

Computer Vision

Dr. Nabeel Mohammed

Course Information

Course Code: CSE553/EEE660/CSE468

Course Title: Computer Vision

Credits: 3

Faculty: Dr. Nabeel Mohammed (NbM)

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Class Time: Tuesday 7pm - 10pm

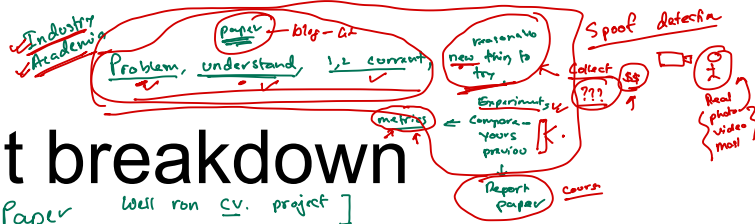
Assessment breakdown

Project - 40%

Assignment - 20%

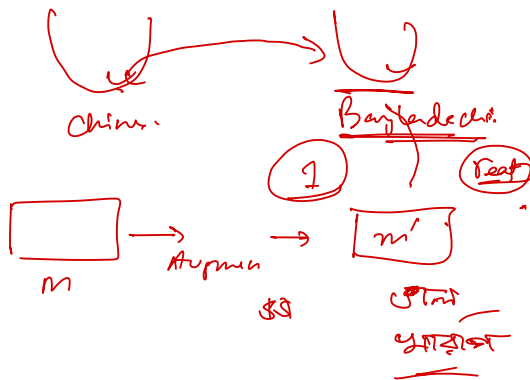
Midterm - 20%

Final - 20% (Extra questions for MS Students)



(Group Project. Between 3-4 members)

Spool



Prerequisite knowledge

- Programming (Python, MATLAB, Julia)
- Data Structures — Hash, List Tensors
- Linear Algebra —
- Calculus of multiple variables —
- Some machine learning will be useful ✓
 - First three chapters of (<http://neuralnetworksanddeeplearning.com/>)
 - Terminologies: Supervised, Unsupervised, Accuracy, Train-Validation-Test split, Regression, Classification, Mini-batch, loss/error function, backpropagation etc..
- Opencv (or other image processing libraries) ←
- PyTorch / Tensorflow / Keras
↑

Math

Scalar value (Single number) \mathbb{R}

Vectors more than one number \mathbb{R}^d
(Magnitude, Direction)

$$\vec{v} = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix}$$

\mathbb{R}^4

$$\vec{v}^T = [v_1 \ v_2 \ v_3 \ v_4]$$

$$\begin{bmatrix} \vdots & \vdots & \vdots & \vdots \end{bmatrix} \vec{v} = \vec{p}$$

$$= \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}^k$$

P cols
k rows

\textcircled{I}

Matrix

↓

identity

$$\begin{bmatrix} \odot & \odot & \odot \\ \cdot & \cdot & \cdot \end{bmatrix} \begin{bmatrix} \otimes_1 \\ \otimes_2 \\ \otimes_3 \end{bmatrix} = \begin{bmatrix} \otimes_1 \\ \otimes_2 \\ \otimes_3 \end{bmatrix}$$

$$, \begin{bmatrix} \cdot & \cdot & \cdot & \cdot \end{bmatrix}$$

$$\vec{v} = \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix} \quad \begin{array}{l} L_2\text{-norm} \rightarrow \|\vec{v}\|_2 = ? \\ L_1\text{-norm} \rightarrow \|\vec{v}\|_1 = ? \end{array}$$

$$L_2\text{-norm} = \sqrt{2^2 + 1^2 + 4^2} = \sqrt{4 + 1 + 16} = \sqrt{21}$$

$$L_1\text{-norm} = \sqrt{|2| + |1| + |4|} = \sqrt{2 + 1 + 4} = \sqrt{7}$$

$$\vec{v}, \quad \|\vec{v}\|_2 = \sqrt{21}$$

$$\left\| \frac{\vec{v}}{\|\vec{v}\|_2} \right\|_2 = 1$$

$$\frac{\vec{v}}{\|\vec{v}\|_2} = \begin{bmatrix} 2/\sqrt{21} \\ 1/\sqrt{21} \\ 4/\sqrt{21} \end{bmatrix}$$

$$\begin{aligned} & \sqrt{\left(\frac{2}{\sqrt{21}}\right)^2 + \left(\frac{1}{\sqrt{21}}\right)^2 + \left(\frac{4}{\sqrt{21}}\right)^2} \\ &= \sqrt{\frac{4}{21} + \frac{1}{21} + \frac{16}{21}} \\ &= \sqrt{\frac{21}{21}} = 1 \end{aligned}$$

$$\vec{v} = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix}$$

$$W \vec{v} = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}$$

$$W = \begin{bmatrix} \vec{w}_1^T \\ \vec{w}_2^T \\ \vec{w}_3^T \end{bmatrix}$$

$$t_1 = \text{dot}(\vec{w}_1, \vec{v})$$

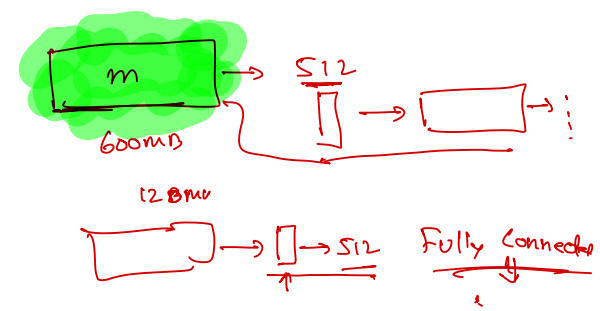
$$= \|\vec{w}_1\| \|\vec{v}\| \cos \Theta$$

$$= \cos \Theta$$

$$-1 \leq t_1 \leq 1$$

$$\|\vec{w}_1\| = 1$$

$$\|\vec{v}\| = 1$$

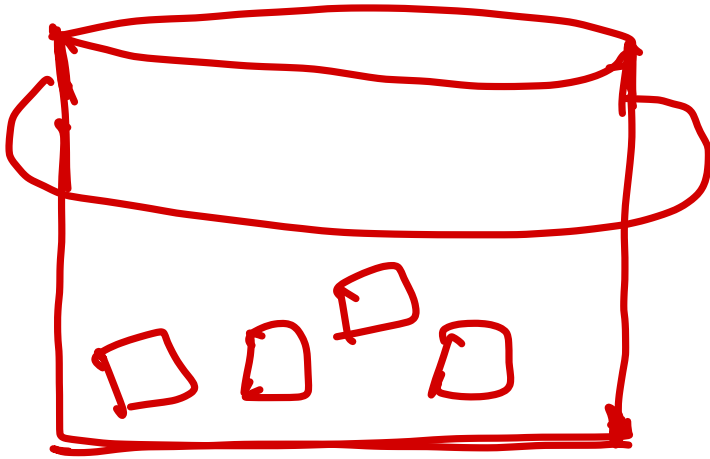


W -
Col - 4
Row - 3

$$\vec{z}_1 = \begin{bmatrix} w_{1,1} \\ w_{1,2} \\ w_{1,3} \\ w_{1,4} \end{bmatrix}$$

(Θ is the angle between \vec{w}_1, \vec{v})

Probability



0, 2, 2, 9,
8, 1, 4, 9, 6
2

P.D has 10 probability values

$p_1 \dots p_{10}$

$$0 \leq p_i \leq 1$$

$$\sum_{k=1}^{10} p_k = 1$$

$$15 \text{ kg} - 0.2$$

$$60 \text{ kg} - 0.5$$

$$90 \text{ kg} - 0.3$$

$$\begin{aligned} \text{Average weight} &= 15 * 0.2 + 60 * 0.5 + 90 * 0.3 \\ &= 60 \end{aligned}$$

$$15 \text{ kg} - 2$$

$$60 \text{ kg} - 5$$

$$90 \text{ kg} - 3$$

$$\text{Average weight} = \frac{(15 + 15 + 60 + 60 + 60 + 60 + 60 + 60 + 90 + 90 + 90 + 90)}{10}$$

$$\begin{aligned} &= \frac{15 * 2 + 60 * 5 + 90 * 3}{10} \\ &= \left(\frac{2}{10} \right) * 15 + \frac{5}{10} * 60 + \frac{3}{10} * 90 \end{aligned}$$

Computer Science

$$K = 2x^2 + 3x \quad (x = 2)$$

$$\begin{aligned} &= 2 \cdot (4) + 3 \cdot (2) \\ &= 8 + 6 = 14. \end{aligned}$$

$$\begin{aligned} \frac{dK}{dx} &= 4x + 3 \\ &= 4 \cdot 2 + 3 \\ &= 11 \end{aligned}$$

$$\begin{aligned} t &= K^2 + 4 = 14^2 + 4 \\ &= 196 + 4 = 200 \end{aligned}$$

$$\frac{dt}{dK} = 2K = 2 \cdot 14 = 28.$$

$$\left(\frac{dt}{dx} \right) = \left(\frac{dt}{dK} \cdot \frac{dK}{dx} \right) = 28 \times 11 = \underline{308}$$

Topics for this course (this semester)

Deep Learning

Math & procedure

- **Classification**
 - This is crucial for understanding the rest



- Detection (RNN → YOLO →

- Segmentation →

- Transfer learning intuition
2 Step (freeze)

- Adversarial Samples ??

- Generative Models

- Generative Adversarial Networks (GAN)

- Open Set Problems (Face Recognition)

- Search (CBIR)

- Other interesting topics (if time permits)



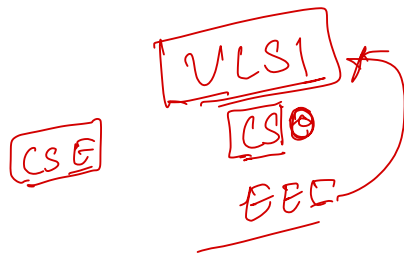
(Angular Margin Loss)
Face Net

$$\frac{\|\vec{a}\| \|\vec{b}\| \cos \theta}{\|\vec{a}\| \|\vec{b}\|} = \cos \theta$$

$\|\vec{a}\| = 1$
 $\|\vec{b}\| = 1$

This Lecture

- What is computer vision?
 - How is it separate from image processing?
- History
- Image classification
 - Naive non-parametric approach



What is Computer Vision?

- Image Processing
- Cognitive Neuroscience
- Machine Learning
- Robotics
- Information Retrieval
- Graphics
- Algorithms
- Mathematics
- And much more

Image Denoising

Acq

Consider this image

CHAIN HARROWS.
CARTWRIGHT'S
PATENT
SELF CLEANING
CHAIN
HARROWS.



THEIR PRINCIPAL USES ARE FOR
Preparing Mowing and Pasture Land.
Preparing Seed Beds.
Covering Seeds after the Drill; and
Killing ruminants.
Prices £2 17s. 6d. and £4 4s.
JAMES and GEORGE BAYWOOD, Sole Agents,
Market-place, Derby.



AGRICULTURAL IMPLEMENT DEPOT,
Derby, February 26th 1861.
TO AGRICULTURISTS AND OTHERS.
GENTLEMEN—We beg to inform you that Mr.
James Baywood of Atwell, has this day entered
his name for the transfer of the whole of

connected, patients are independent of the weather. Extensive exercise grounds; covered, over 200 feet long, with walks and alcoves. Mild treatment. Charges—Two Guineas per week, Matlock Bridge Station, Derby.—Smedley's Hydrotherapy, 312 pages, 2s. 6d.



For sale:
Baby shoes.
Never worn
16a Romero Street, Derby

No. 1. Now Ready.
NEW ILLUSTRATED MONTHLY MAGAZINE.
Price Two pence.
ENTERTAINING THING
A Magazine of THOUGHTFUL and INTELLECTUAL
AMUSEMENT. Thirty-Two Pages demy octavo, beau-
tifully printed on superior Paper, and done up in an
elegantly Illustrated Wrapper.
THE ILLUSTRATIONS will be continued by W. T.

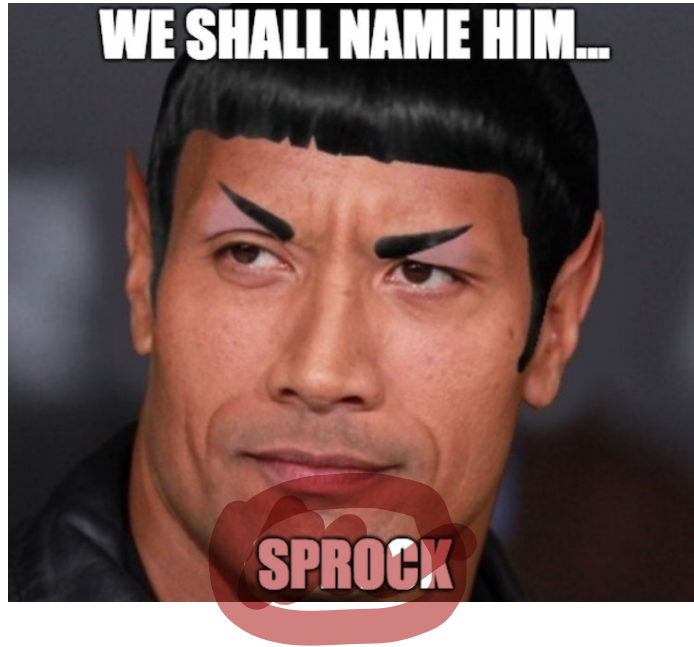
Johnson's Music: Wanted
The Ninth Corps
April 12th, and the Rest

DERBYSHIRE
THE FIRST GENE
SOCIATION, will
be Drawn, on FRIDAY
at 1 30 p.m., for the purp
PRESIDENT and COU
father business connecte

NORMANT
A B
UNDER THE
THE COUNTESS
THE COUNTESS
THE HON. MRS.
MRS. W. T. COX
MRS. MUNDY.
MRS. CHANDOS
MRS. MILLER, Fir
MRS. OSBORNE
MRS. P. BARBER
MRS. GIBSON
MRS. MONLEY.

WILL be sent to the
THURSDAY
April, 1861, to all of
MARTON CHURCH
Parties of not less than
Railway for one party
Station.

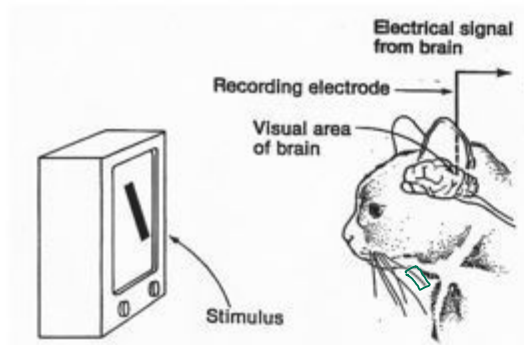
Consider this image



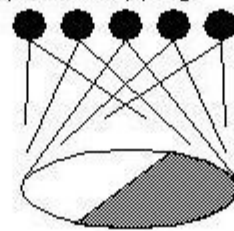
Consider this image



History

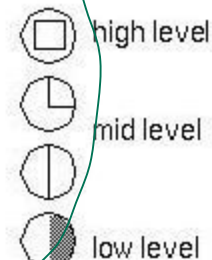


Hubel & Weisel
topographical mapping



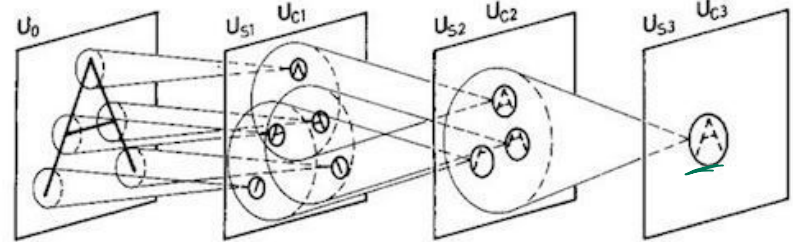
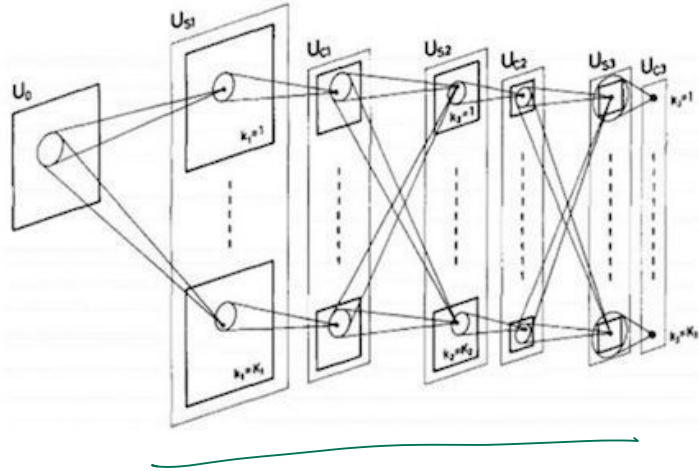
featural hierarchy

hyper-complex cells
complex cells
simple cells



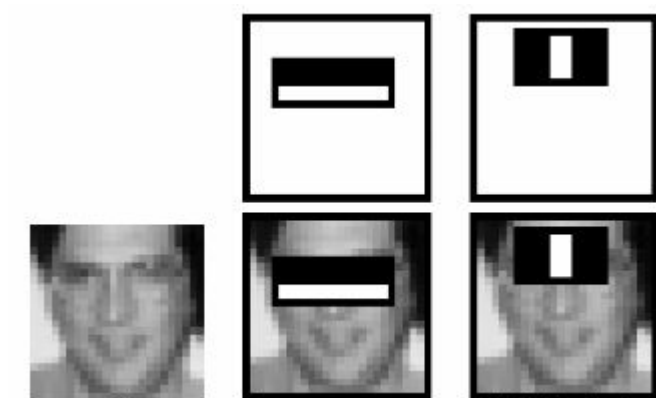
History

Fukushima's Neocognitron (1982)



History

Viola-Jones 2001



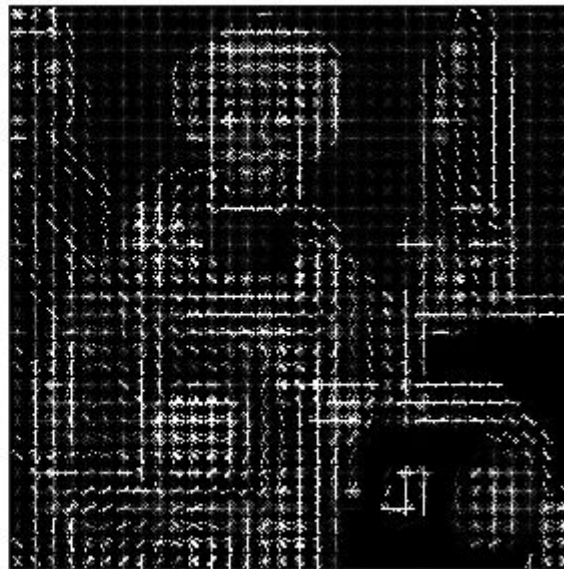
History

Histogram of Oriented Gradients, Dalal and Triggs (2005) ✓

Input image





Histogram of Oriented Gradients



History

Imagenet, Deng, Dong, Socher, Li, Li, & Fei-Fei, 2009




IM  **GENET**

www.image-net.org

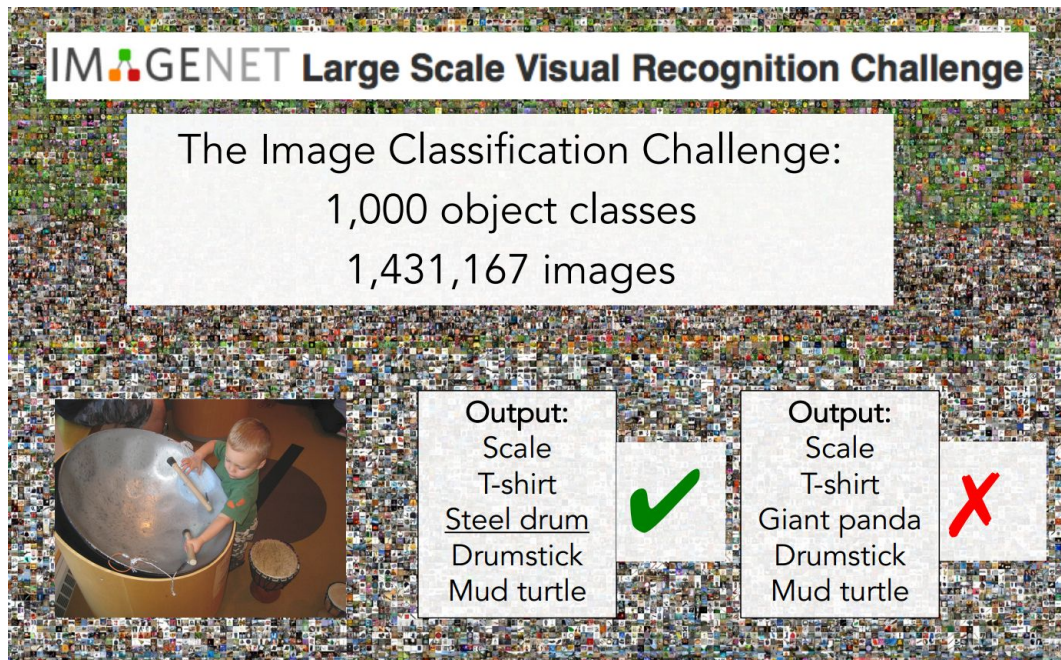
22K categories and **14M** images

- Animals
 - Bird
 - Fish
 - Mammal
 - Invertebrate
- Plants
 - Tree
 - Flower
- Food
- Materials
- Structures
 - Artifact
 - Tools
 - Appliances
 - Structures
- Person
 - Scenes
 - Indoor
 - Geological Formations
 - Sport Activities




History


Imagenet, Deng, Dong, Socher, Li, Li, & Fei-Fei, 2009




IMAGENET Large Scale Visual Recognition Challenge

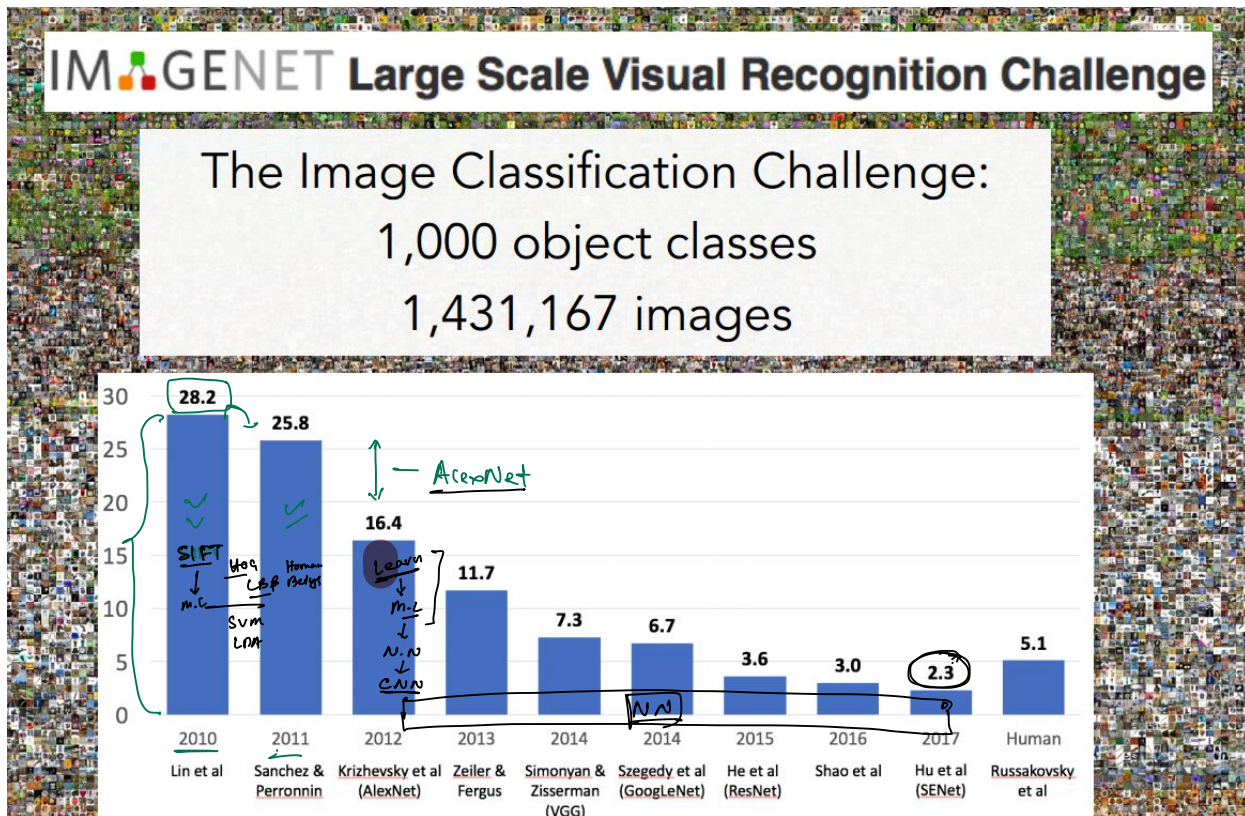
The Image Classification Challenge:
1,000 object classes
1,431,167 images



Output:		Output:
Scale		Scale
T-shirt		T-shirt
<u>Steel drum</u>		Giant panda
Drumstick		Drumstick
Mud turtle		Mud turtle



History - Context



Historical perspective

For our purpose we will simplify into two parts

Pre-2012

- Hand crafted features used with classifiers/search modules

Post-2012

- Learn features
 - Feature engineering is less of a concern, network engineering seems to be more useful

nn

In this course

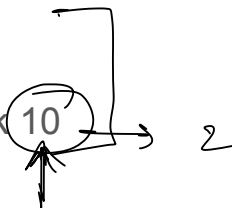
- We will mostly concentrate of Deep Learning-based architectures and techniques.
- Initially we will look at a non-parametric approach
- Also, some non-deep learning techniques
 - These are good to know for completeness of knowledge
- We will cover theory in course
- You will need to pick up a Deep Learning framework
- Pick a **suitable** project
 - 3-4 member teams
 - Paper must be ready by week 10

~~Costs~~ N. ~~Revel~~
Neighbour

f709

Images Repres

P. Torch



Project


- Fit your computational budget (capacity)
Google Collab / Kaggle kernels
- Do not attempt to collect your data.]
- Where there is scope for improvement.
- Follow (initially) your mentor's direction.
 ...

Image Classification

Image Classification

-



Wicket

Image Classification

- Is a core part of Computer Vision
- Extremely Challenging
- Semi formalised version is only slightly less challenging
 - Given a finite set of labels $L = \{l_1, l_2, l_3 \dots l_n\}$ and an Image M , ascribe to M one or more labels from L
 - We are not worrying about the “do not know” class

