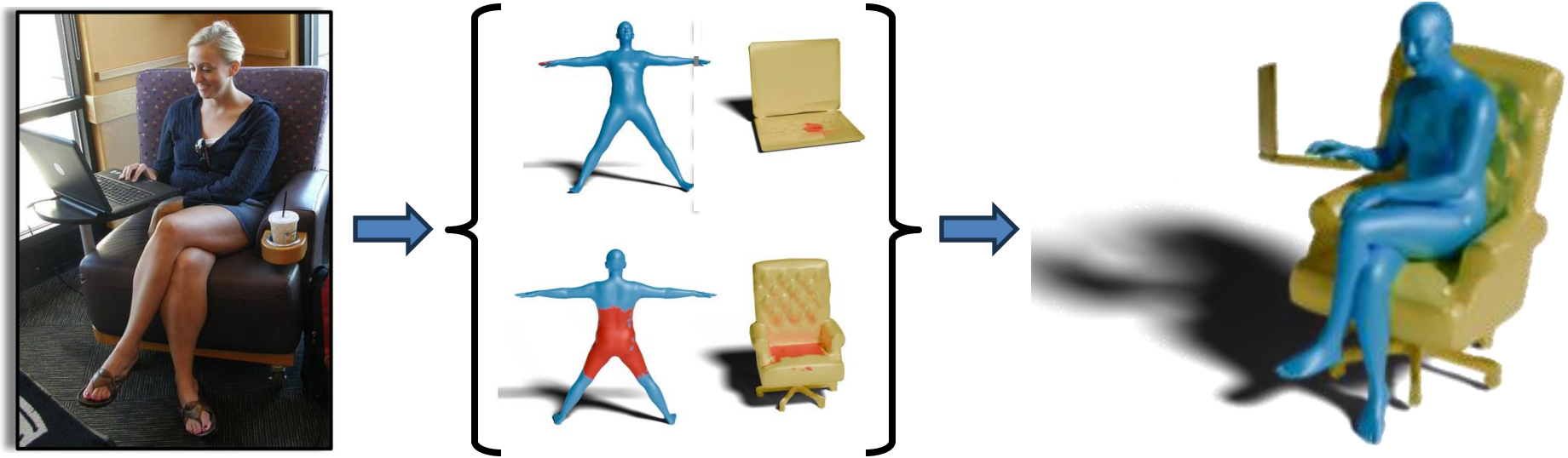
3D Object from a Single Image

SDFit: 3D Object Shape and Pose by Fitting a Morphable SDF to a Single Image

Dimitrije Antić · G. Paschalidis · S. Tripathi · T. Gevers · S. K. Dwivedi · D. Tzionas

ICCV 2025

3D Interactions from a Single Image



InteractVLM: 3D Interaction Reasoning from 2D Foundational Models

Sai K. Dwivedi, Dimitrije Antić, S. Tripathi, O. Taheri, C. Schmid, M. J. Black, D. Tzionas

CVPR 2025

Reenactment – aka DeepFakes

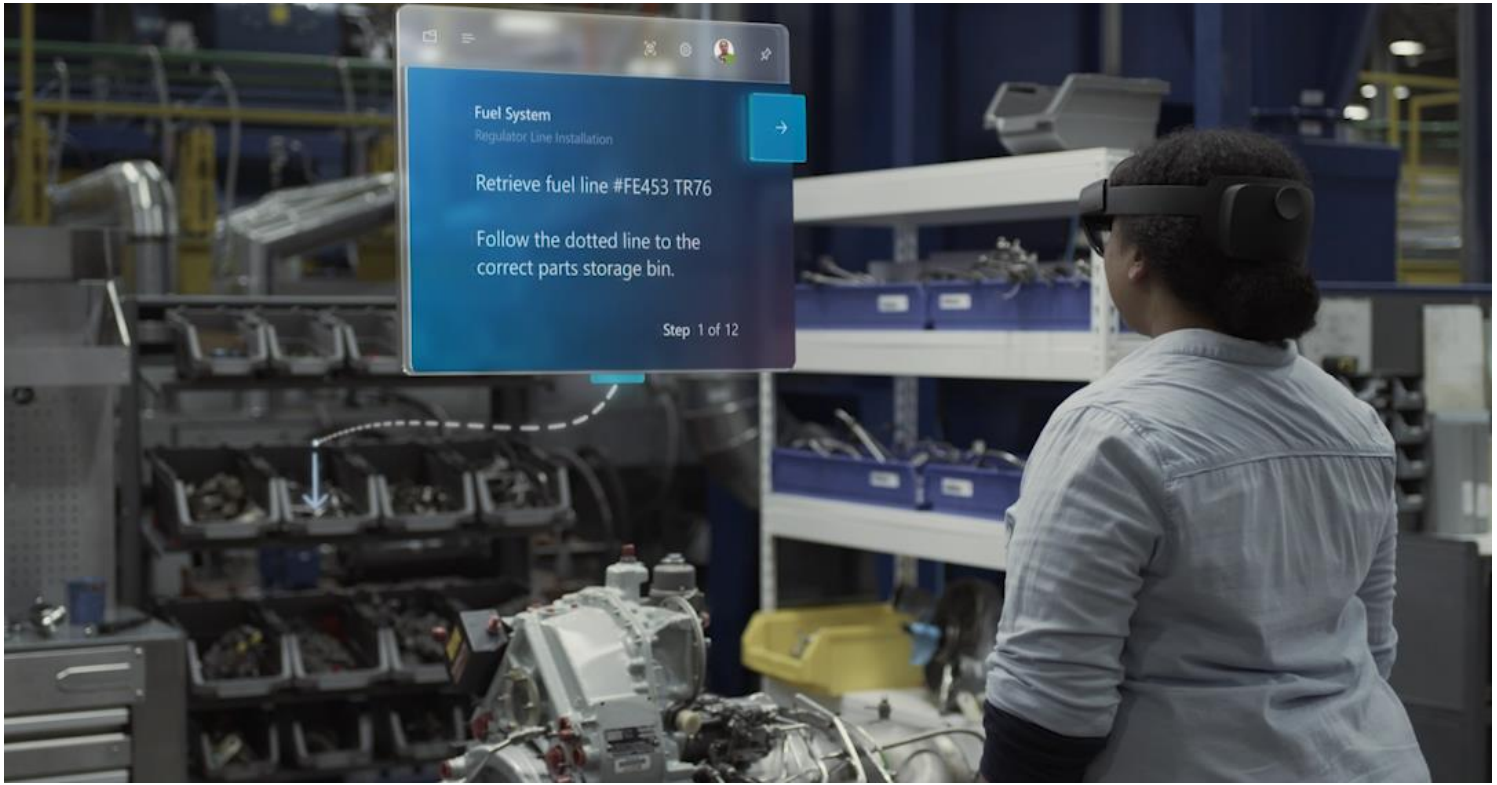
Face2Face [Thies et al., CVPR 2016]

Mixed Reality: 3D Video Conferencing

Microsoft HoloPortation, 2016
[https://www.microsoft.com/en-us/research/project/holoportation-3]

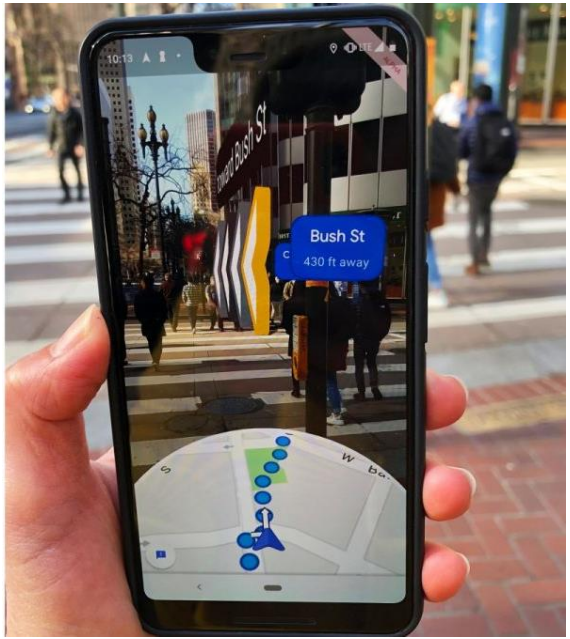
Facebook Reality Labs - Lombardi et al., TOG 2018
[https://www.youtube.com/watch?v=gpdX9jkhv2U]

Mixed Reality: (Remote) Training & Assistance



MS Guides, 2022

Mixed Reality: Navigation



Google maps AR
[https://edition.cnn.com/2019/02/11/tech/google-maps-ar/index.html]

Google visual positioning system (VPS)
[https://ai.googleblog.com/2019/02/using-global-localization-to-improve.html]

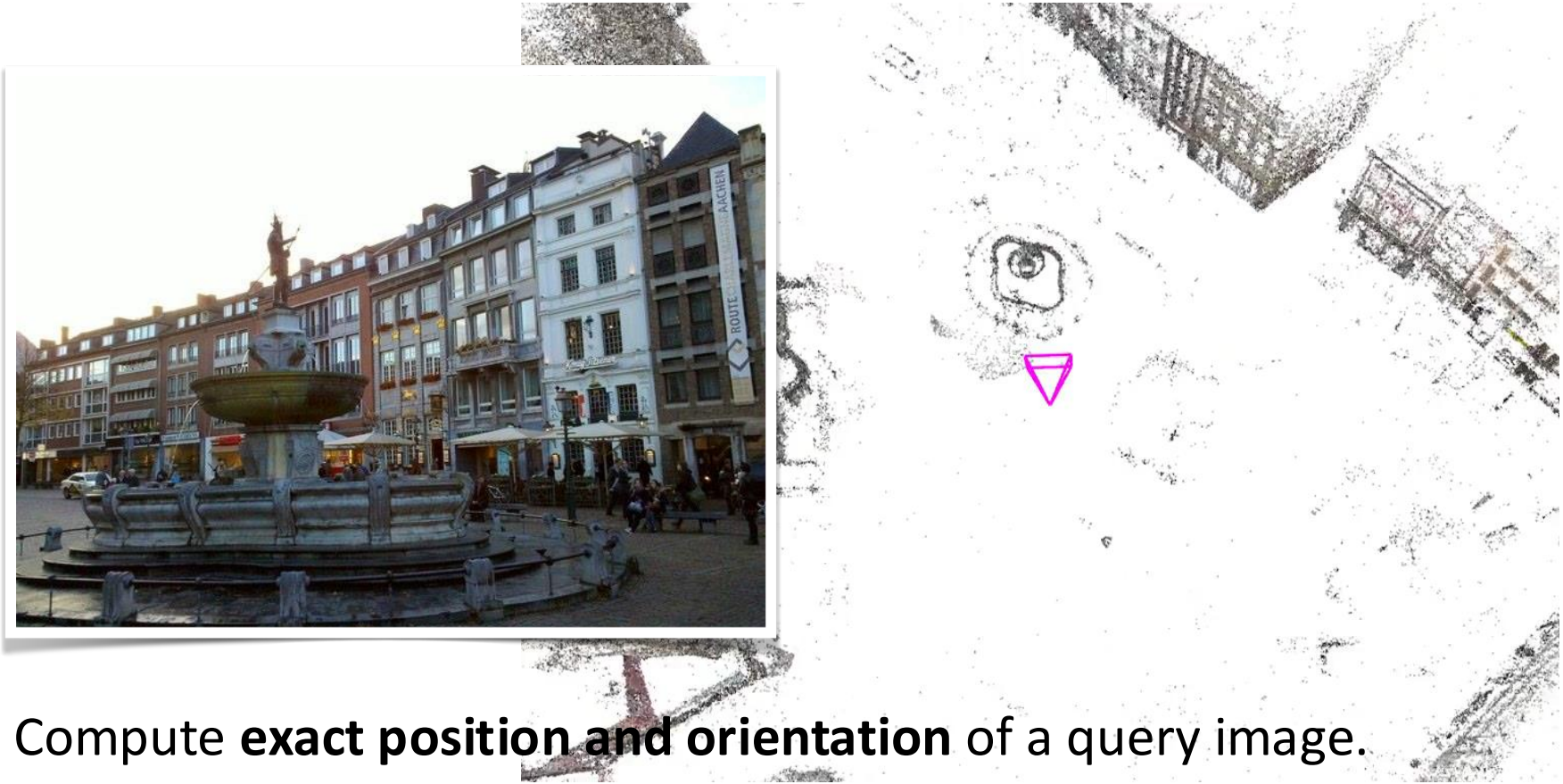
Image-based 3D Reconstruction

Building Rome in a Day

S. Agarwal, N. Snavely, I. Simon, S. M. Seitz, R. Szeliski

ICCV 2009

Image-based Localization



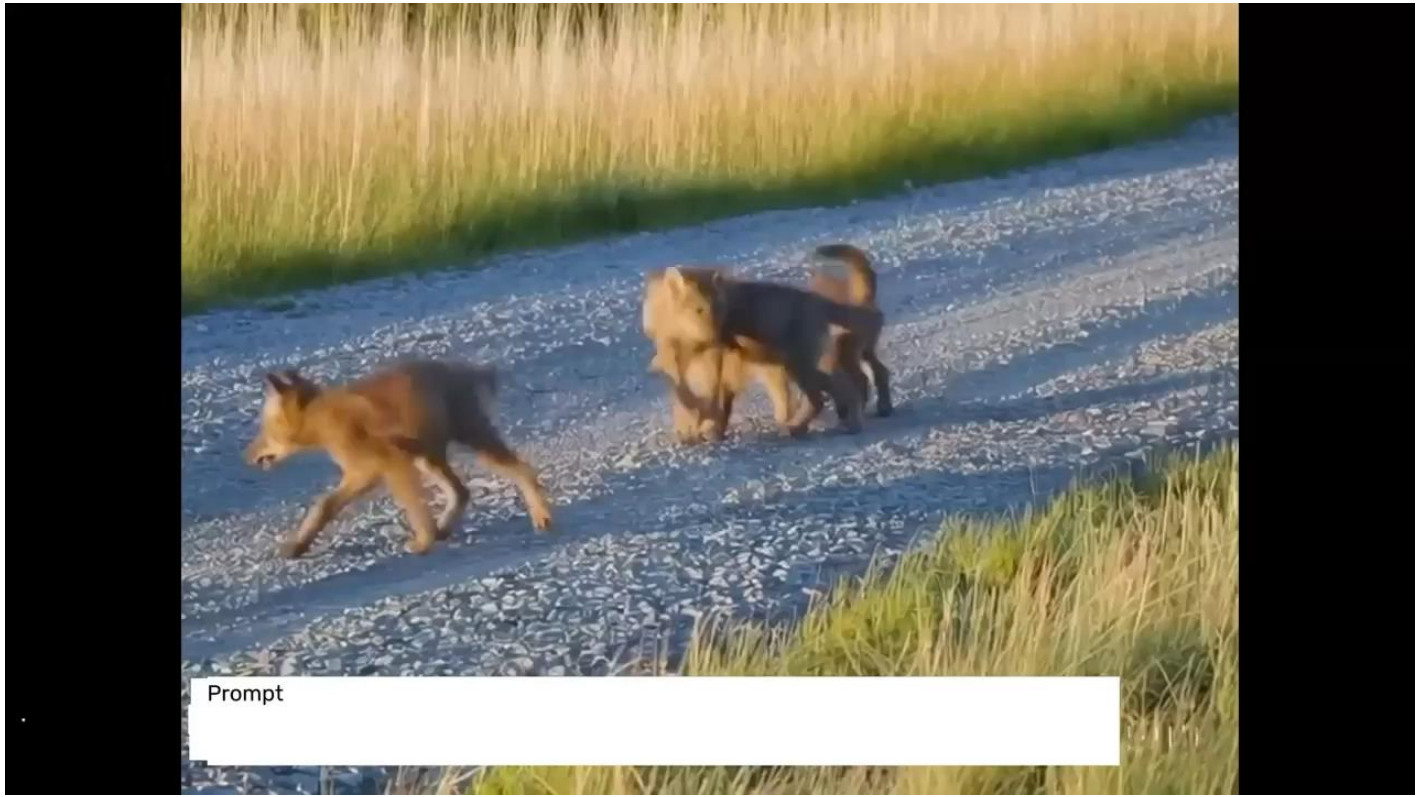
Compute **exact position and orientation** of a query image.

Dense Reconstruction

Generative Models (Text → Video) – Success

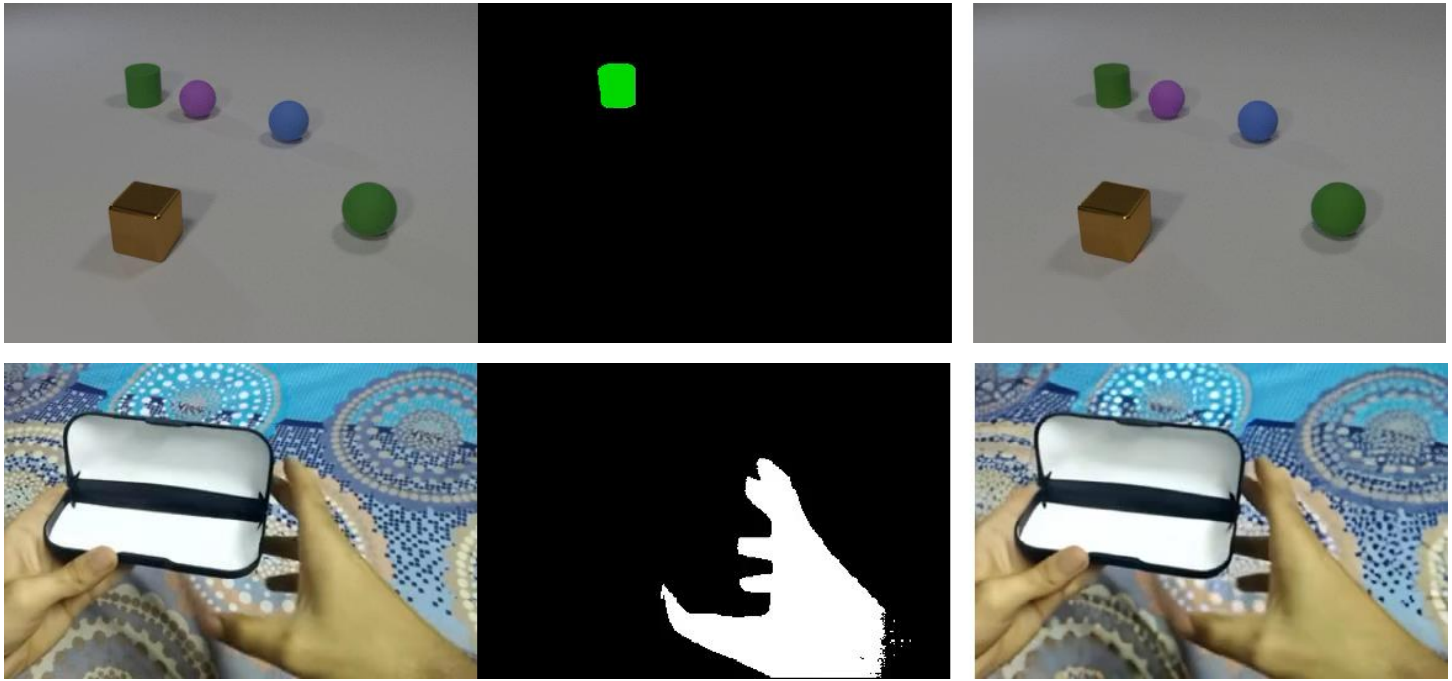
[OpenAI, SORA] [Examples, 2024]

Generative Models (Text → Video) – Failure



[OpenAI, SORA] [Examples, 2024]

Generative Models (Img+DriveSignal→Video)



Inputs (Image + Masks as **driving signal**)

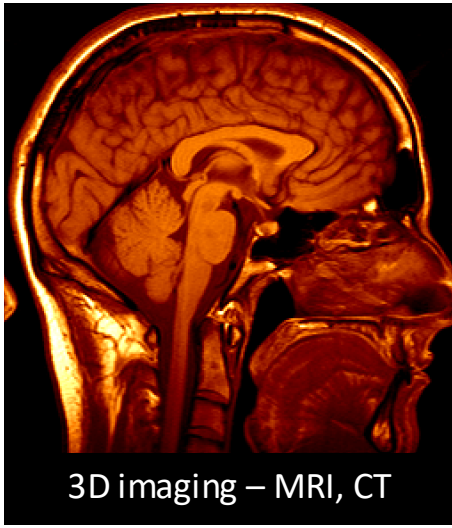
Output

InterDyn: Controllable Interactive Dynamics with Video Diffusion Models

Rick Akkerman* · Haiwen Feng* · M. J. Black · D. Tzionas · V. F. Abrevaya

CVPR, 2025

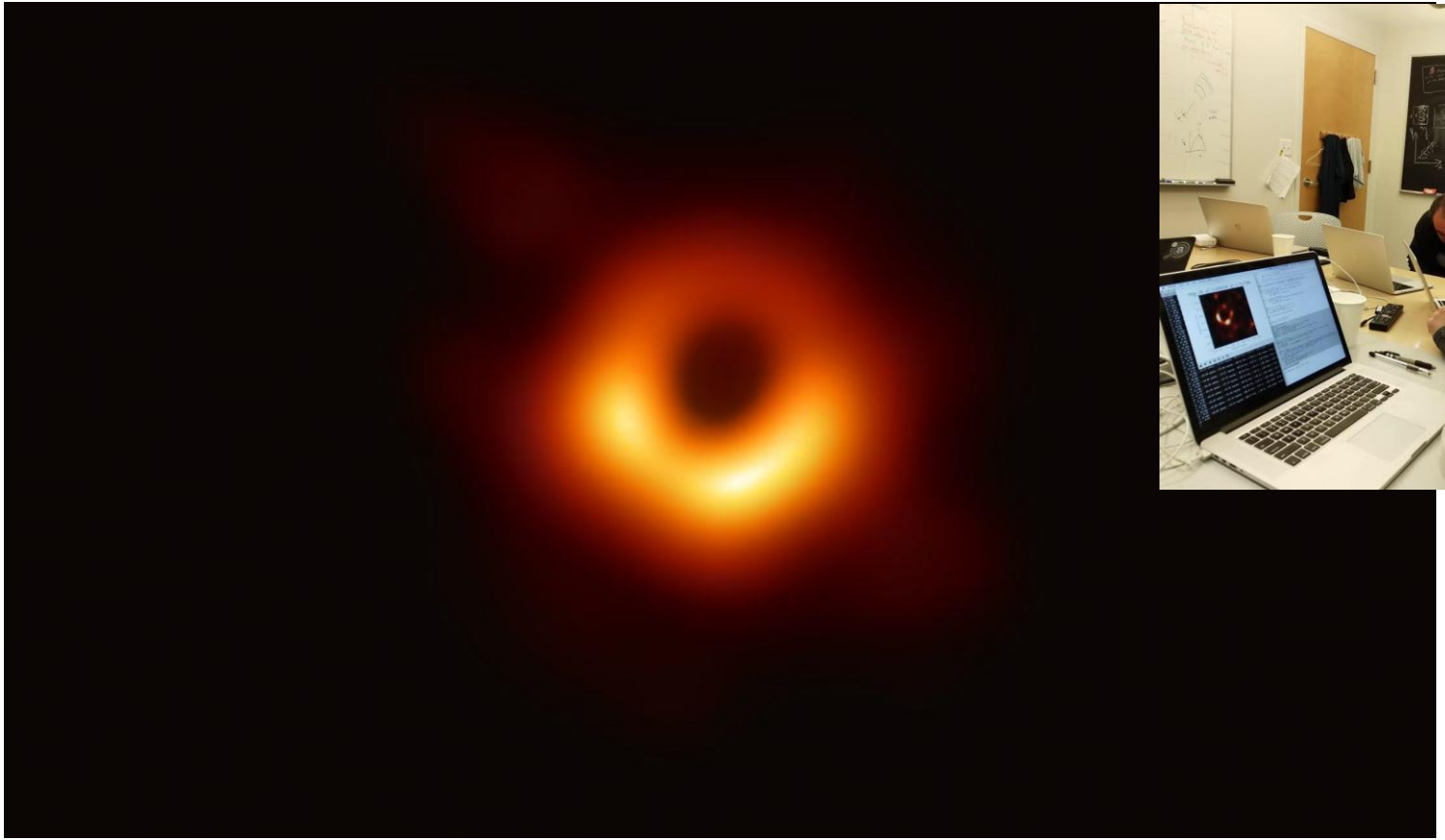
Medical Imaging



3D imaging – MRI, CT

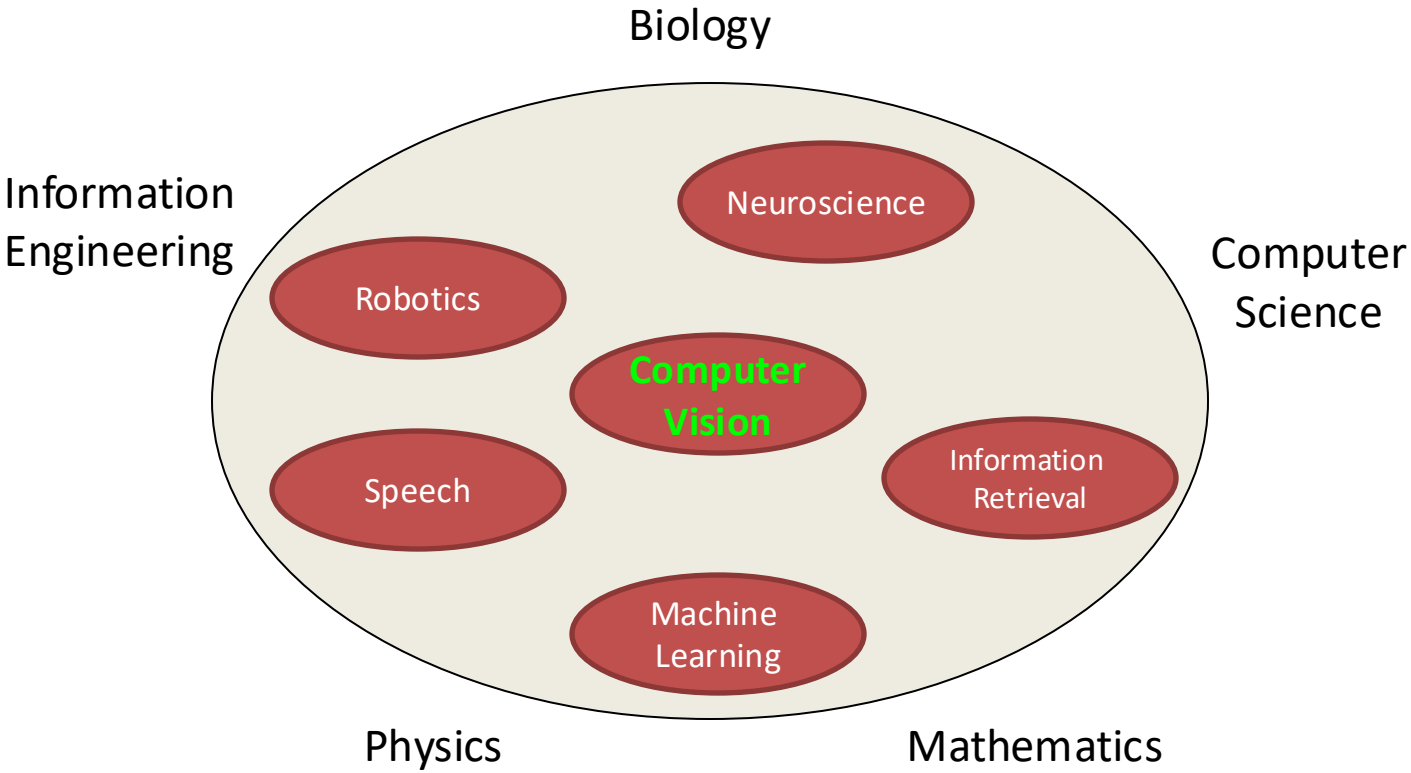
Augmented-Reality guided Surgery – https://www.youtube.com/watch?v=bkzkelf7IpI

Astronomy



https://edition.cnn.com/2019/04/10/world/black-hole-photo-scn

Multi-disciplinary Research Field



Impact – Across all sciences

Google Scholar

Top publications

Categories ▾ English ▾

Annual

#2 - CVPR

	Publication	h5-index	h5-median
1.	Nature	490	784
2.	IEEE/CVF Conference on Computer Vision and Pattern Recognition	450	702
3.	The New England Journal of Medicine	441	854
4.	Science	415	653
5.	Nature Communications	399	509
6.	The Lancet	375	712
7.	Neural Information Processing Systems	371	637
8.	International Conference on Learning Representations	362	652

...

Biannual

#22 - ECCV

21.	Advanced Functional Materials	263	342
22.	European Conference on Computer Vision	262	417
23.	Chemical Society Reviews	260	393
24.	International Journal of Environmental Research and Public Health	258	372

#25 - ICCV

25.	IEEE/CVF International Conference on Computer Vision	256	412
26.	Sustainability	250	328

https://scholar.google.com/citations?view_op=top_venues

Impact – Engineering & Computer Science

Google Scholar

Top publications

Categories > **Engineering & Computer Science** > Subcategories

	Publication	h5-index	h5-median
1.	IEEE/CVF Conference on Computer Vision and Pattern Recognition	450	702
2.	Neural Information Processing Systems	371	637
3.	International Conference on Learning Representations	362	652
4.	Advanced Materials	330	440
5.	Journal of Cleaner Production	298	384
6.	IEEE Access	288	401
7.	International Conference on Machine Learning	272	471
8.	Advanced Functional Materials	263	342
9.	European Conference on Computer Vision	262	417
10.	IEEE/CVF International Conference on Computer Vision	256	412
11.	Chemical engineering journal	245	310
...			
18.	Energy & Environmental Science	219	318
19.	Conference on Empirical Methods in Natural Language Processing (EMNLP)	218	323
20.	IEEE Transactions on Pattern Analysis and Machine Intelligence	217	376

#1 - CVPR

#9 - ECCV

#10 - ICCV

#20 - TPAMI

https://scholar.google.com/citations?view_op=top_venues&hl=en&vq=eng

Open Access & Discovery

CVPR, ICCV, WACV papers: https://openaccess.thecvf.com

ECCV papers: https://www.ecva.net/papers.php

arXiv pre-prints: https://arxiv.org/list/cs.CV/recent

Scholar Inbox: https://scholar-inbox.com

LinkedIn

Bluesky

Course Info

Course Team (1/3) – Lecturers, D4, PhD TAs

Asst. Prof. Martin Oswald
(Coordinator, Lecturer)

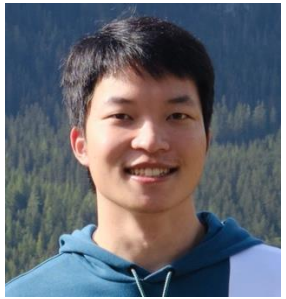
Asst. Prof. Dimitris Tzionas
(Lecturer)

Dr. Arun Mukundan
(Senior-TA, Trusted Person)

Alvaro Budria

Dimitrije Antić

Georgios Paschalidis



Yue Li

Course Team (2/3) – MSc TAs

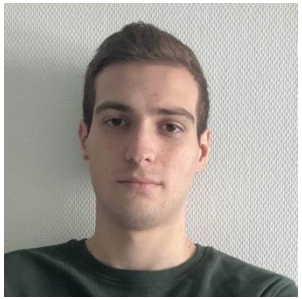
Adrian Sauter

Alisia Baielli

Andro Erdelez

Devin Pereira

Koen Veldhorst



Konstantinos Zafeirakis

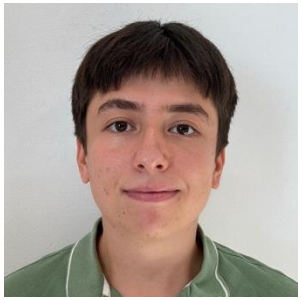
Marom Sverdlov

Matei Nastase

Course Team (2/3) – MSc TAs

Meher Changlani

Michał Mazuryk



Oliver van Erven

Teo Stereciu

Udit Thakur

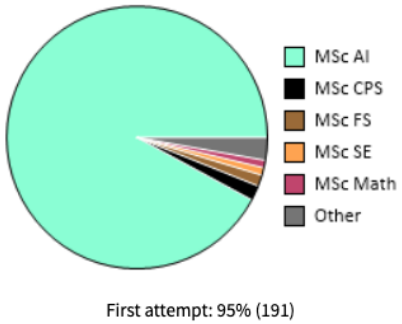
Viktória Pravdová

Wojciech Trejter

Wojciech Kosiuk

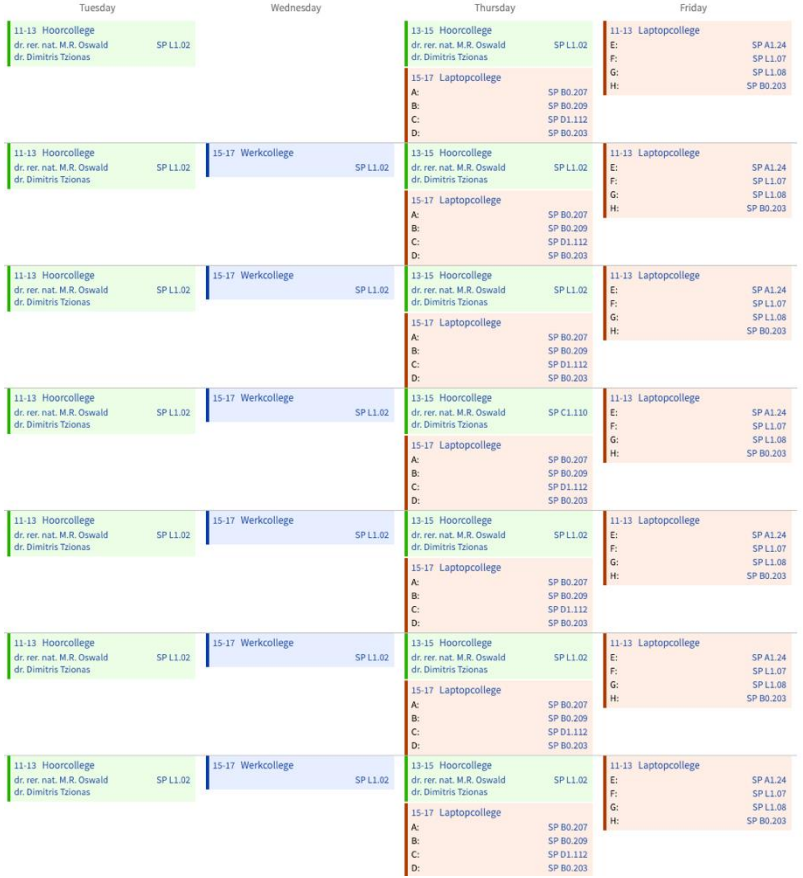
Tentative Schedule (Weekly)

- Introductory MSc-level course for C. Vision



First attempt: 95% (191)

- It contains:
  - 14 Lectures,
  - 05 Computer Labs (Python-based),
  - 05 Theoretical exercises (Lab assignments)
  - Final exam



Tentative Schedule (Weekly)

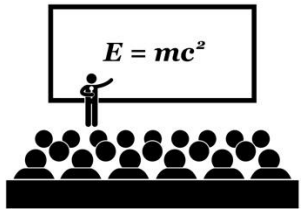
Monday	Tuesday	Wednesday	Thursday	Friday
	11-13 Hoorcollege dr. rer. nat. M.R. Oswald SP L1.02 dr. Dimitris Tzionas	15-17 Werkcollege SP L1.02	13-15 Hoorcollege dr. rer. nat. M.R. Oswald SP L1.02 dr. Dimitris Tzionas 15-17 Laptopcollege A: SP B0.207 B: SP B0.209 C: SP D1.112 D: SP B0.203	11-13 Laptopcollege E: SP A1.24 F: SP L1.07 G: SP L1.08 H: SP B0.203

- Repeats every week (no WC for first week)
- All classes at SP L1.02 (except for Thu, 25 Sep @ SP C1.110)

- Hoorcollege HC slots → Lectures (video recorded*)
- WerkCollege WC slots → Seminars (video recorded*)
- LaptopCollege LC slots → Computer Labs

* Do not rely on this, equipment can fail. No rights can be claimed.

Learning Approach



- HC – Lectures
  - Cover fundamental Computer Vision concepts, Math foundations, Applications
  - Focus on higher-level concepts and intuitions
  - MSc → Lectures will not cover everything → self study (slides, textbook, search online) is important!
- WC – Seminars
  - Practice theoretical problems – with a PhD-TA → Alvaro, Dimitrije, Georgios, Yue Li
  - Last week – discuss mock exam
- Lab Assignments (5x ones, graded)
  - Design and Implement a hands-on solution for fundamental Computer Vision problem
  - Work within a group of 3 people

- LC – Computer Labs
  - Receive help for Lab Assignment → Free-form structure. You 'lead' this actively – not passively
  - Last week – discuss mock exam
- Quizzes (5x ones, weeks 2-6, graded – low stakes)
  - Multi-choice Canvas questionnaires. (Rule of thumb: Release after Tuesday's HC. Ddl 1h before Thursday's HC)

Intended Learning Outcomes – HC Lectures

- Understand the basic concepts (*What*) and motivation (*Why*) of Computer Vision
- Understand the key theories & techniques (*How*)
- Know the *trends* of modern Computer Vision
- Gain the basis knowledge for *future* courses, such as:
  - Computer Vision 2
  - Deep Learning

Intended Learning Outcomes – WC Seminars

- Use key theories & techniques

  with emphasis on *theory*
- Reflect on the pros and cons of algorithms
- Get prepared for future courses

Intended Learning Outcomes – LC Labs

- Use key theories & techniques

  with emphasis on *practice*
- Propose improvements over existing methods
- Get prepared for future courses

Tentative Schedule (Weekly)

Week	Lecture	Date	Lectures
1	HC1a	02 Sep	Introduction and Camera Geometry
	HC1b	04 Sep	Camera Model and Image Formation
2	HC2a	09 Sep	In-Place Processing & Photometric Stereo
	HC2b	11 Sep	Neighborhood Processing & Image Filtering
3	HC3a	16 Sep	Local Feature, Edge, Line and Corner
	HC3b	18 Sep	Optical Flow, Motion and Tracking
4	HC4a	23 Sep	Global Transform and Image Stitching
	HC4b	25 Sep	Object Recognition
5	HC5a	30 Sep	Retrieval, Detection and Segmentation
	HC5b	02 Oct	Convolutional Neural Networks
6	HC6a	07 Oct	Single Shot Detection Network Architectures
	HC6b	09 Oct	Shape-from-X and Multi-view Stereo
7	HC7a	14 Oct	Guest lectures
	HC7b	16 Oct	Guest lecture & exam recap

Lab ddls (tentative – check Canvas)

Fri 05 Sep: **Lab0 ddl** – Intro to Numpy & OpenCV

Fri 12 Sep: **Lab1 ddl** – covers HC1a, HC1b, HC2a

Fri 19 Sep: **Lab2 ddl** – covers HC2b, HC3a

Fri 26 Sep: **Lab3 ddl** – covers HC3a, HC3b

Fri 03 Oct: **Lab4 ddl** – covers HC4a

(post exam) Fri 24 Oct: **Lab5 ddl** – Img Classification

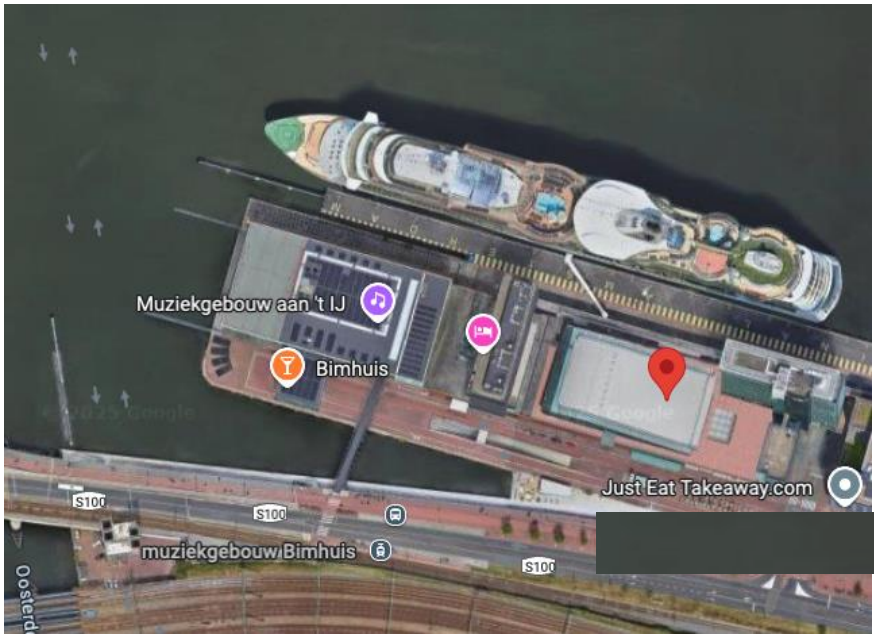
Tentative Schedule (Exams)

Exam-1 (Tentamen)

21 Oct, 13:00 – 16:00

Passenger Terminal Amsterdam (Piet Heinkade 27)

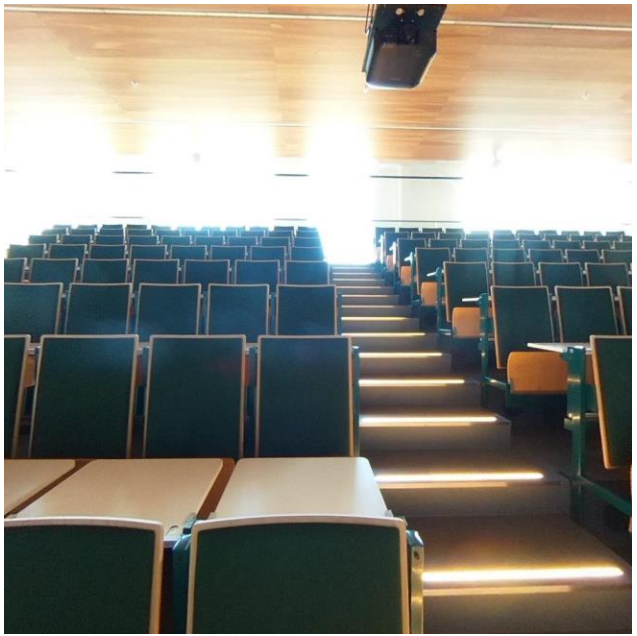
https://maps.app.goo.gl/qhmXC6g3txLW2jHT9



Exam-2 (Hertentamen)

05 Jan, 13:00 – 16:00

SP L1.02



Tentative Schedule (Exams)

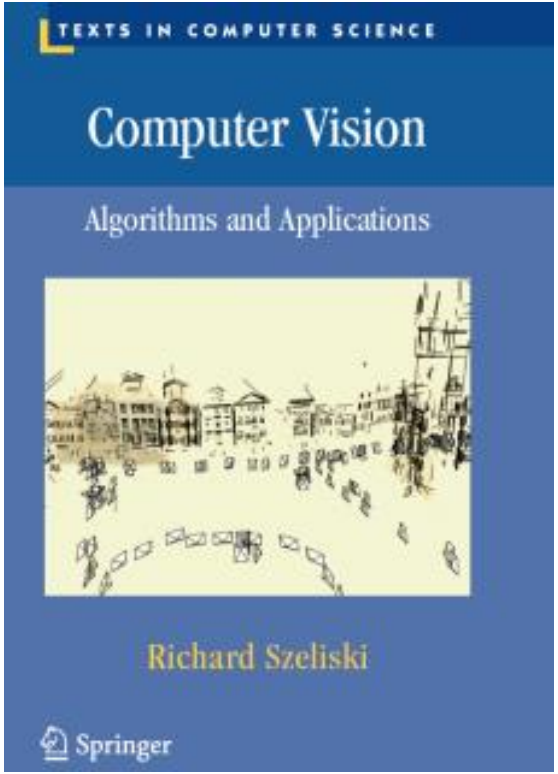
Exam-1 (Tentamen)
21 Oct, 13:00 – 16:00
Passenger Terminal Amsterdam (Piet Heinkade 27)

Exam-2 (Hertentamen)
05 Jan, 13:00 – 16:00
SP L1.02

- Study material: Slides (+Book for completeness), Quizzes, Lab Assignments
- Mock exam released for study @ Week 7 (also discussed at that Seminar)
- You can bring only:
  - Valid ID
  - Pen
  - Drink
  - Standard scientific calculator
  - Your single page (double-sided) hand-written cheat-sheet
- You do not need to register
- If you show up at Exam-2 → Grade of Exam-1 automatically overwritten

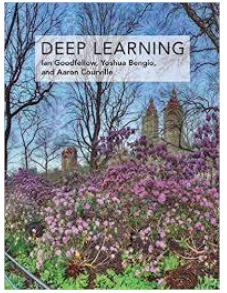
Textbook References (main)

- Computer Vision:
  Algorithms and Applications
  - by Richard Szeliski
  - freely available to download at http://szeliski.org/Book

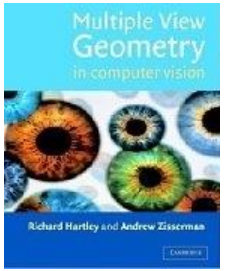


Textbook References II (extras)

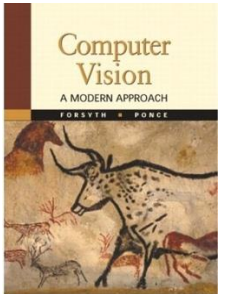
- Deep Learning
  - by Ian Goodfellow, Yoshua Bengio and Aaron Courville
  - freely available to download at http://www.deeplearningbook.org



- Multiple View Geometry in Computer Vision
  - by Richard Hartley and Andrew Zisserman
  - https://www.robots.ox.ac.uk/~vgg/hzbook



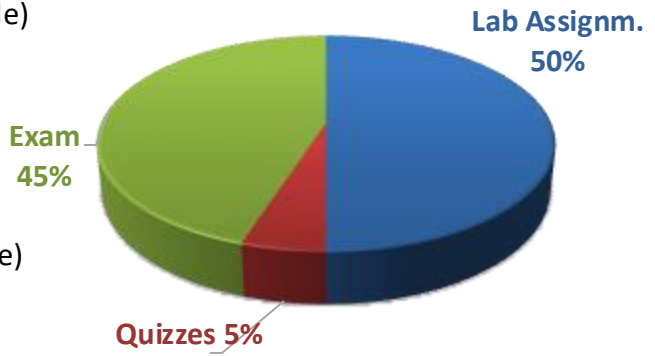
- Computer Vision: A Modern Approach
  - by David A. Forsyth, and Jean Ponce



Grading

- **50 %** Lab Assignments [group]: 4x weekly assignments + 1x longer one. Retakes can transfer (email Martin + Arun)
- **05 %** Quizzes [individual]: 5x online questionnaires (each 1% of final grade)
- **45 %** Final exam [individual]: written exam (3h)

Note: Lab Assignment grading varies per week
(2024 → Lab1: 6%, Lab2: 7%, Lab3: 7%, Lab4: 5%, FinalLab: 25% of final grade)
(Percentages may change this year)



To **pass the course**, meet ***both*** conditions:

- Obtain at **least a 5.5** for the average over **Lab Assignments**
- Obtain at **least a 5.5** for **Exam**

If you fail the Exam-1 (Tentamen), you can take the Exam-2 (Hertentamen / resit)

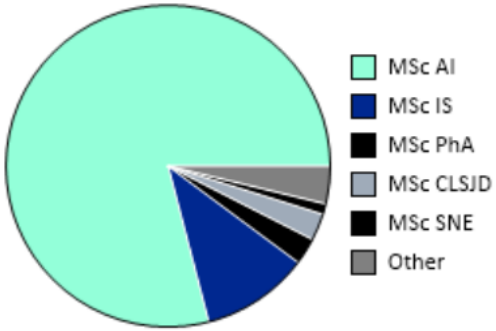
You cannot resit Lab Assignments or Quizzes

Course Prerequisites

- Canvas → Modules → Week0 → Before you start
- Linear algebra, calculus, & probability
  - For a refresher check: Canvas → Modules → Math Revision
- Machine Learning (in parallel)
- Data Structures
- Python

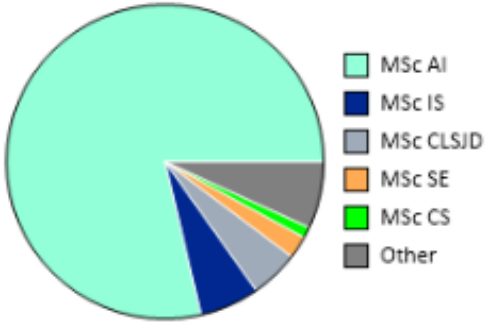
Course Statistics

2022/2023



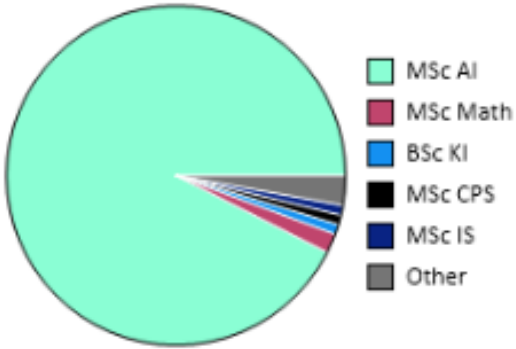
First attempt: 94% (139)

2023/2024



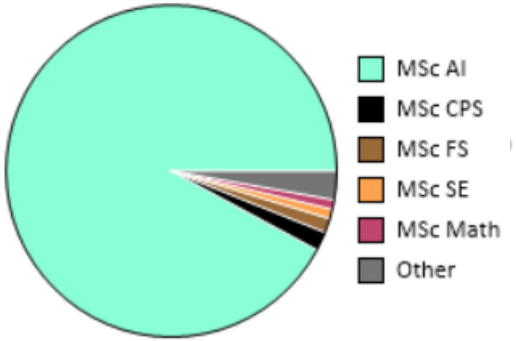
First attempt: 90% (186)

2024/2025



First attempt: 90% (181)

2025/2026



First attempt: 95% (191)

Course Tools

- **Study Guide:**
  https://studiegids.uva.nl/xmlpages/page/2025-2026-en/search-course/course/129975
  → General course info

- **DataNose (DNose):**
  https://datanose.nl/#course[137426]
  → Tutors (and emails)
  → Schedule
  → Groups for LC slots

- **Canvas:**
  https://canvas.uva.nl/courses/52846
  → All course material
  → Book chapters for each lecture
  → Announcements – Override this PPT
  → Schedule updates – Overrides DNose
  → Groups for Lab Assignments
  → Lab Assignments
  → Quizzes
  → Grades
  → Ask questions + Give answers + Look for answers @ Ed forum
  → **Please do not use Canvas messages**

Instead:
- [Preferred] Use the Ed forum in Canvas
- [Alternative] Email us and CC Arun in and your TA

Closing Remarks

Action Points

- Check information regularly on Canvas
- Canvas announcements – They overwrite everything!
- Download the textbooks
- Find your group members!
- Use the Math Revisions checklist
- Install Python & practice NumPy & OpenCV (Exercise: Lab0)
- Go to lab-office hours (LC slots) if needed (Thursdays/Fridays)
- Find time to attend HC, WC, LC sessions (not mandatory)
- Q&A in Canvas' Ed Discussion Forum

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Questions?