COSI 165B
Deep Learning

Chuxu Zhang
Computer Science Department
Brandeis University

2/1/2021

Course Information

COSI 165B – Deep Learning

Covers core techniques of deep learning.
Main content: deep learning basics, feed-forward neural network, recurrent neural network, convolutional neural network, graph neural networks, and others.
Students should read book and materials, attend lecture, and work on programming homework and course project.

Instructor: Dr. Chuxu Zhang

Assistant Professor
General research: data mining, machine learning, deep learning
Specific research: graph and network mining, interdisciplines (e.g., chemistry), recommender systems, time series and spatial-temporal data analysis
Contact: chuxuzhang@brandeis.edu
Webpage: https://chuxuzhang.github.io

Course Information

- Time: Monday/Wednesday 4:00 – 5:30pm
- Location: Remote by Zoom
- Office Hour: Tuesday 9-11pm (Remote by Zoom)
- Teaching Assistant: Han Yue (hanyue@brandeis.edu)
- LATTE Forum (Announcement, Discussion, Submission, etc.)
- Course Website: https://chuxuzhang.github.io/course/COSI165B.html

Course Logistics

❑ Prerequisites

Data structures (COSI 21A), Applied linear algebra (MATH 15A), Probability and statistics (MATH 8A), Calculus (MATH 10A), proficiency in Python programming, Machine learning background (preferred).

❑ Course Objectives

Be familiar with the core techniques and tools of deep learning.
The skills, techniques, and implementations of deep learning algorithms and models.
Students are expected to apply deep learning techniques to solve real-world problems or start deep learning related research during or after this course.

Course Logistics

❑ Course Materials

Deep Learning, Ian Goodfellow and Yoshua Bengio and Aaron Courville, MIT Press
https://www.deeplearningbook.org
Dive into Deep Learning, Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola
https://d2l.ai
Machine Learning | Andrew Ng: YouTube, Coursera

❑ Special Statement for Covid-19

Remote lectures via Zoom

Remote office hours via Zoom

Course Logistics

❑ Grading

Five programming homework (60% = 10%, 10%, 10%, 15%, 15%)
A course project with presentation (40%: midterm presentation 10%, final presentation 10%, final report 20%)

Grades (4 points in Brandeis)
A (A+) = 4.00; A- = 3.67; B+ = 3.33; B = 3.00; B- = 2.67; C+ = 2.33; C = 2.00; C- = 1.67; D+ = 1.33; D = 1.00; D- = 0.67 and E = 0.00

Grades (100 points)
A (A+) = [90, 100]; A- = [87, 90); B+ = [84, 87); B = [81, 84); B- = [78, 81); C+ = [75, 78); C = [72, 75); C- = [69, 72); D+ = [66, 69); D = [63, 66); D- = [60, 63); and E = [0, 60)

More About Homework

❑ Programming homework (60%)

Five Python programming homework. Each homework covers one topic of deep learning techniques.

Homework requirement: See requirement of each homework.

Code submission: Attach code (executable) with readme file.

Contact TA for homework/grading questions.

Grading is based on both homework submission and code submission.

More About Course Project

❑ Course Project (mid pre. 10%, final pre. 10%, final report 20%)

Project chosen by students and should use deep learning models to solve a real-world problem.

Could be an open competition in Kaggle, implementation of previous work (paper), a follow up work of current research work, or a new problem and its solution of deep learning research.

Group project: up to 3 students. (Form group by yourself)

Midterm presentation: late-March, Final report/presentation: last week.

Grading based on quality of your project, report, and presentation.

Course Logistics

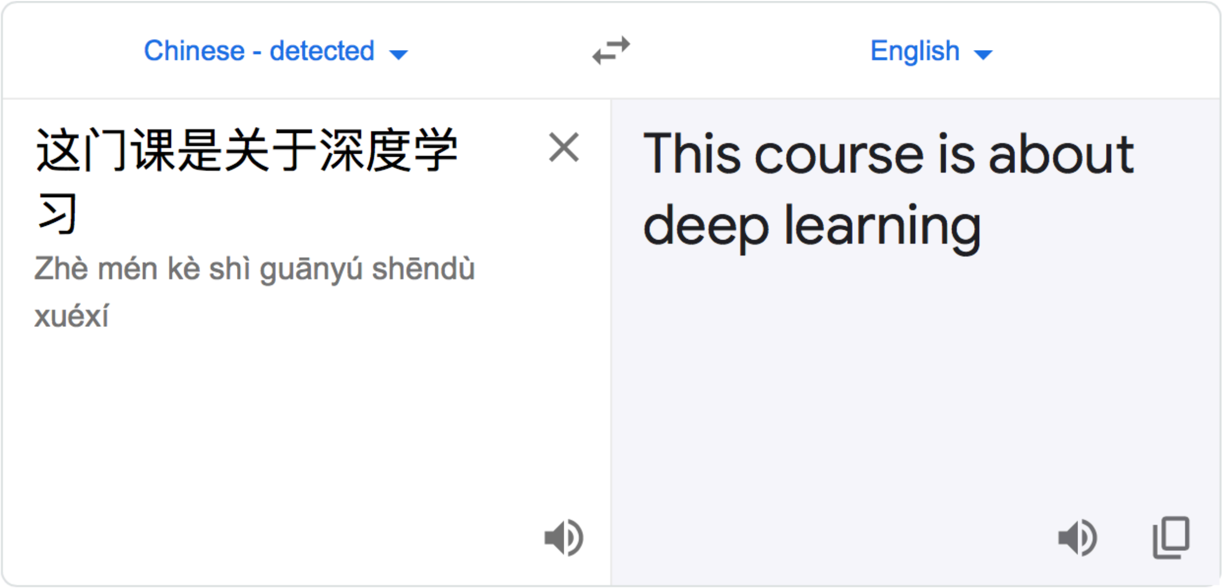
❑ Schedule

Week-1	Introduction/ML	
Week-2	Feed-forward Neural Networks	Homework 1
Week-3	Frameworks (Pytorch)	
Week-4	Neural Networks Optimization and Regularization	
Week-5	Convolutional Neural Networks	Homework 2
Week-6	Convolutional Neural Networks	
Week-7	Recurrent Neural Networks	Homework 3
Week-8	Recurrent Neural Networks	
Week-9	Project Midterm Presentation	
Week-10	Autoencoder Networks	Homework 4
Week-11	Attention Networks	
Week-12	Graph Embedding and Graph Neural Networks	Homework 5
Week-13	Deep Generative Networks	
Week-14	Project Final Presentation	Final Report Due

Q & A

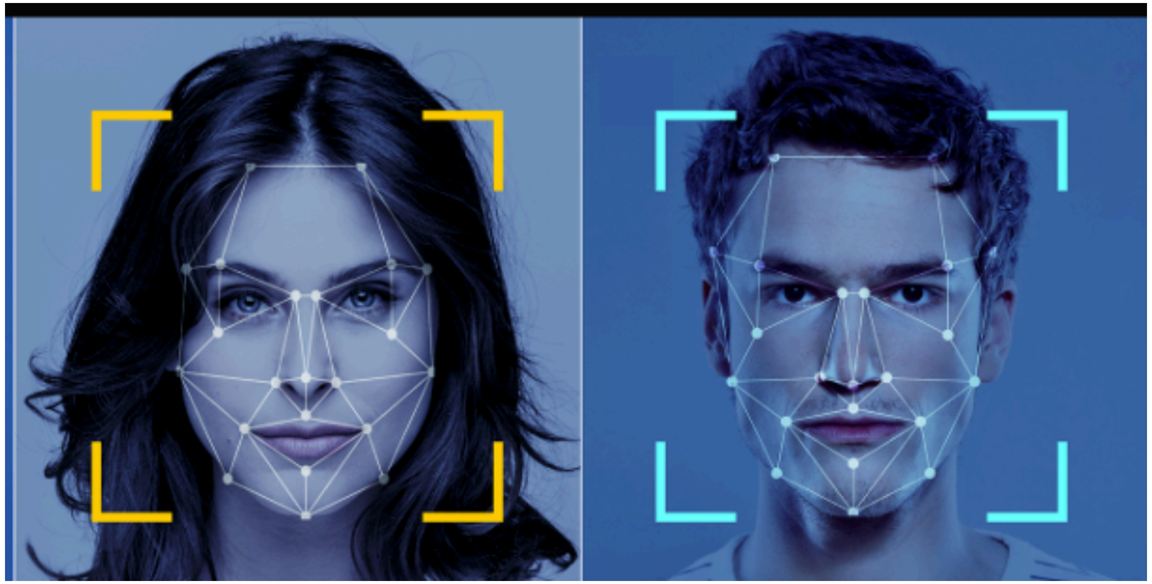
- We use

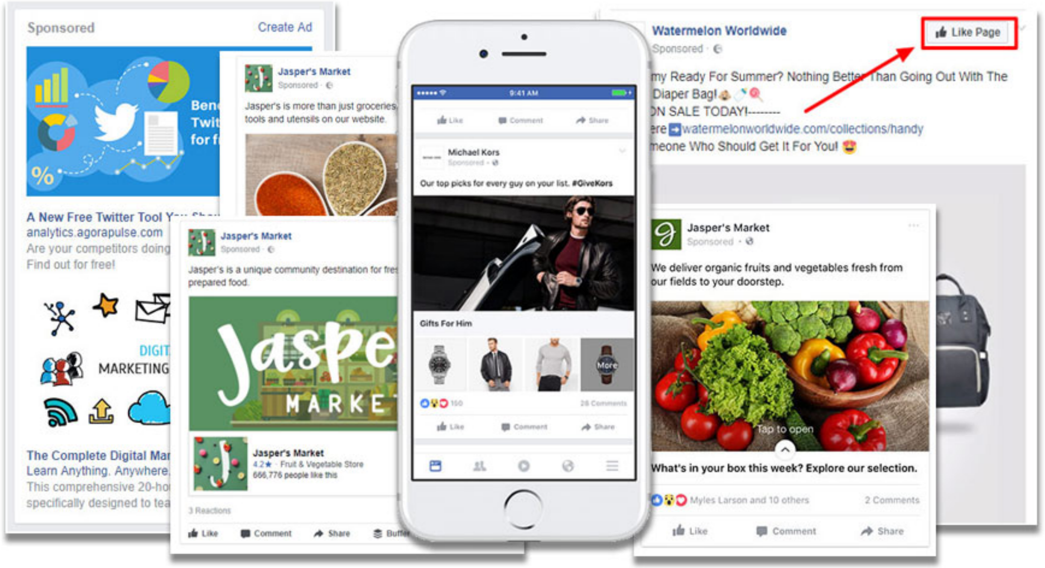

9:41
Cancel
5 of 5
Now say:
"Hey Siri, it's me."
Set Up "Hey Siri" Later


Chinese - detected
English
这门课是关于深度学习
Zhè mén kè shì guānyú shēndù xuéxí
This course is about deep learning

Introduction

- We experience





Introduction

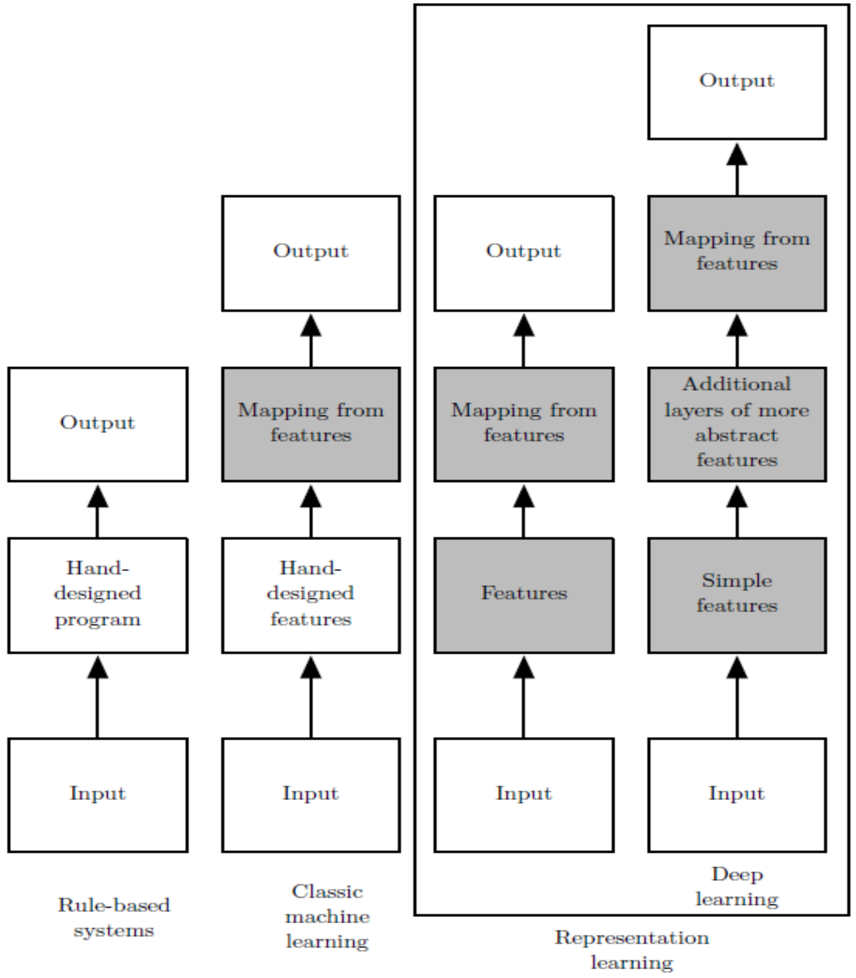
- We know

Introduction

- ❑ **What is Deep Learning**
- ❑ Why Deep Learning
- ❑ Deep Learning History
- ❑ Deep Learning Application
- ❑ Structure of This Course

What is Deep Learning

❑ Feature Engineering vs Representation Learning

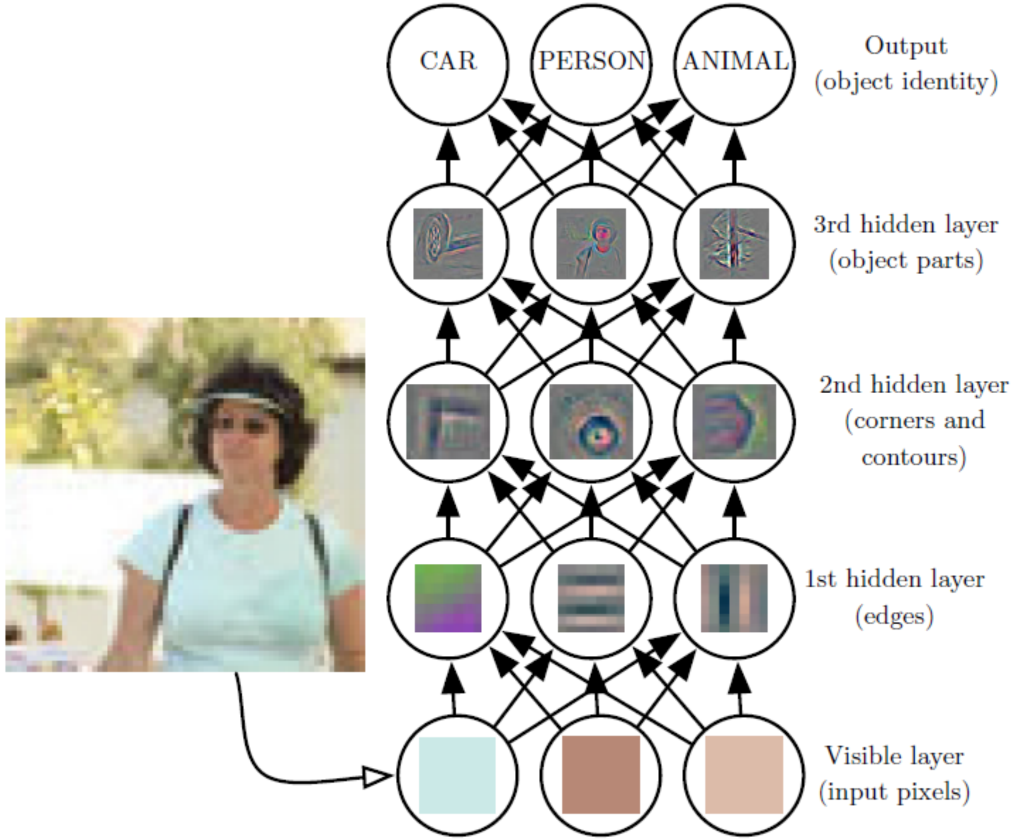


- Classic ML: Feature engineering
  - use features to represent data (e.g., house price prediction)
  - Hand-designed feature problems (missing features, improper features, domain knowledge, time consuming)

- DL: Representation learning
  - learn feature representation automatically
  - little human/domain knowledge
  - strong performance

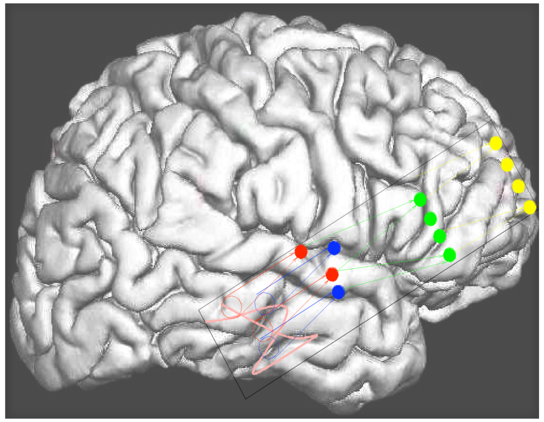
What is Deep Learning

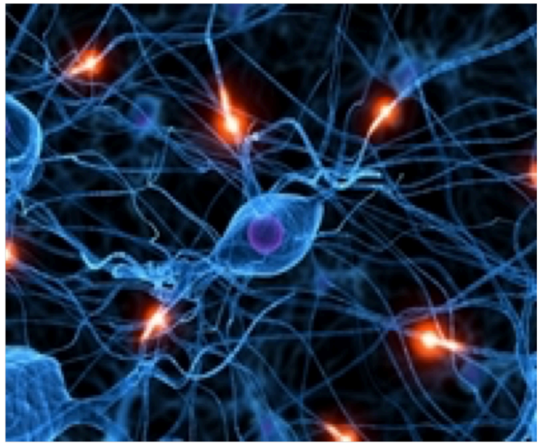
❑ Example



- Image classification
  - transform raw data (input layer) to feature representation (hidden layer)
  - build complicated architecture to learn high level representation
  - take high level representation as feature for classification model

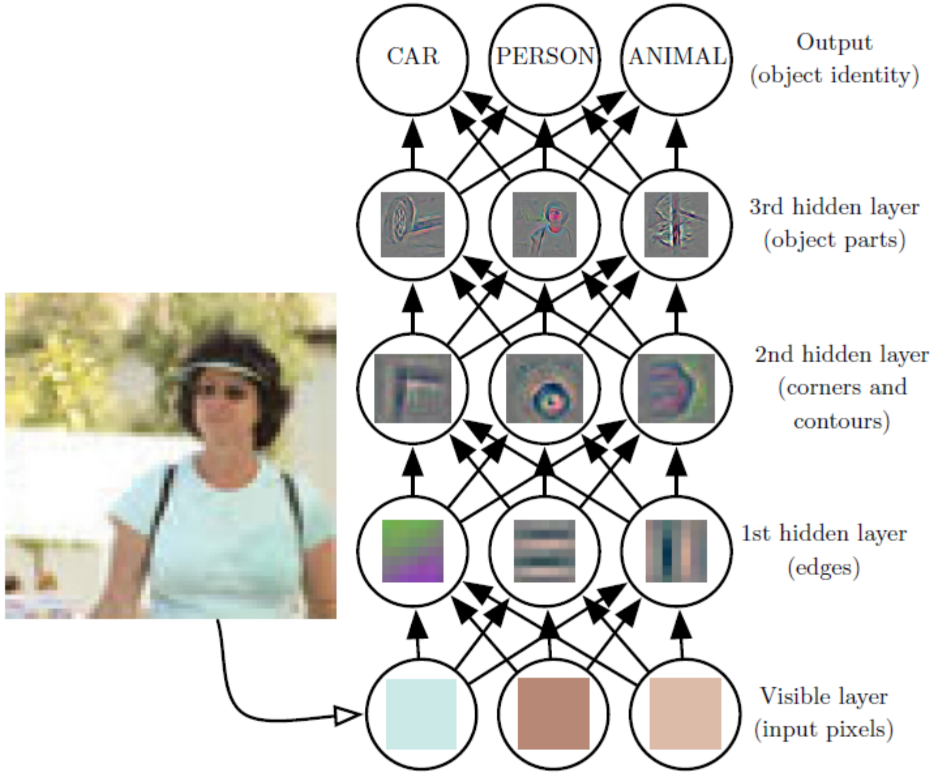
❑ Motivation



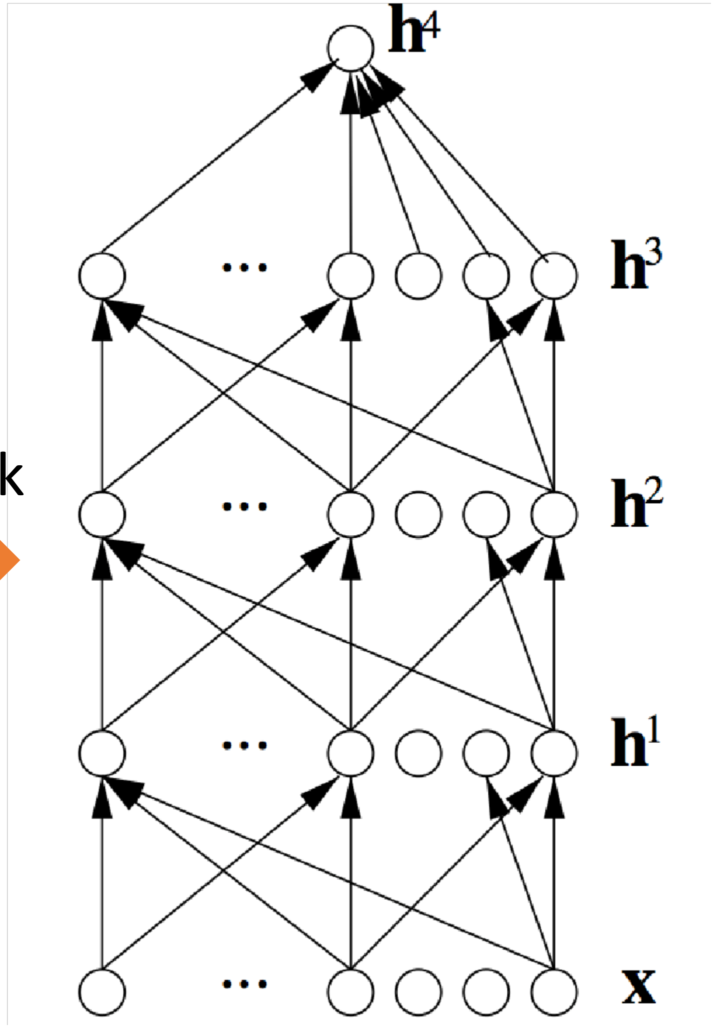


- Human brains are actual intelligence
- Neurons in brain work for intelligence
- Develop abstraction of function of actual neurons
- Simulate large, massively, parallel artificial neural networks
- Try to approximate human learning

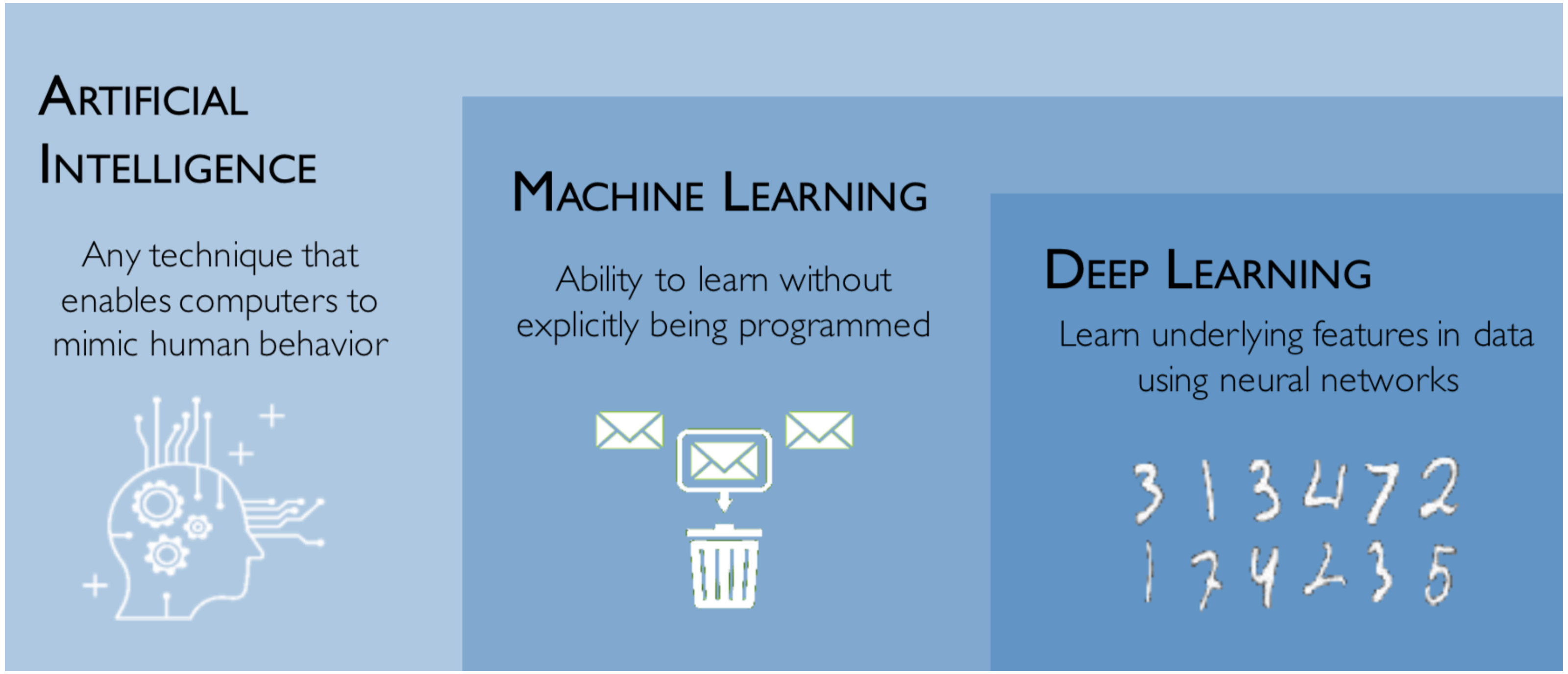
❑ Artificial Neural Network

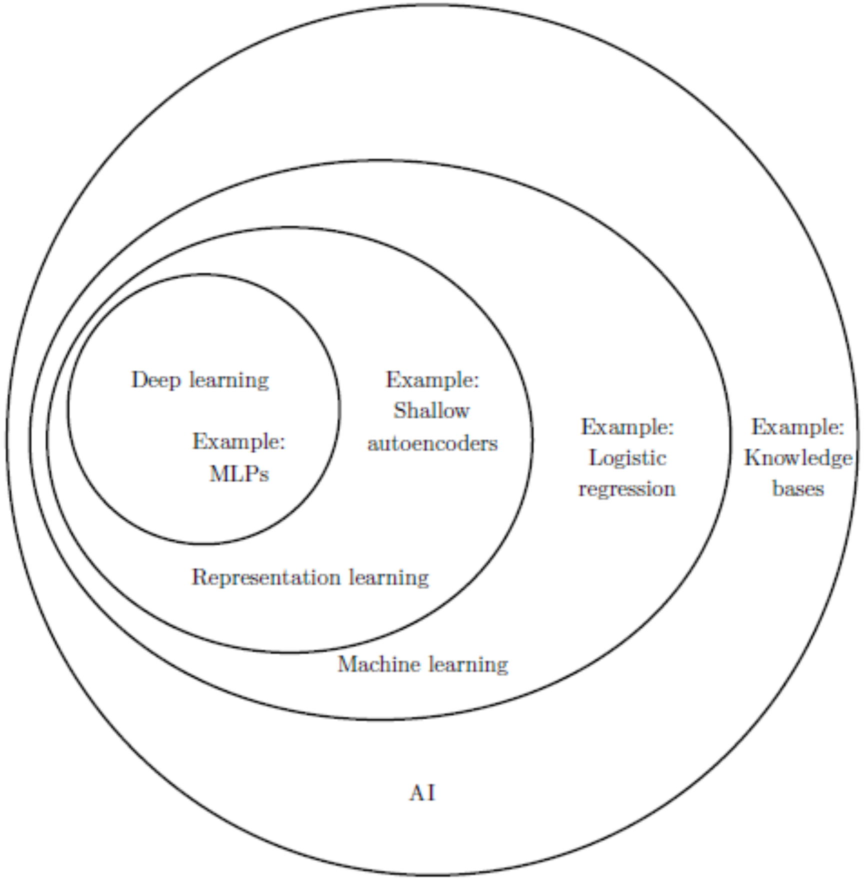


Artificial
neural network



What is Deep Learning





Introduction

- ❑ What is Deep Learning
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Why Deep Learning

- ML: handcrafted feature problems: missing features, improper features, domain knowledge, time consuming
- DL: little domain knowledge, learn feature representation automatically, high level/abstract features
- Imitate human brain process by artificial neural network
- Similar architecture for different tasks/scenarios

❑ Distributed Representation Learning

- Many to many mappings (each feature maps to multiple hidden/output layers)
- Color: red, blue, green
- Shape: bird, car, truck
- Hidden layer/neuron
- Independent, in parallel

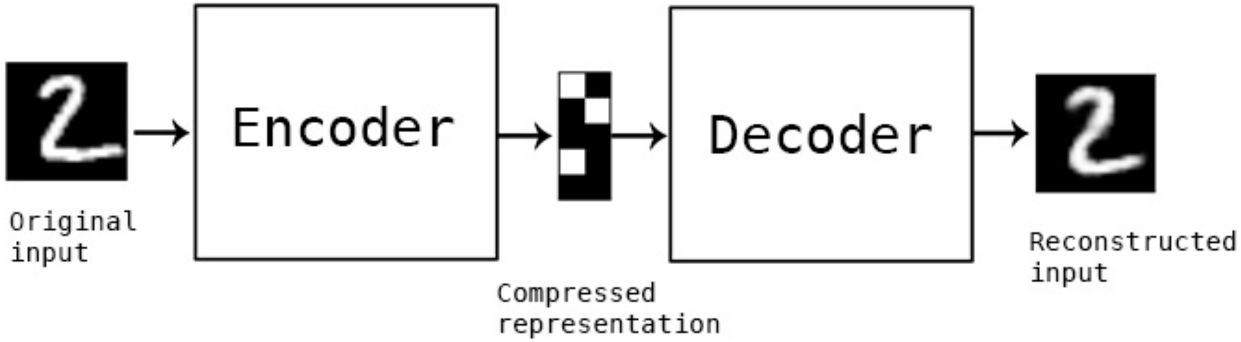
❑ Multi-level Representation Learning

Deeper layers: More abstract and complicated feature representations

Low Level Features | **Mid Level Features** | **High Level Features**

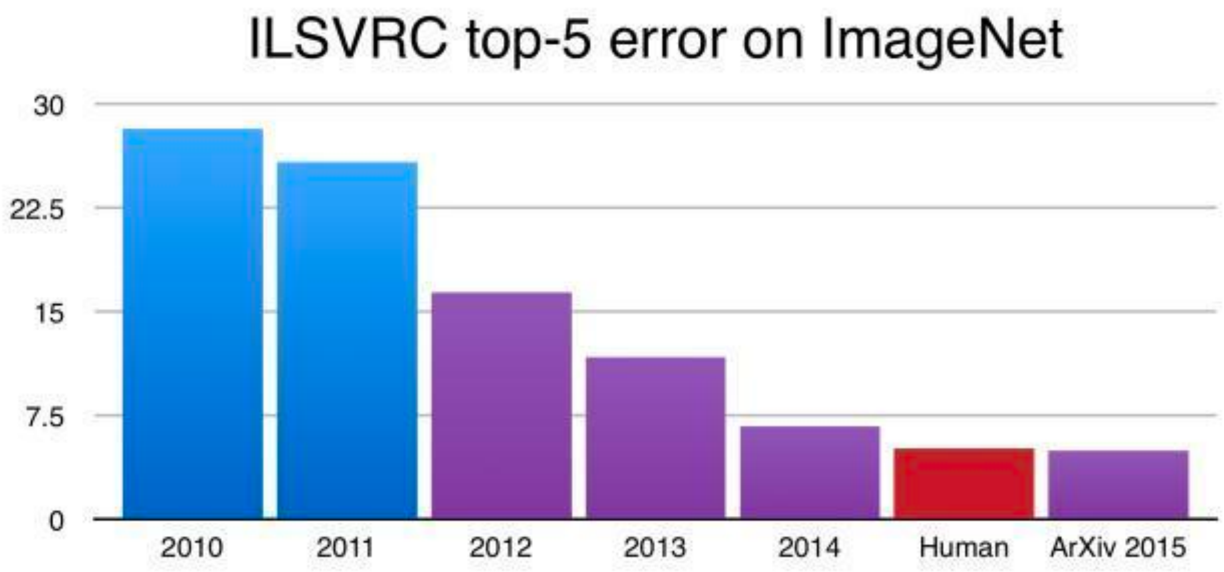
Lines & Edges | Eyes & Nose & Ears | Facial Structure

❑ Unsupervised Representation Learning



- ML: requires sufficient labels (time, money, resource)
- Unsupervised deep learning (e.g., encoder-decoder)
- Reconstruct original data
- Learn representation without label

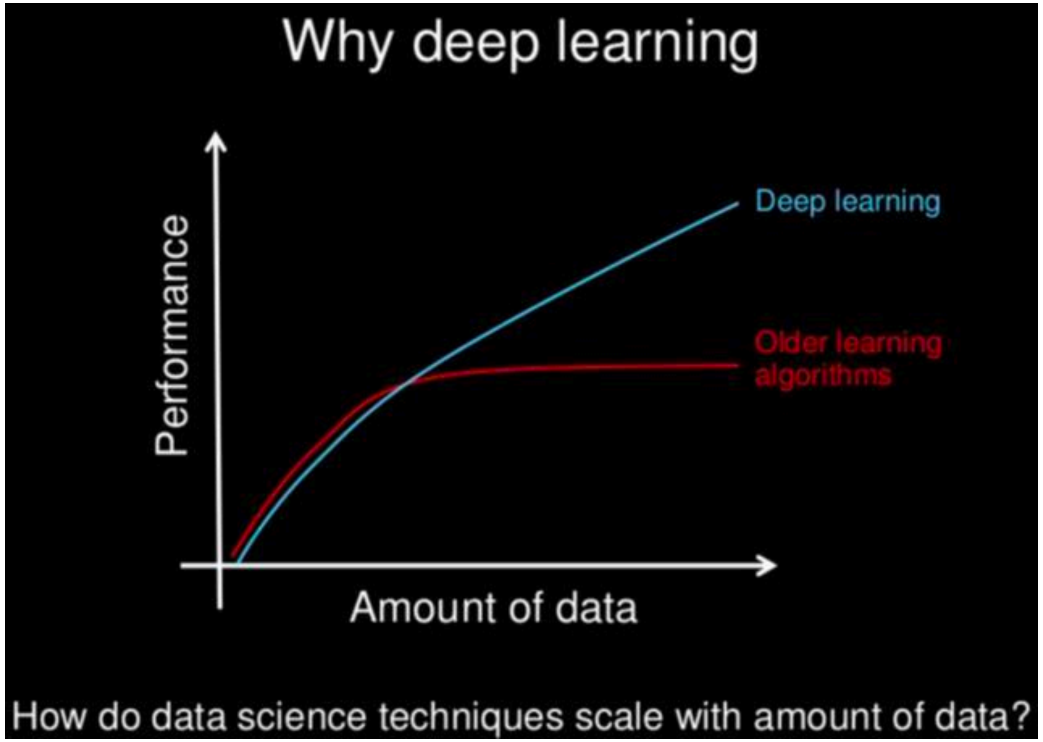
❑ Performance



- Much better than ML (e.g., image classification)
- Green: classic ML
- Purple: Deep CNN
- Red: human

Why Deep Learning

❑ Data



- ML: more data, stable performance
- DL: more data, better performance
- Larger learning capability with more data

Why Deep Learning

❑ Resource

1. Big Data

- Larger Datasets
- Easier Collection & Storage

IMAGENET

WIKIPEDIA
The Free Encyclopedia

2. Hardware

- Graphics Processing Units (GPUs)
- Massively Parallelizable

3. Software

- Improved Techniques
- New Models
- Toolboxes

TensorFlow

Introduction

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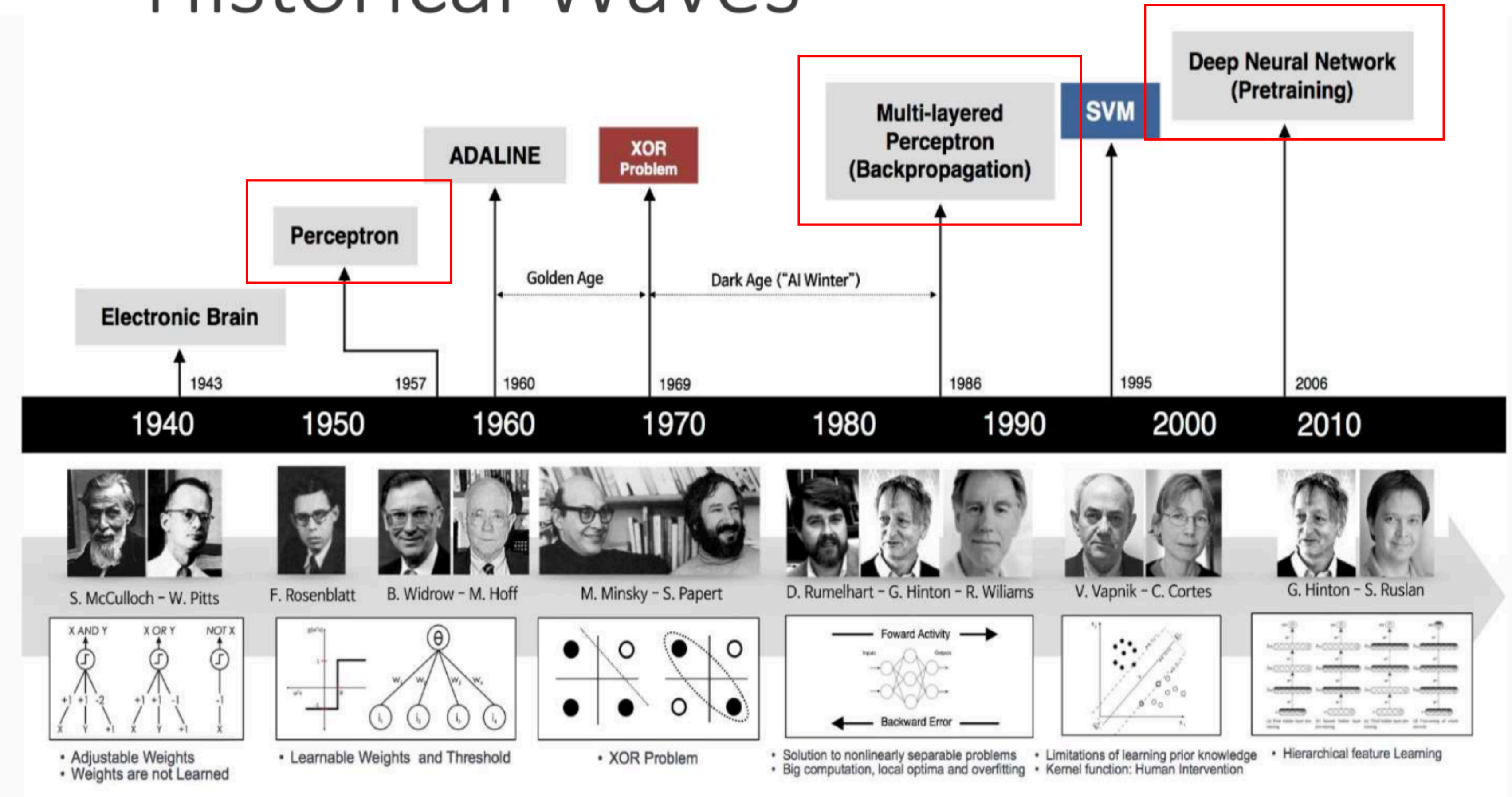
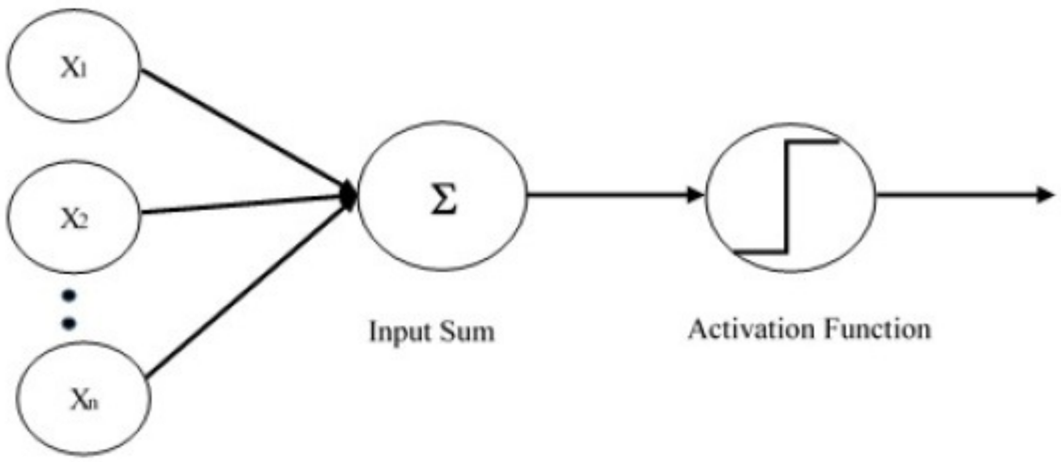
Deep Learning History

Historical Waves



- Perceptron
- Multi-layer perceptron
- Deep neural network

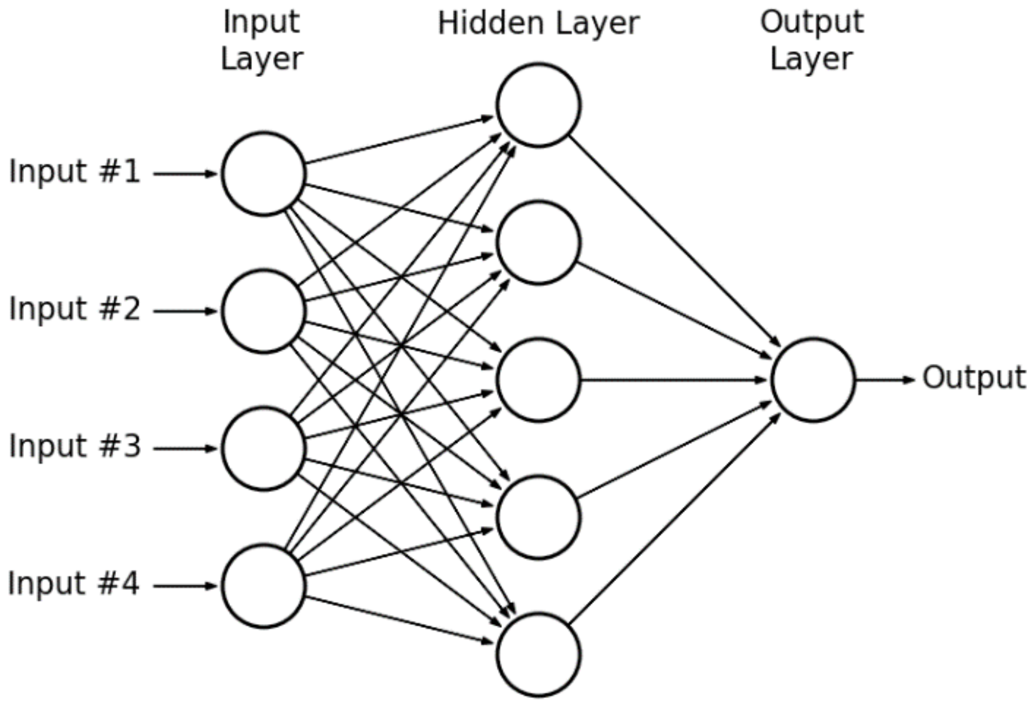
❑ Perceptron: First-generation Neural Networks



One-layer neural network

- Input: feature
- Learnable weights
- Action function
- Output: prediction

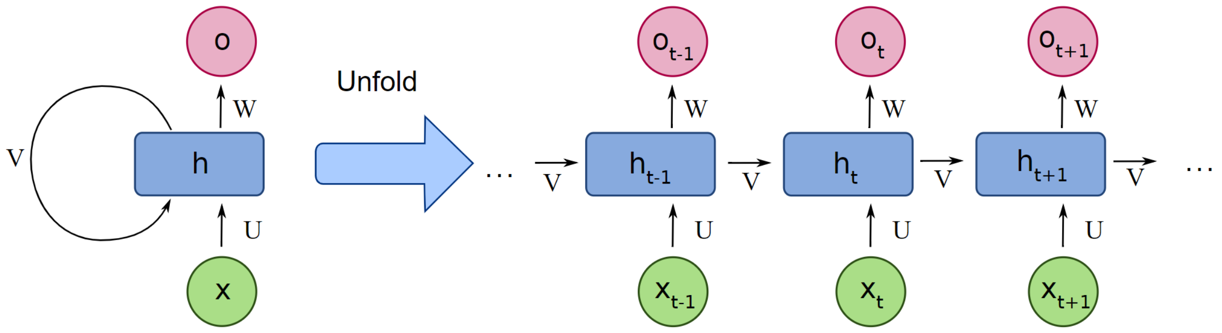
❑ Multi-layer Perceptron



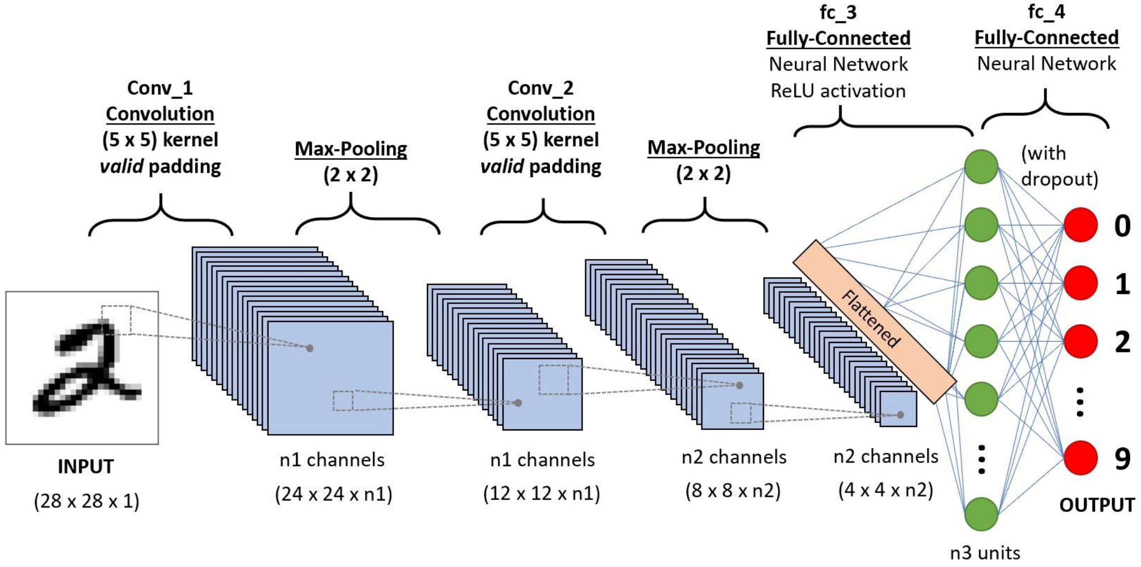
Multiple-layer neural network

- Input data: feature
- Learnable weights
- Hidden layer: abstract representation
- Action function
- Output: prediction

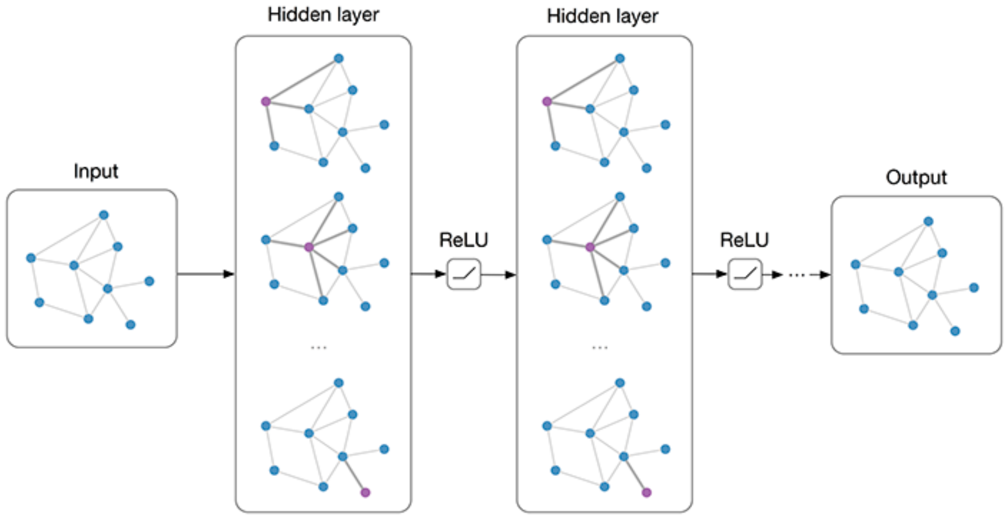
❑ Deep Neural Networks



Recurrent neural network



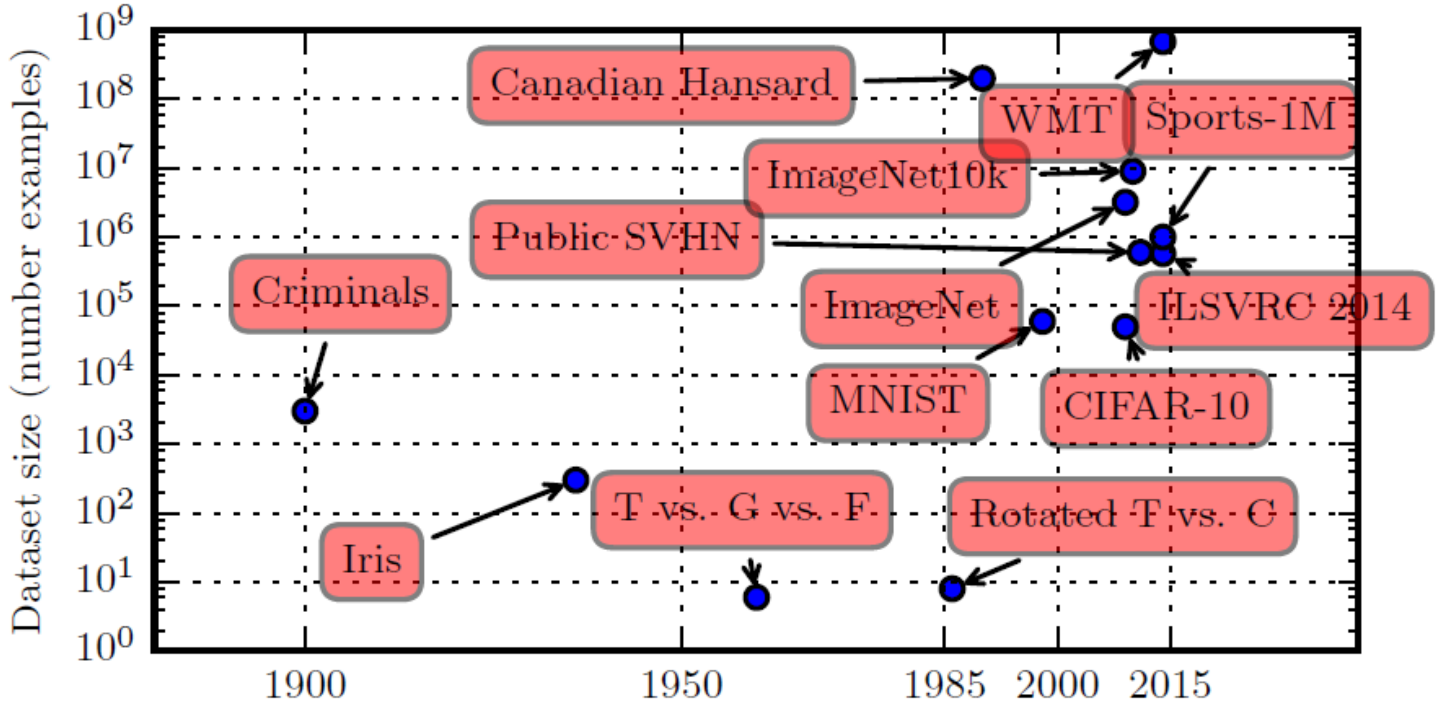
Convolutional neural network



Graph neural network

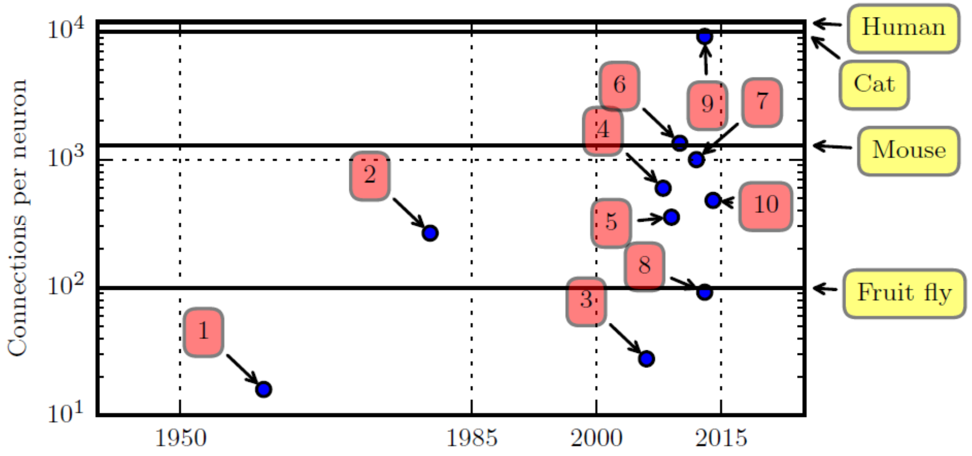
Deep Learning History

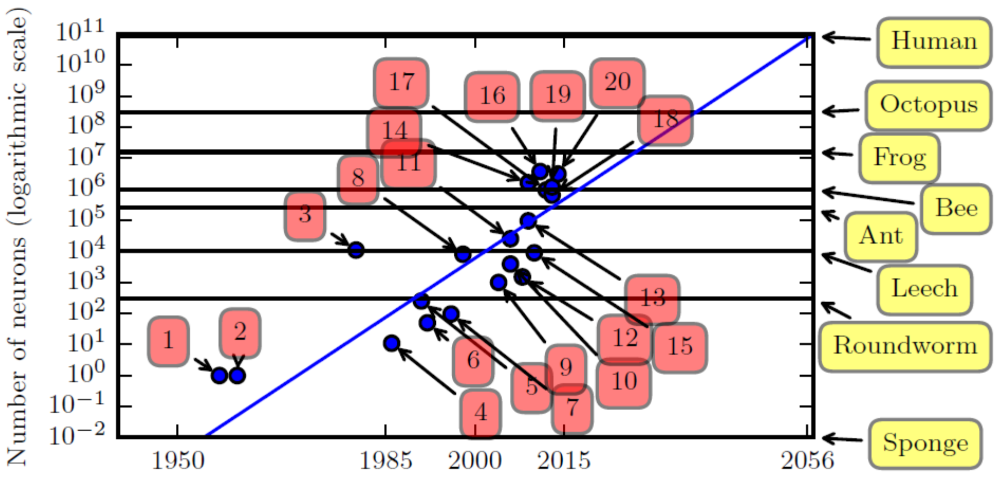
❑ Current Trends



- Larger dataset
- Ten thousand to billions

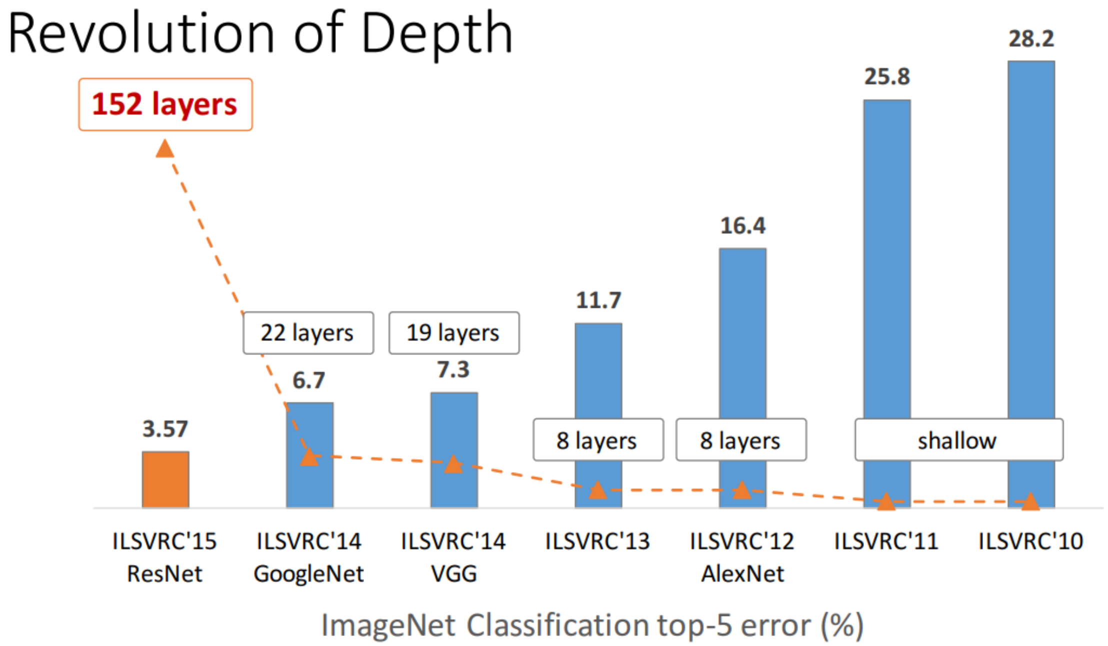
❑ Current Trends





- Larger model size
- Neuron connection number close to human level

❑ Current Trends



- Deeper model
- Better performance

Introduction

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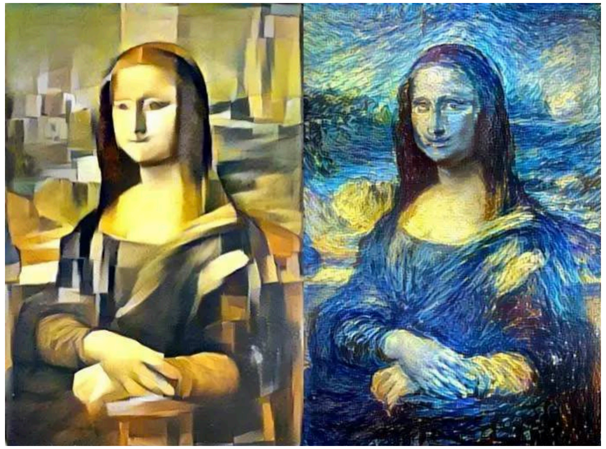
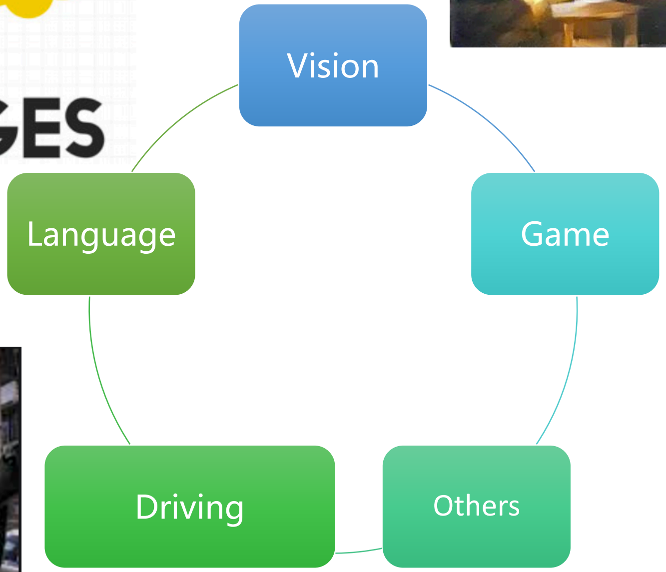
Deep Learning Application

Brandeis University

❑ Multiple Domains





❑ Vision

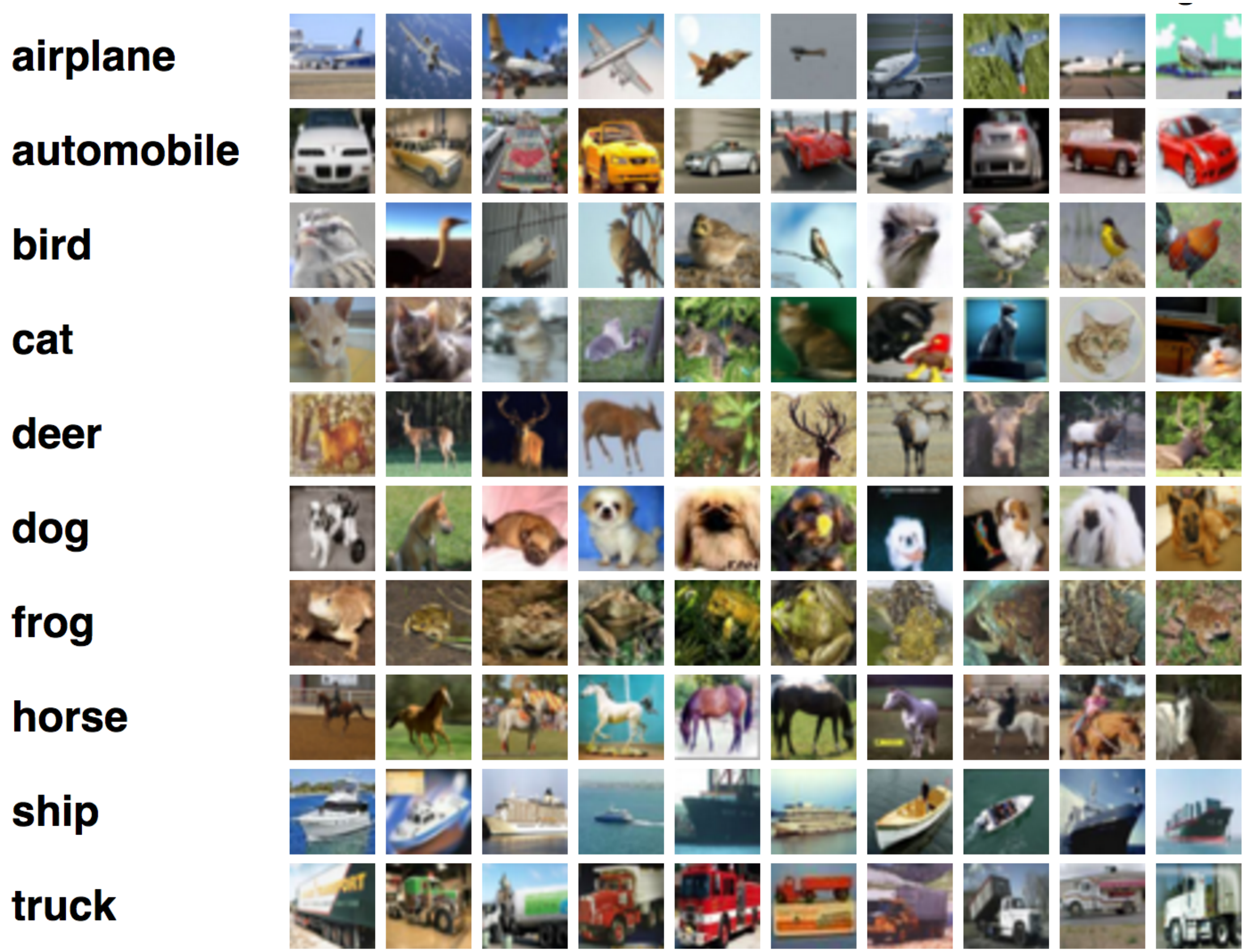
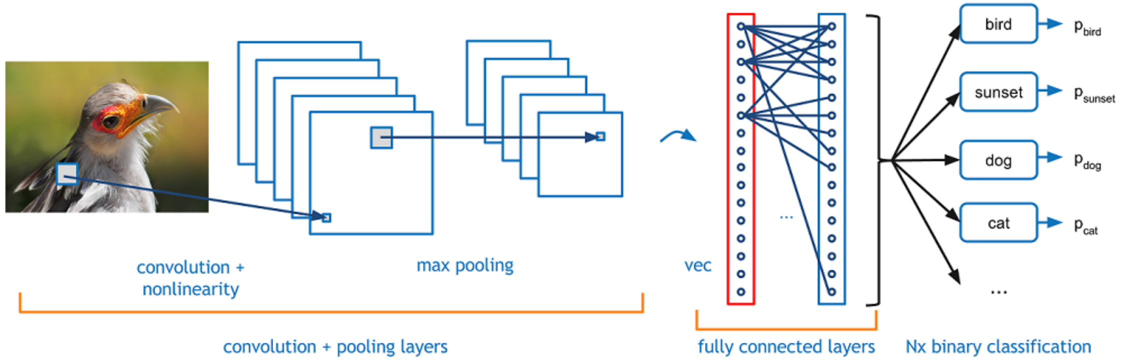


Image classification
(convolutional neural network)



❑ Vision

Image coloring

❑ Vision

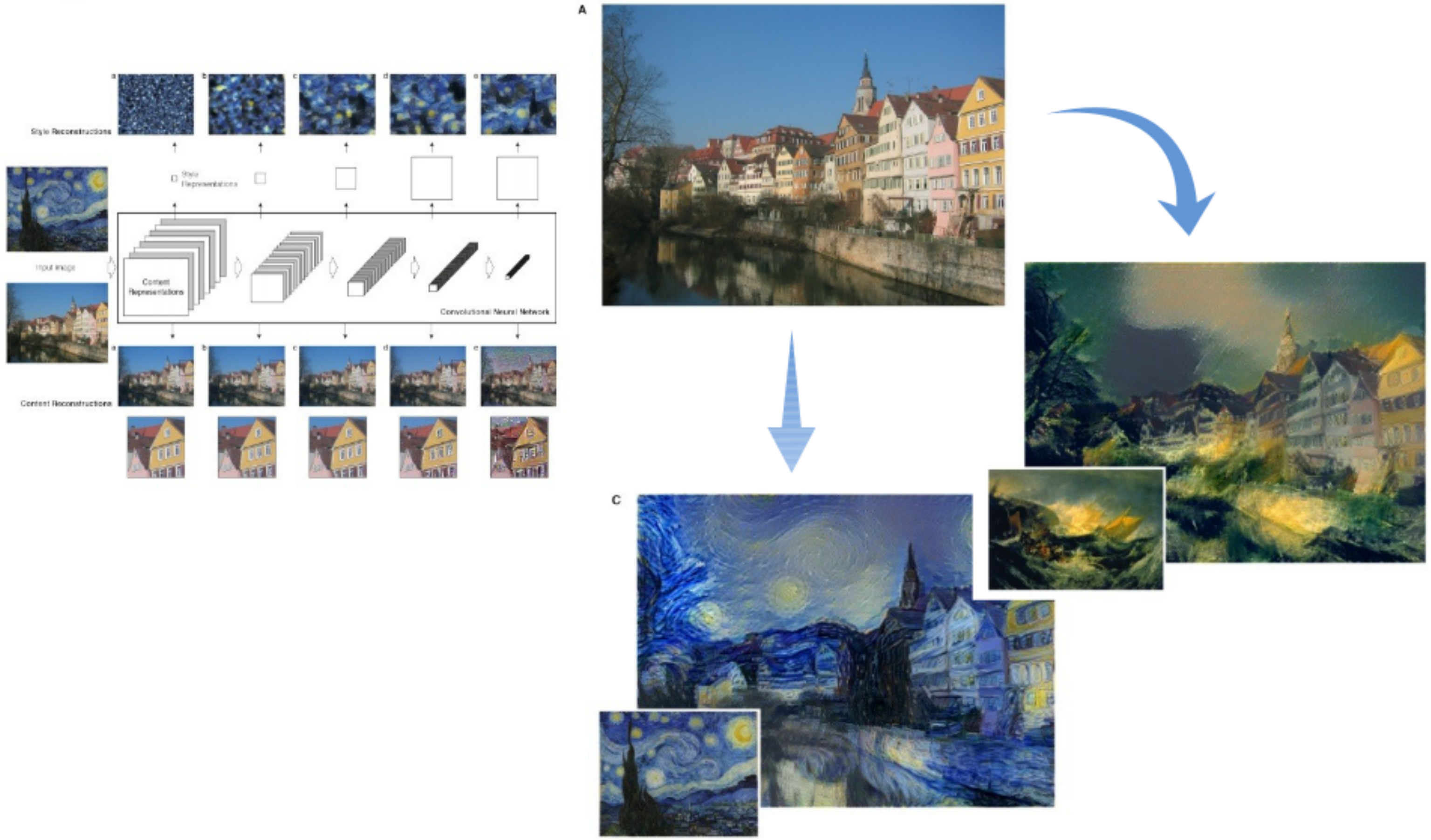
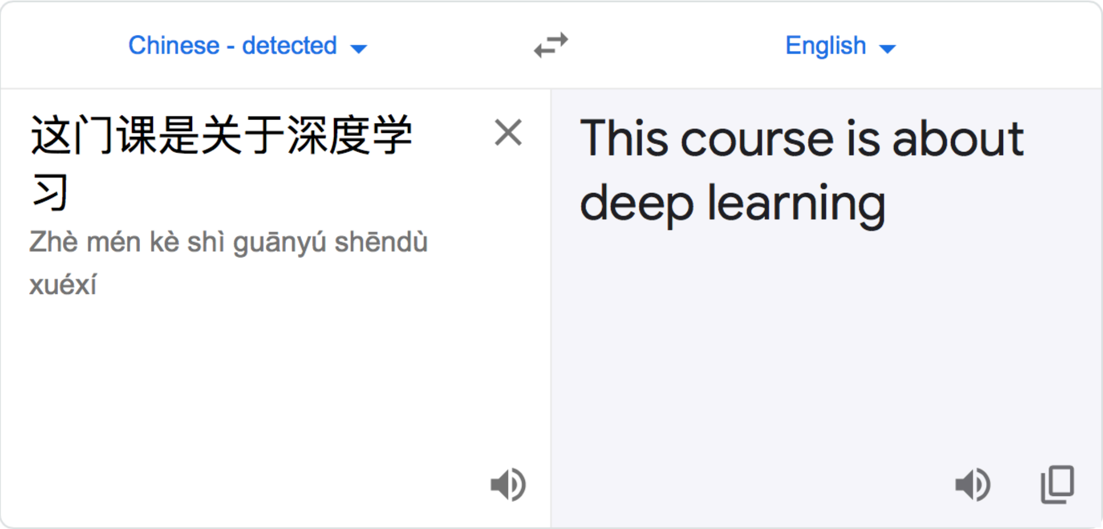
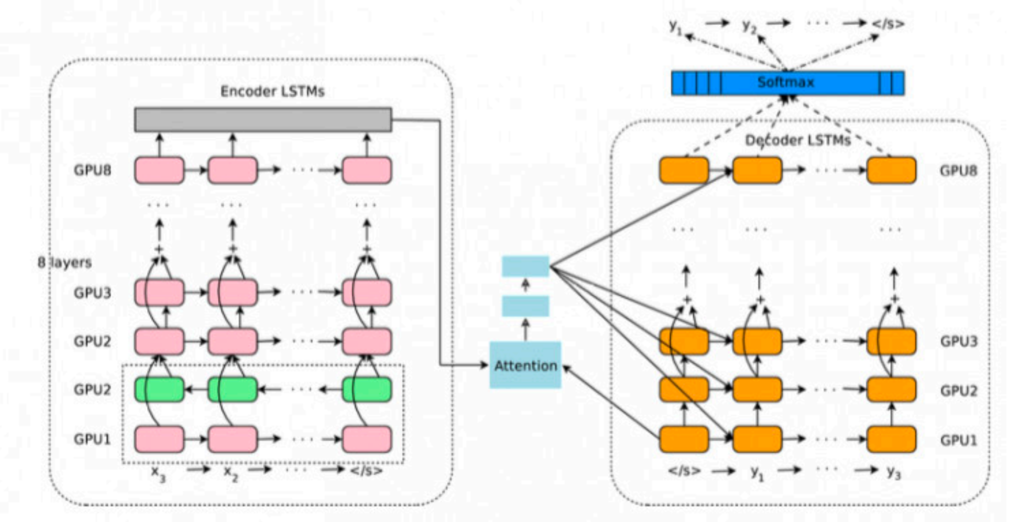


Image drawing

❑ Language





Machine translation
(recurrent neural network)

❑ Language

Tell GPT-3 to invent cooking recipes with non-sensical ingredients, and she'll make something good out of it.

(p.s: 'she' because, in Spanish, "inteligencia artificial" is a female noun)

TITLE: Hawaiian pancakes

PREP: 5 MINS
COOK: 20 MINS
DIFFICULTY: EASY
MAKES: 12 PANCAKES

METHOD:

1) Peel and roughly chop the bananas. Slice the tomatoes.

2) Whisk together the milk, eggs, sugar and a pinch of salt. Heat a small frying pan over a medium heat and brush with a little of the oil.

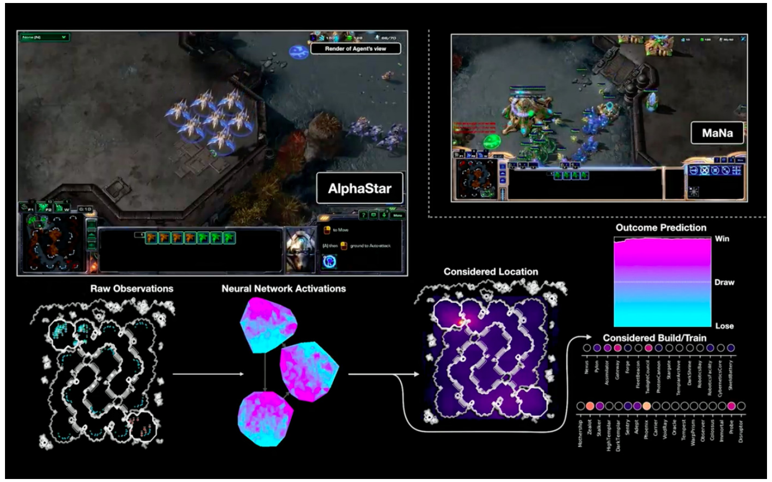
3) Pour 1 ladleful of batter into the frying pan and top with a quarter of the bananas and tomatoes. Cover and cook for 2-3 mins. Remove the lid and flip the pancake over. Cook for 1-2 mins

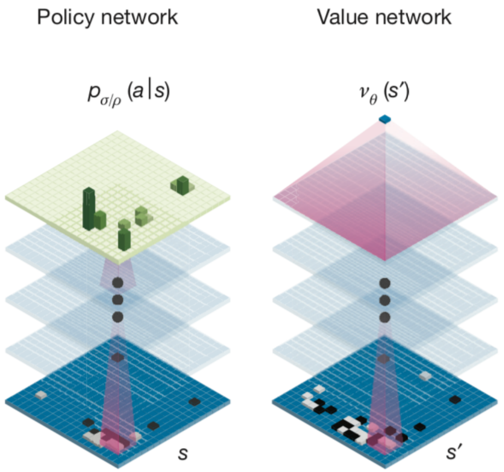
Text generation
(attention/transformer)

❑ Language

Digital assistant

❑ Others



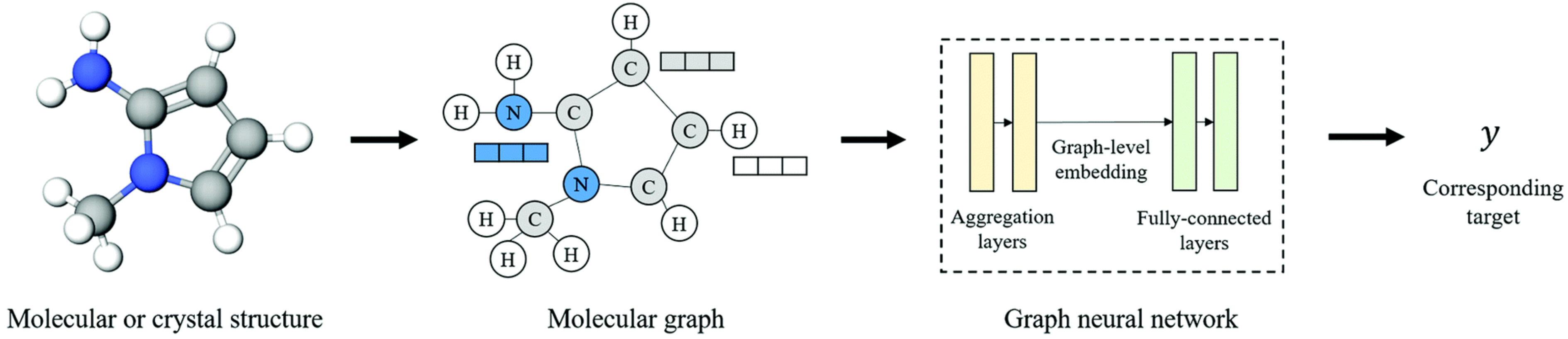


Game
(reinforce-learning)

Self-driving

Deep Learning Application

❑ Others



Healthcare
(graph neural network)

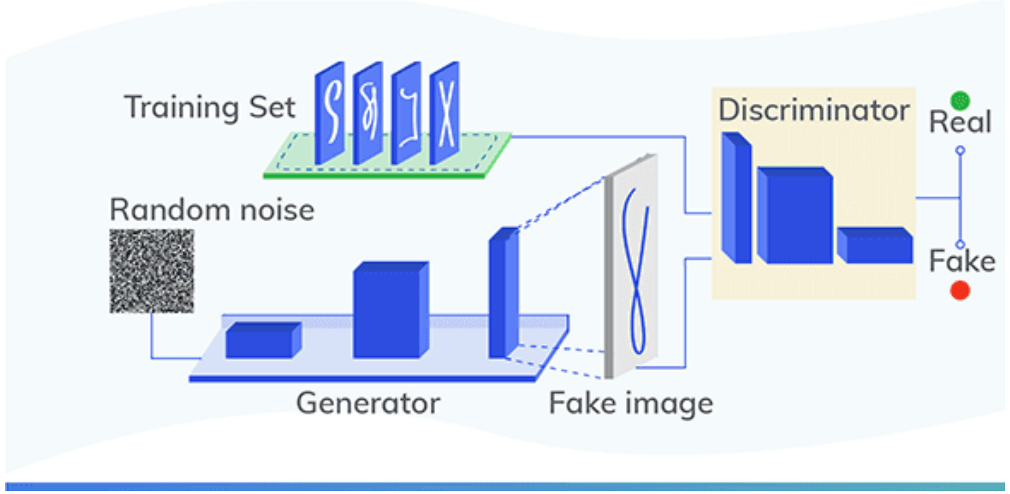
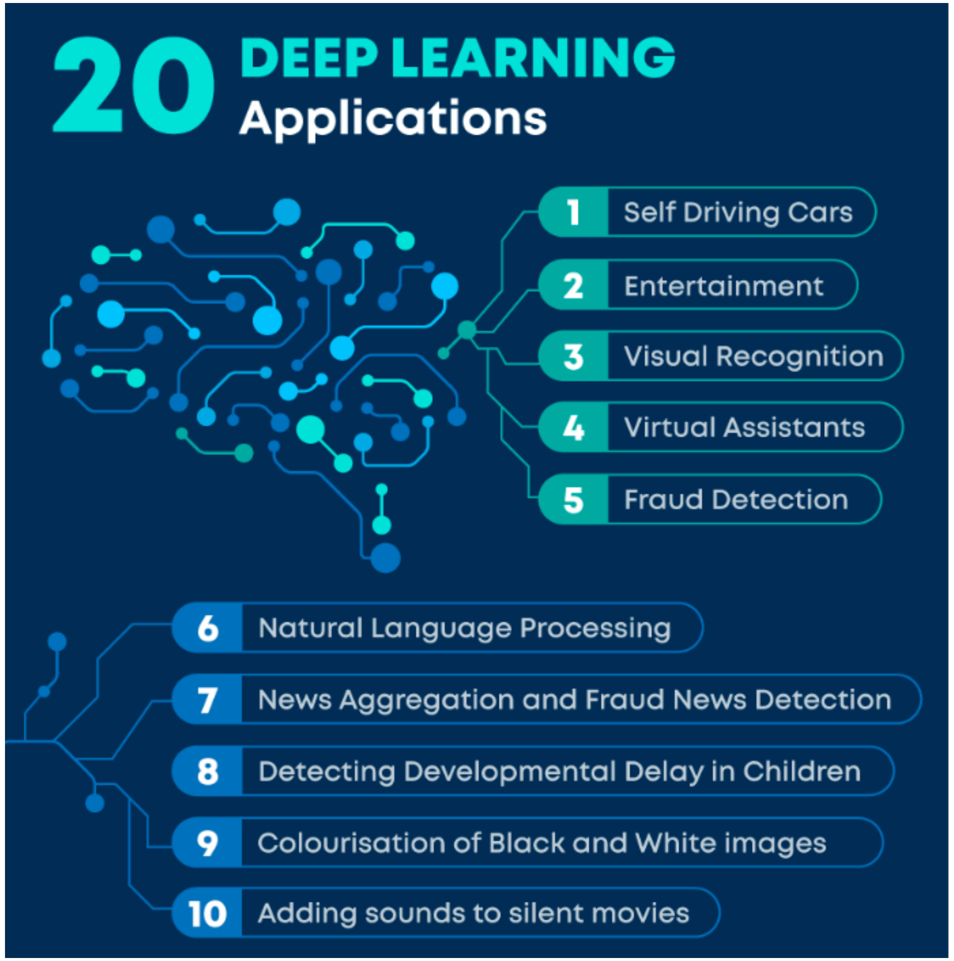
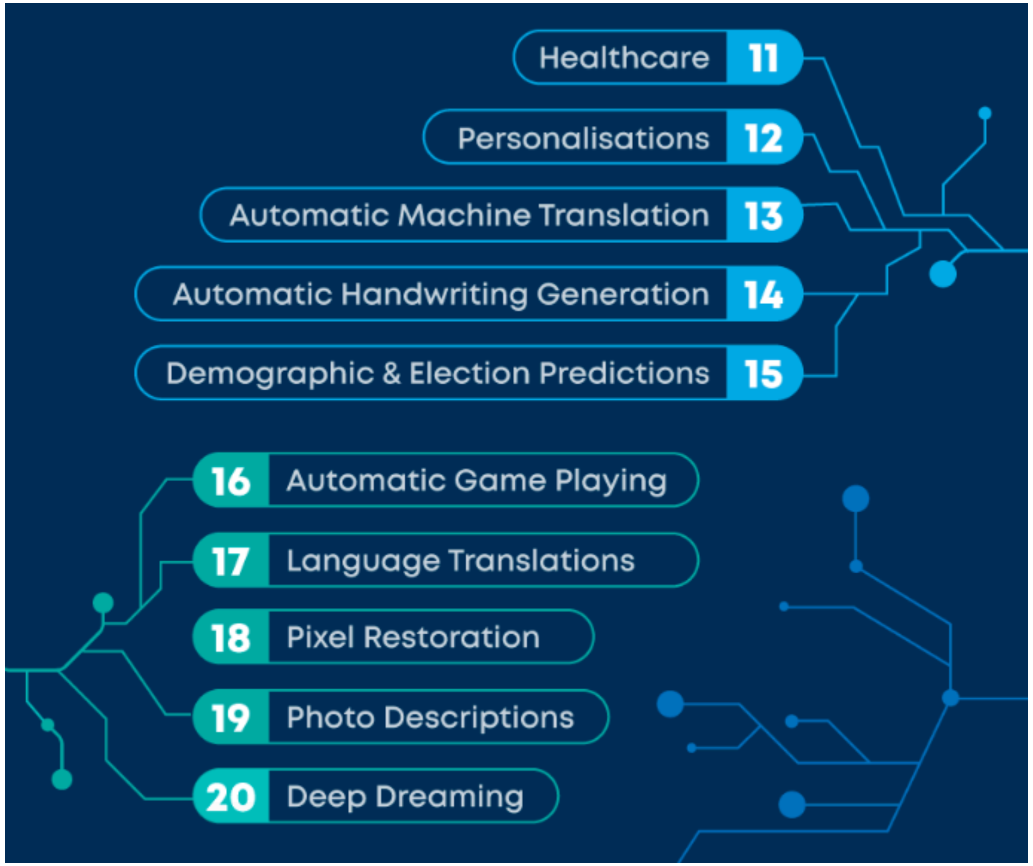


Image generation
(deep generative model)

❑ Others


20 DEEP LEARNING Applications
1 Self Driving Cars
2 Entertainment
3 Visual Recognition
4 Virtual Assistants
5 Fraud Detection
6 Natural Language Processing
7 News Aggregation and Fraud News Detection
8 Detecting Developmental Delay in Children
9 Colourisation of Black and White images
10 Adding sounds to silent movies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Personalisations 12
Automatic Machine Translation 13
Automatic Handwriting Generation 14
Demographic & Election Predictions 15
16 Automatic Game Playing
17 Language Translations
18 Pixel Restoration
19 Photo Descriptions
20 Deep Dreaming

Introduction

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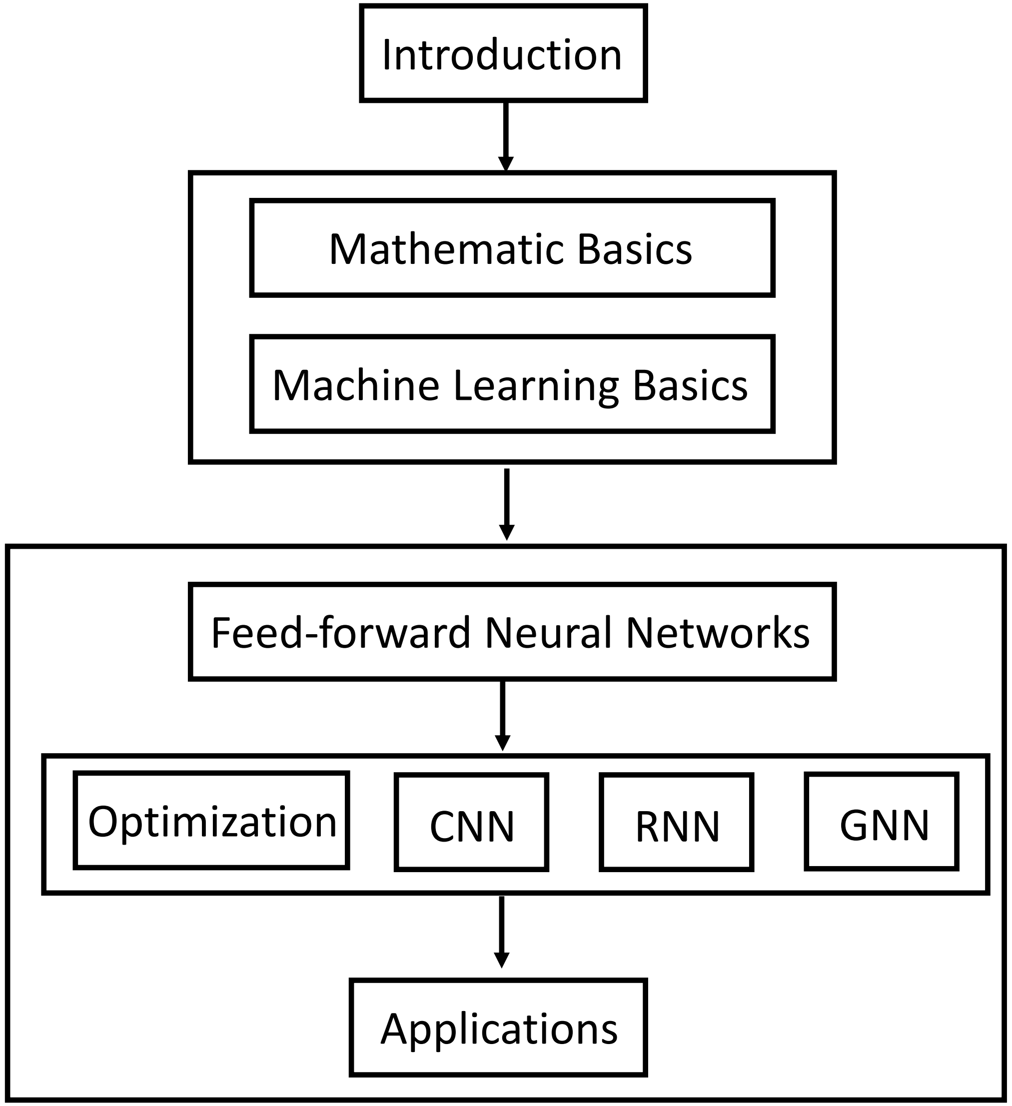
- ❑ Deep Learning Application
- ❑ **Structure of This Course**

Structure of This Course



Structure of This Course

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