Deep Learning for Computer Vision

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Mehta Family School of Data Science and Artificial Intelligence
IIT Guwahati
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Outline

- Computer Vision: What and Why?

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- Brief history of Computer Vision

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- This Course: structure, organization

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- This Course: structure, organization
- Logistics and Resources

What is Computer Vision?

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  - Extract meaningful information from the visual world via digital images and videos

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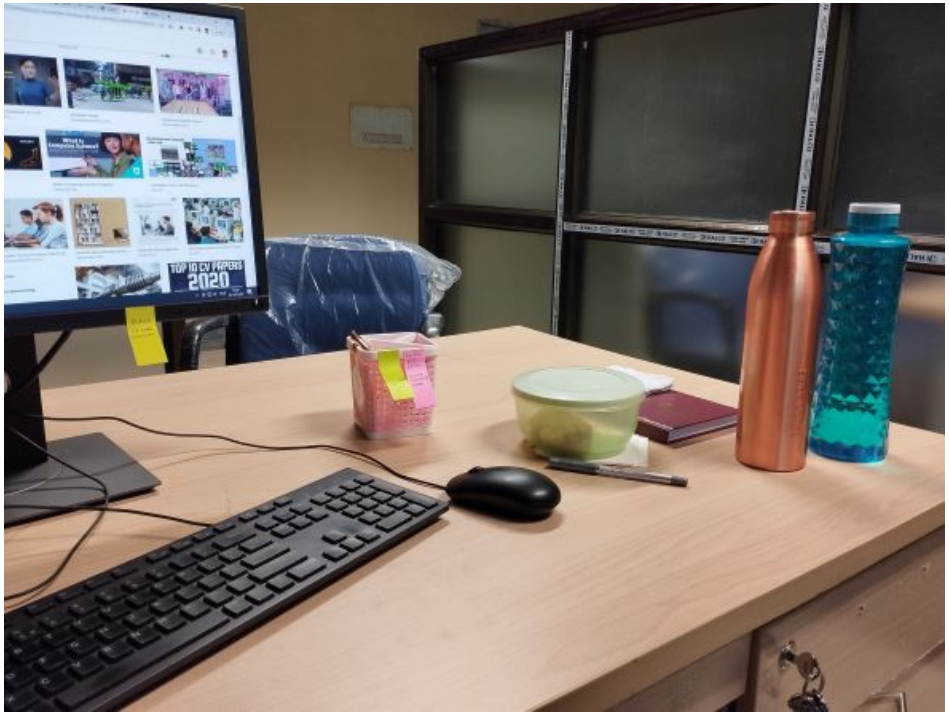
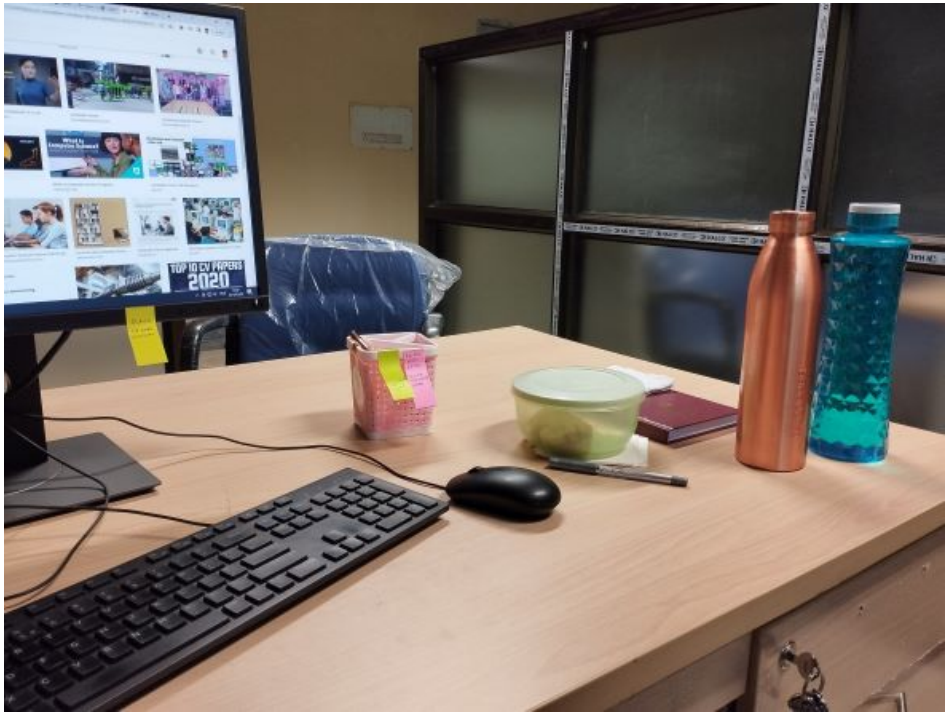
- Field of AI that enables machines to
  - Extract meaningful information from the visual world via digital images and videos
  - And, recommend appropriate actions based on that
- Simply, enabling machines to see as humans do!

What is Computer Vision?



What is Computer Vision?



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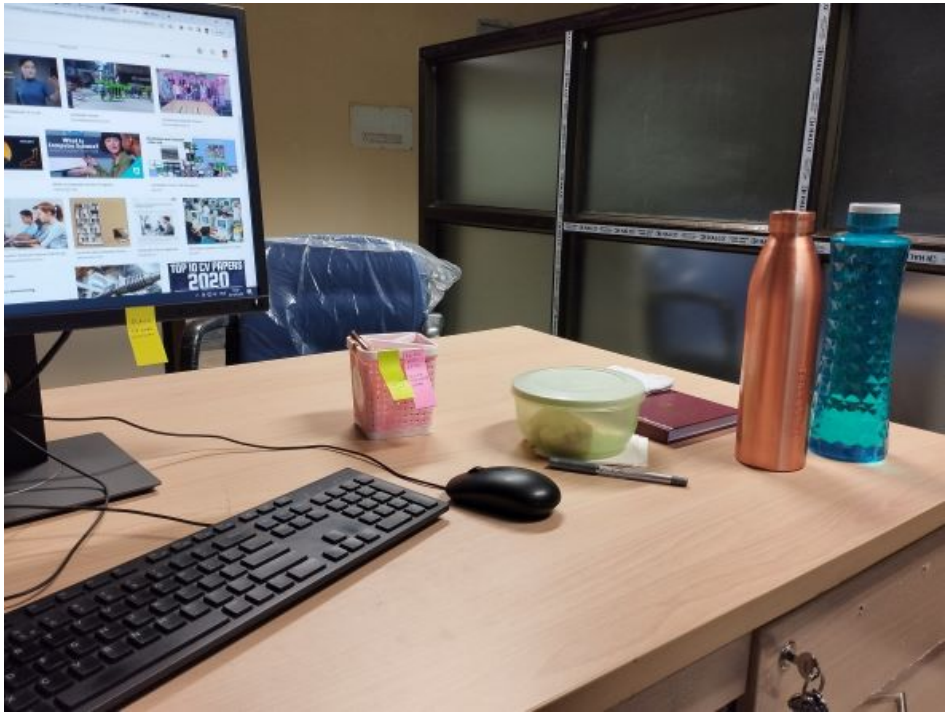

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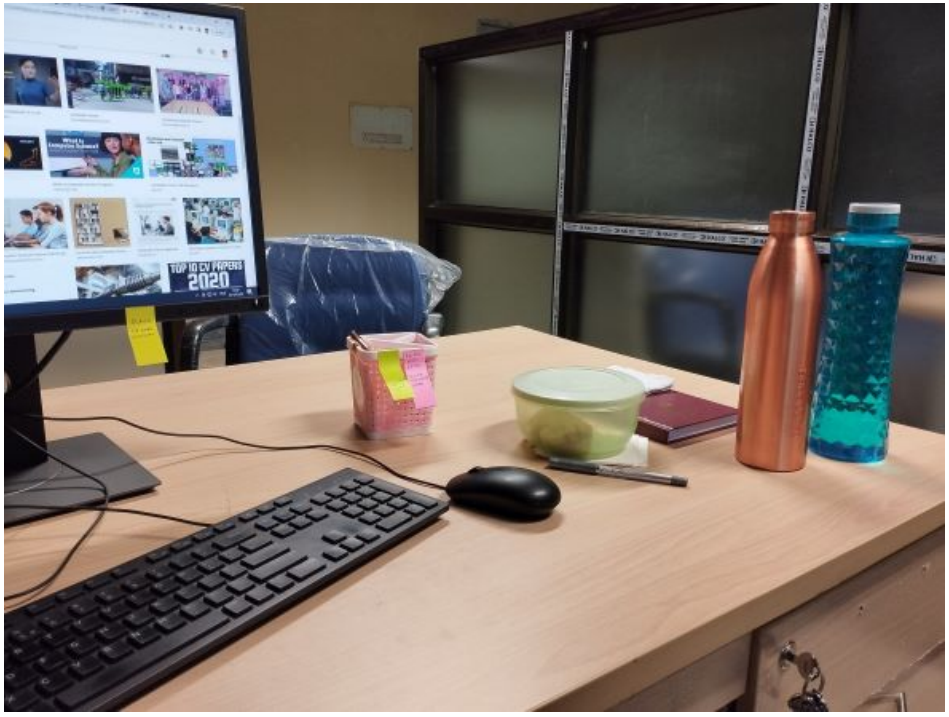

- How many sticky notes are there?
- What is the object that is new in the scene?
- Is there something to eat/drink here?

What is Computer Vision?

Images from the 'Objects out of the context' dataset

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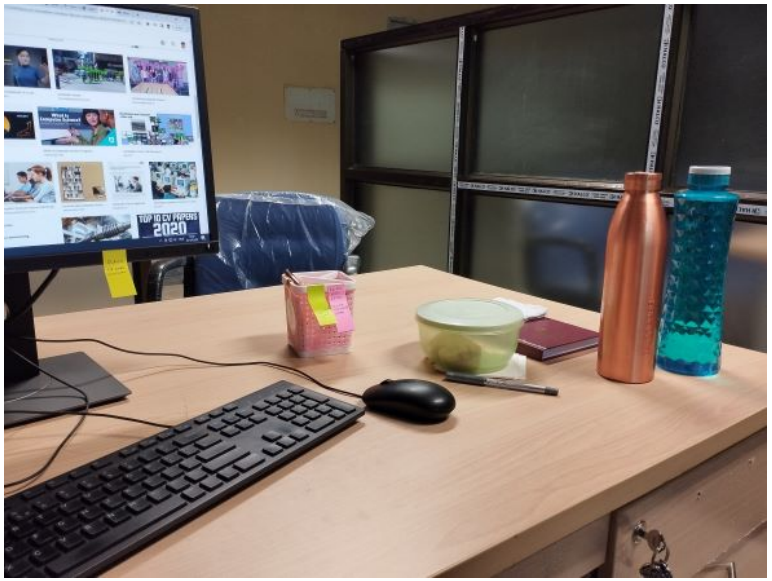
Images from the 'Objects out of the context' dataset

- What is wrong with each of these images?

What is Computer Vision?



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Computer Vision

Can we make machines answer these questions?

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More formally

Building artificial systems that can process, perceive, and reason about the visual world (Taken from Justin Johnson, U.Mich.)

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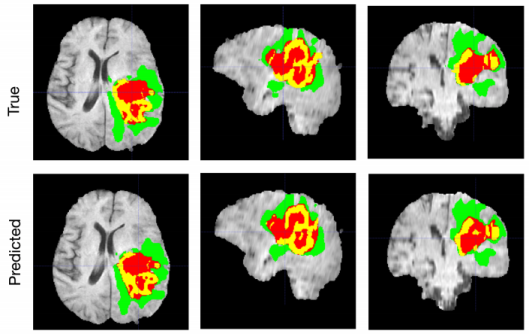
Other definitions

- “construction of explicit, meaningful descriptions of physical objects form images" (Ballard & Brown, 1982)
- “computing properties of the 3D world from one or more images" (Trucco & Verri, 1998)
- “to make useful decisions about real physical objects and scenes based on sensed images" (Sockman & Shapiro, 2001)

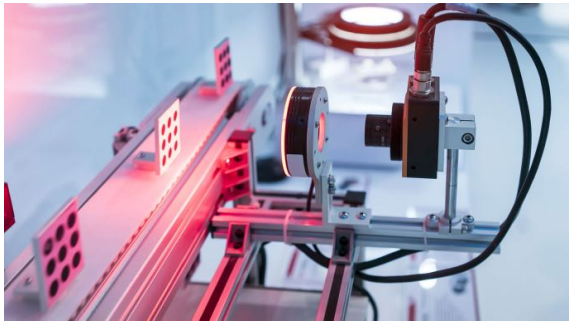
Why CV? Application Areas

Autonomy
(Credits: Getty Images)



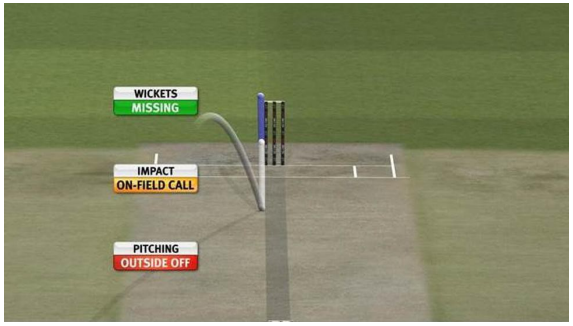
Healthcare
(Credits:Nvidia.Developer)

Surveillance
(Credits:Flickr)



Manufacturing
(Credits: Moonvision)

HCI
(Credits:X-tech.am)



Sports
(Credits:Medium and Sasank Gurajapu)

Why is it hard?

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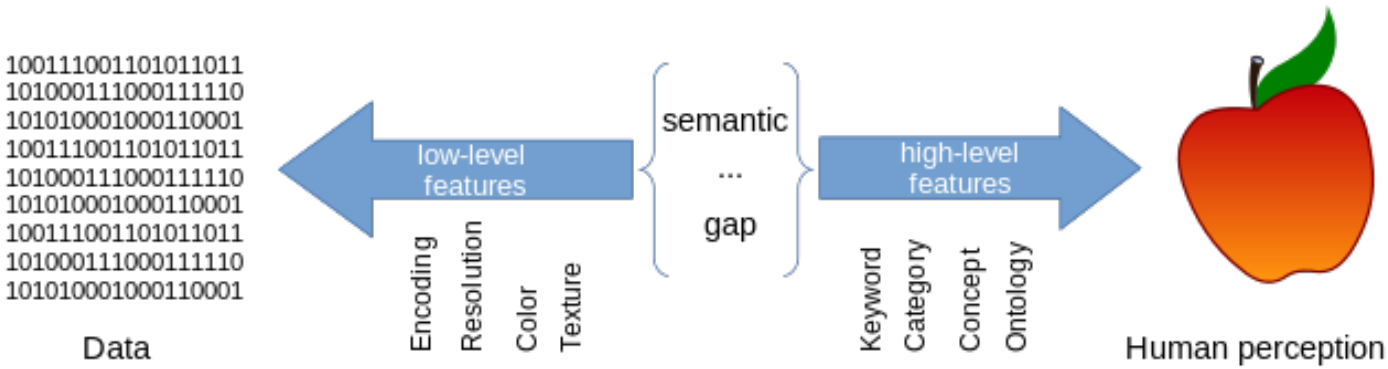
- Forward models are generally developed in physics and computer graphics

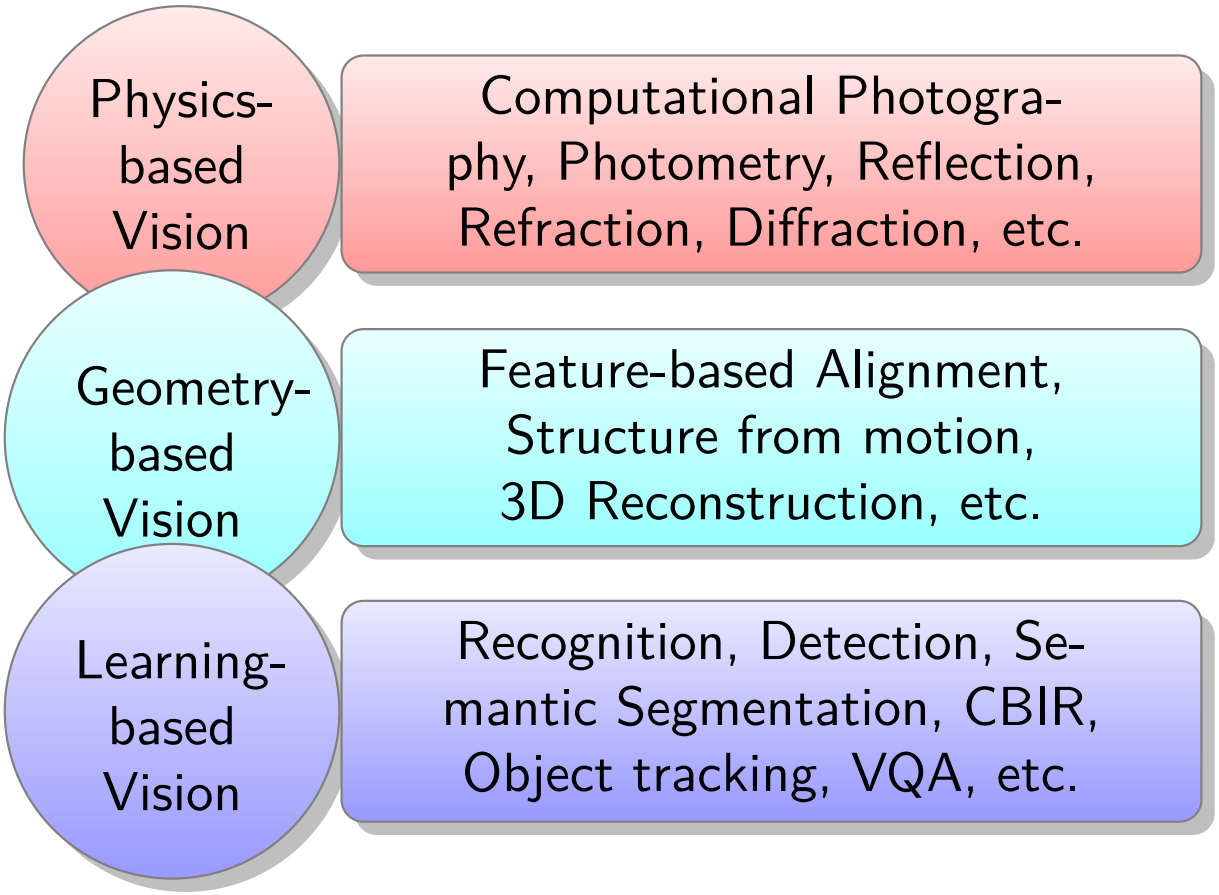
Why is it hard?

- Semantic gap



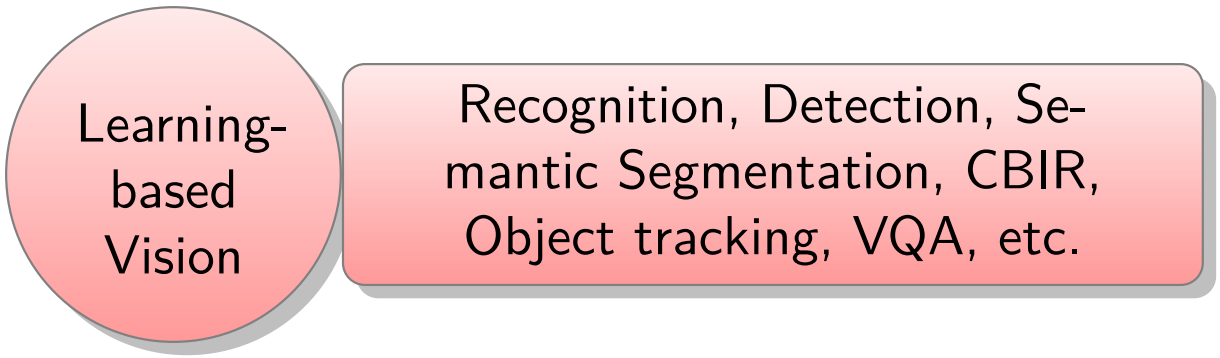
Source: Wikipedia

Computer Vision: Themes



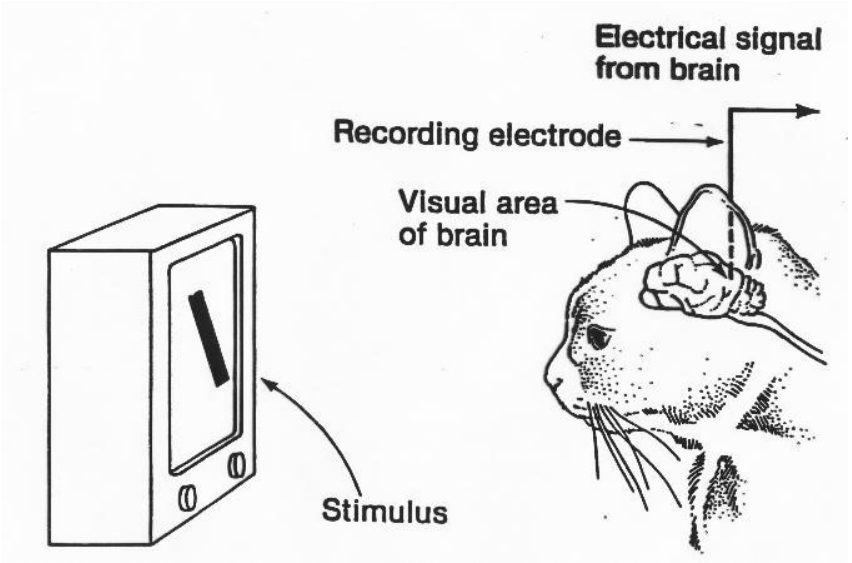
Taken from Prof. Vineet N Subramanian, IITH

Computer Vision: this course



Brief History: David Hubel and Torsten Wiesel (1959)

- Receptive fields of single neurons in the cat's striate cortex [Link to the experiment]



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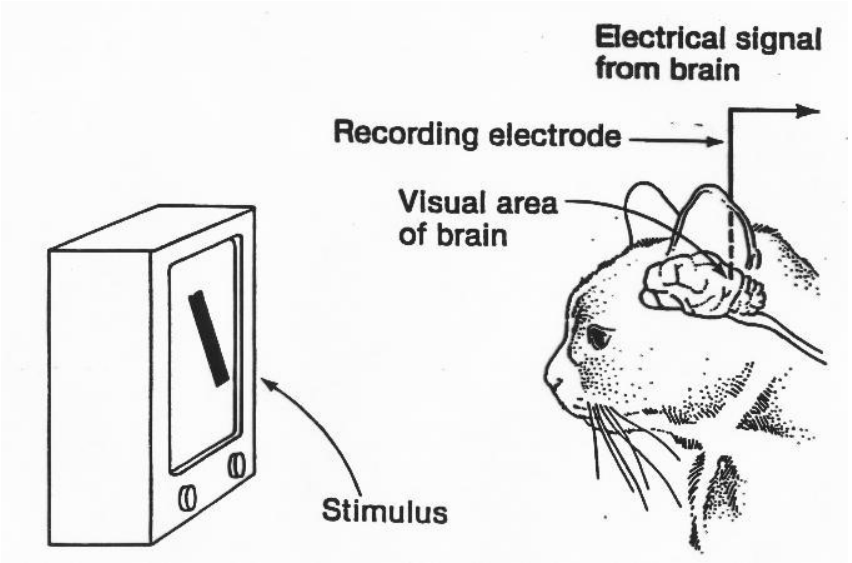

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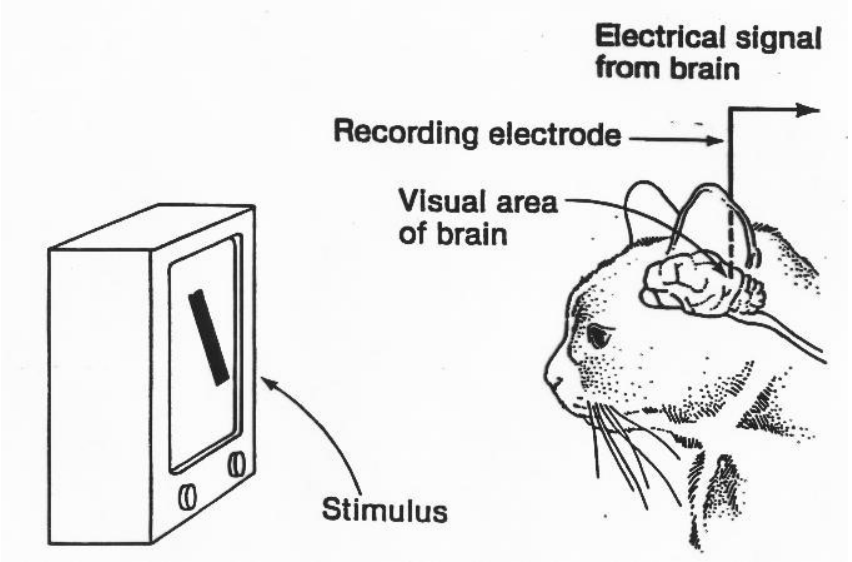

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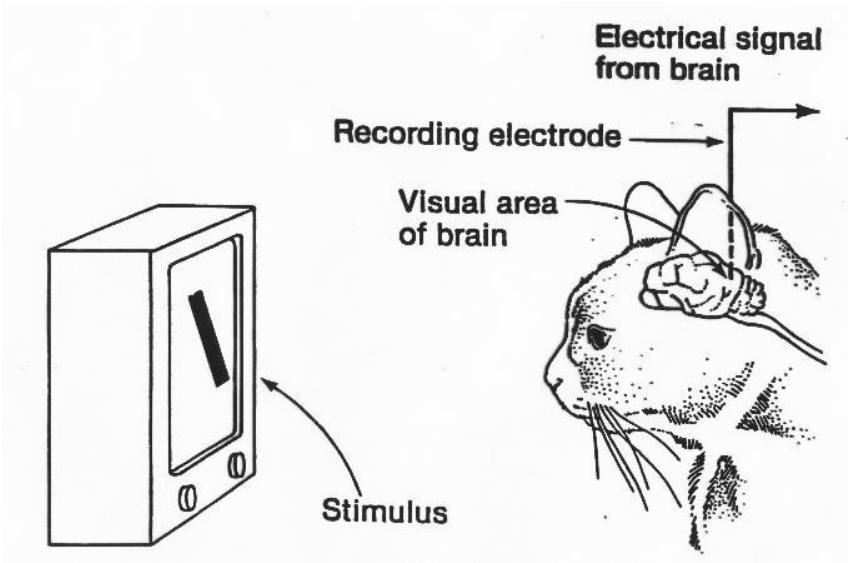
- Went on to win a Nobel in 1981!



Source

Brief History: Russel kirsch (1959)

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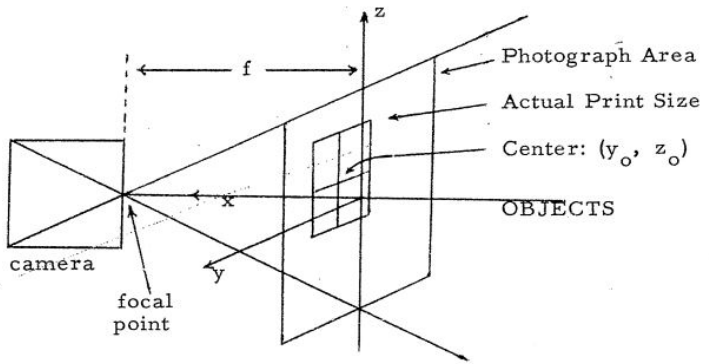
- Preserved in the Portland Art Museum

Source

Brief History: Lawrence Roberts (1963)

- Machine perception of three-dimensional solids



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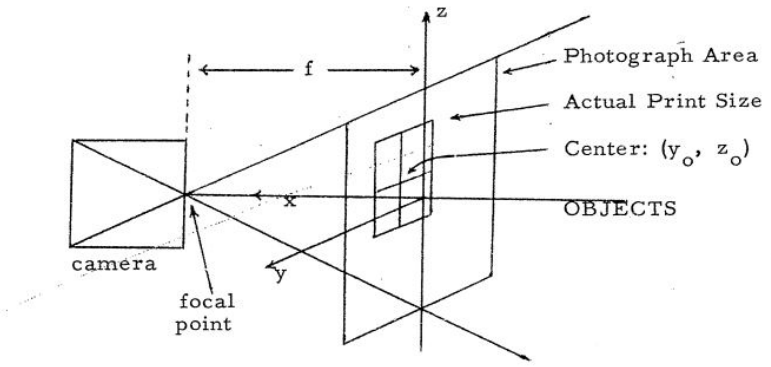

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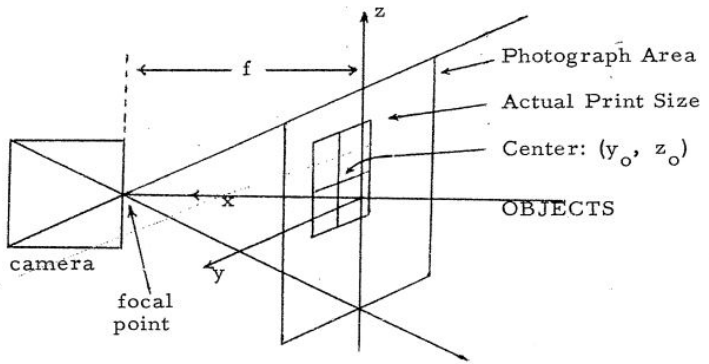
- Camera transformations, perspective effects, depth perception, etc.



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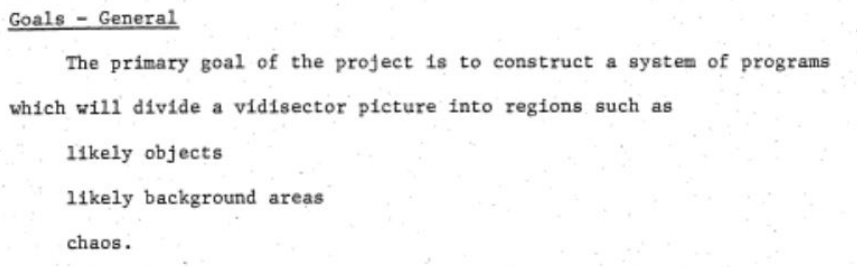

Goals - General

The primary goal of the project is to construct a system of programs which will divide a vidisector picture into regions such as

likely objects

likely background areas

chaos.

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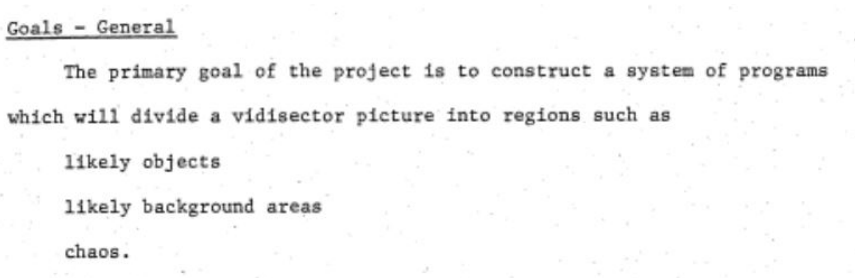

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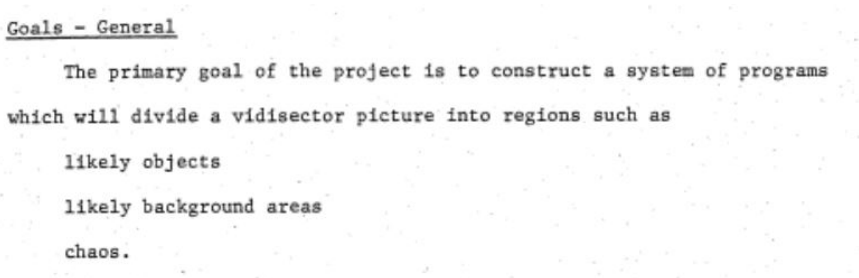
- 60 years later, the world is still working on it!



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- Object recognition through shape analysis (Generalized Cylinders, Skeletons, etc.)

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- "Vision: A computational investigation into the human representation and processing of visual information"
- Established the "Hierarchy" of the vision: high-level understanding of visual data is built on top of the low-level tools for detecting edges, curves, corners, etc.

David Marr's Representational framework (1982)

- Primal sketch of the image (edges, boundaries, etc.) are represented

Rostyslav Demush, medium.com

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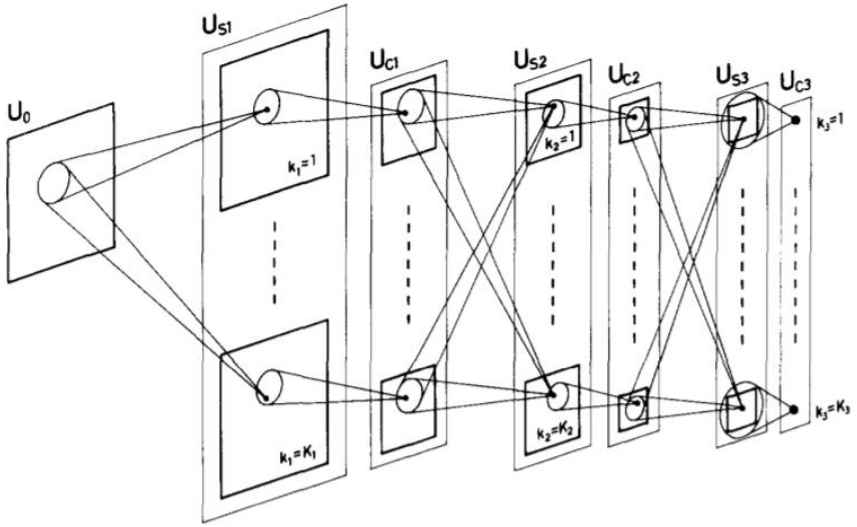
David Marr's Representational framework (1982)

- Primal sketch of the image (edges, boundaries, etc.) are represented
- $2.5D$ representation: depth and discontinuities are represented
- $3D$ model hierarchically organized in terms of surface and volumetric primitives

Rostyslav Demush, medium.com

Brief History: Neocognitron (1979-82)

- Fukushima implements the Hubel and Wiesel's principles



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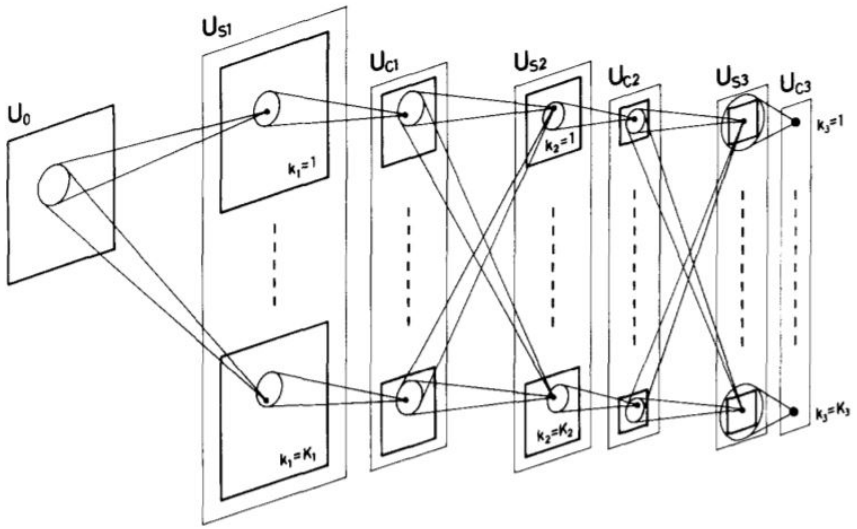

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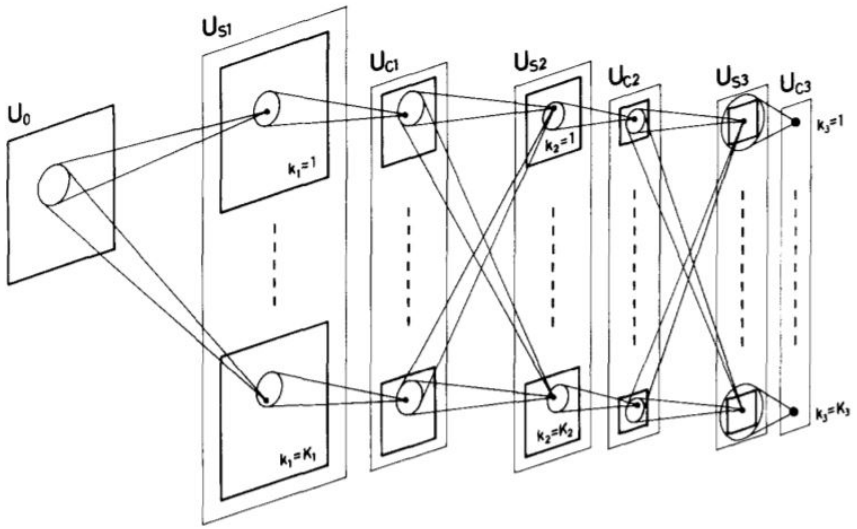
- Fukushima implements the Hubel and Wiesel's principles
- Used for hand-written digit recognition
- Viewed as precursor for the modern CNNs (had conv filters and layers, spatial invariance)



Brief History: Optical Flow (1981)

- Determining Optical Flow by Horn and Schunck

Source

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- Estimates the direction and speed of moving objects across pair of images

Source

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- Multi-stage approach for detecting the edge content in an image

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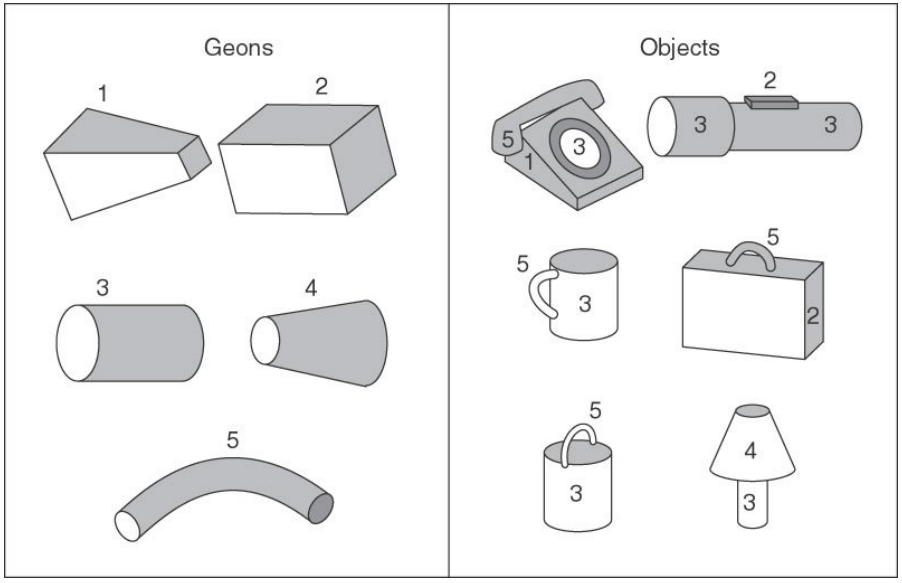
- Multi-stage approach for detecting the edge content in an image
- Signal variations are dealt with calculus (simple but popular method)
- Developed as a masters student, published in Trans. on PAMI, 1986 (Link)

Source:OpenCV

Brief History: Recognition by components (1987)

- Bottom-up process for object recognition proposed by Irving Biederman



Source: Prof. Kenneth M. Steele

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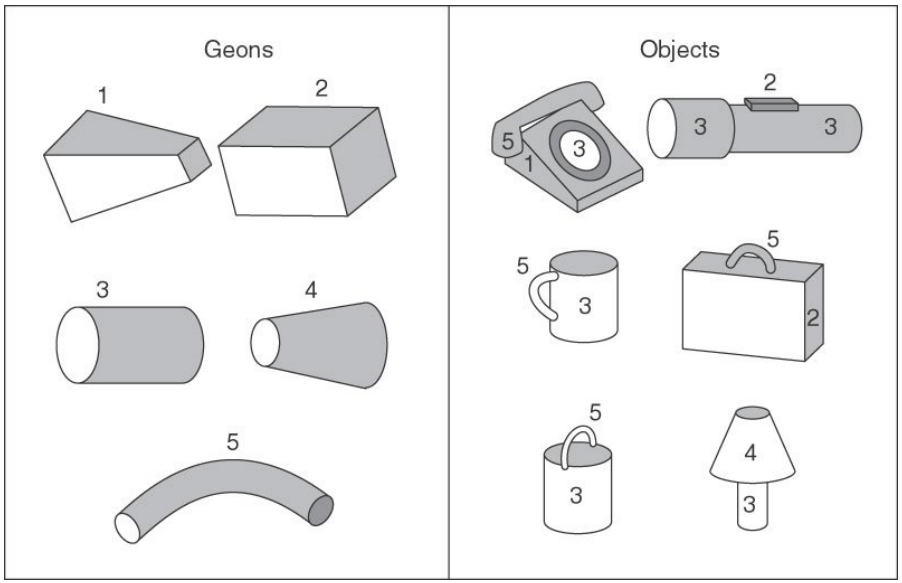
- Simple $3D$ shapes (geons) such as cones and cylinders compose objects



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- Widely applied in edge detection, segmentation, shape recognition, object tracking, etc.

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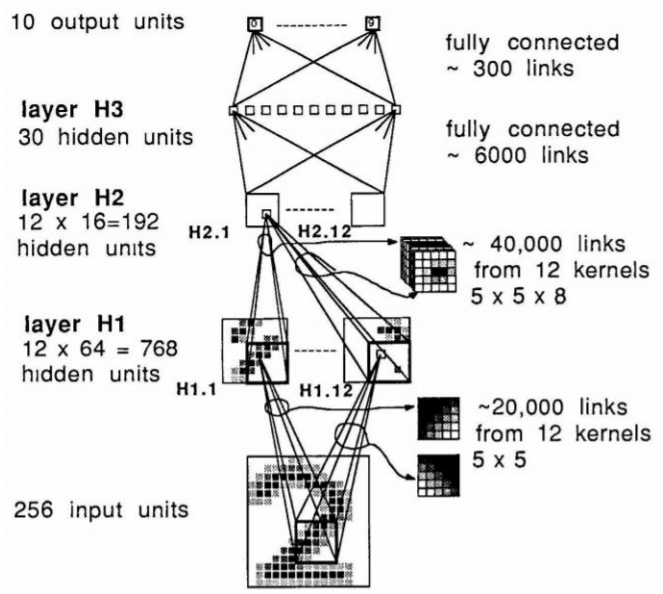
- Prof. Yan Lecun applied a backprop style learning algorithm to Fukushima's convolutional neural network



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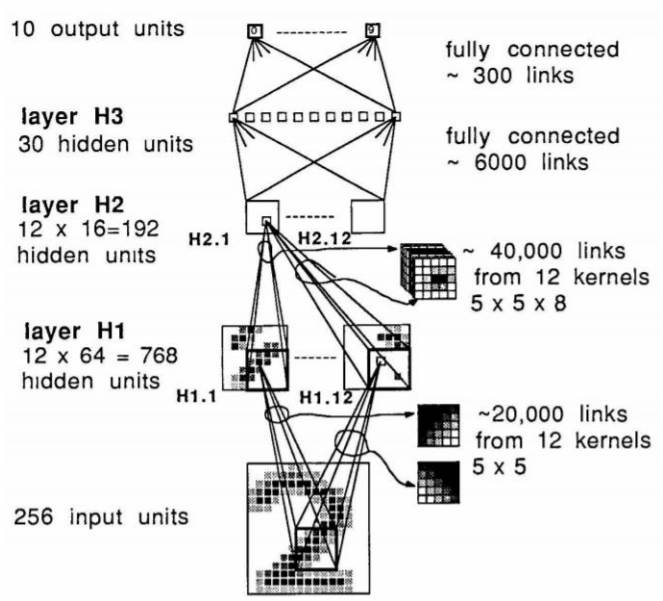

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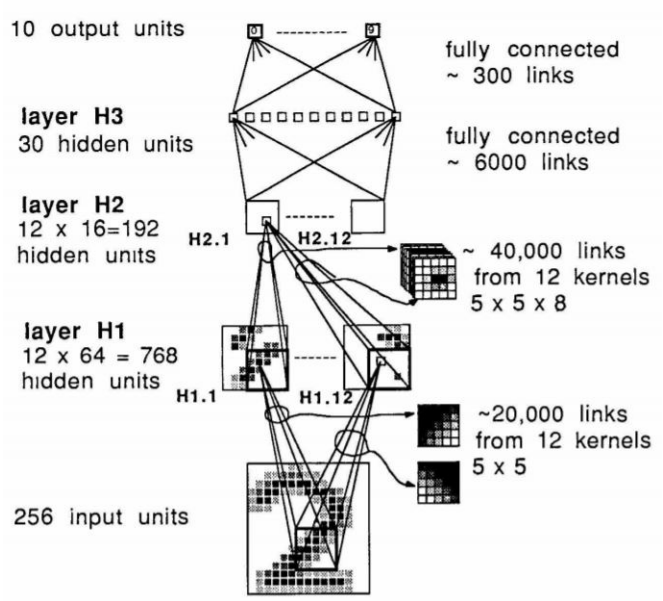

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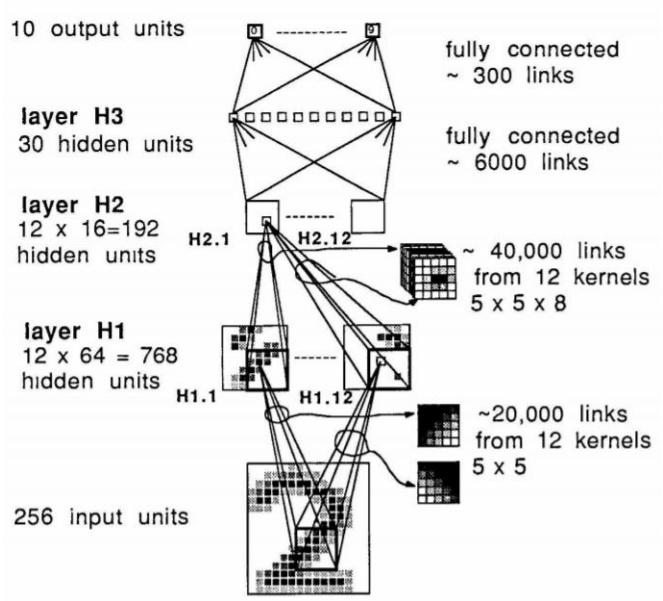

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- Deformable parts model (Felzenszwalb et al, 2009)

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- Higher-levels of abstraction: VCR dataset, panoptic segmentation, etc. (2018-19)

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- SSD and YOYO for object detection; Visual Genome dataset (2016)
- Scene-graphs; (2017)
- Higher-levels of abstraction: VCR dataset, panoptic segmentation, etc. (2018-19)

Brief History: Deep learning era in 2010s

Turing Award winners for 2018

Course Contents

- Part-1: Foundations of Deep learning (Implementing and training different types of neural networks)
  - (MP, perceptron), MLP, CNNs, and RNNs (LSTM and GRU)
  - Gradient Descent technique using the Backpropagation
  - Implement them in PyTorch framework (this is not a lab course, so it is majorly your responsibility!)

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  - Implement them in PyTorch framework (this is not a lab course, so it is majorly your responsibility!)
- Part-2: Applications in Computer Vision (with a slight research flavour)
  - Object recognition, detection, semantic segmentation Vision and Language
  - Generative models: GANs and VAEs
  - Recent trends

Prerequisites

Theory

- Knowledge on basics of probability, linear algebra, and calculus
- Basic course on ML
- Exposure to Deep learning (a course greatly helps)

Practicals

- Programming in Python
- Knowledge of a deep learning framework (we work with PyTorch)

Time slot

- D1 slot
  - Monday 4 - 4:55 PM
  - Tuesday 4 - 4:54 PM
  - Friday 3 - 3:55 PM

Time slot

- Open elective (Final year B.Tech, M.Tech, and Ph.D.)

Time slot

- Open elective (Final year B.Tech, M.Tech, and Ph.D.)
- Class Room - 4104 (CORE-4, First Floor)

Logistics

- Course website: https://krmopuri.github.io/dl4cv/
  - Course updates
  - Lecture slides and other material
  - Assignments
  - etc.

Evaluation (Tentative)

- Assignments - 30%
- Mid-semester - 20%
- End-semester - 30% Mini-project - 20%

Textbooks and References

- Computer Vision
  - Computer Vision: A Modern Approach, Forsyth and Ponce
  - Computer Vision: Algorithms and Applications, Richard Szeliski
- Deep Learning
  - Deep Learning textbook by Ian Goodfellow *et al.*
  - NPTEL course by Prof. Mitesh Khapra, IITM.
  - Michael Nielsen's text book on NN & DL
  - DL course by François Fleuret, EPFL and Uni. of Geneva
  - PyTorch - `https://pytorch.org/`
  - Many more that I could not list and am not aware of...
- DL for CV
  - NPTEL Course by Prof. Vineet Balasubramanian, IITH.
  - Course by Dr. Justin Johnson, University of Michigan