Deep Learning for Computer Vision

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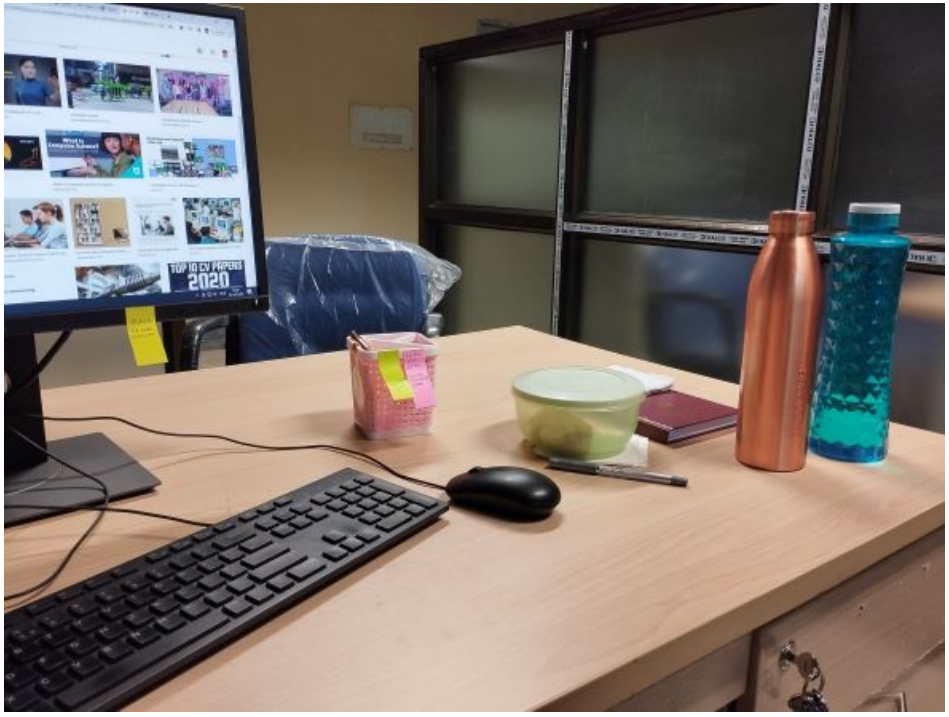
- Field of AI that enables machines to
  - Extract meaningful information from the visual world via digital images and videos
  - And, recommend appropriate actions based on that
- Simply, enabling machines to see as humans do!

What is Computer Vision?



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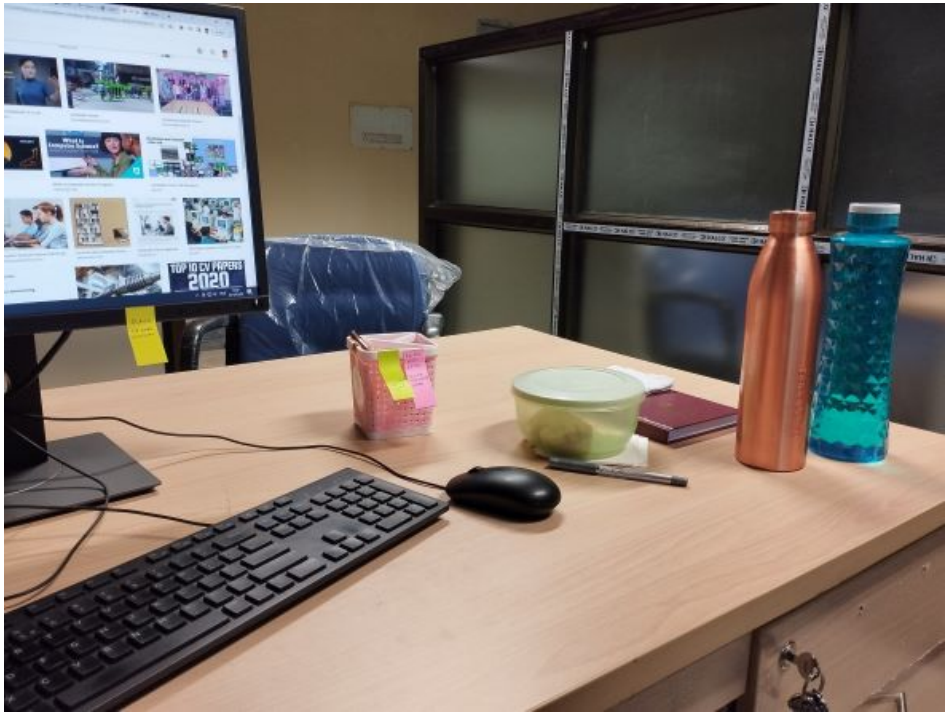

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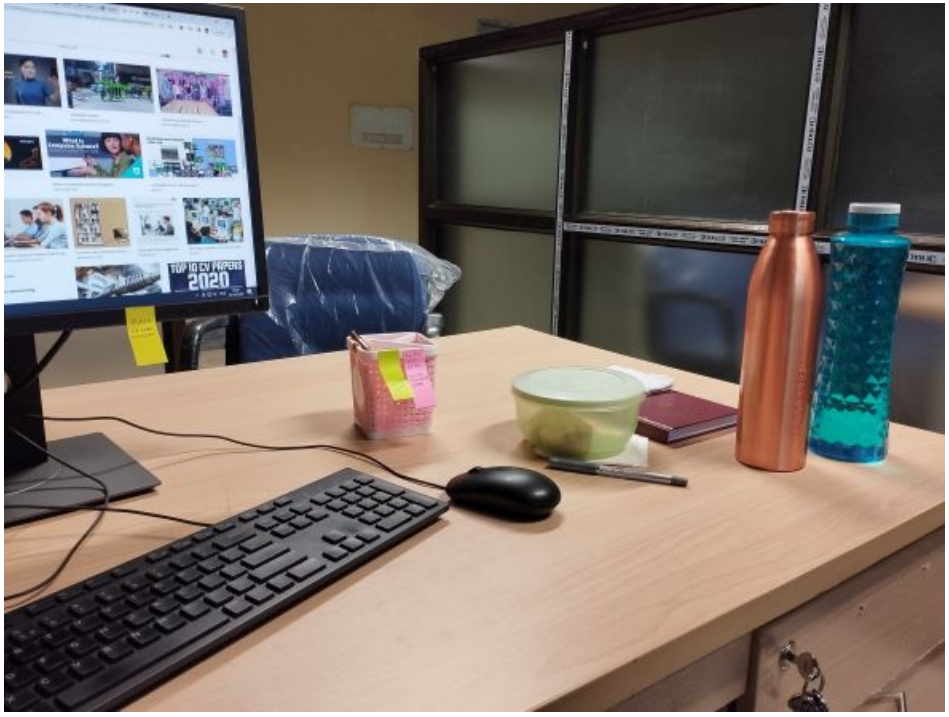

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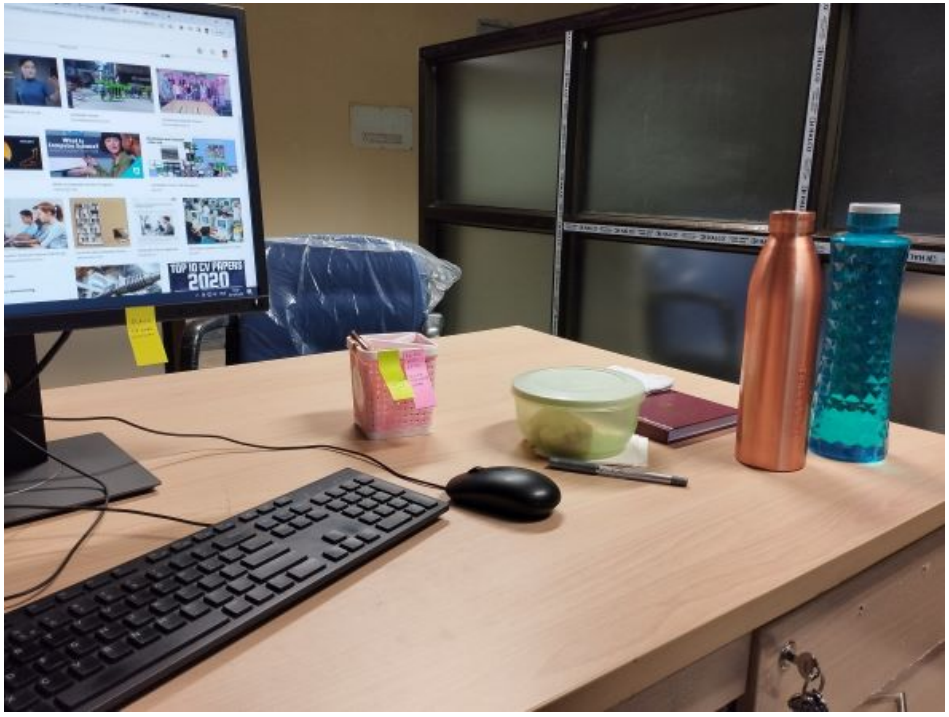

- How many sticky notes are there?
- What is the object that is new in the scene?
- Is there something to eat/drink here?

What is Computer Vision?

Images from the 'Objects out of the context' dataset

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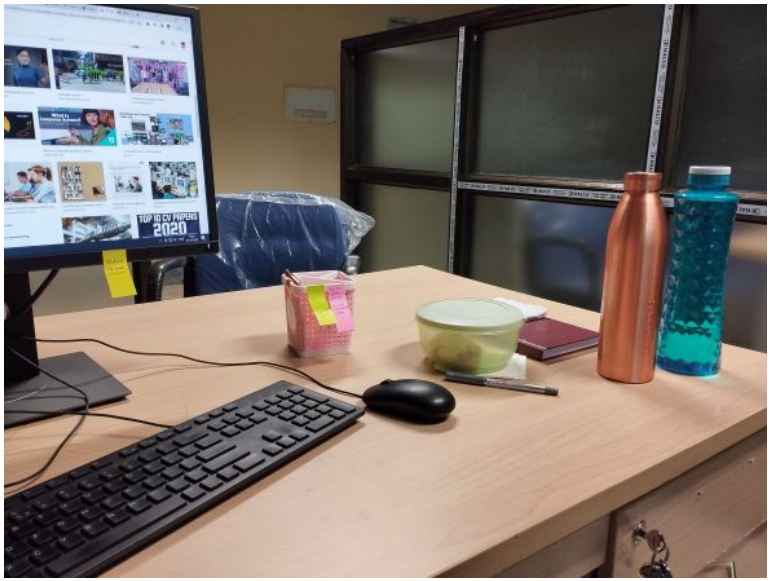
Images from the 'Objects out of the context' dataset

- What is wrong with each of these images?

What is Computer Vision?



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- What is the object that is new in the scene?
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Computer Vision

Can we make machines answer these questions?

What is Computer Vision?

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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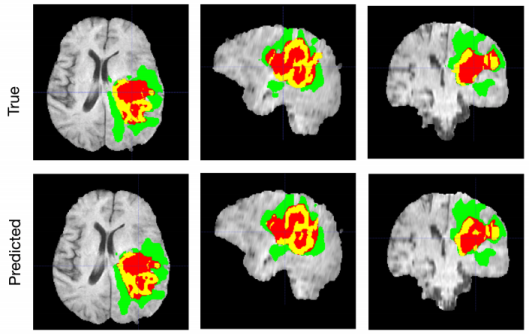
Other definitions

- “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)

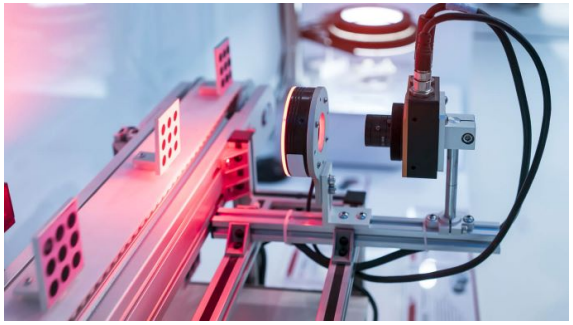
Why CV? Application Areas

Autonomy
(Credits: Getty Images)



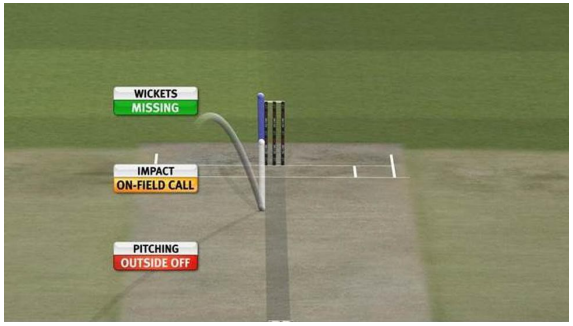
Healthcare
(Credits:Nvidia.Developer)

Surveillance
(Credits:Flickr)



Manufacturing
(Credits: Moonvision)

HCI
(Credits:X-tech.am)



Sports
(Credits:Medium and Sasank Gurajapu)

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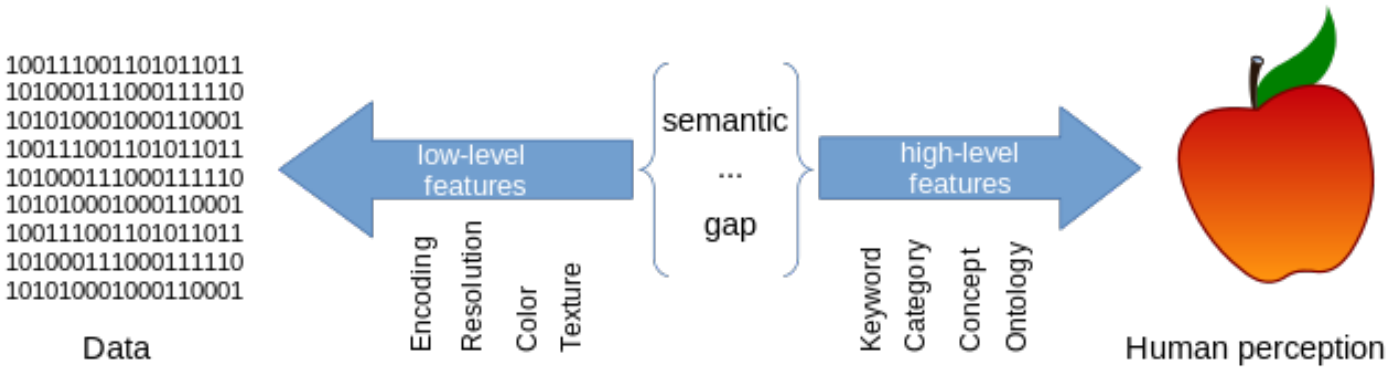
AI-Complete

- One of the most difficult problems in AI
- Would not be possible to solve with a simple specific algorithm

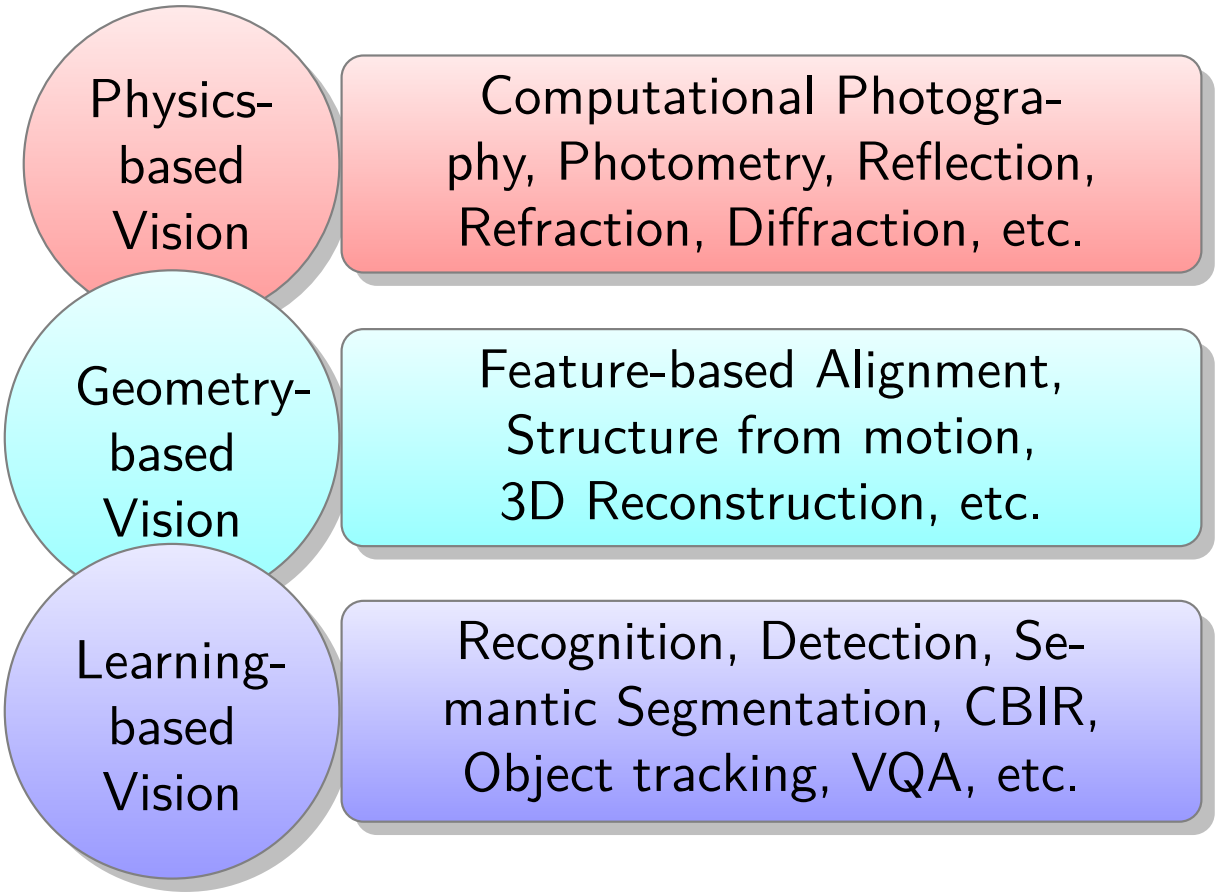
Why is it hard?

- Semantic gap



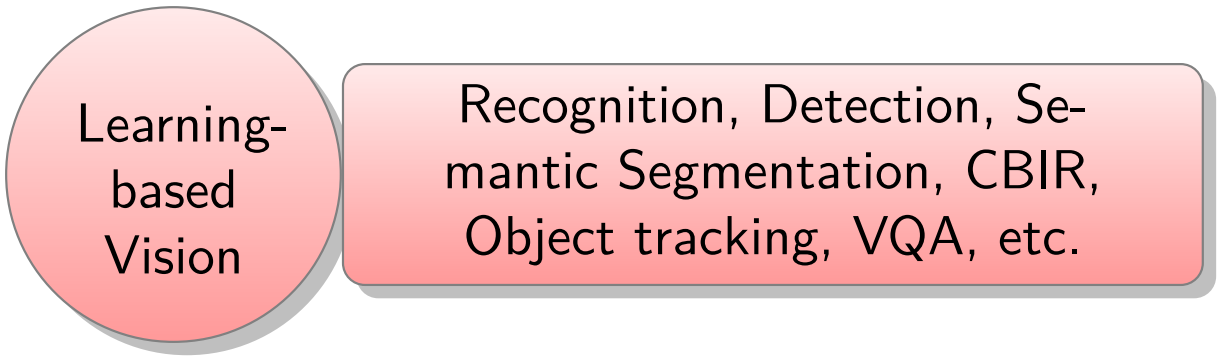
Source: Wikipedia

Computer Vision: Themes



Taken from Prof. Vineet N Subramanian, IITH

Computer Vision: this course



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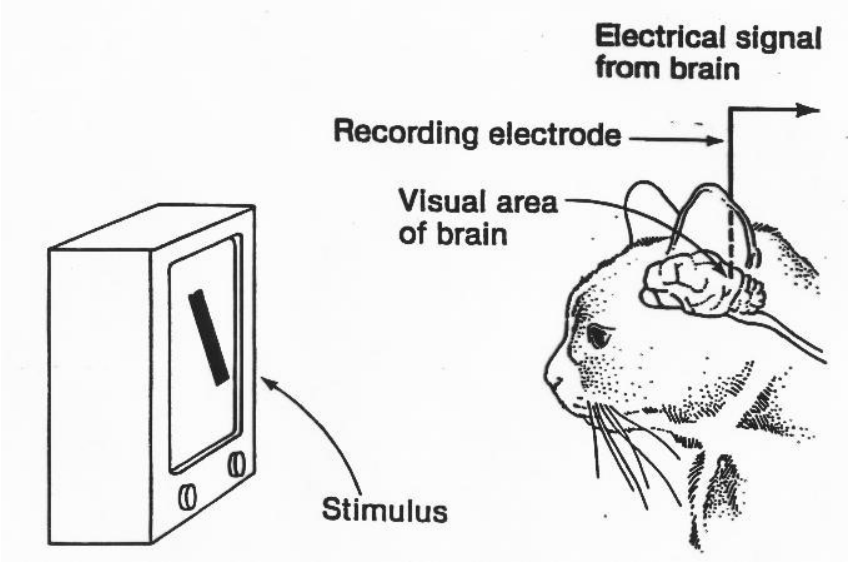
- Receptive fields of single neurons in the cat's striate cortex [Link to the experiment]



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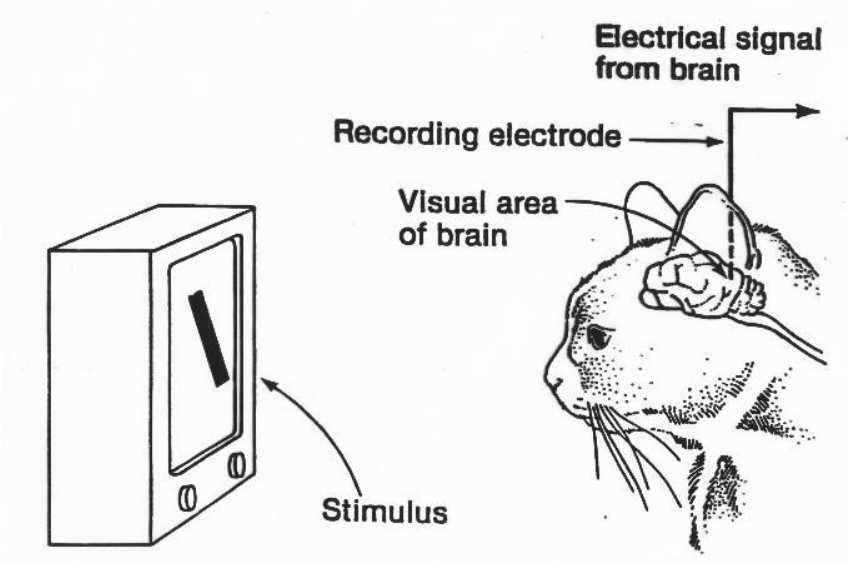

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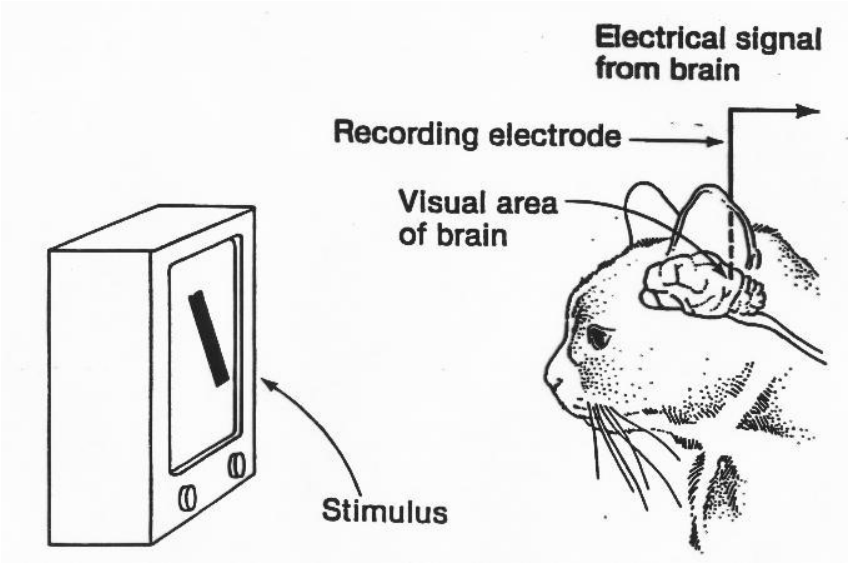

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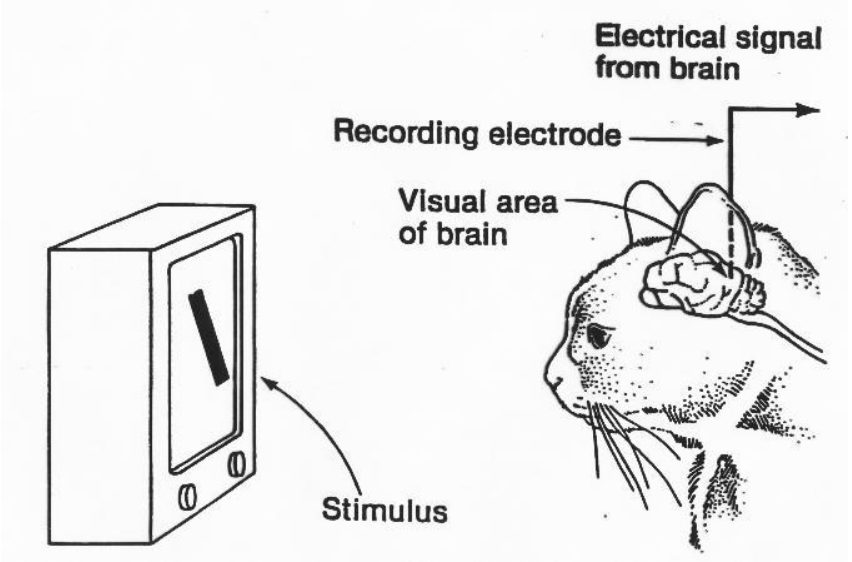
- Went on to win a Nobel in 1981!



Source

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Source

Brief History: Lawrence Roberts (1963)

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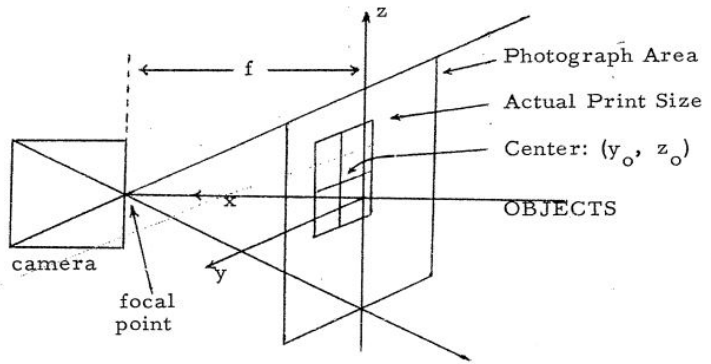

Camera Transformation

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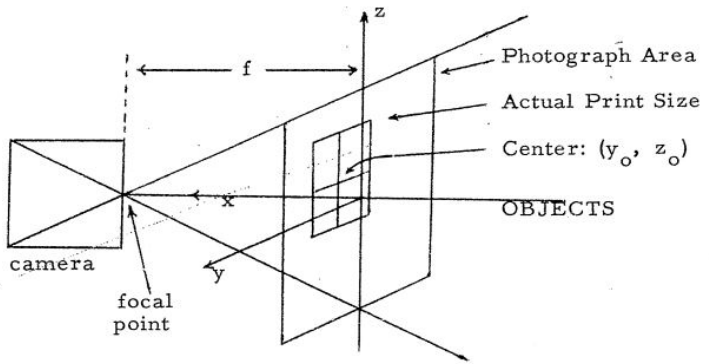

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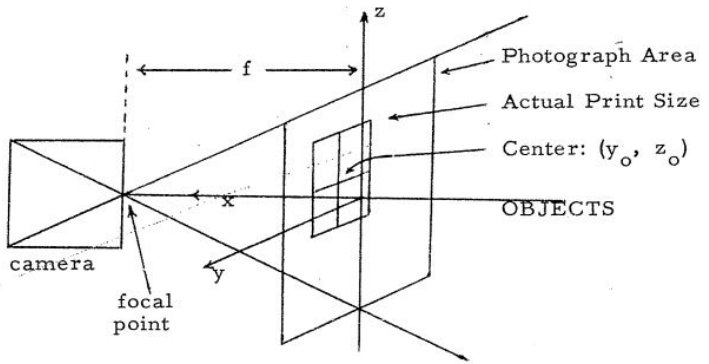
- Camera transformations, perspective effects, depth perception, etc.



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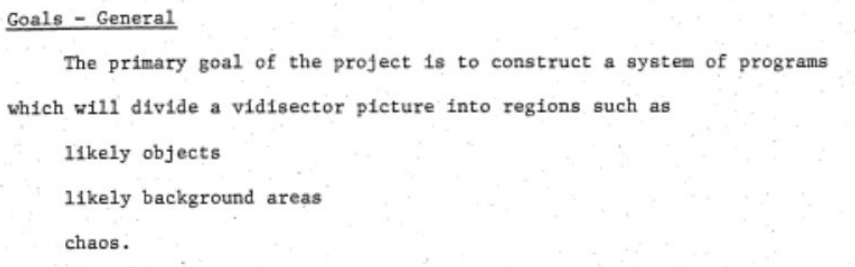

Goals - General

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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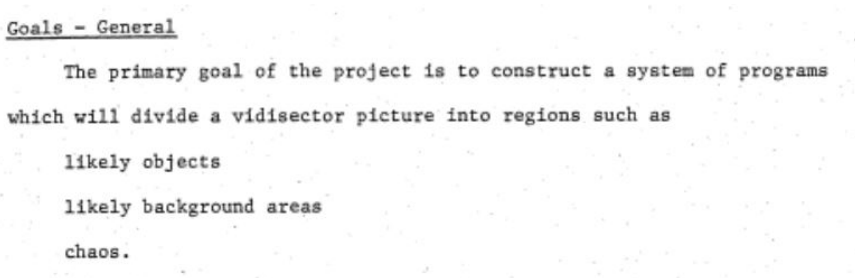

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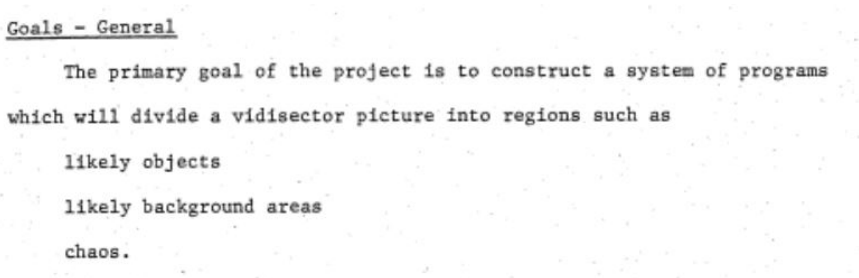
- 60 years later, the world is still working on it!



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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

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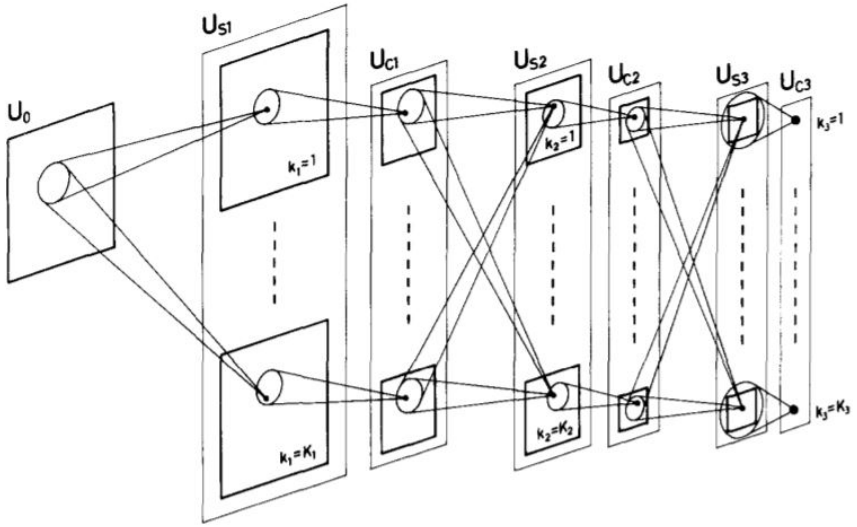
Brief History: Neocognitron (1979-82)

- Fukushima implements the Hubel and Wiesel's principles



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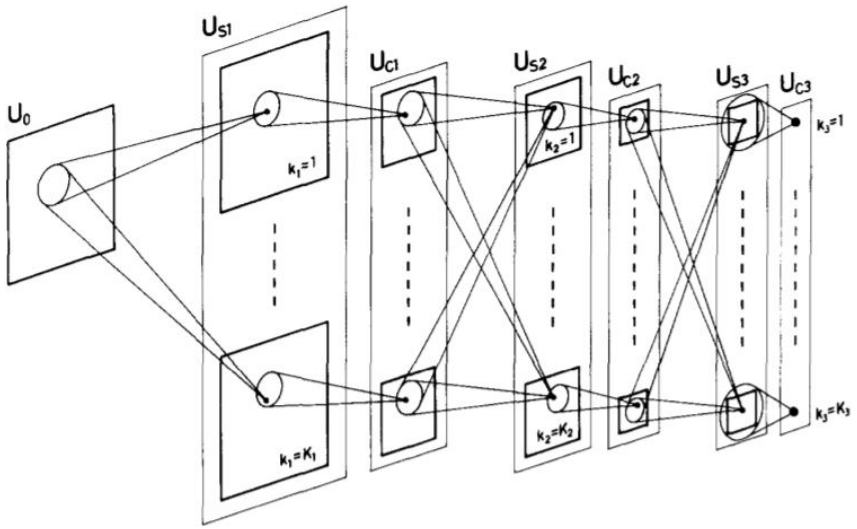
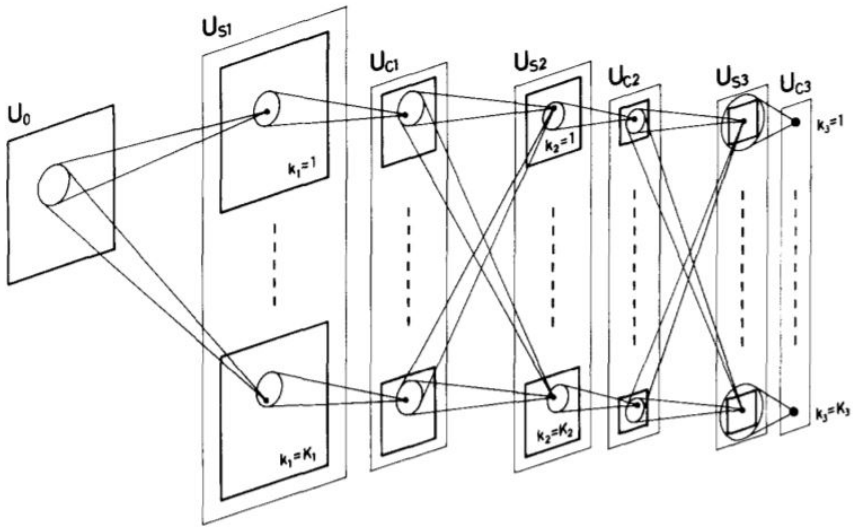


Brief History: Neocognitron (1979-82)

- 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

Source:OpenCV

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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)

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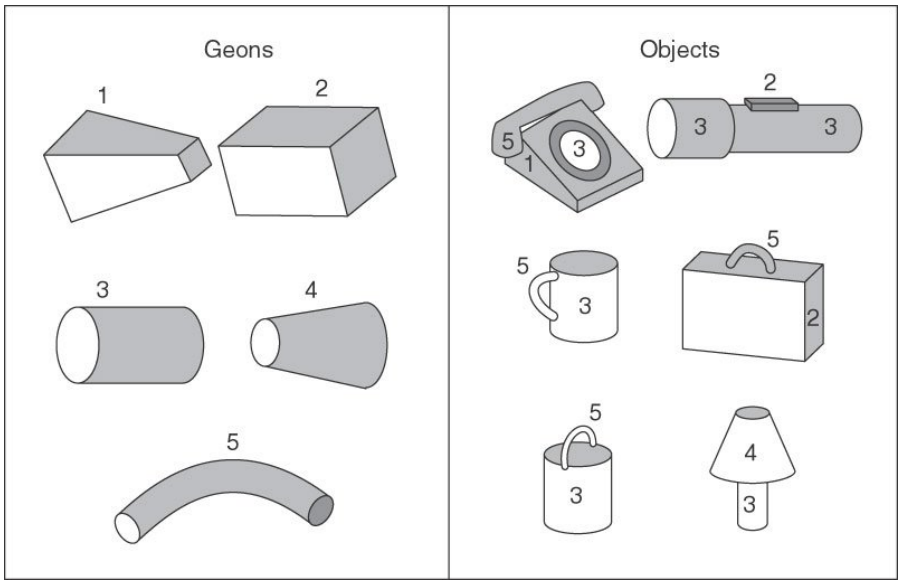
Brief History: Recognition by components (1987)

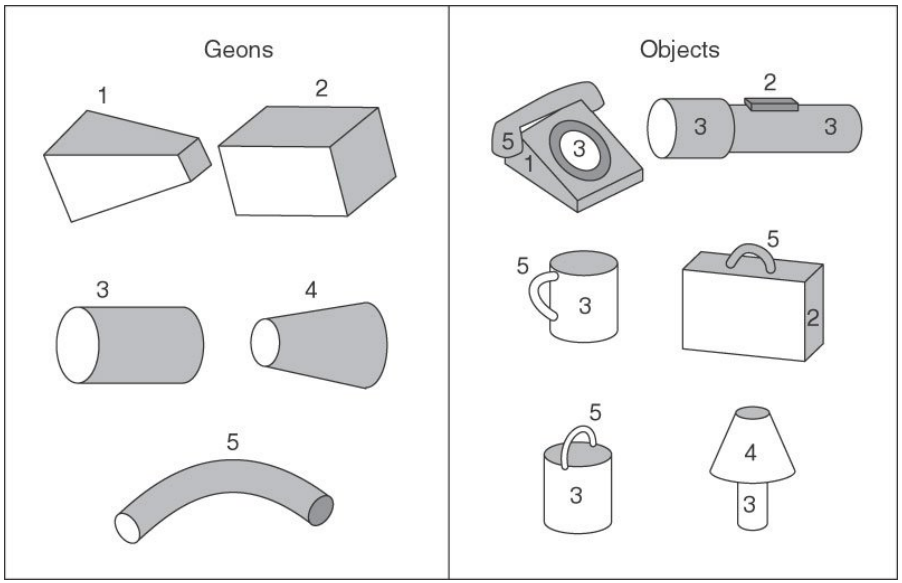
- Bottom-up process for object recognition proposed by Irving Biederman



Source: Prof. Kenneth M. Steele

Brief History: Recognition by components (1987)

- Bottom-up process for object recognition proposed by Irving Biederman
- 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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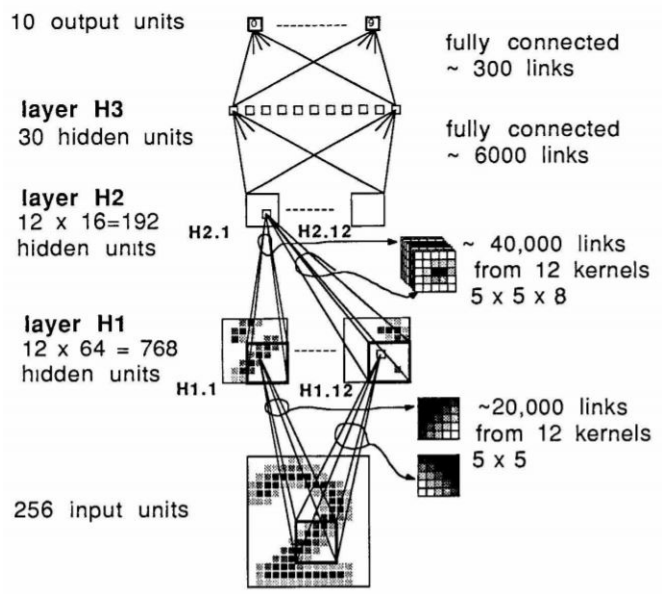
- Prof. Yan Lecun applied a backprop style learning algorithm to Fukushima's convolutional neural network



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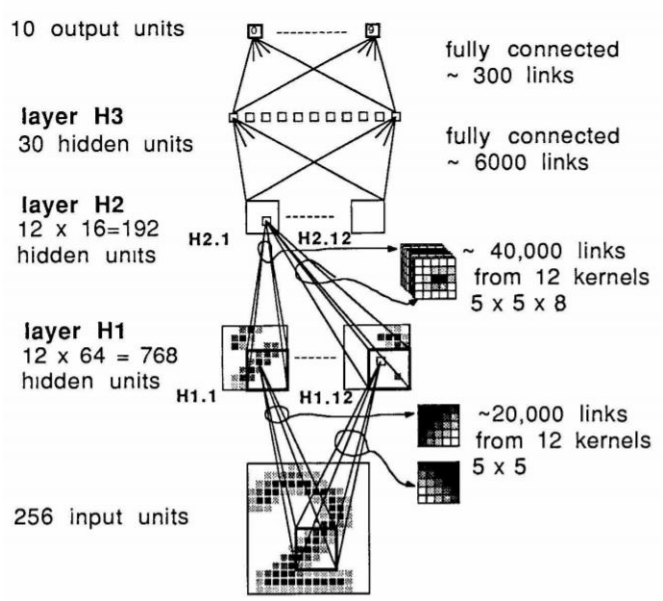

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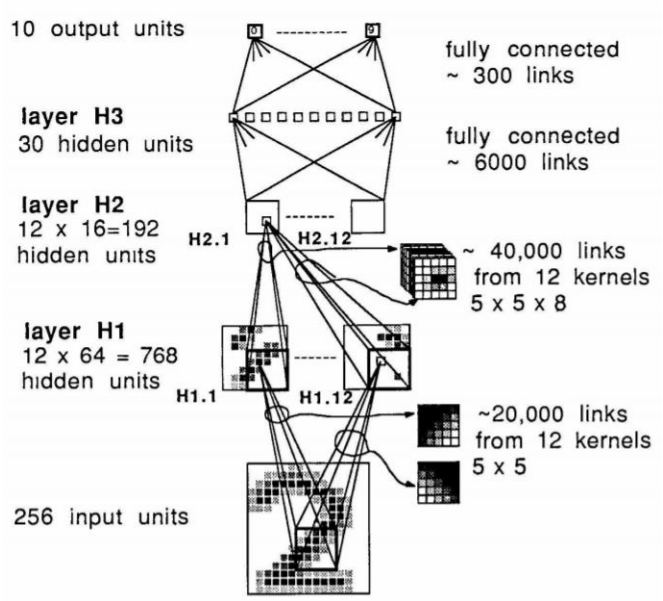

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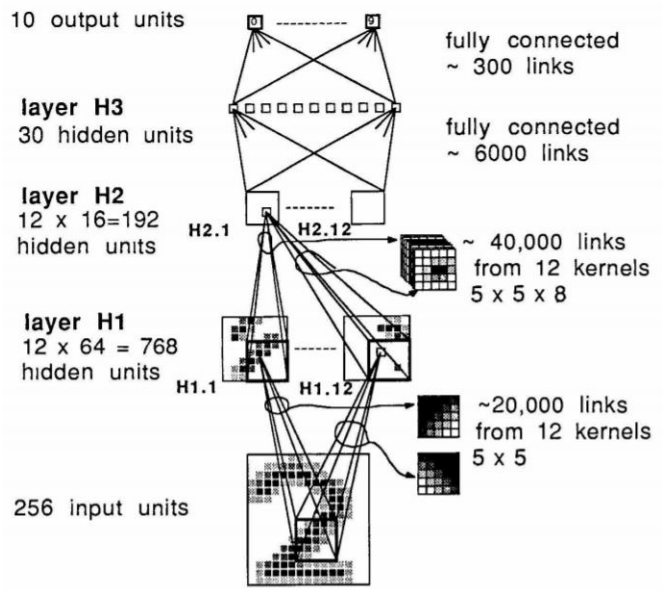
- Backpropagation is attributed 'Majorly' to Paul Werbos 1974 (although it was independently discovered by multiple from 1960s)



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- Particle filters and Mean-shift for tracking (Liu and Chen, 1998) (Cheng, 1998)
- Scale-Invariant Feature Transform (D Lowe, 2004)

Brief History: Moving from low-level processing in 1990s

- Face recognition by Eigen faces (Turk and Pentland, 1991)
- Normalized cuts (J Shi and J Malik, 1997)
- Particle filters and Mean-shift for tracking (Liu and Chen, 1998) (Cheng, 1998)
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Brief History: Moving from low-level processing in 2000s

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Brief History: Deep learning era in 2010s

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Turing Award winners for 2018

More history: to be written!

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)
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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

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- 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