Lecture 1

Introduction to Deep Learning

CSE465: Pattern Recognition and Neural Network
Sec: 3
Faculty: Silvia Ahmed (SvA)
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Tentative Topics

- ANN (Artificial Neural Networks)
- CNN (Convolutional Neural Networks)
- RNN (Recurrent Neural Networks)
- Autoencoders and GAN
- Object Detection and Image segmentation

Prerequisites

1. Python
2. Basics of Machine Learning
3. Linear Algebra
4. Probability Theory
5. Calculus

Today's Topic

1. Artificial Neural Networks (ANN)
    a. Basics:
        - What is Deep Learning
        - Deep Learning vs Machine Learning
        - Why deep learning is getting famous now?
        - Deep Learning Application
        - Deep Learning Types
        - History of Deep Learning

What is Deep Learning?

- Deep learning is a subfield of Artificial Intelligence and Machine Learning that is inspired by the structure of a human brain.
- Deep learning algorithms attempt to draw similar conclusions as humans would by continually analyzing data with a given logical structure called Neural Network.

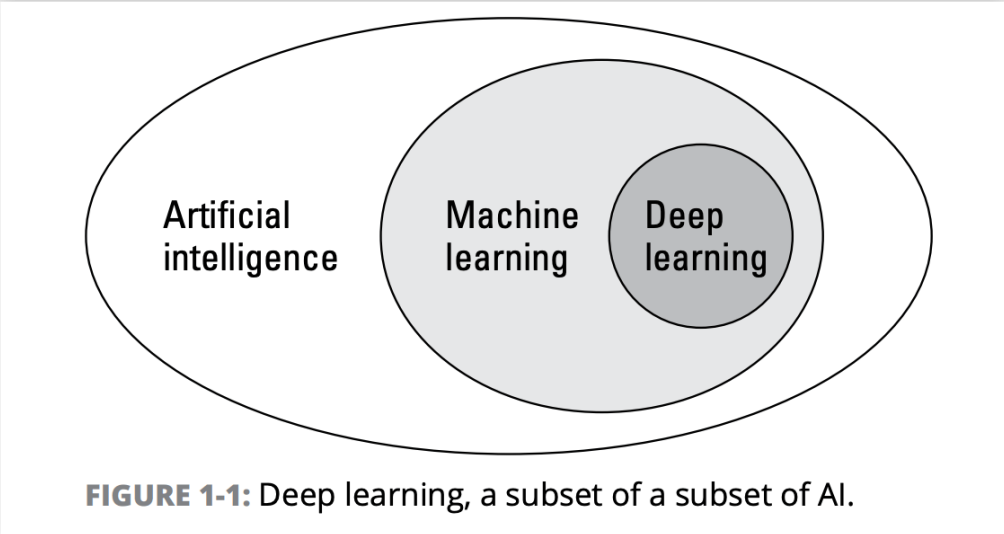
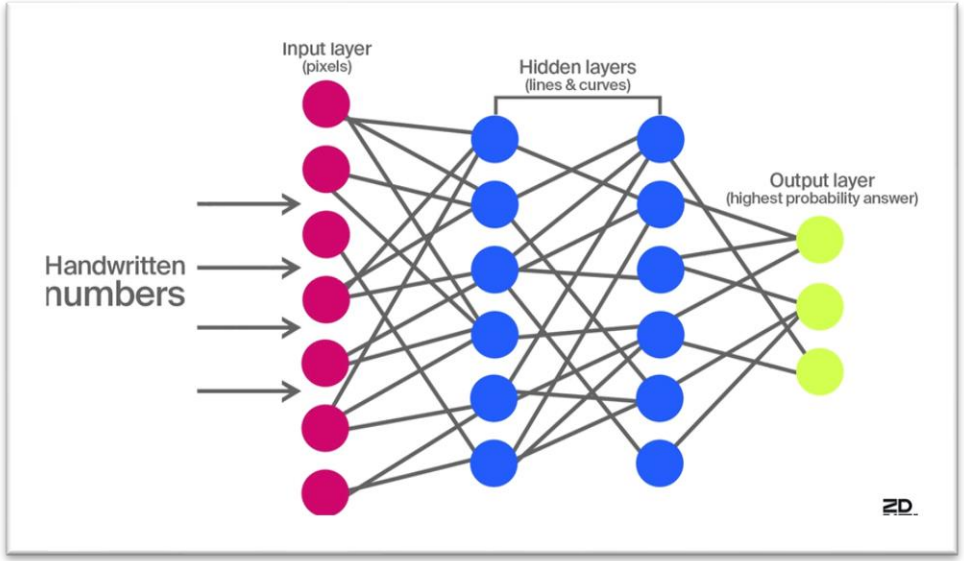
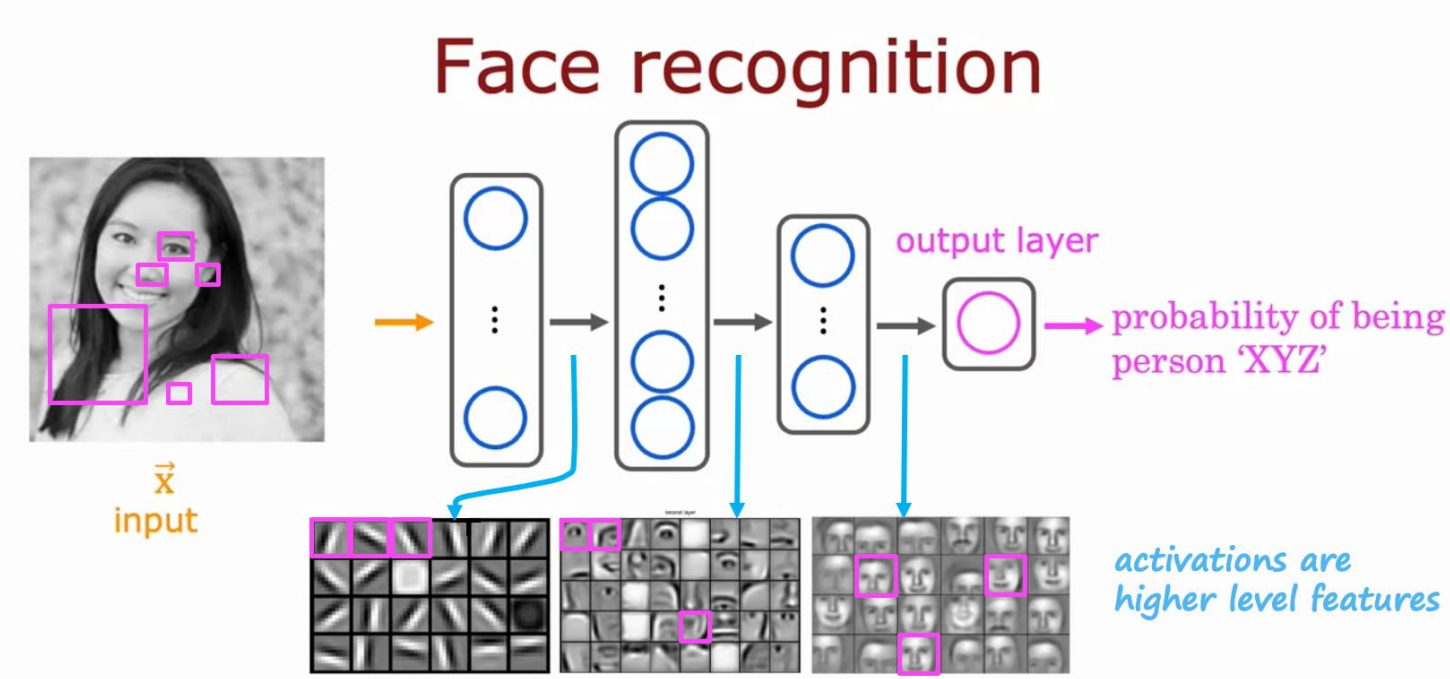


FIGURE 1-1: Deep learning, a subset of a subset of AI.



What is Deep Learning?

- Deep learning is part of a broader family of machine learning methods based on artificial neural networks with representation learning.
- Deep learning algorithms uses multiple layers to progressively extract higher-level features from the raw input.



source: Convolutional Deep Belief Networks for Scalable Unsupervised Learning of Hierarchical Representations by Honglak Lee, Roger Grosse, Ranganath Andrew Y. Ng

- For example, in image processing, lower layers may identify edges, while higher layers may identify the concepts relevant to a human such as digits or letters or faces.

Why deep learning is getting famous now?

- Applicability:
  - Computer vision
  - Speech recognition
  - NLP
  - Machine Translation
  - Bio-informatics
  - Drug design,
  - Medical image analysis
  - Climate science
  - Board games programs
- Performance

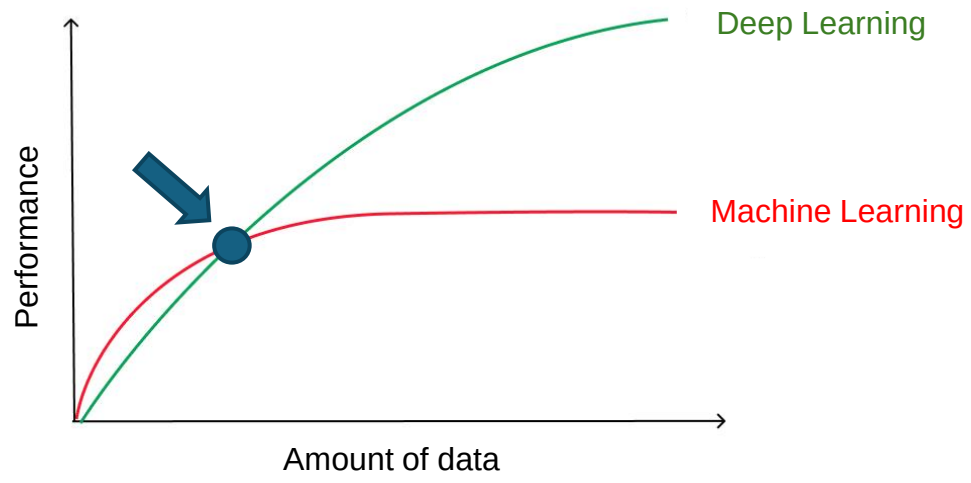
- Performance:
  - Example: Chinese Go game. DL defeated 4 out of 5 times the world champion

Deep learning vs Machine learning

1. Data Dependency
2. Hardware Dependency
3. Training Time
4. Feature Selection
5. Interpretability

DL vs ML (contd.)

1. Data Dependency



- Compared to machine learning, deep learning requires a lot more data.
- For less data, ML works better than DL but after a certain point the performance saturates.
- Whereas, performance of DL starts increasing almost linearly after a certain point.
- DL is data hungry

DL vs ML (contd.)

2. Hardware Dependency

- Machine learning algorithms can work in CPU.
- But in DL, there are complex matrix multiplications. So running them in CPU will be slow. It requires powerful GPUs with more memory.

3. Training Time

- DL models are complex, so model training time is high (as high as in weeks)
- ML model training time is low compared to low.
- Prediction time for DL is very fast. On the other hand, in ML, prediction with algorithms like KNN is very slow.

4. Feature Selection:

- DL uses representation learning, where features are automatically extracted.
- But in ML, features are manually chosen first and then need feature engineering for performance enhancement.

DL vs ML (contd.)

5. Interpretability:

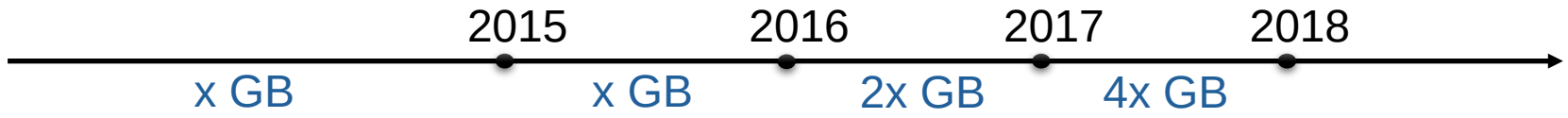
- Because of representation learning in DL, features are extracted automatically and the entire architecture works as a black box. So not interpretable.
- For example, in a social media platform if a DL model is deployed to ban a user for his/her comment, then it will read a comment and simply decide whether or not to ban a user. If the user then asks why he/she was banned then we won't be able to determine exactly for which reason he/she was banned. This is a big flaw.
- As opposed to that, if logistic regression is applied for a problem with 2 features and there will be 2 weights (w1 and w2) seeing which we will be able to understand feature importance.

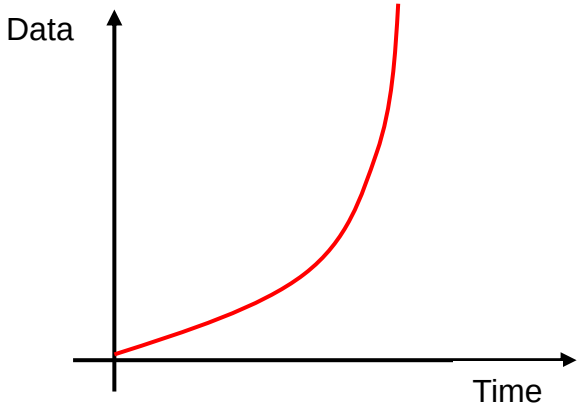
Why now?

- DL work started as early as 1960's in Alan Turing's time.
- Regained popularity in 2012

#1. Datasets

- DL is data hungry
- Usual ML can work with 100, 1000 rows.
- DL starts working from 100,000 rows.
- In 2010: Smart phones, internet pricing (Tiktok, snapchat, etc.)





- Some public dataset examples:
  1. Image: Microsoft COCO
  2. Video: Youtube 8M
  3. Text: SquAd
  4. Audio: Google Audioset

#2. Hardware

- **Moore's Law:** The number of transistors on a microchip doubles about every two years, though the cost of computers is halved.
- **Deep Learning Needs:** High computational power for massive data and matrix operations.
- **Challenges with CPUs:** Slow processing for parallel matrix operations.
- **2010 Breakthrough:** Use of GPUs for parallel matrix computations, inspired by high-resolution image rendering.
  - NVIDIA CUDA: Revolutionized GPU programming for deep learning.
- **FPGAs:** Fast, low power, reprogrammable hardware.
  - Example: Bing AI uses FPGAs.
- **ASICs:** Specialized chips for AI
  - TPU (Tensor Processing Unit): Optimized for DL.
  - Edge TPU: Used in drones, smartwatches, and smart glasses.
  - NPU (Neural Processing Unit): Advanced AI processing

#3. Frameworks

- Tensorflow by Google
- PyTorch by Facebook
- 2011: Dist Belief -> Google but very attached to google products
- 2015: Tensorflow (but very difficult to use)
- Keras: Worked on top of Tensorflow.
- 2016: Pytorch came to deal with shortcomings of Tensorflow
- 2018: Caffe 2 which worked with Tensorflow
- 2019: Tensorflow 2.0 (built-in Keras)
- To convert from one framework to another some dropdown GUI based applications: AutoML

#4. DL Architectures

- ANN
- CNN
- RNN
- Pre-trained model (ready-to-use)
- Transfer learning
    - Image classification: ResNET
    - Text classification: BERT
    - Image segmentation: Unet
    - Image translation: Pix2Pix
    - Object detection: YOLO
    - Speech generation: WaveNet

#5. Community

- Started in 1960, failed couple of times then became popular around 2010
- Thanks to:
  - Researchers,
  - Teachers,
  - Students,
  - Kaggles,
  - HuggingFace, etc.

Reference and further reading

- “Deep Learning”, Ian Goodfellow, et al.
- https://www.coursera.org/specializations/deep-learning
- Python Tutorials:
- https://www.w3schools.com/python/python_syntax.asp
- Video tutorial: Jupyter Notebook Tutorial for Beginners with Python
- https://www.geeksforgeeks.org/how-to-use-jupyter-notebook-an-ultimate-guide/
- Google Colab tutorial: https://colab.research.google.com/drive/16pBJQePbqkz3QFV54L4NIkOn1kwpuRrj