Introduction to Computer Vision

Lecture 1 - Overview

Prof. He Wang

About Me

- 王鹤
- Assistant Professor in Center on Frontiers of Computing Studies (CFCS)
- Joined PKU in September, 2021
- Received Ph.D. from Stanford in 2021
- Received Bachelor from Tsinghua in 2014

- Our lab: *Embodied Perception and InteraCtion (EPIC) Lab*
- Research interest: 3D vision, Robotics
- Homepage: https://hughw19.github.io/

北京大学前沿计算研究中心
Center on Frontiers of Computing Studies, Peking University

Stanford University

清華大學
Tsinghua University

Course Logistics

Objective: A Great Course on Computer Vision

- A self-included beginning course on computer vision
- A broad coverage of classic and deep vision from a modern perspective, to distinguish from online available vision courses
- To lay a solid foundation for applying and researching in computer vision

Logistics

- Instructor
  - He Wang (hewang@pku.edu.cn)
  - Office Hour: Friday 5:00PM - 6:00PM or under appoint.
  - Office location: Room 106-1, Courtyard No.5, Jingyuan
- TAs:
  - Mi Yan (dorisyan@pku.edu.cn)
  - Hao Shen (2301112029@pku.edu.cn)
  - Yuxing Chen (yuxingc_20@stu.pku.edu.cn)
- Class Time & Location
  - Wednesday 3:10PM - 6:00PM
  - Room 507, Teaching Building 2, Peking University

Prerequisite

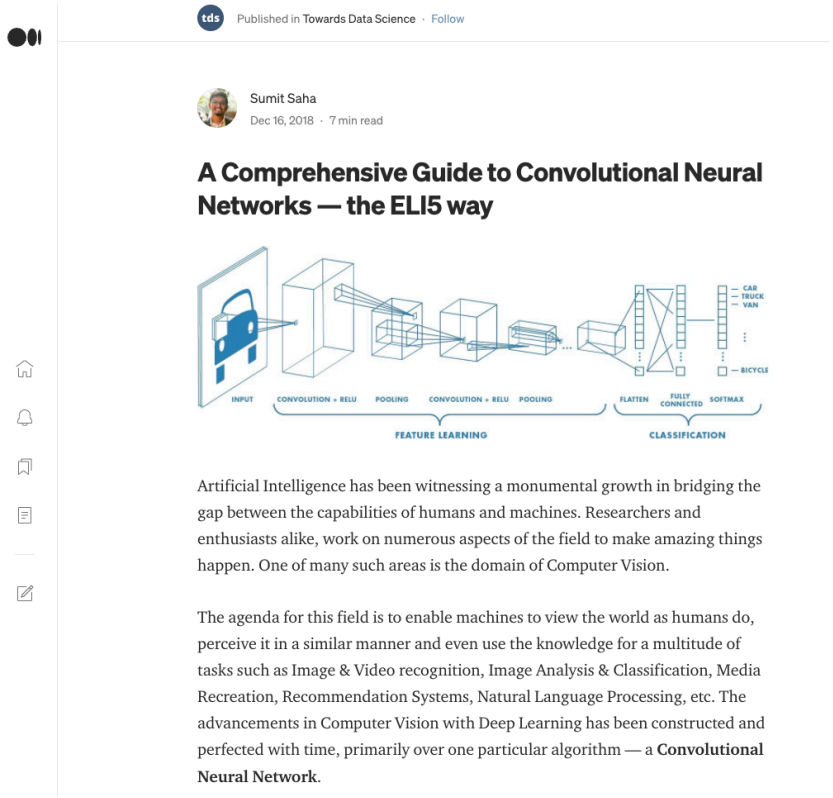
- Math:
  - Calculus
  - Linear Algebra
  - Basics of probability and statistics
- Proficiency in Python
- Optionally, have taken *Introduction to AI* or know some basic knowledge of machine learning and neural networks.

Books and References

- No required textbooks.
- Books for references:
  - On Deep Learning:
    - Ian Goodfellow and Yoshua Bengio and Aaron Courville. *Deep Learning.* MIT Press, 2016.
  - On Classic Computer Vision:
    - R. Szeliski. *Computer Vision: Algorithms and Applications.* Springer, 2011.
    - D. A. Forsyth and J. Ponce. *Computer Vision: A Modern Approach (2nd Edition).* Prentice Hall, 2011.

Books and References

- The most effective way to learn and check things:
  - Just google it!
  - Search in wikipedia!



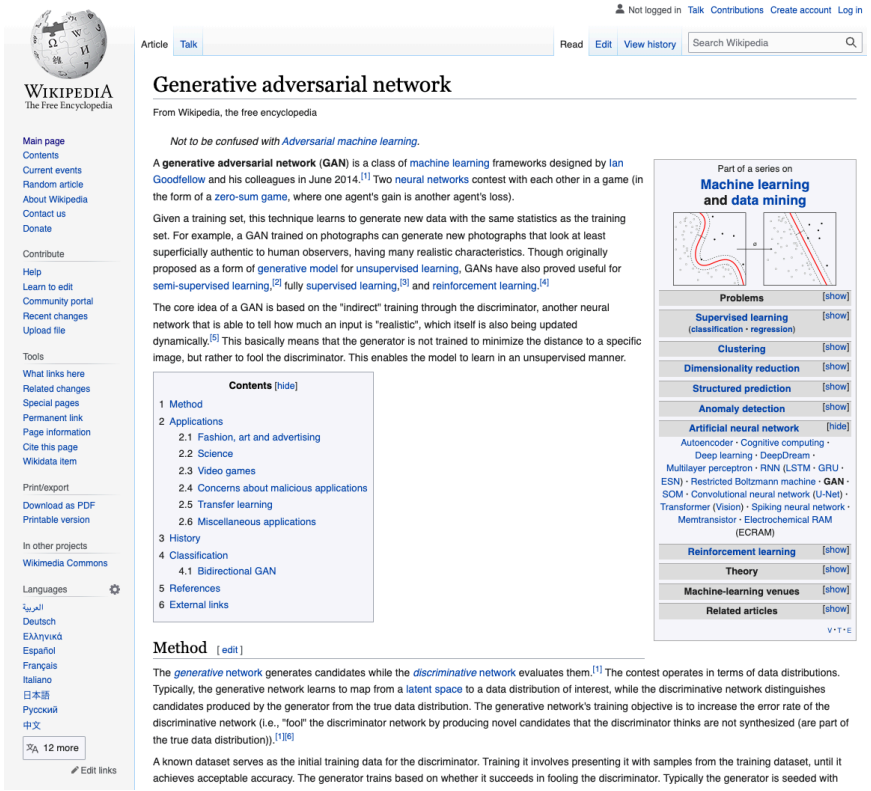
Published in Towards Data Science · Follow

Sumit Saha
Dec 16, 2018 · 7 min read

A Comprehensive Guide to Convolutional Neural Networks — the ELI5 way

Artificial Intelligence has been witnessing a monumental growth in bridging the gap between the capabilities of humans and machines. Researchers and enthusiasts alike, work on numerous aspects of the field to make amazing things happen. One of many such areas is the domain of Computer Vision.

The agenda for this field is to enable machines to view the world as humans do, perceive it in a similar manner and even use the knowledge for a multitude of tasks such as Image & Video recognition, Image Analysis & Classification, Media Recreation, Recommendation Systems, Natural Language Processing, etc. The advancements in Computer Vision with Deep Learning has been constructed and perfected with time, primarily over one particular algorithm — a **Convolutional Neural Network**.



Not logged in Talk Contributions Create account Log in

Article Talk Read Edit View history Search Wikipedia

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Current events
Random article
About Wikipedia
Contact us
Donate
Contribute
Help
Learn to edit
Community portal
Recent changes
Upload file
Tools
What links here
Related changes
Special pages
Permanent link
Page information
Cite this page
Wikidata item
Print/export
Download as PDF
Printable version
In other projects
Wikimedia Commons
Languages
العربية
Deutsch
Ελληνικά
Español
Français
Italiano
日本語
Русский
中文
12 more
Edit links

Generative adversarial network

From Wikipedia, the free encyclopedia

Not to be confused with Adversarial machine learning.

A **generative adversarial network** (**GAN**) is a class of machine learning frameworks designed by Ian Goodfellow and his colleagues in June 2014.[1] Two neural networks contest with each other in a game (in the form of a zero-sum game, where one agent's gain is another agent's loss).

Given a training set, this technique learns to generate new data with the same statistics as the training set. For example, a GAN trained on photographs can generate new photographs that look at least superficially authentic to human observers, having many realistic characteristics. Though originally proposed as a form of generative model for unsupervised learning, GANs have also proved useful for semi-supervised learning,[2] fully supervised learning,[3] and reinforcement learning.[4]

The core idea of a GAN is based on the "indirect" training through the discriminator, another neural network that is able to tell how much an input is "realistic", which itself is also being updated dynamically.[5] This basically means that the generator is not trained to minimize the distance to a specific image, but rather to fool the discriminator. This enables the model to learn in an unsupervised manner.

Contents [hide]
1 Method
2 Applications
2.1 Fashion, art and advertising
2.2 Science
2.3 Video games
2.4 Concerns about malicious applications
2.5 Transfer learning
2.6 Miscellaneous applications
3 History
4 Classification
4.1 Bidirectional GAN
5 References
6 External links

Part of a series on
Machine learning and data mining

Problems [show]
Supervised learning (classification · regression) [show]
Clustering [show]
Dimensionality reduction [show]
Structured prediction [show]
Anomaly detection [show]
Artificial neural network [hide]
Autoencoder · Cognitive computing · Deep learning · DeepDream · Multilayer perceptron · RNN (LSTM · GRU · ESN) · Restricted Boltzmann machine · GAN · SOM · Convolutional neural network (U-Net) · Transformer (Vision) · Spiking neural network · Memtransistor · Electrochemical RAM (ECRAM)
Reinforcement learning [show]
Theory [show]
Machine-learning venues [show]
Related articles [show]
v · t · e

Method [edit]

The *generative* network generates candidates while the *discriminative* network evaluates them.[1] The contest operates in terms of data distributions. Typically, the generative network learns to map from a latent space to a data distribution of interest, while the discriminative network distinguishes candidates produced by the generator from the true data distribution. The generative network's training objective is to increase the error rate of the discriminative network (i.e., "fool" the discriminator network by producing novel candidates that the discriminator thinks are not synthesized (are part of the true data distribution)).[1][6]

A known dataset serves as the initial training data for the discriminator. Training it involves presenting it with samples from the training dataset, until it achieves acceptable accuracy. The generator trains based on whether it succeeds in fooling the discriminator. Typically the generator is seeded with

Courseworks and Grading Policy

- 4 assignments: each 10%, in total 40%
- 1 midterm exam: 30%
- 1 final exam: 30%
- Class/discussion board participation: up to 5% bonus

- Look up class schedule (https://pku-epic.github.io/Intro2CV_2024/schedule/) for release and due dates.

Assignments

- Late policy for assignments
  - If 1 day (0 - 24 hours) past the deadline, 15% off
  - If 2 day (24 - 48 hours) past the deadline, 30% off
  - Zero credit if more than 2 days.

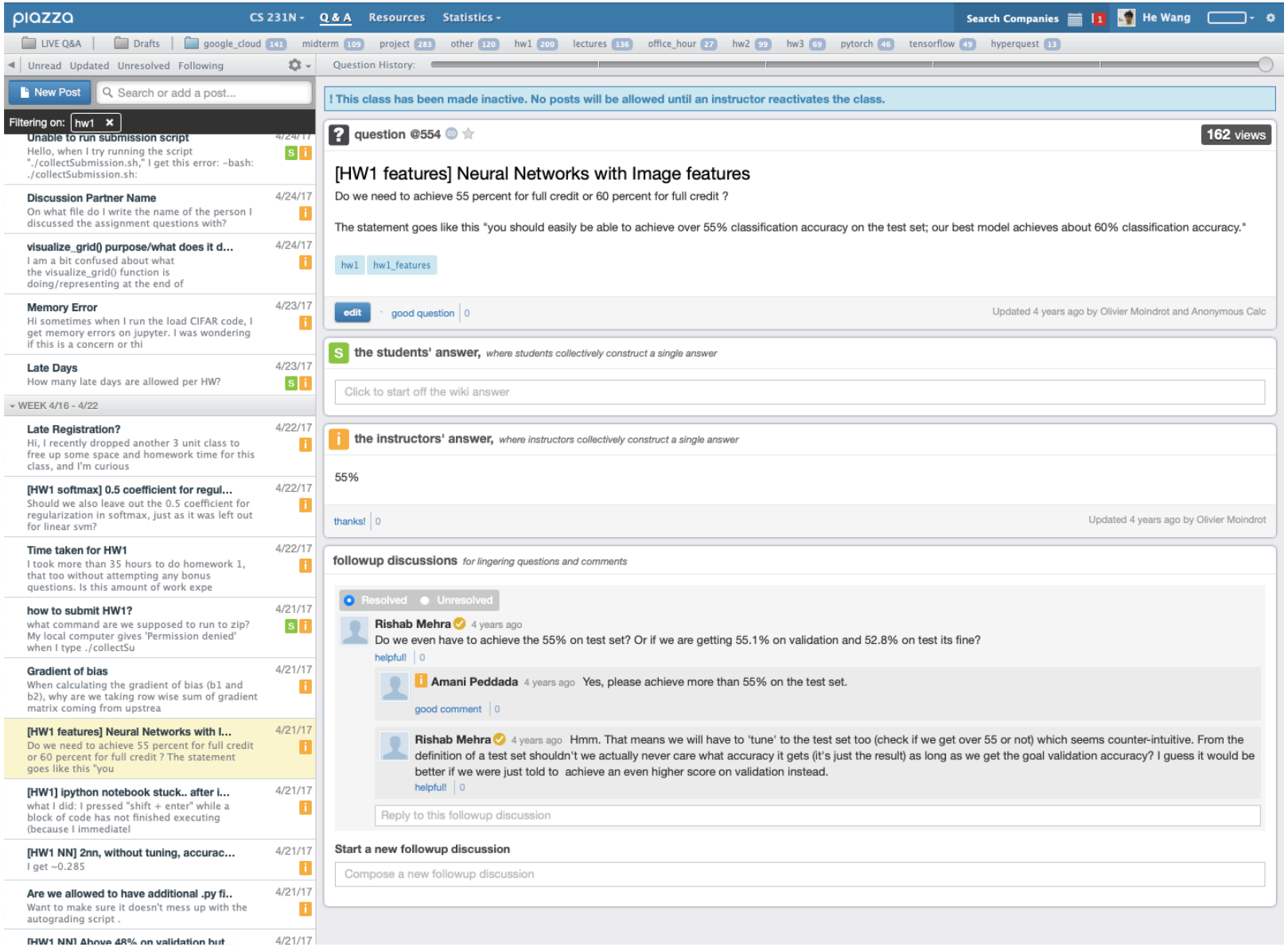
Midterm and Final Exams

- Midterm exam will be held in class.
- Final exam will be held in the afternoon of June 19.
- 1-page cheat sheet is allowed for both.

Course Website

- Website accessible to everyone: https://pku-epic.github.io/Intro2CV_2024/schedule/
- Internal course website in https://course.pku.edu.cn/
  - Slides/videos download
  - Assignment submission
  - Grades
  - Discussion board

My Experience back to Stanford



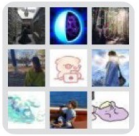
Discussion Board

- Course discussion board: share your questions!
- Will have a constant forum for discussing course material and three assignment forums each for one assignment.
- Your active participation in classes, discussions and my office hours will all count towards bonus.

论坛	描述	帖子总数
课程问题讨论		12
作业一		107
作业二		29
发帖规范	1. 如果是作业相关的帖子，请在对应论坛内将标题设为具体的小问名称+简要概括内容，如 "Task 1(a) 题干描述有误"，便于其他同学查找 2. 如果是询问某次作业中一个函数是否可以使用，请在对应论坛内助教发的帖子下回复具体小问+函数名称，如 "Task 1(a) np.vectorize" 3. 请大家发帖前先查看是否已有过相同或者相似的问题，如果是相似问题请直接在已有帖子下回复。	0
期中线上答疑	期中考范围是Lec1～Lec8。英文题面，作答中英文皆可。题型：多选，判断，简答，计算。	17
作业三		40
作业四		53
期末答疑		10

WeChat Group

- WeChat group:
  - Use for notifications and announcements
  - Not an ideal place for tracking each individual questions.
  - Not recommended to WeChat me or TAs in person to ask questions that may also be interesting the other students. Use discussion board!



群聊: 2024春计算机视觉导论

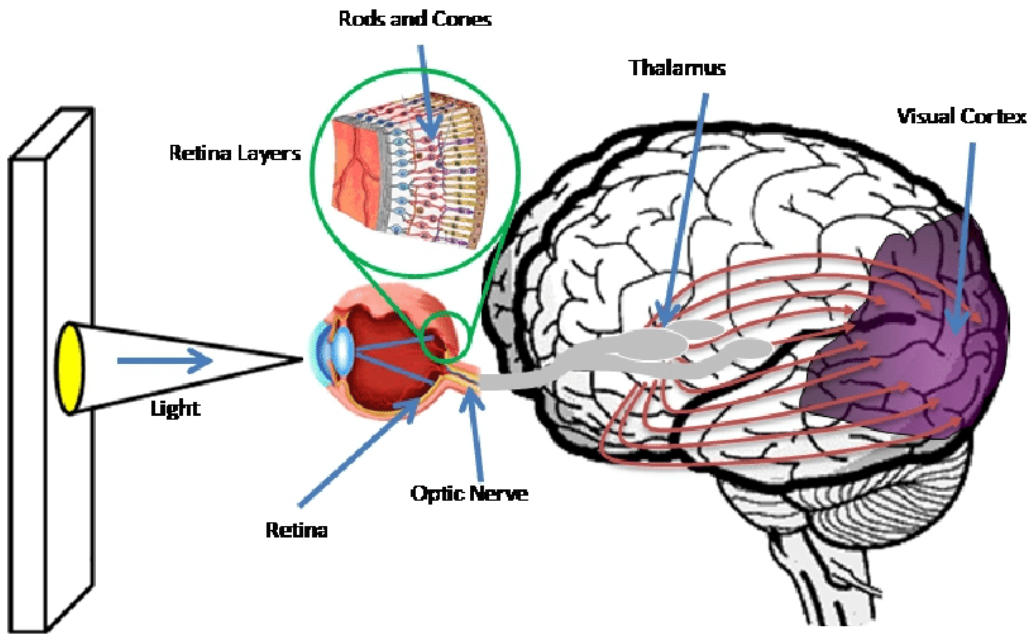
该二维码7天内(2月28日前)有效，重新进入将更新

What is Vision?

What is Vision?

Human Visual System

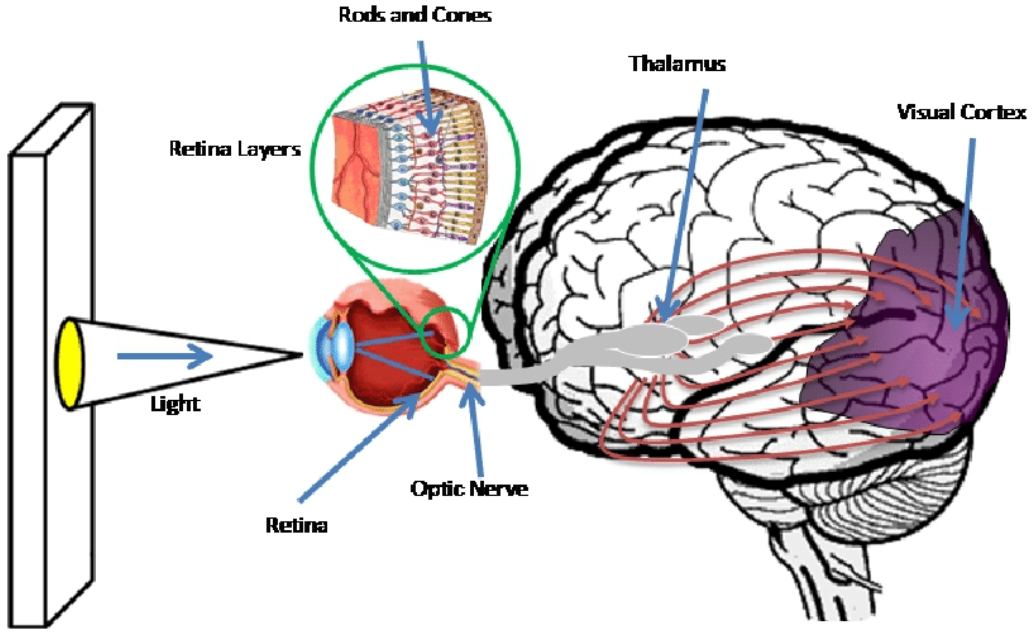
- The visual system comprises
  - Eyes (sensory organ)
  - Parts of the central nervous system
    - Retina layers
    - Optic nerve
    - Optic tract
    - Visual cortex



Maghami, Mohammad Hossein & Sodagar, Amir & Zabihian, Alireza & Asgarian, Farzad. (2012). Implantable Biomedical Devices. 10.5772/50336.

Human Visual System

- The visual system comprises
  - Eyes (sensory organ)
  - Parts of the central nervous system
    - Retina layers
    - Optic nerve
    - Optic tract
    - Visual cortex



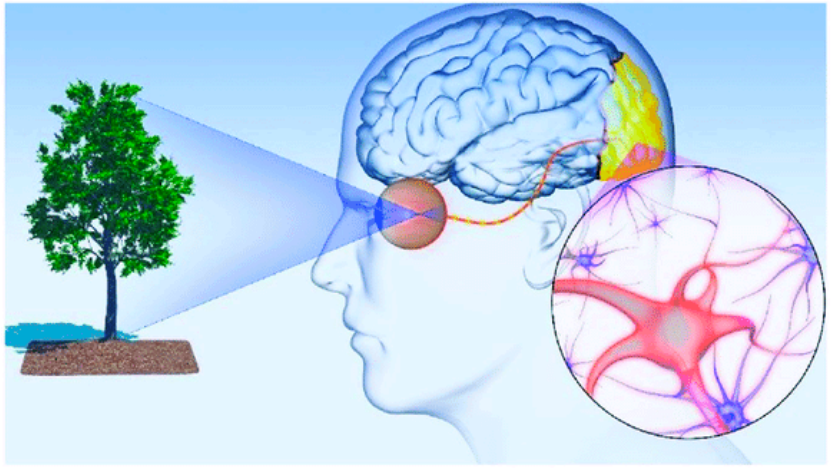
- Visual pathway: visual field→retina→optic nerve →…→optic tract→… →visual cortex

Maghami, Mohammad Hossein & Sodagar, Amir & Zabihian, Alireza & Asgarian, Farzad. (2012). Implantable Biomedical Devices. 10.5772/50336.

Human Visual System

- 83% information comes from vision (11% from audio, the others from smell, touch and taste).

- Carry outs a number of complex tasks:
  - visual sensation
  - visual perception
  - and visual motor coordination.



Wikipedia contributors. "Visual system." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 18 Jan. 2022. Web. 22 Feb. 2022.
Deng, Wei & Zhang, Xiujuan & Jia, Ruofei & Huang, Liming & Zhang, Xiaohong & Jie, Jiansheng. (2019). Organic molecular crystal-based photosynaptic devices for an artificial visual-perception system. NPG Asia Materials. 11. 77. 10.1038/s41427-019-0182-2.

Our Visual System Needs to Do

- the reception of light
- the formation of monocular neural representations
- color vision
- stereopsis and assessment of distances to and between objects

} Visual sensation

- pattern recognition
- the identification of particular object of interest
- motion perceptions
- the analysis and integration of visual information
- accurate motor coordination under visual guidance
- …

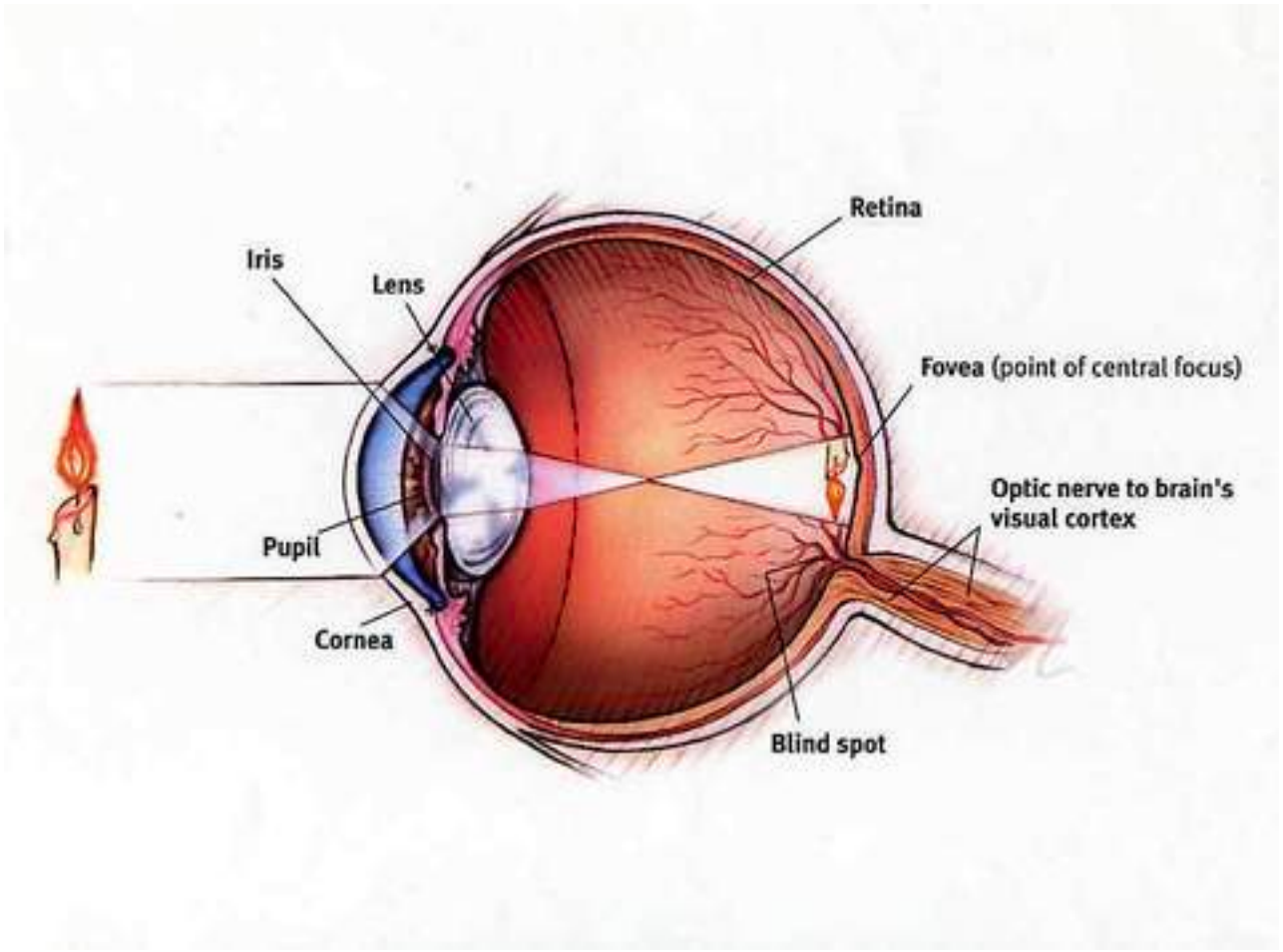
} Visual perception

- Integrating proprioception and vision signals (eye sensory feedbacks)
- Moving body parts as required to accomplish intended actions, *e.g.* eye-hand coordination in writing, eye-muscle coordination in sports
- …

} Visual motor coordination

Wikipedia contributors. "Visual system." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 18 Jan. 2022. Web. 22 Feb. 2022.

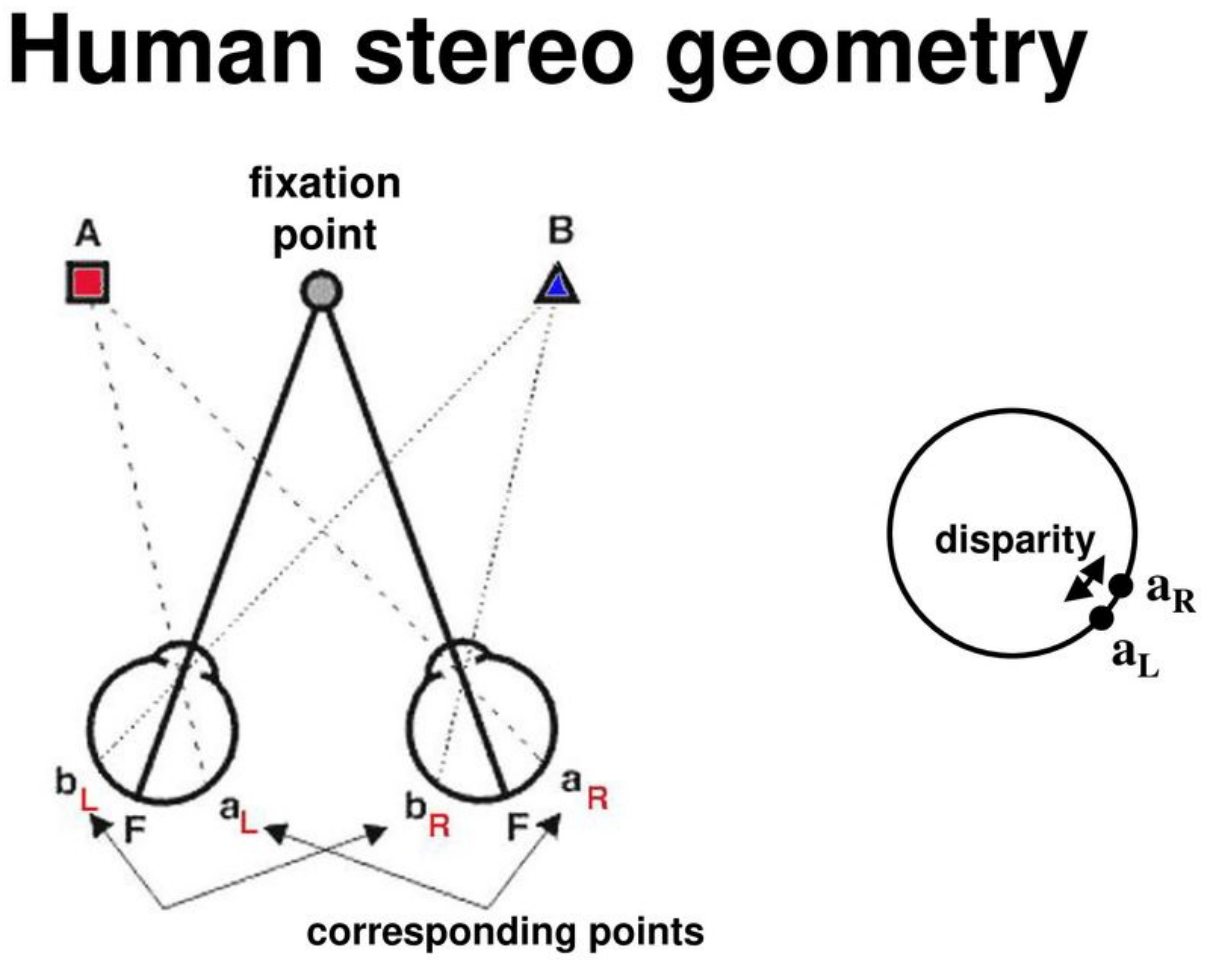
Visual Sensation: Monocular Vision



http://thebrucezone.weebly.com/3-image-formation.html

Visual Sensation: Binocular Vision and Stereopsis

- Human eyes are binocular.
- Senses distances through stereopsis



http://webvision.med.utah.edu/space_perception.html

S. Birchfield, Clemson Univ., ECE 847, http://www.ces.clemson.edu/~stb/ece847

Visual Perception

- Definition of visual perception in *Vision Science*:
  - the process of acquiring knowledge about environmental objects and events by extracting information from the light they emit or reflect.

Palmer, Stephen E. *Vision science: Photons to phenomenology*. MIT press, 1999.

Visual Perception

- Concerns the acquisition of knowledge.
  - Fundamentally a cognitive activity.
  - Distinct from purely optical processes such as photographic ones.
  - Vision = eyes = camera? No, cameras have no perceptual capabilities at all.

Palmer, Stephen E. *Vision science: Photons to phenomenology*. MIT press, 1999.

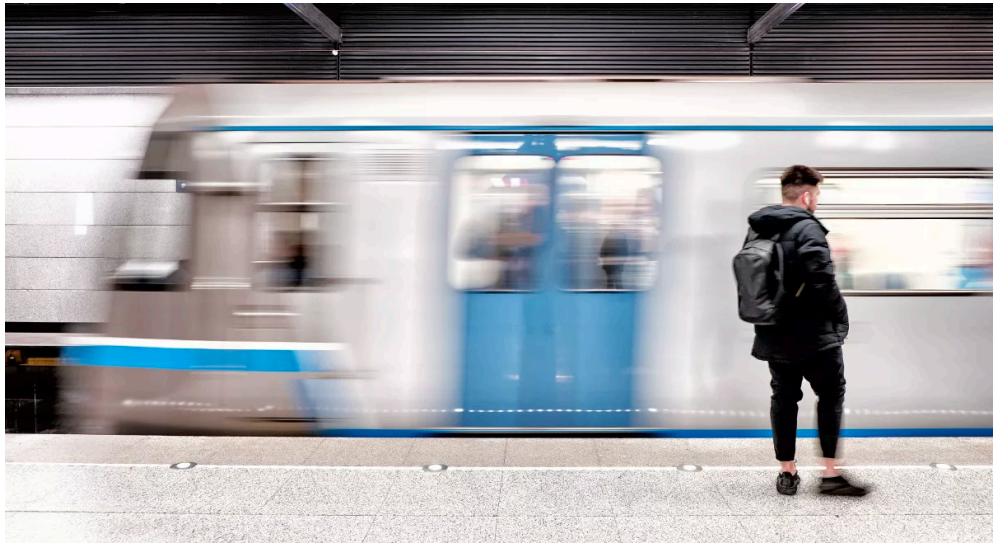
Visual Perception

- Concerns the acquisition of knowledge.
- The knowledge achieved by visual perception concerns objects and events in the environment.

Palmer, Stephen E. *Vision science: Photons to phenomenology*. MIT press, 1999.

Examples of Perception: Motion Perception

- Motion perception:the ability of the nervous system to discern the distance and speed of a moving object in relation to the **eye** that is seeing the object.

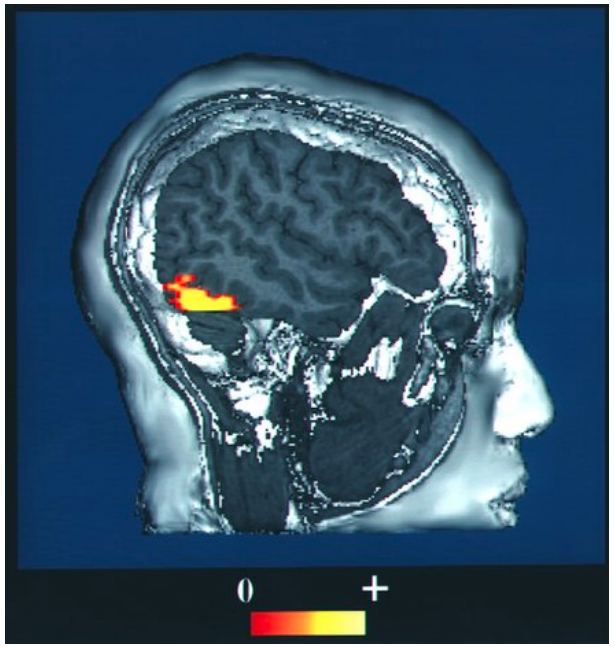


Wikipedia contributors. "Visual system." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 18 Jan. 2022. Web. 22 Feb. 2022.
Hülsdünker, Thorben, Martin Ostermann, and Andreas Mierau. "The speed of neural visual motion perception and processing determines the visuomotor reaction time of young elite table tennis athletes." *Frontiers in behavioral neuroscience* 13 (2019): 165.

Examples of Perception: Pattern Recognition

- One great example of pattern recognition is facial recognition.

Facial recognition: detect faces, perceive emotion, distinguish similar faces
(Dimitri Otis | Getty Images)



Corresponding area in the brain

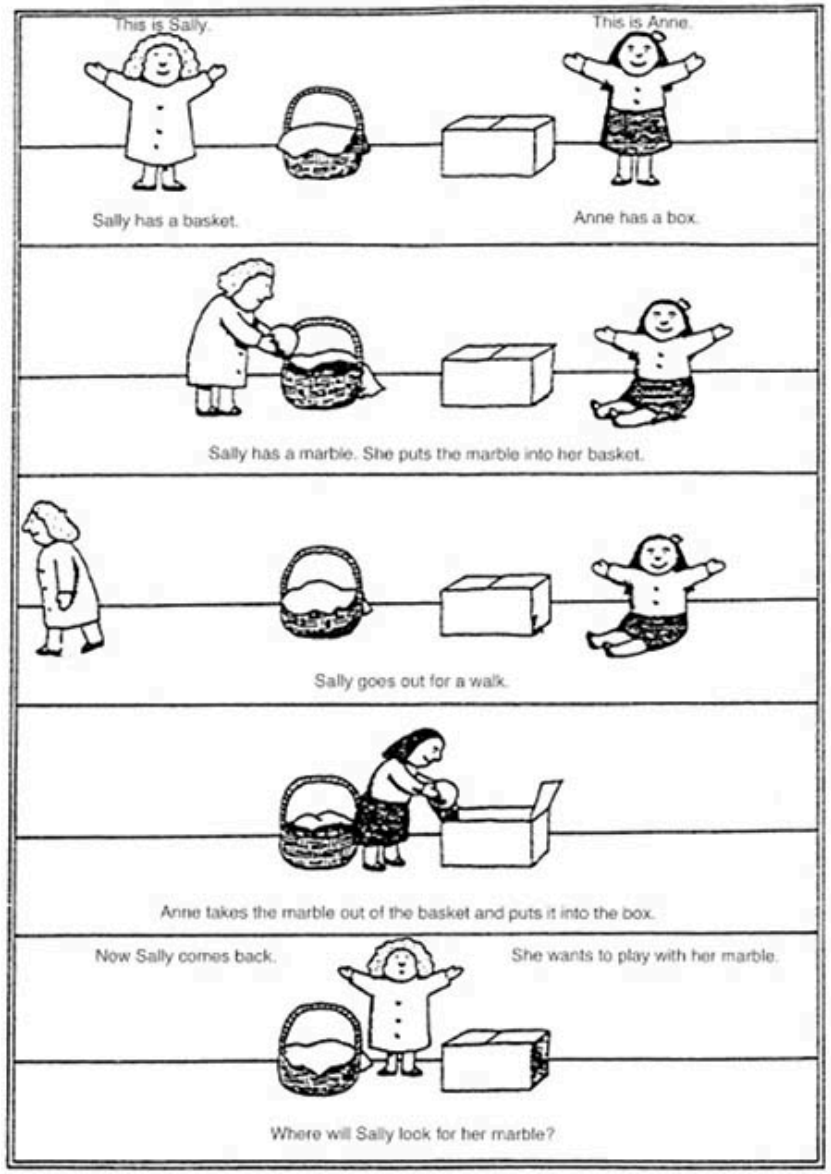
Wikipedia contributors. "Face perception." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 28 Jan. 2022. Web. 22 Feb. 2022.

Examples of Perception: Visual Cognition

- One example of visual cognition is false belief.

- Sally-Anne Test

  Sally takes a marble and hides it in her basket. She then "leaves" the room and goes for a walk. While she is away, Anne takes the marble out of Sally's basket and puts it in her own box. Sally is then reintroduced and the child is asked the key question, the *Belief Question*: "Where will Sally look for her marble?"



Wikipedia contributors. "Sally–Anne test." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 9 Feb. 2022. Web. 22 Feb. 2022.

Kosinski, Michal. "Theory of Mind May Have Spontaneously Emerged in Large Language Models." *arXiv preprint arXiv:2302.02083* (2023).

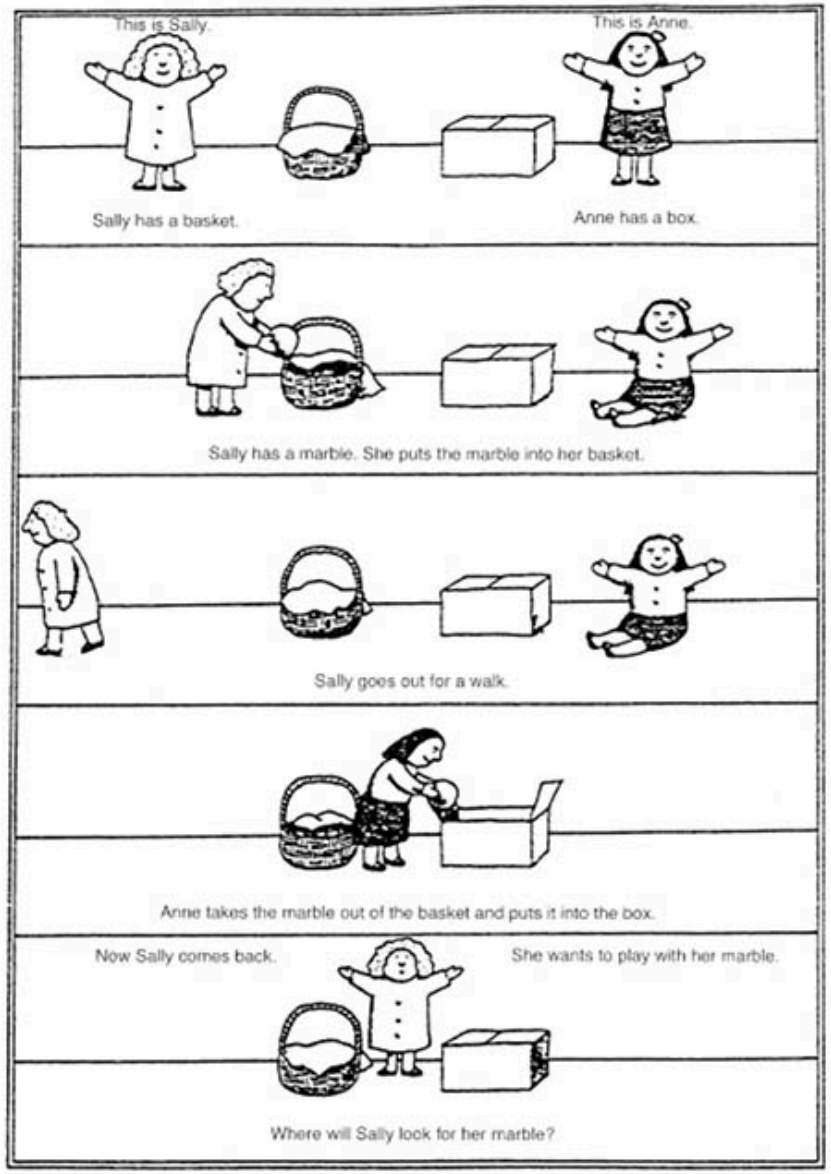
Examples of Perception: Visual Cognition

- One example of visual cognition is false belief.

- Sally-Anne Test

  Sally takes a marble and hides it in her basket. She then "leaves" the room and goes for a walk. While she is away, Anne takes the marble out of Sally's basket and puts it in her own box. Sally is then reintroduced and the child is asked the key question, the *Belief Question*: "Where will Sally look for her marble?"

- **Does ChatGPT have theory of mind?**



Wikipedia contributors. "Sally–Anne test." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 9 Feb. 2022. Web. 22 Feb. 2022.

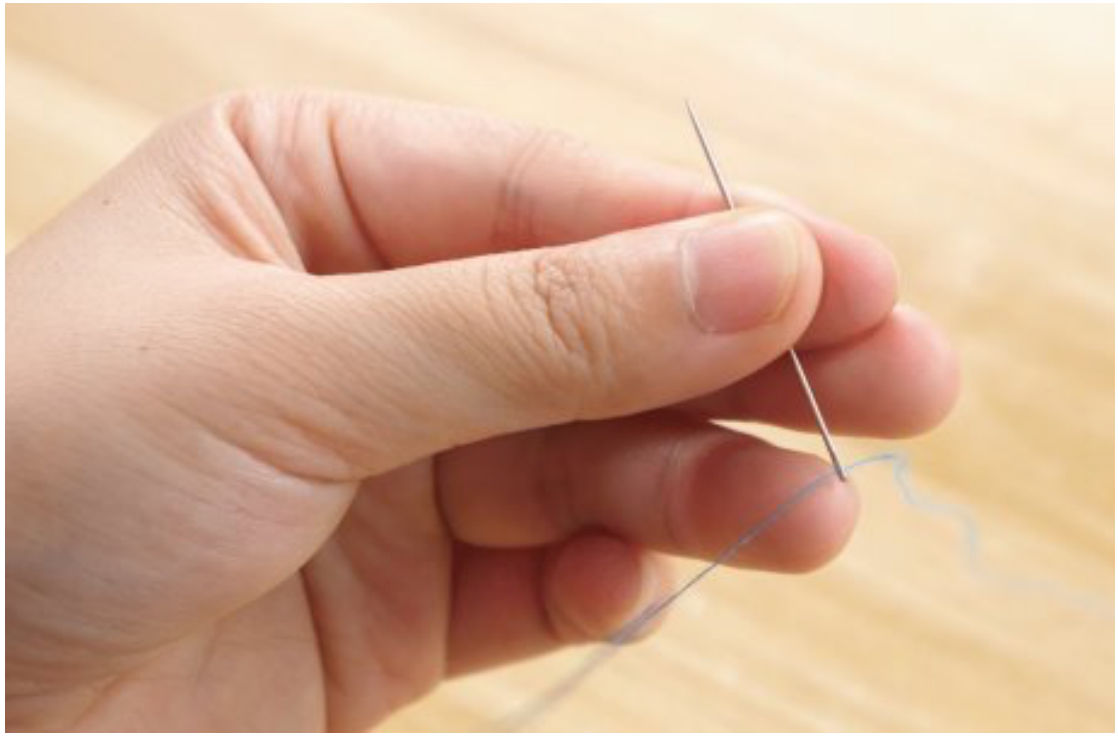
Kosinski, Michal. "Theory of Mind May Have Spontaneously Emerged in Large Language Models." *arXiv preprint arXiv:2302.02083* (2023).

Visual Motor Coordination/Integration

- Visual motor control is the ability to coordinate visual information with motor output, where the eyes provide sensory feedback to adjust body motion.

- It is crucial for coordinating the hands, legs, and the rest of the body's movements with what the eyes perceive.

Examples of Visuomotor coordination: Eye-Hand Coordination

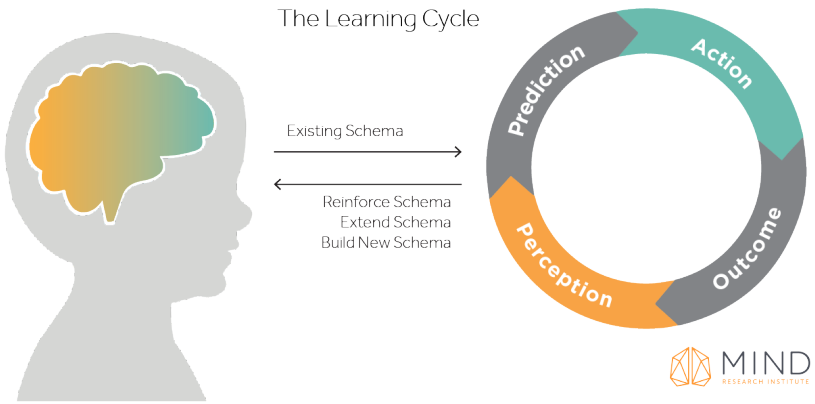


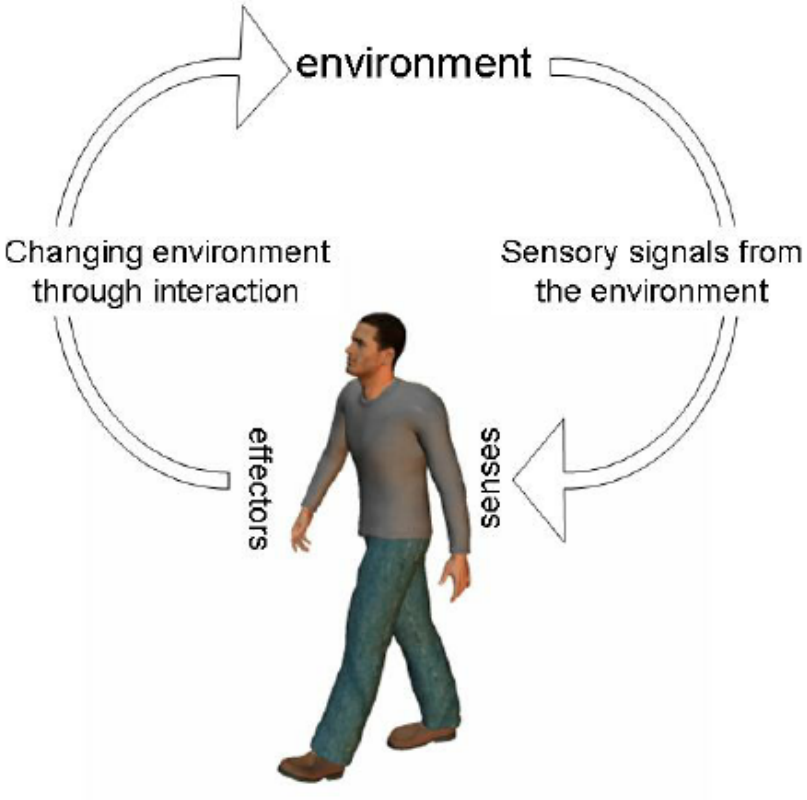
Use vision signal as feedback to perform closed-loop control

More Examples: Running, Balancing, etc.

Perception-Action Loop

- Perceive, forms hypotheses, and then take action to examine.
- Our brain makes sense of the world around us by creating and testing hypotheses about the way the world works.

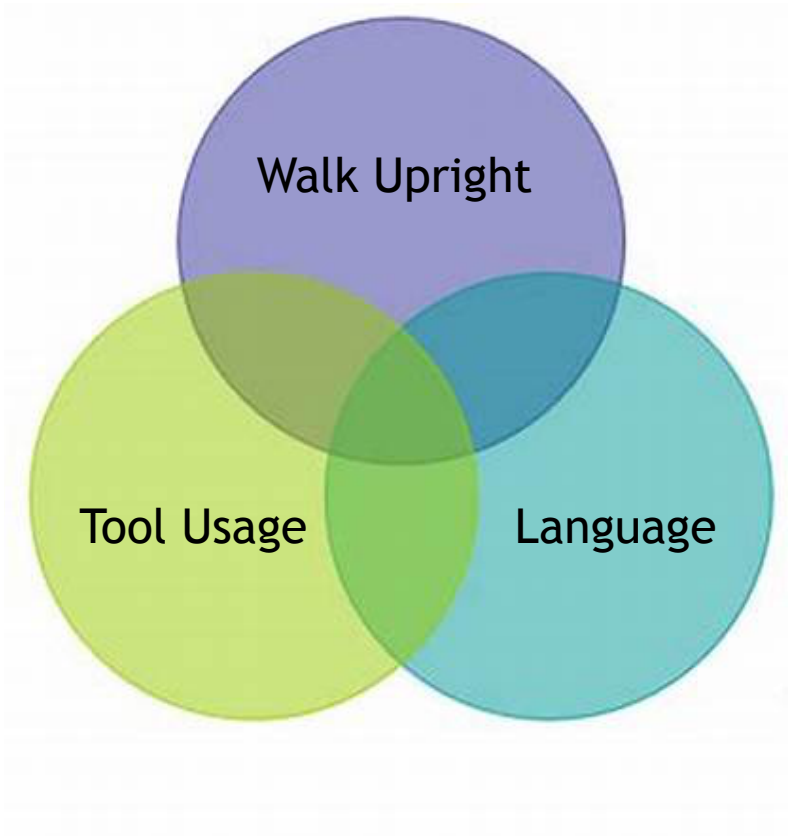




Perception-Action Loop

Vision and Language

The keys to evolution of human intelligence:



The interactions between vision and language:

Talk about what you see

Grounding according to language description

Summary of Human Visual System

- The visual system comprises eyes as sensor organ, which are connected to visual cortex in the brain.

- Visual tasks:
  - sensation
  - processing
  - perception
  - cognition
  - visuomotor coordination
  - interaction with language system
  - and more.

Computer Vision

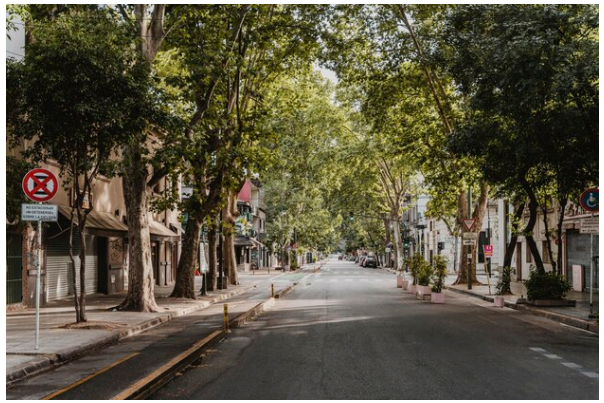
What is Computer Vision?

- Computer vision deals with
  - acquiring
  - processing and analyzing
  - understanding
  - generating or imagining

  visual data, …

Visual Data Acquisition

RGB camera



RGB image

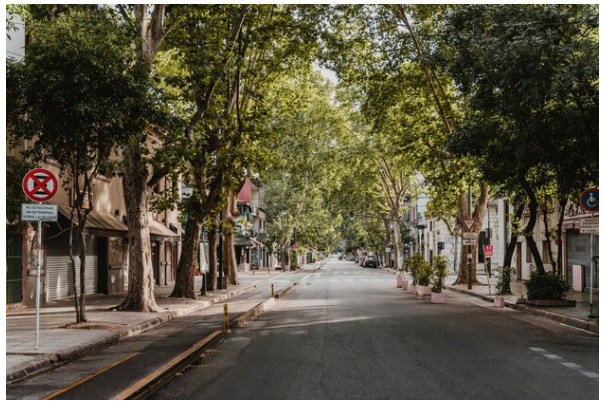
Visual Data Acquisition

- Different types of sensors and visual data

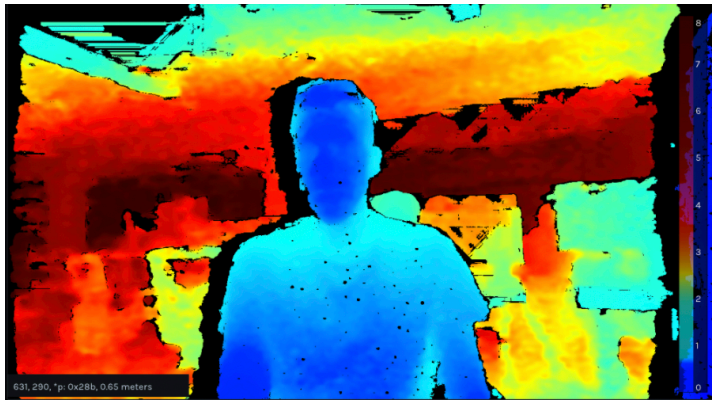
RGB camera

Depth camera

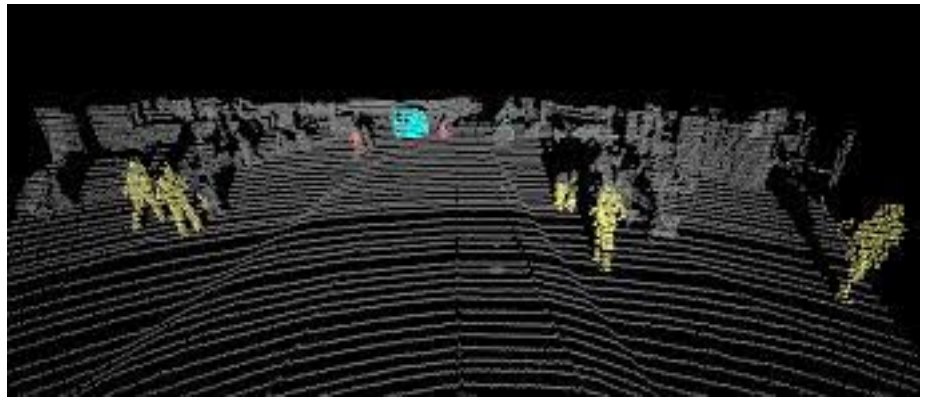
LiDAR



RGB image



Depth image



LiDAR point cloud

Beyond Single Frame and Single View

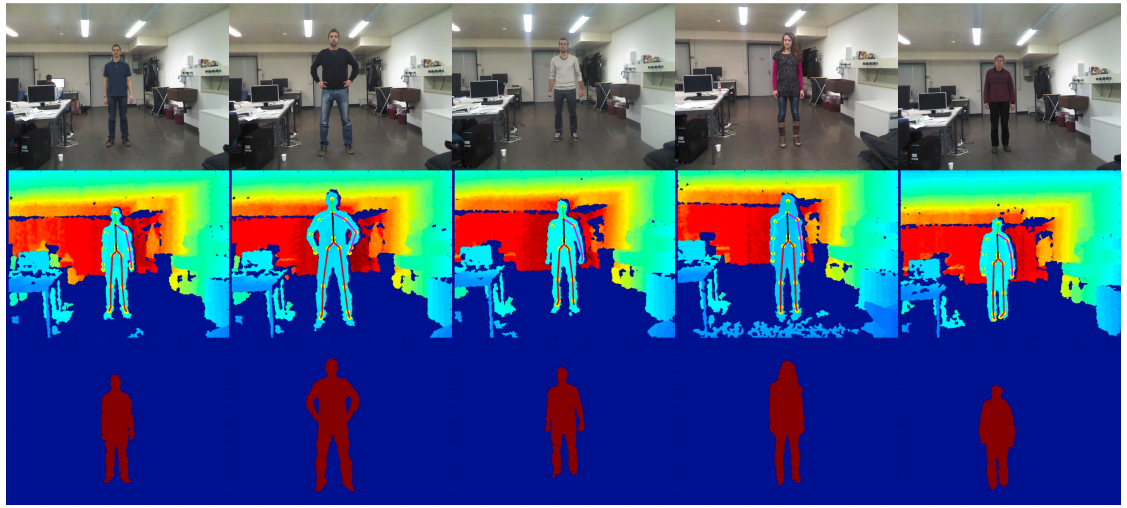
Stereo images

Multiview images

Panoramic images

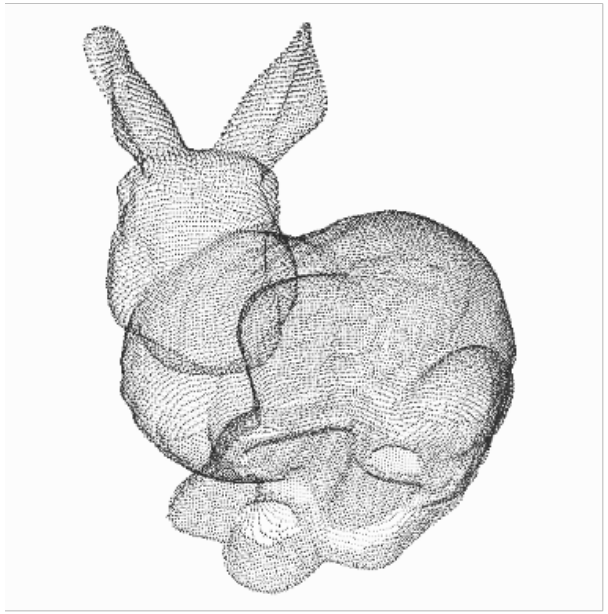
Beyond Single Frame and Single View

- RGB video

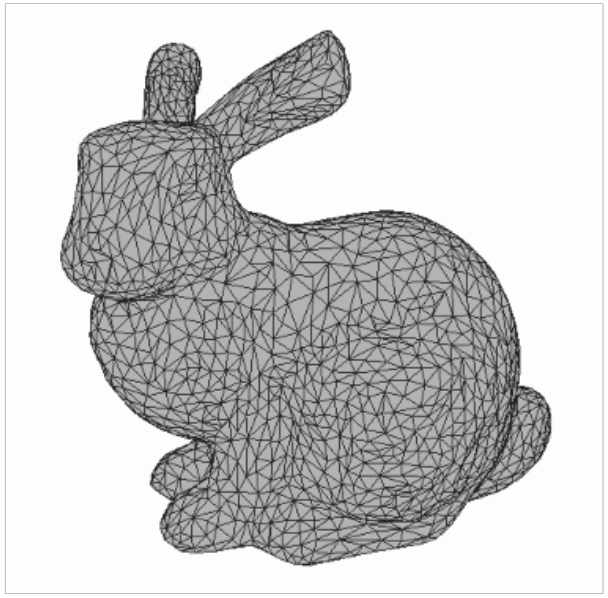


- RGBD video

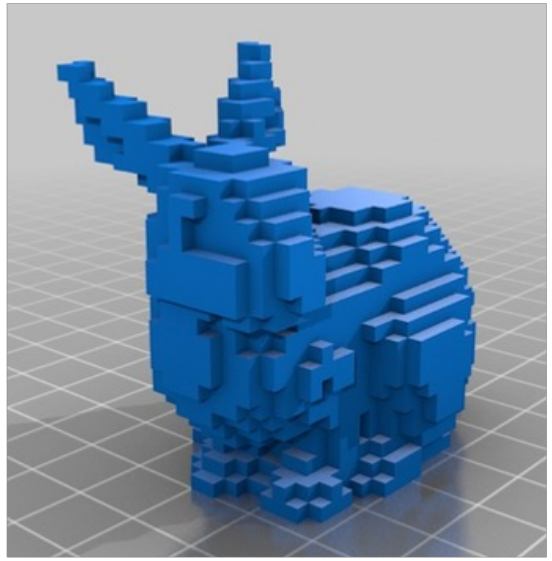
True 3D Visual Data



Point Cloud



Surface Mesh

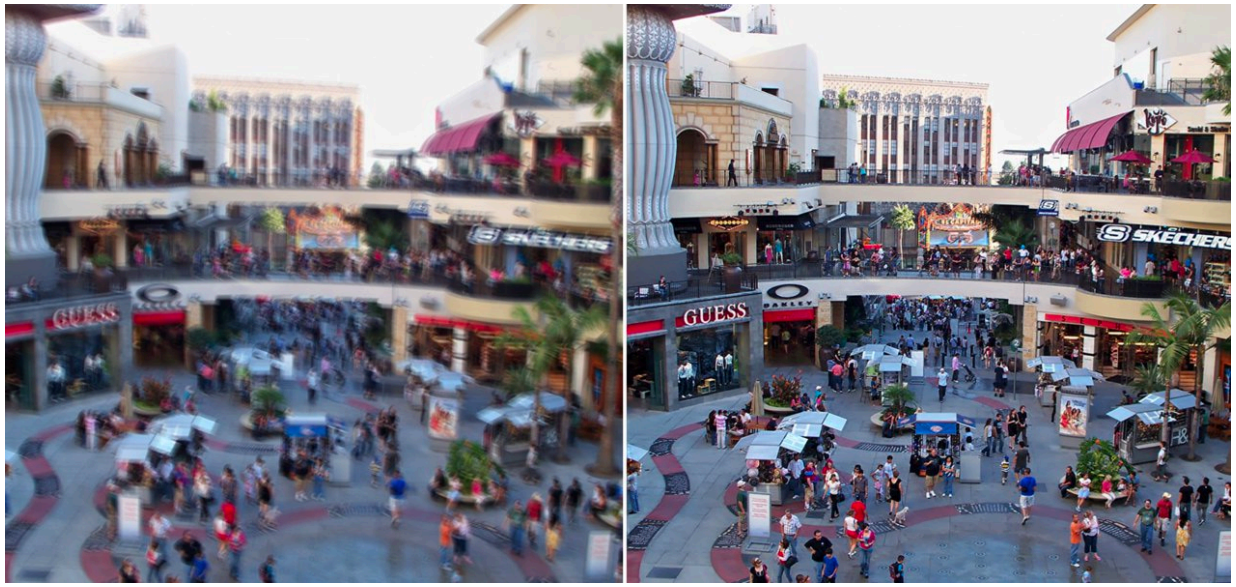


Volumetric

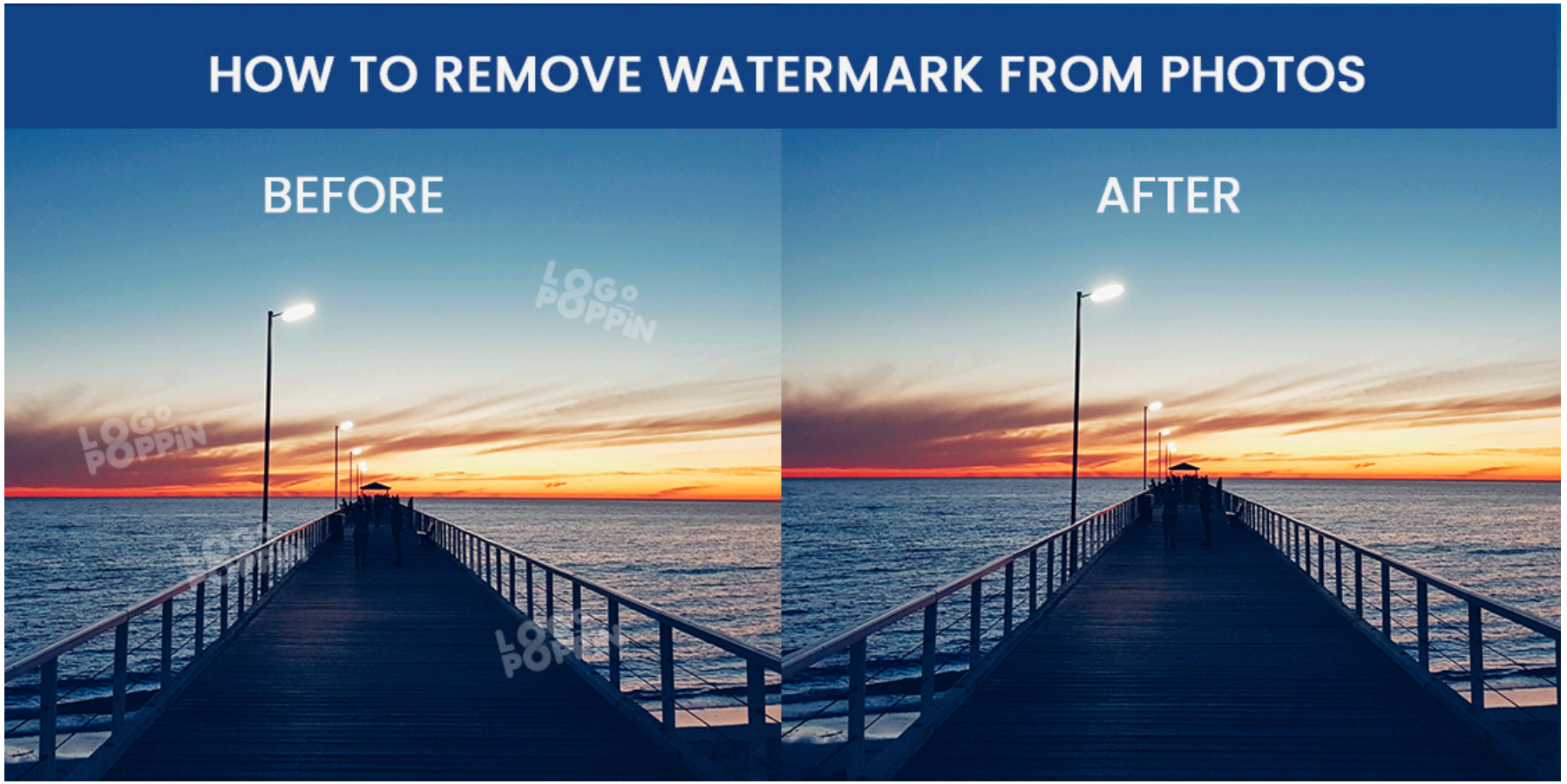
Low-Level Vision: Processing and Feature Extaction

- Low-level vision deals with
  - Image processing
    - image denoising/deblur
    - contrast enhancement
    - …
  - Feature extractions
    - edge/corner detection
    - optical flow/correspondence

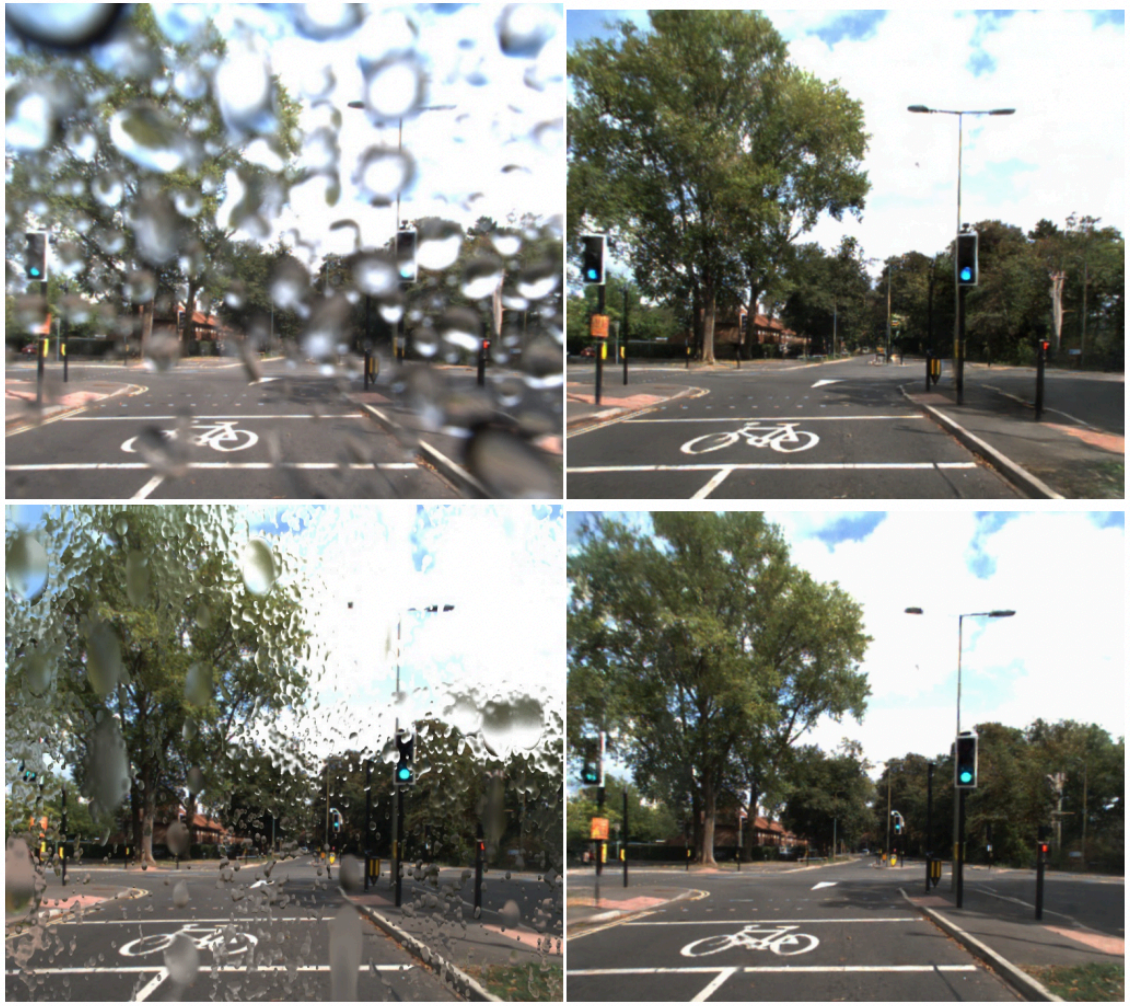
Applications: Motion Deblurring



Applications: Watermark Removal



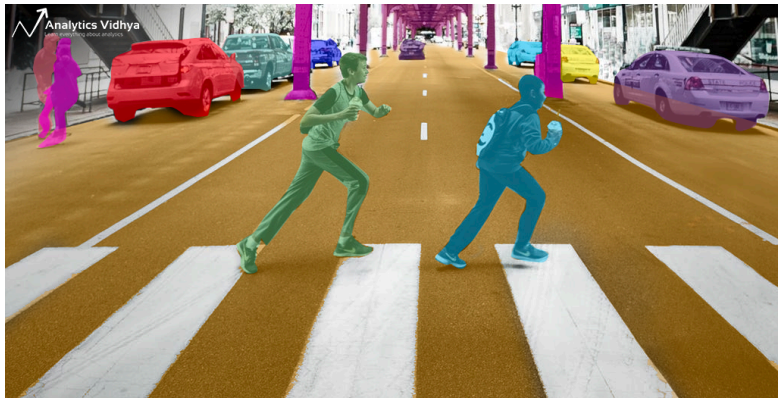
Applications: De-Raining

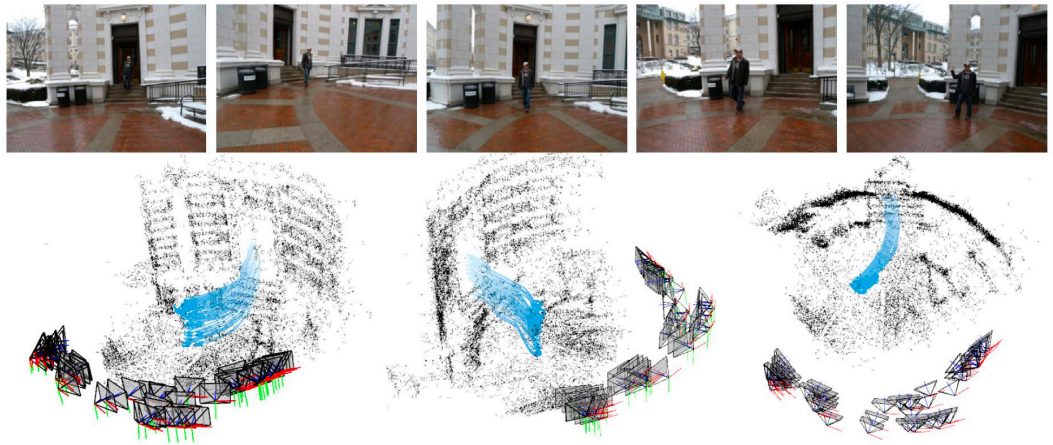


Porav, Horia, Tom Bruls, and Paul Newman. "I can see clearly now: Image restoration via de-raining." *2019 International Conference on Robotics and Automation (ICRA)*. IEEE, 2019.

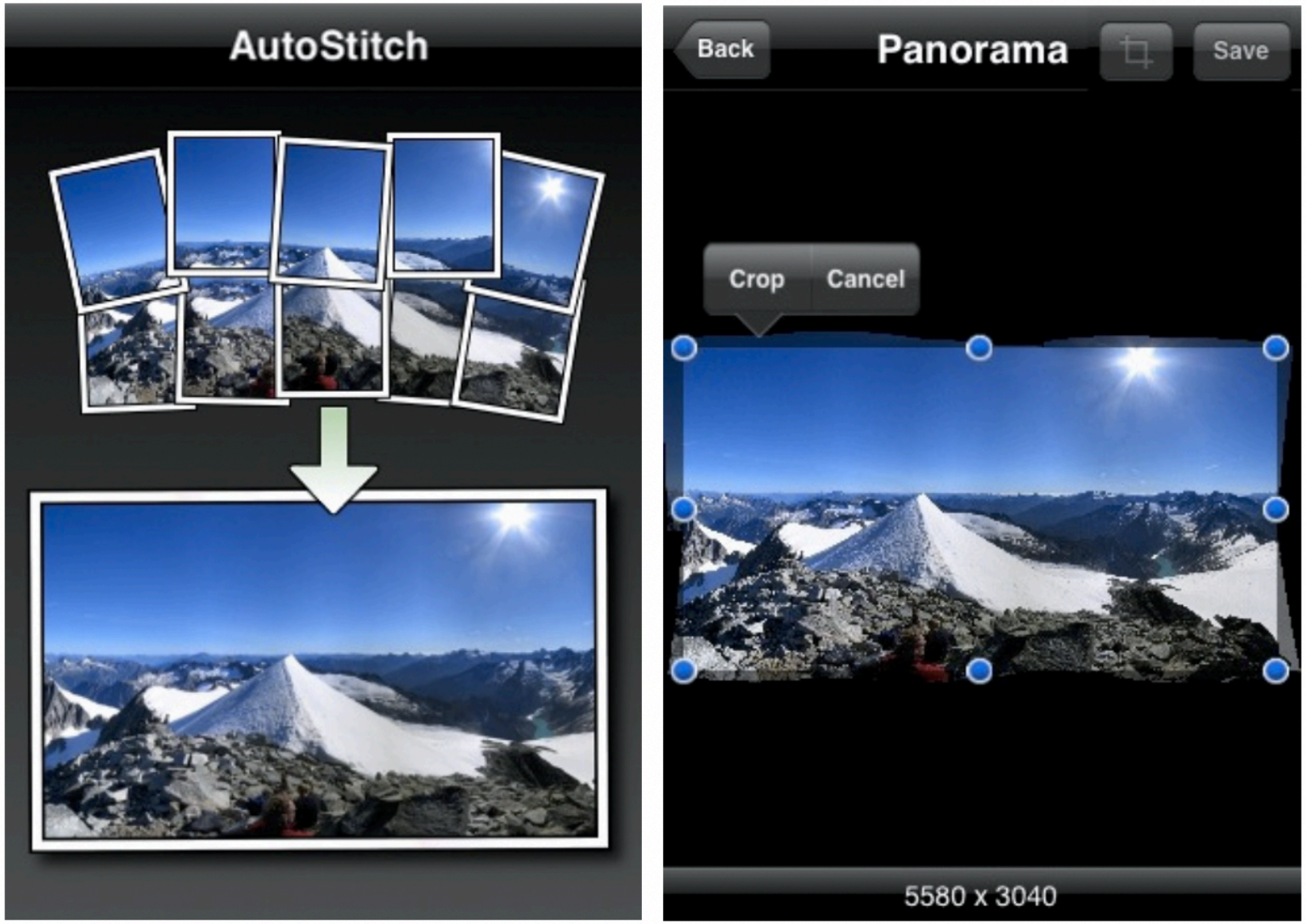
Mid-Level Vision

- Mid-level vision begins to make inferences about the world based on those measurements.
  - Analyzing local structures (grouping based segmentation, motion analysis, etc.)
  - 3D reconstruction using features obtained from the low-level vision.



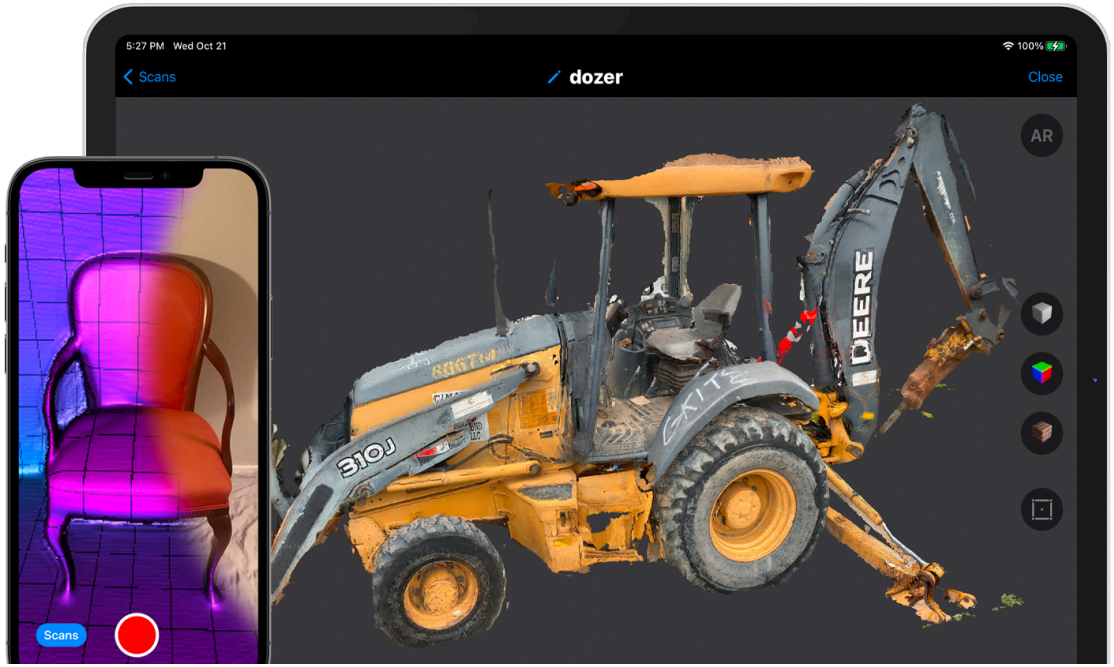


Applications: Panoramic Photography



Applications: 3D Object Scanner

Traditional line scanner



iPad Pro LiDar Scanner App

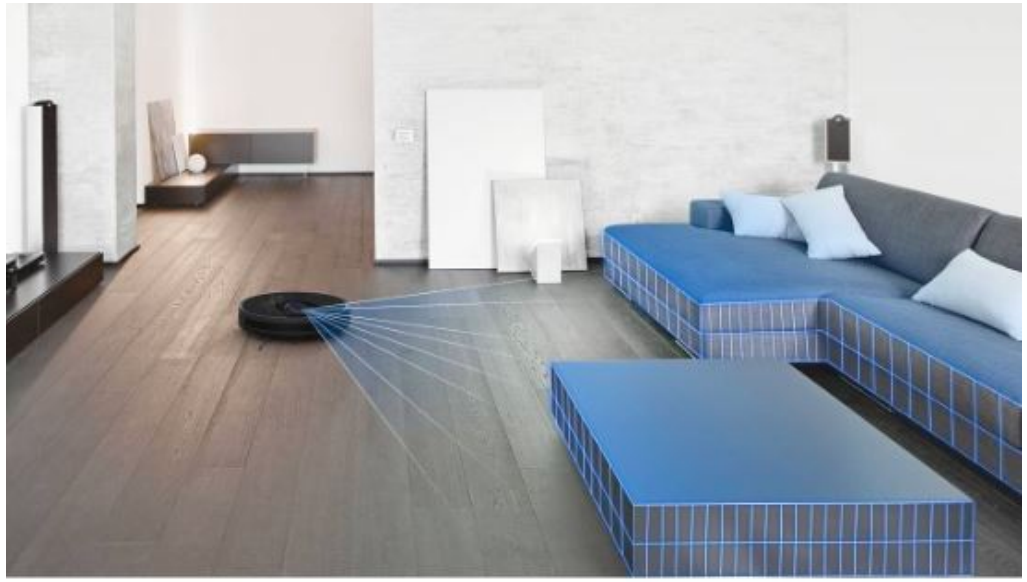
Applications: 3D Modeling of Landmarks

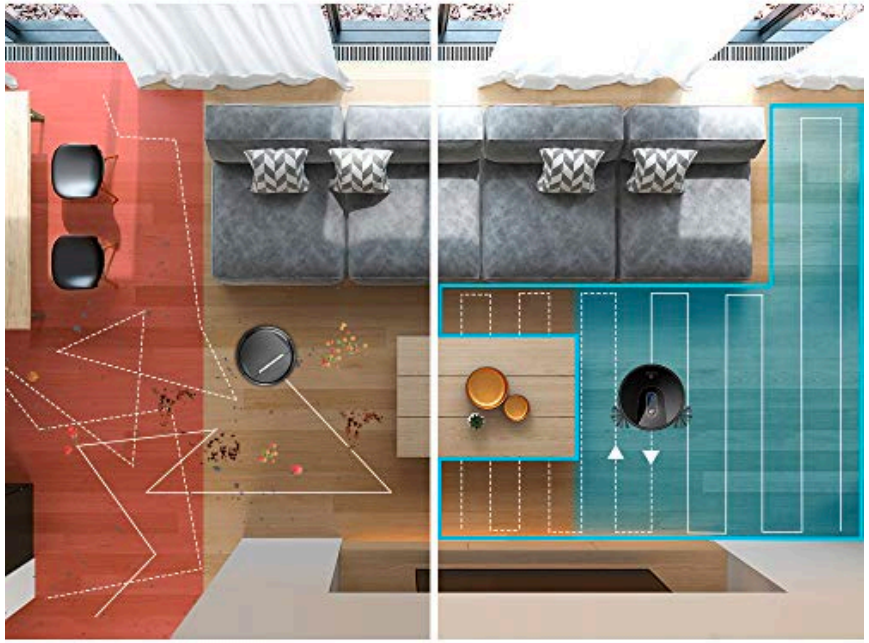
Building Rome in a day.

Agarwal, S., Furukawa, Y., Snavely, N., Simon, I., Curless, B., Seitz, S. M., & Szeliski, R. (2011). Building rome in a day. *Communications of the ACM*, *54*(10), 105-112.

Applications: SLAM

- SLAM = Simultaneous localization and mapping

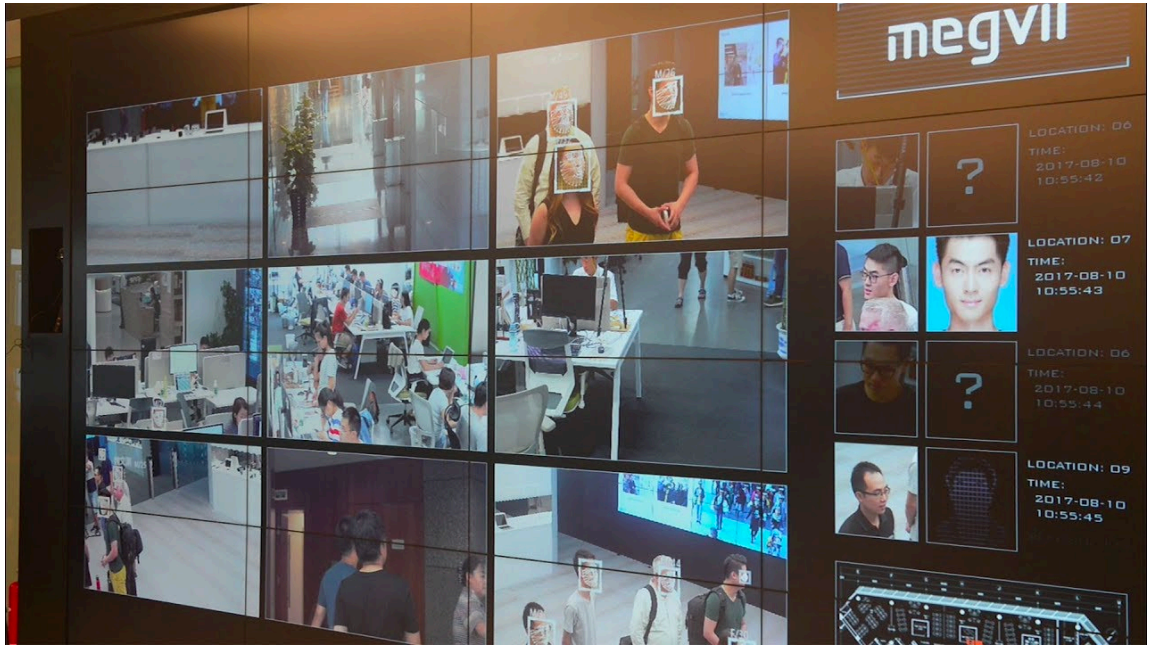


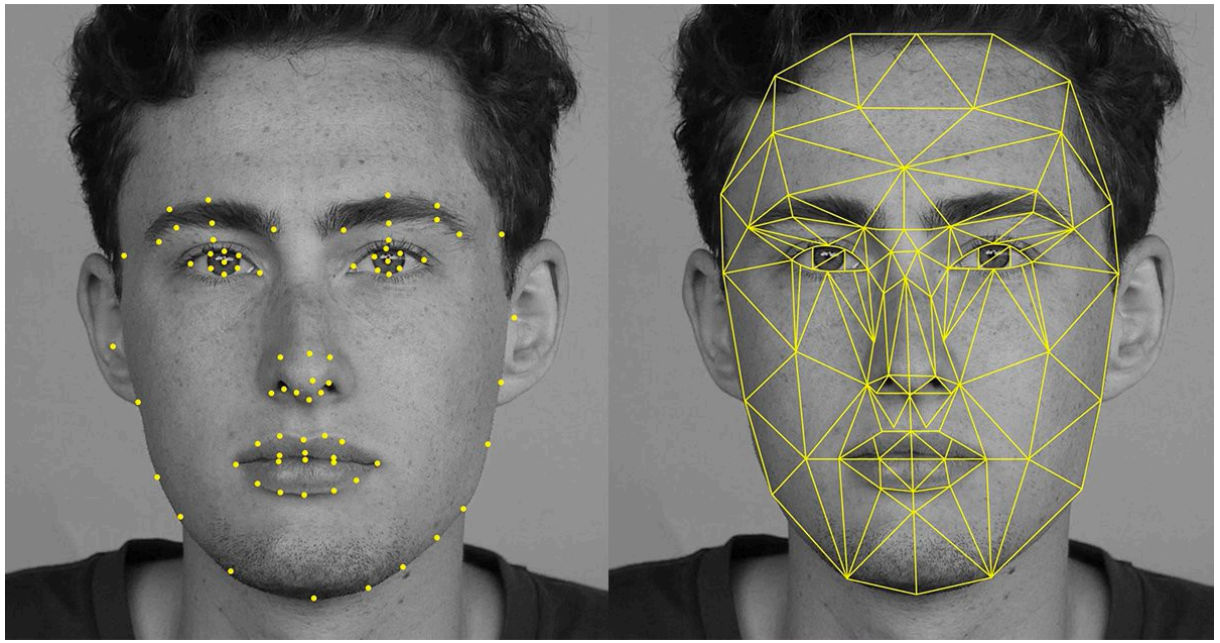


High-Level Vision: Understanding

- High-level vision analyzes the structure of the external world that produced those images and generates **semantic representation/interpretations**, including
  - object recognition and detection
  - scene understanding
  - activity understanding
  - etc.

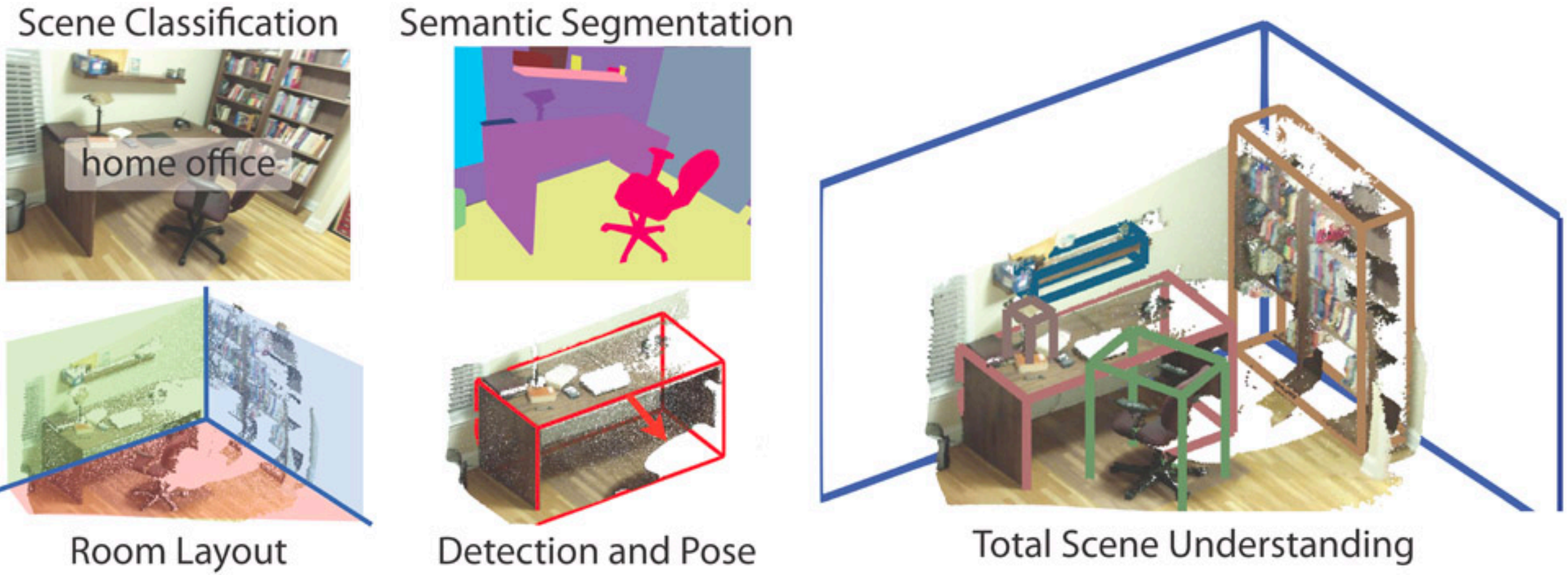
Applications: Facial Recognition





https://github.com/3ba2ii/Facial-Keypoints-Detector-CVND

Task: Scene Understanding



Song, Shuran, Samuel P. Lichtenberg, and Jianxiong Xiao. "Sun rgb-d: A rgb-d scene understanding benchmark suite." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2015.

Applications: Augmented Reality

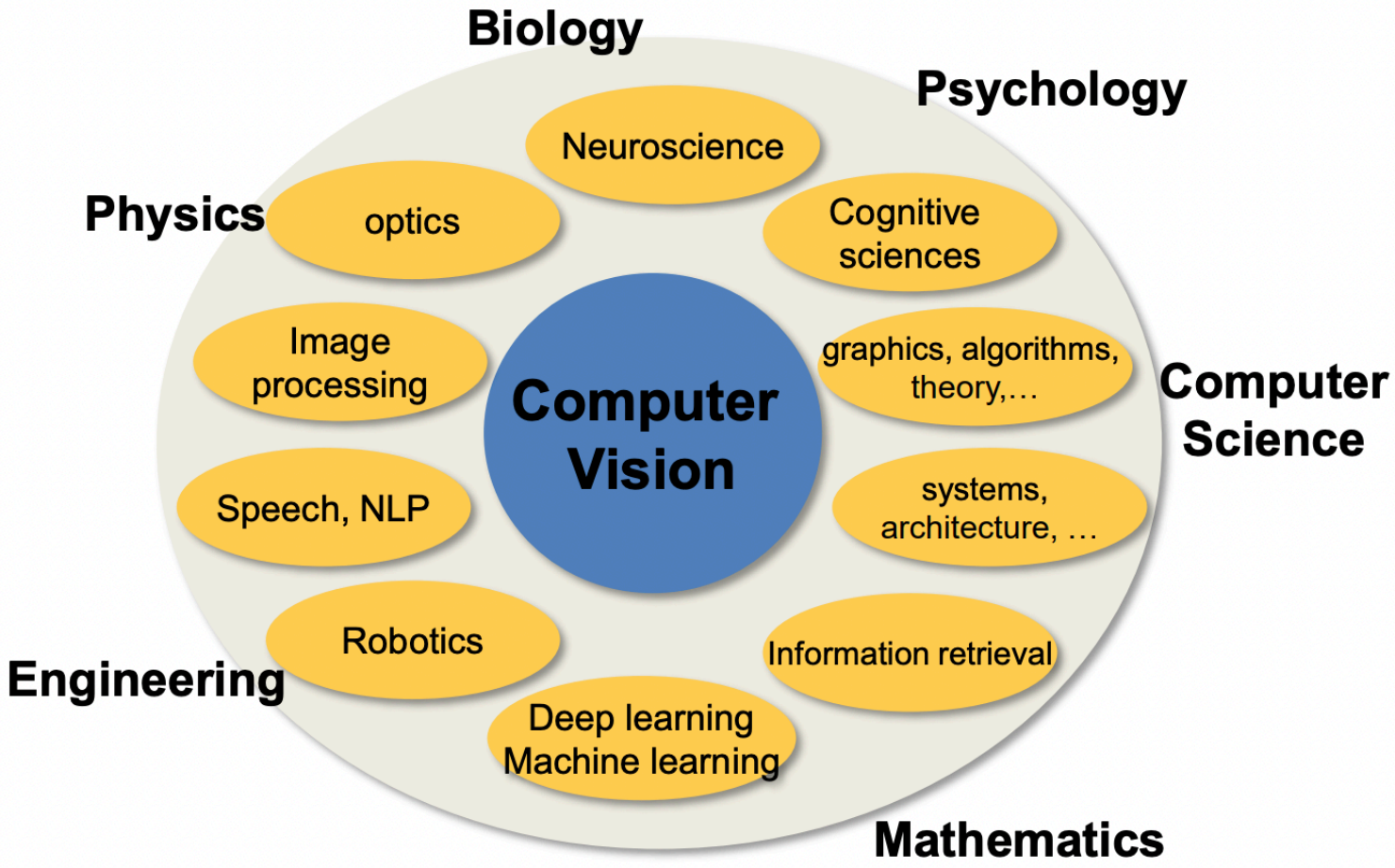
Assisting furniture layout

E-Learning

Applications: Amazon Go

- Cashier-free store. A very complicated vision system.

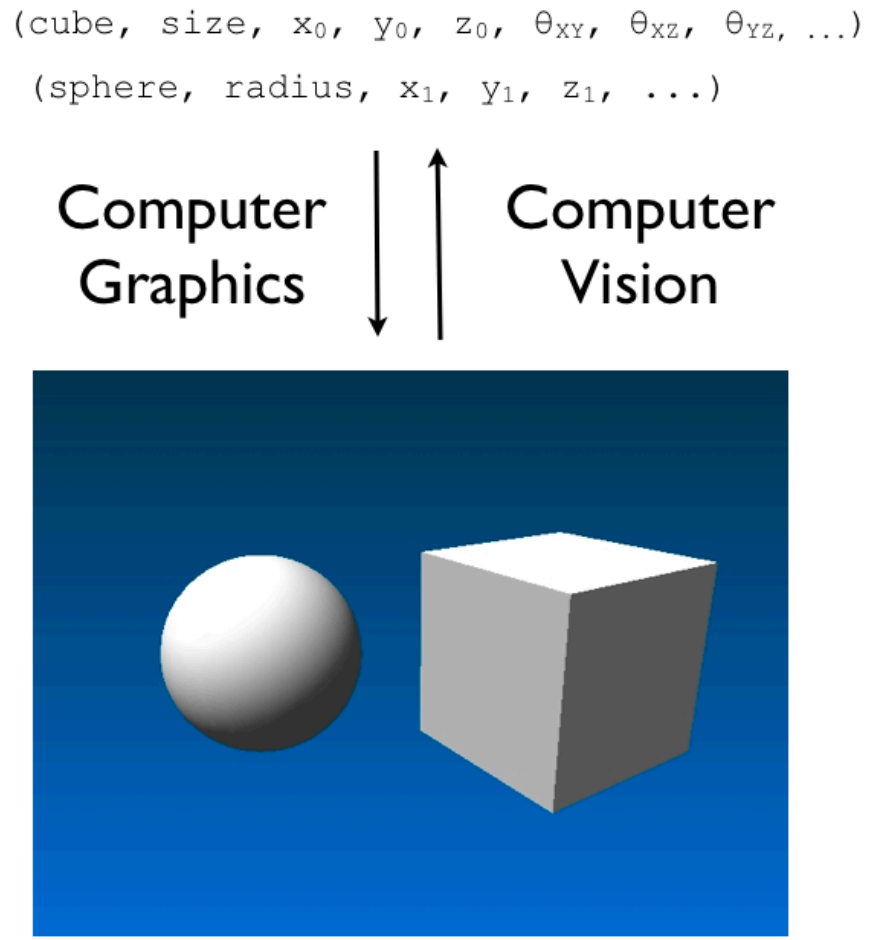
Interdisciplinary Nature of Computer Vision



Borrowed from Stanford CS231N Lecture 01.

Vision and Graphics

- Graphics:
  - go from the parameter space to the image space (rendering)
- Vision:
  - inverse graphics
  - more ill-posed
  - arguably harder



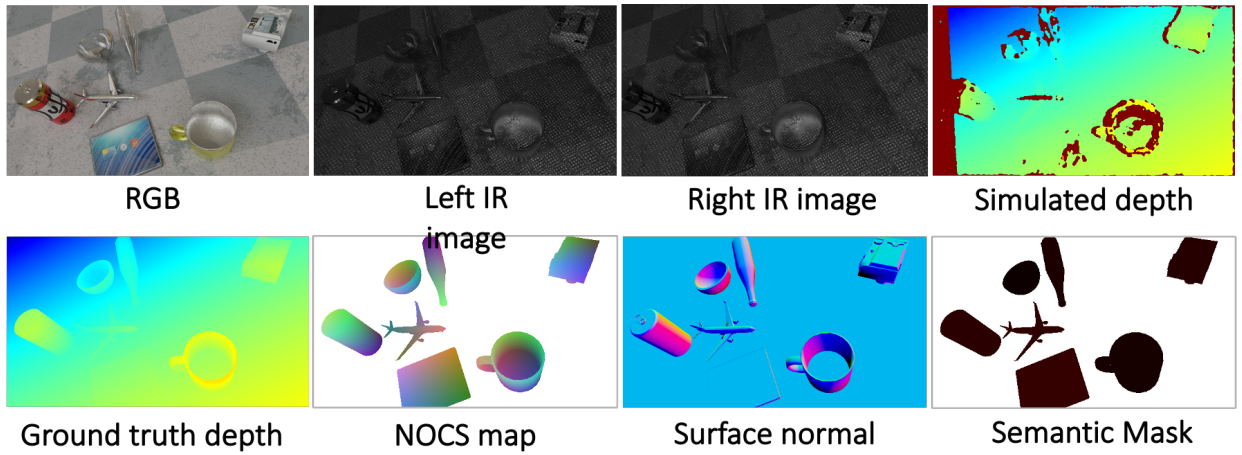
http://aboutintelligence.blogspot.com/2009/01/computer-vision-vs-computer-graphics.html

Leveraging Graphics for Vision

Synthetic data comes with free labels!

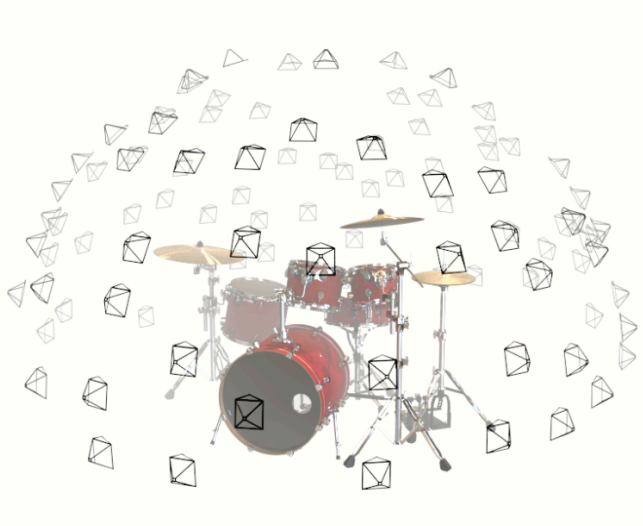
For outdoor semantic segmentation

For table-top depth/pose/surface normal prediction (ECCV 2022 from EPIC Lab)



Vision does Graphics Job

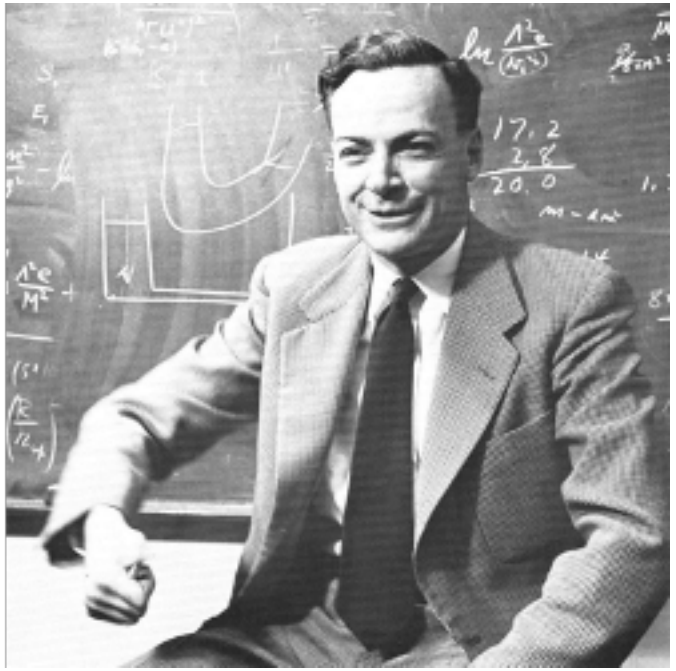
Training network to reproduce all input views of the scene

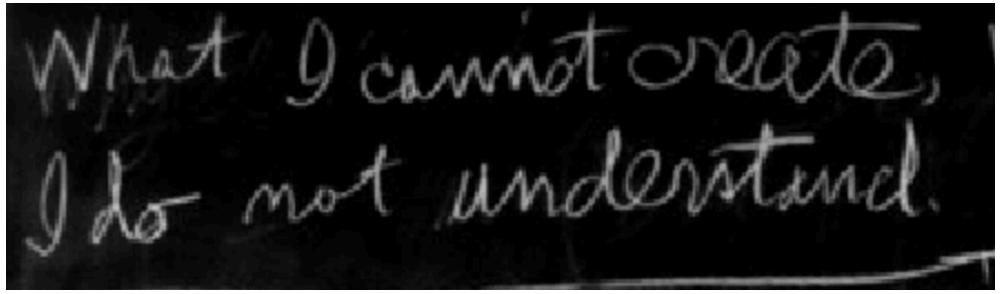


Neural Radiance Field (NeRF)

A brief intro to NeRF: https://www.youtube.com/watch?v=JuH79E8rdKc

Visual Content Generation





- Generation or imagination is not a core function of human visual system.
- Richard Feynman: “What I cannot create, I do not understand”
- Thus, computer vision also deals with generation.

Applications: Human Face Generation

StyleGAN for facial image generation

Karras, Tero, Samuli Laine, and Timo Aila. "A style-based generator architecture for generative adversarial networks." *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*. 2019.

Applications: Facial Reenactment

Siarohin, A., Lathuilière, S., Tulyakov, S., Ricci, E., & Sebe, N. (2019). First order motion model for image animation. Advances in Neural Information Processing Systems, 32.

Applications: Style Transfer

Content target

+

Style reference

=

Combination image

Neural Style Transfer

https://gitee.com/happyjoejoe/deep-learning-with-python-notebooks/blob/master/8.3-neural-style-transfer.ipynb

Applications: Text-to-Image Diffusion Model

Imagen: https://imagen.research.google/

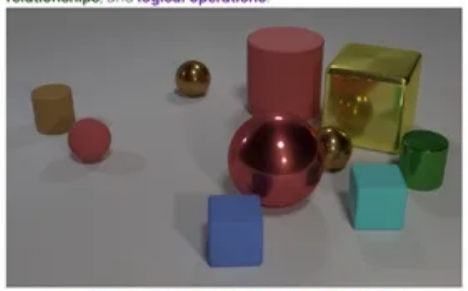
More Vision Language Tasks

- Referring Expression
  - ReferIt Game, *EMNLP 2014*
  - RefCOCO, *ECCV 2016*
  - GuessWhat?!, *CVPR 2017*
- Visual Dialog
  - VisDial, *CVPR 2017*
  - Image Grounded Conversation, *ACL 2017*
  - Dialog-based Image Retrieval, *NIPS 2018*
- Text 2 image/video

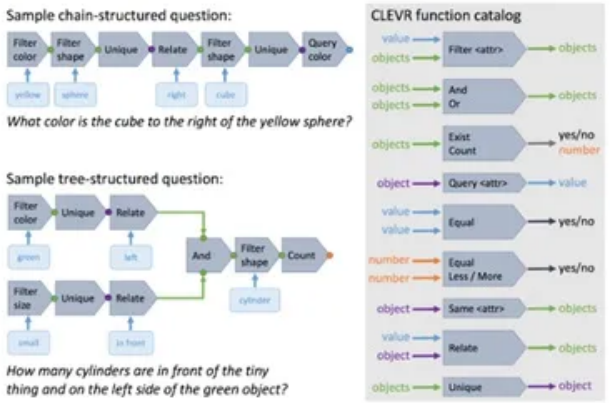
User1: My son is ahead and surprised!
User2: Did he end up winning the race?
User1: Yes he won, he can't believe it!

Intersection between computer vision and natural language processing (NLP)

Questions in CLEVR test various aspects of visual reasoning including attribute identification, counting, comparison, spatial relationships, and logical operations.



Q: Are there an equal number of large things and metal spheres?
Q: What size is the cylinder that is left of the brown metal thing that is left of the big sphere?
Q: There is a sphere with the same size as the metal cube; is it made of the same material as the small red sphere?
Q: How many objects are either small cylinders or red things?



Johnson, Justin, Bharath Hariharan, Laurens van der Maaten, Li Fei-Fei, C. Lawrence Zitnick, and Ross Girshick. "Clevr: A diagnostic dataset for compositional language and elementary visual reasoning." In *CVPR*. 2017.

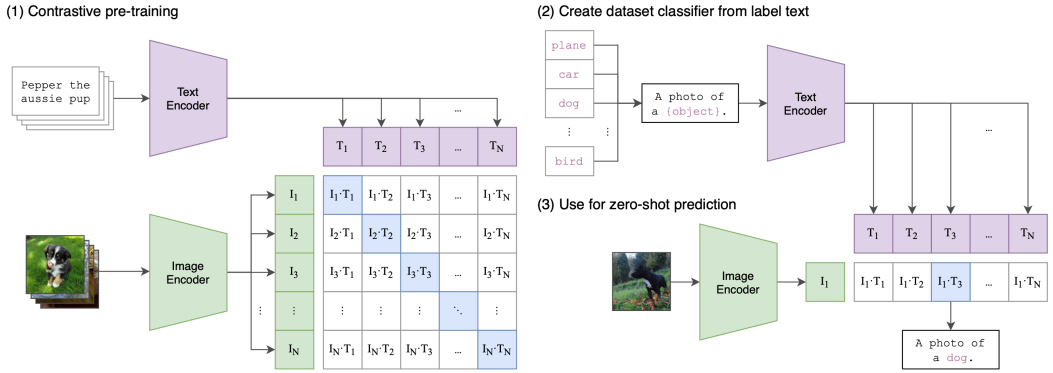


Figure 1. Summary of our approach. While standard image models jointly train an image feature extractor and a linear classifier to predict some label, CLIP jointly trains an image encoder and a text encoder to predict the correct pairings of a batch of (image, text) training examples. At test time the learned text encoder synthesizes a zero-shot linear classifier by embedding the names or descriptions of the target dataset's classes.

What Else in Computer Vision?

- Computer vision deals with
  - acquiring
  - processing and analyzing
  - understanding
  - generating or imagining

  visual data, and, what's more,
  - providing visual feedbacks for body motions
  - helping making decisions

  for embodied agents.

Introduction to Computer Vision

Next week: Lecture 2,
Classic Vision I