SWINBURNE UNIVERSITY OF TECHNOLOGY

COS30082
Applied Machine Learning

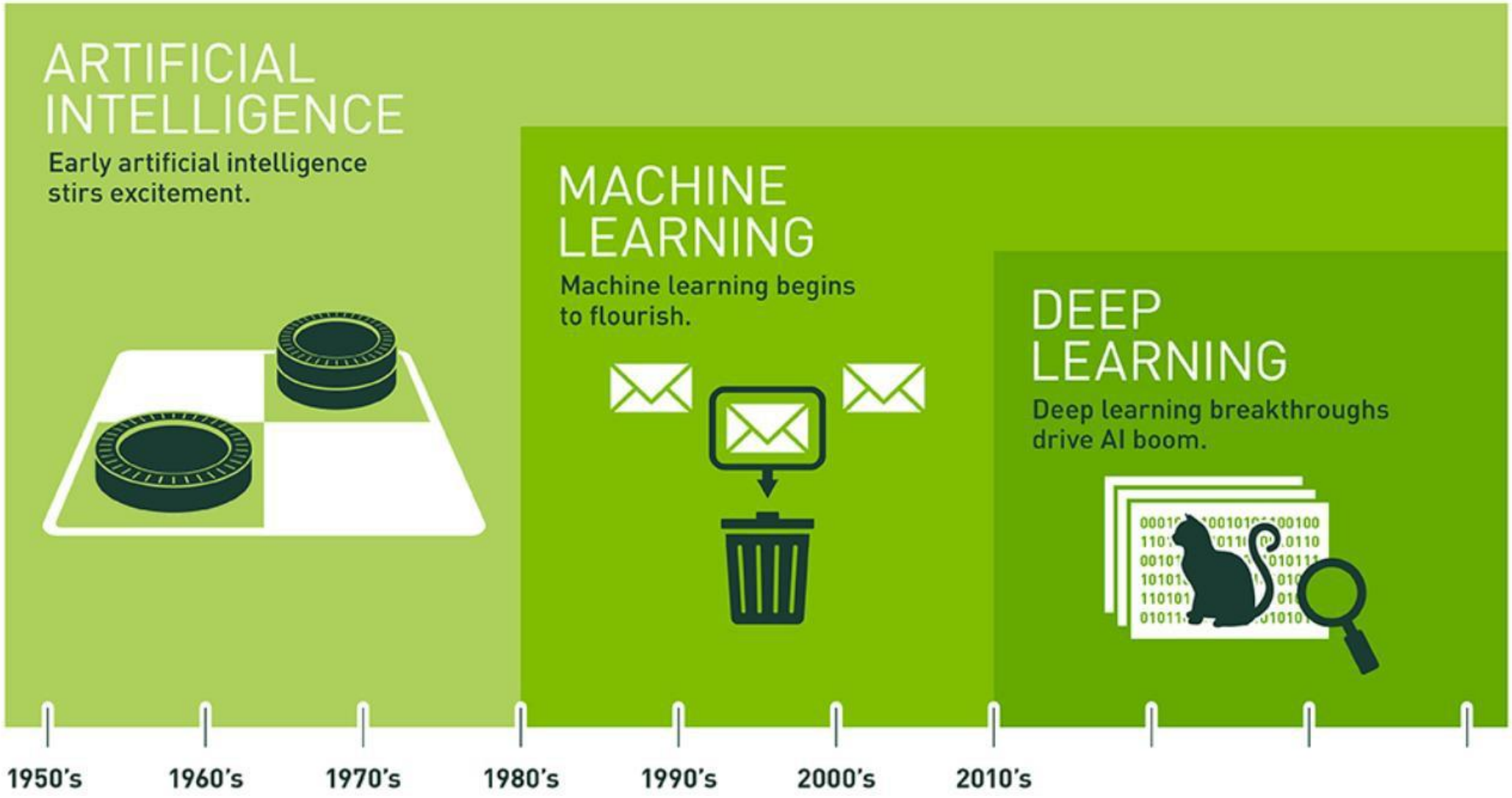
Lecture 1

Introduction to Machine Leaning

Topics

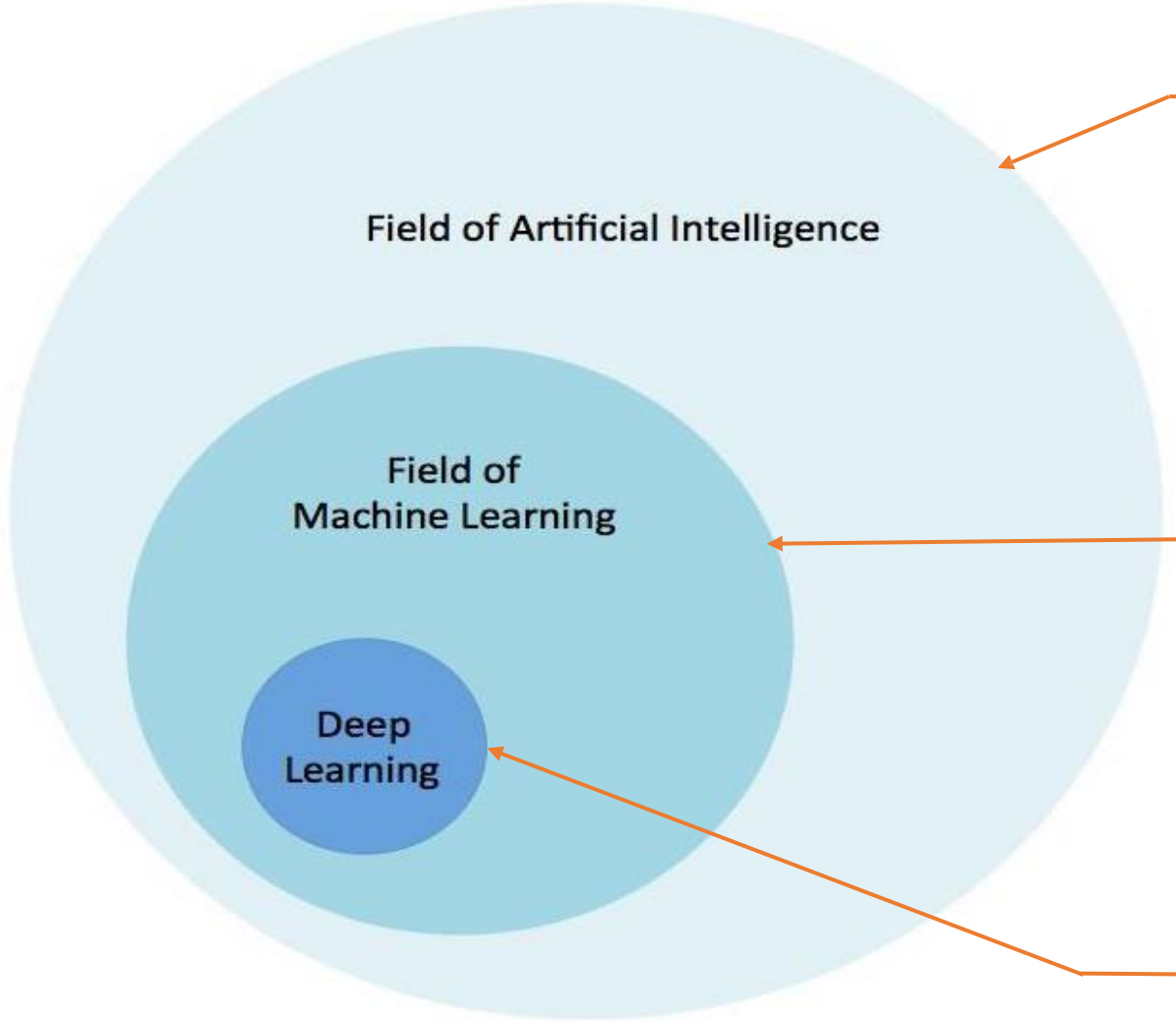
- Introduction to Machine Learning and Deep Learning
- The Machine Learning Lifecycle
- Deep Learning Frameworks
- Applications of Machine Learning

The development of AI



Source: https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

Relationship of AI, ML and DL



Artificial Intelligence
A technique which enables machines to mimic human behaviour

Machine learning
Subset of AI technique which use statistical methods to enables machines to improve with experience

Deep Learning
Subset of ML which make the computation of multi-layer neural network feasible

What is Machine Learning?

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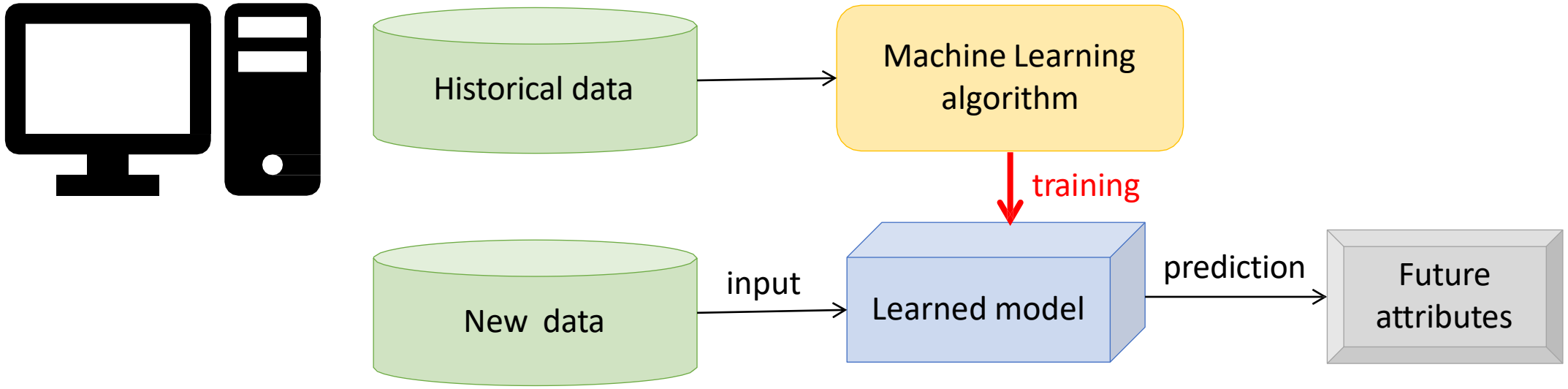
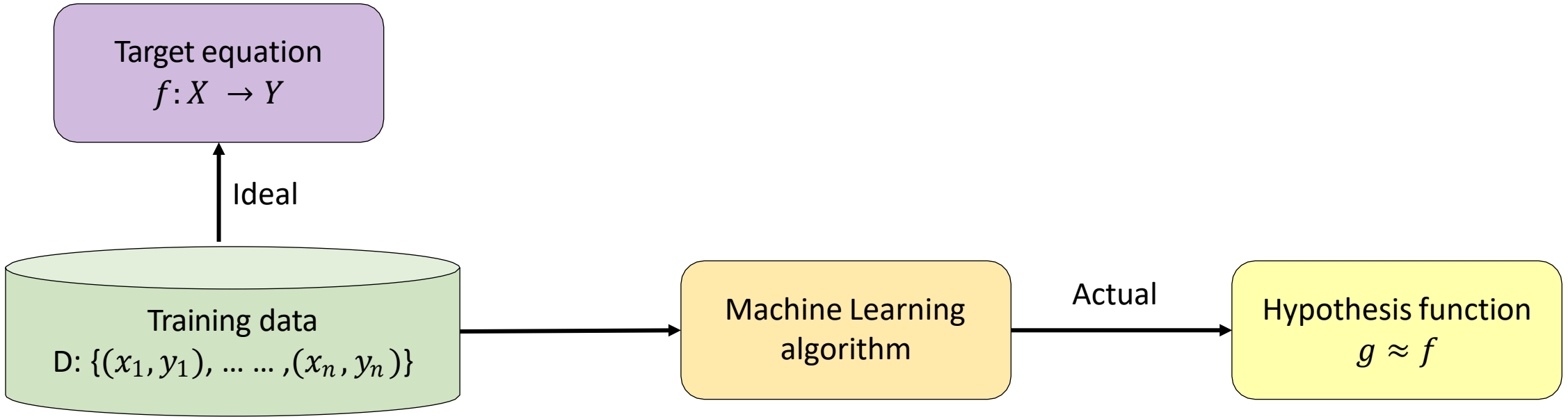
"*Machine Learning (ML) at its most basic is the practice of using algorithms to parse data, learn from it, and then make a determination or prediction about something in the world.*" – Nvidia

What is Machine Learning?

- In basic terms, ML is the process of training a piece of software, called a **model**, to make useful predictions using a data set.
- This predictive model can then serve up predictions about previously unseen data. We use these predictions to take action in a product.
- For example, the system predicts that a user will like a certain video, so the system recommends that video to the user.

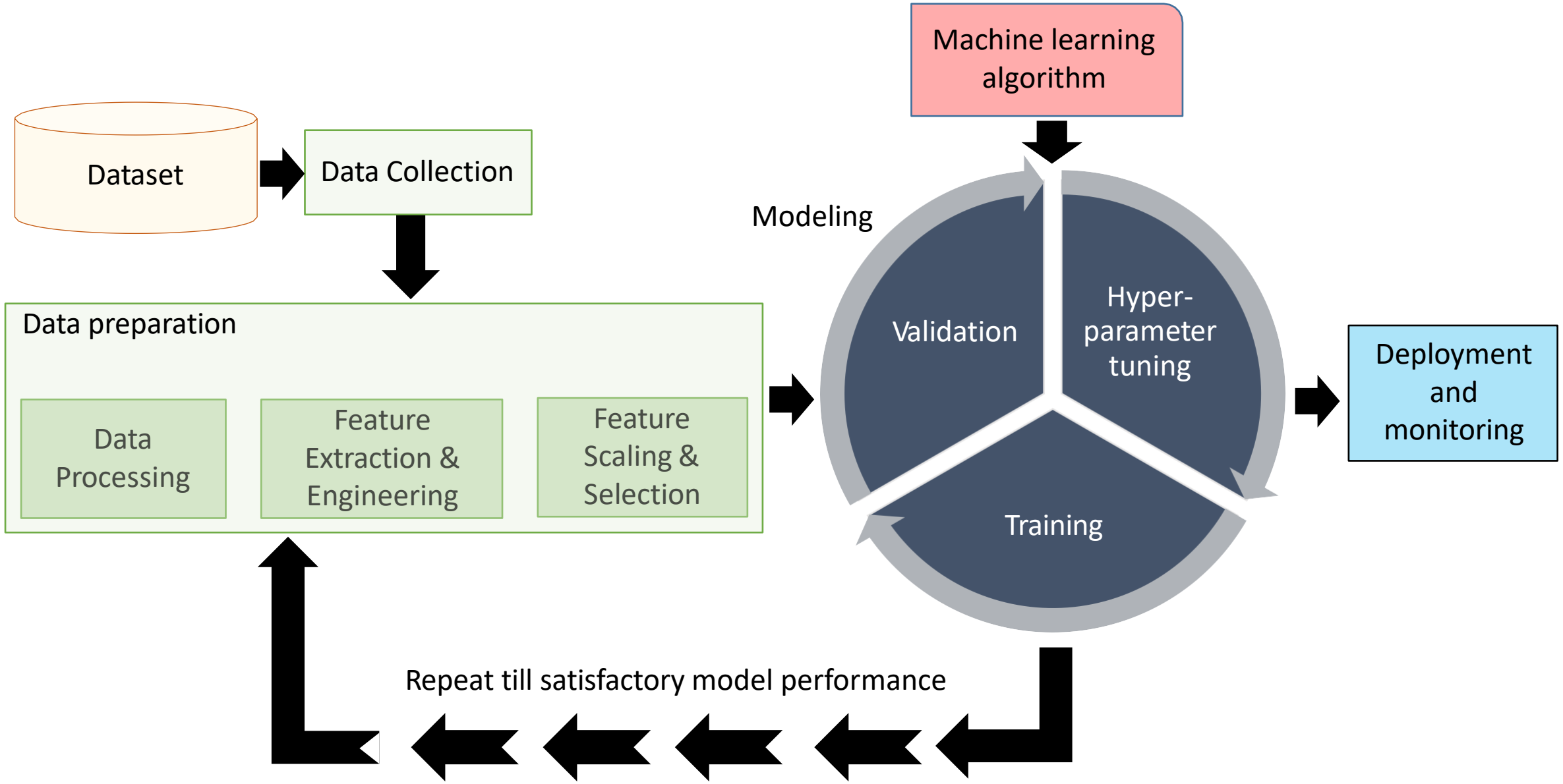


Rational Understanding of ML algorithms



- Target function f is unknown. Learning algorithms cannot obtain a perfect function f.
- Hypotheses function g approximates function f, but maybe different from function f.

Machine Learning process



ML & Rule-based system differences

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Rule-based system

- A rule-based system produces **pre-defined outcomes** that are based on a set of certain rules
  coded by humans.
- For example, in a rules-based algorithm or platform, a bank customer's personal and financial information can be measured against a programmed set of levels, and if the numbers were to match, then a home loan would be granted.

Machine learning

- The machine learning algorithm analyzes the dataset and determines relationships within that data.
- Logic is embedded in the algorithm and **was not coded by a human**.
- The **model trains itself** and learns from the data, creating a cohesive relationship between data inferences and future data outputs.

ML versus Rule-based algorithms

Rule-based Human involved in all aspects		Machine learning No human involved
Deterministic	**System characteristics**	Probabilistic
None	**Learning algorithm**	Statistical rules are automatically learned by machines
Not scalable	**Project scale**	Can be easily scaled
Small and simple data	**Dataset**	Large and good quality data for accurate prediction

When to use ML and Rule-based algorithms

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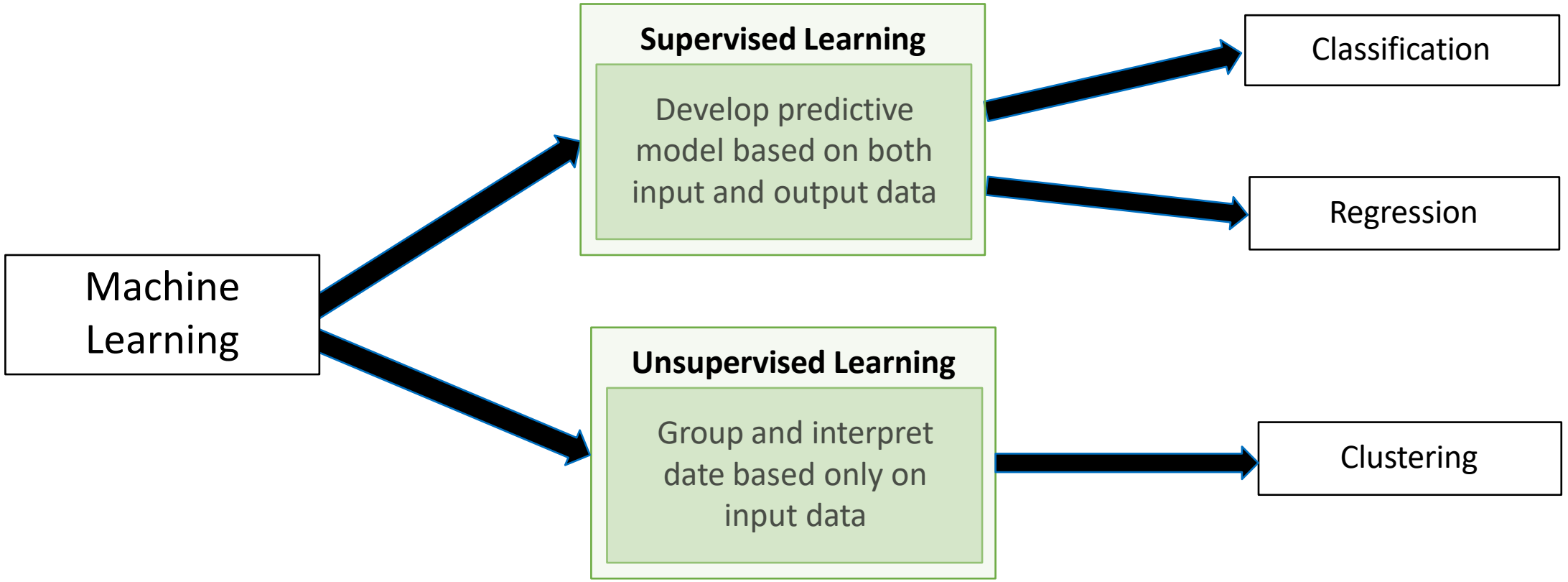
When to use rule-based system?

- The situations in which there are lower volumes of data
- The rules are relatively simple
- Require speedy output
- When there is a clear and constant data distribution

When to use Machine learning?

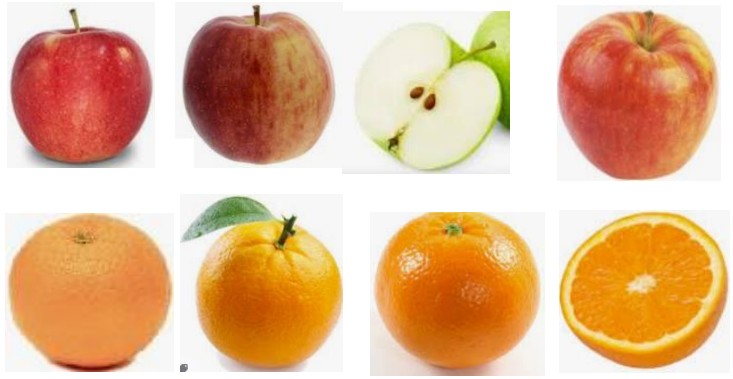
- When simple rules/guidelines don't apply
- To handle complex rules and intensive issues with a relatively variable environment
- For long terms as it is more manageable to constant improvement and enhancement through algorithm and data preparation.
- Data distinction changes over time, requiring constant adaptation of programs.

Machine Learning algorithms



Supervised learning

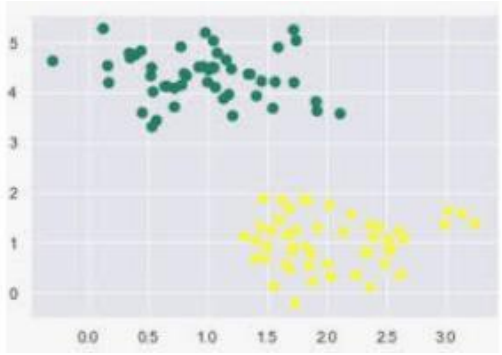
Input data: training data



Output data: labels

apple	apple	apple	apple
orange	orange	orange	orange

Model



Prediction

apple

?

Unseen data: testing data

Unsupervised learning

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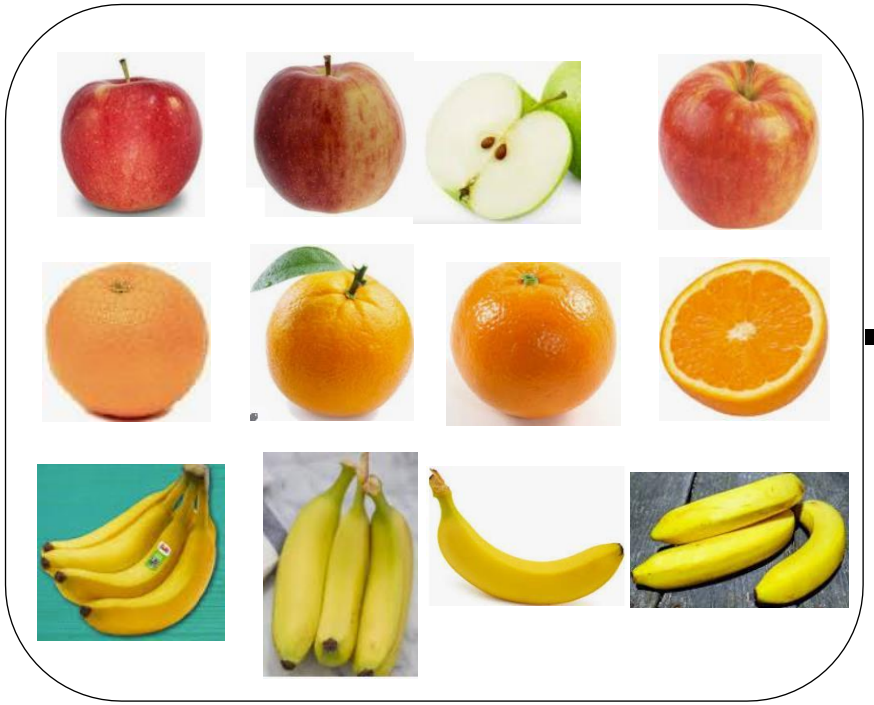
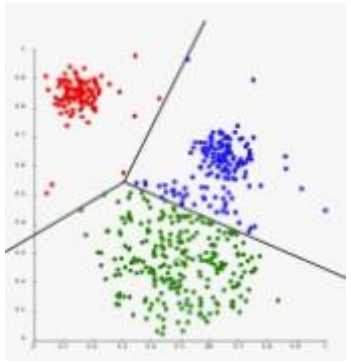
Input data: training data

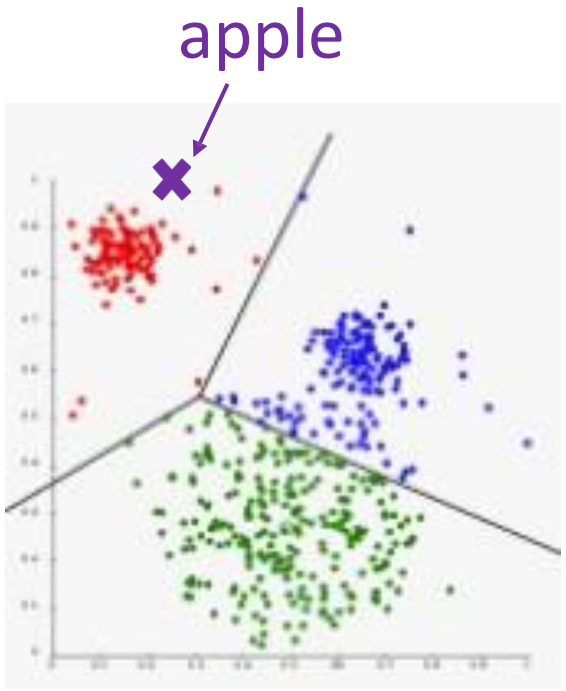


Model

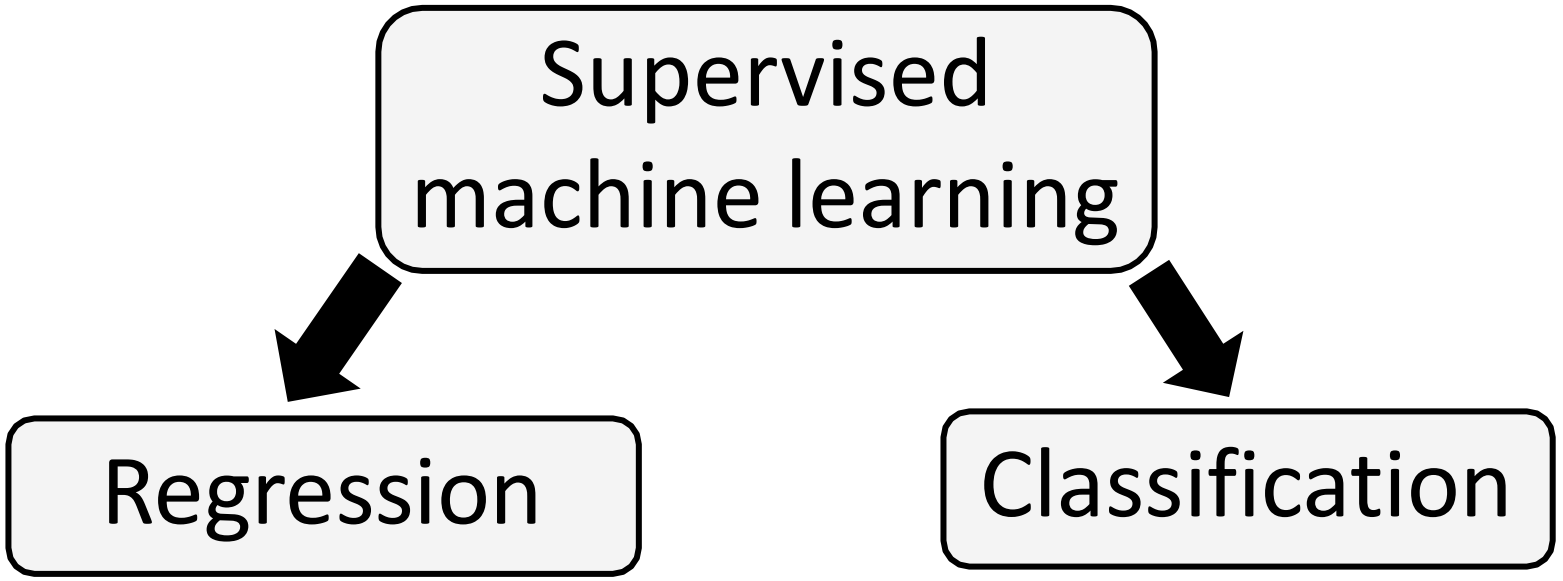


?

Prediction



Supervised learning



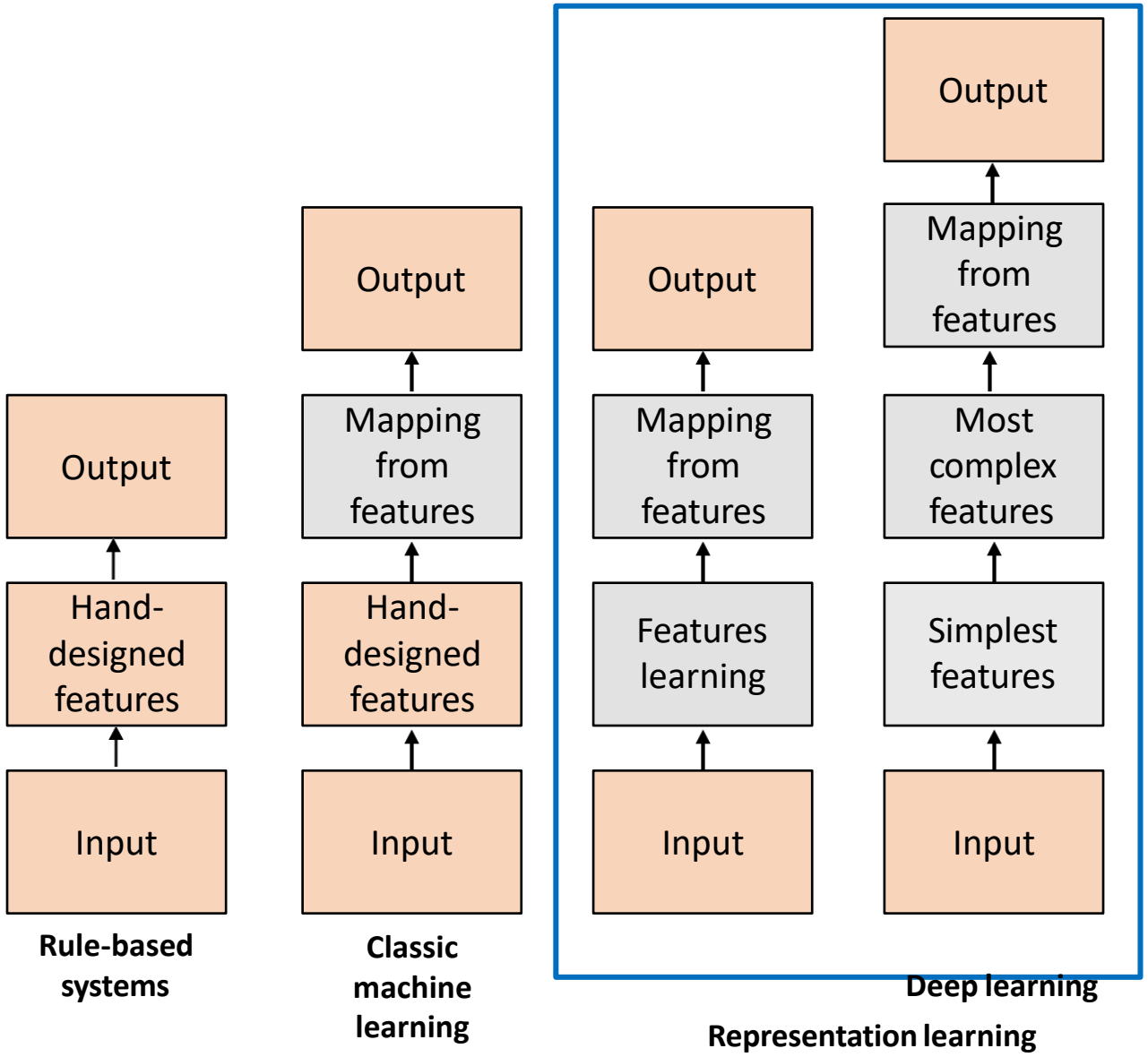
Supervised learning - Regression

- Regression predictive modeling is the task of approximating a mapping function (f) from input variables (X) to a **continuous output variable** (y).
- A continuous output variable is a real-value, such as an integer or floating point value. These are often quantities, such as amounts and sizes.
- Examples of regression problems:
  - What is the price of the houses?
  - What is the height of the students?

Supervised learning - Classification

- Classification predictive modeling is the task of approximating a mapping function (f) from input variables (X) to **discrete output** variables (y).
- The output variables are often called labels or categories. The mapping function predicts the class or category for a given observation.
- Examples of classification problems:
  - Is the person boy or girl?
  - Is the email spam or not spam?
  - Is she happy or not?

What is Deep learning?



- Deep Learning (DL) is a class of techniques in ML.
- It consists of multiple processing layers that allow representation learning of multiple level data abstraction.

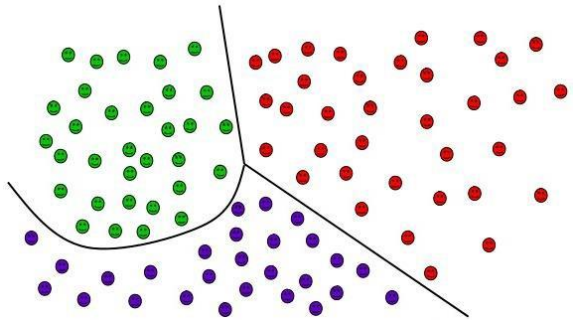
Traditional ML vs. Deep learning

Traditional Machine Learning

Plant disease data

Hand-crafted features extraction

ML algorithms: SVM, KNN, Decision Tree

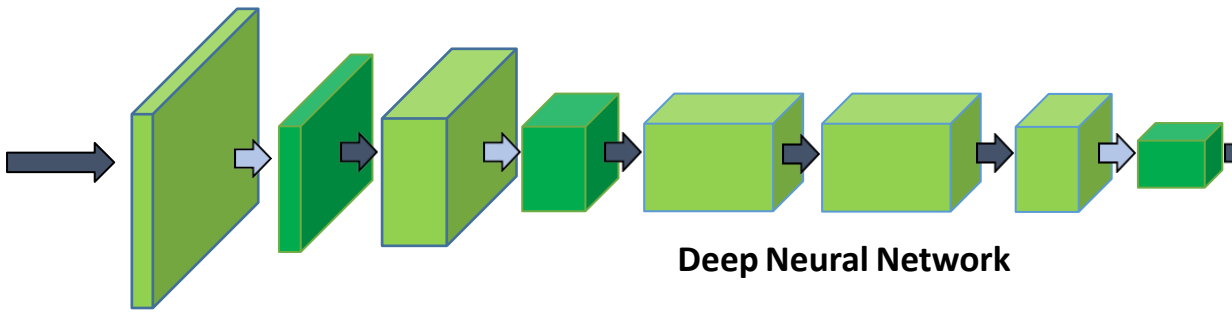


Target classes

- Tomato Bacterial spot
- Peach Bacterial spot
- ⋮
- **Tomato Early blight**

Deep Learning (DL)

Plant Disease data



Deep Neural Network

Output prediction

Target classes

- Tomato Bacterial spot
- Peach Bacterial spot
- ⋮
- **Tomato Early blight**

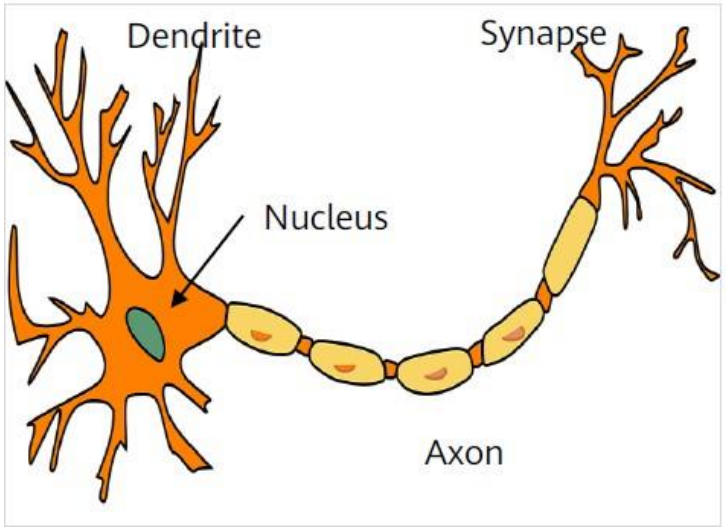
Automatic feature learning

Traditional ML vs. Deep Learning

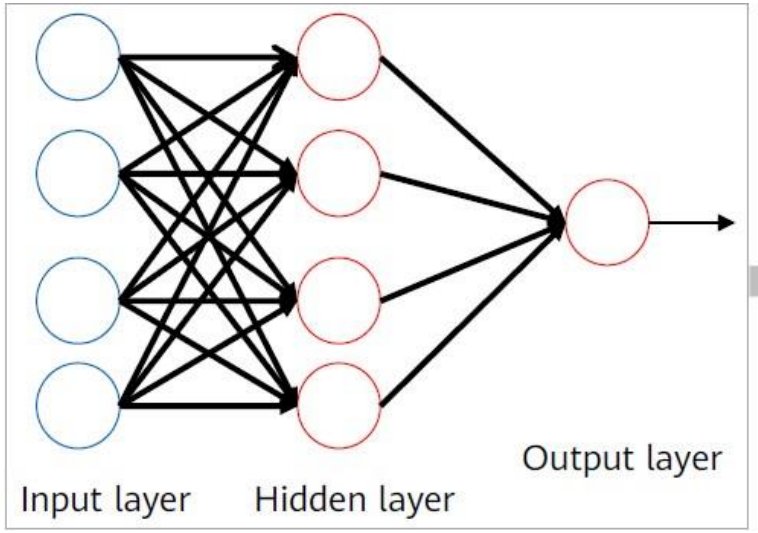
Classic Machine Learning	Deep Learning
Low hardware requirements: Given the limited computing amount, the computer does not need a GPU for parallel computing generally	**High hardware requirements:** To execute matrix operation on massive data, the computer needs GPU to perform parallel computing
Applicable to training under a small data amount and whose performance cannot be improved continuously as the data amount increases	The performance can be high when high dimensional weight parameters and massive training data are provided
Level-by-level problem breakdown	End-to-End learning
Manual feature selection	Algorithm-based automatic feature selection
Easy-to-explain features	Hard-to-explain features

Why is it called Deep Learning?

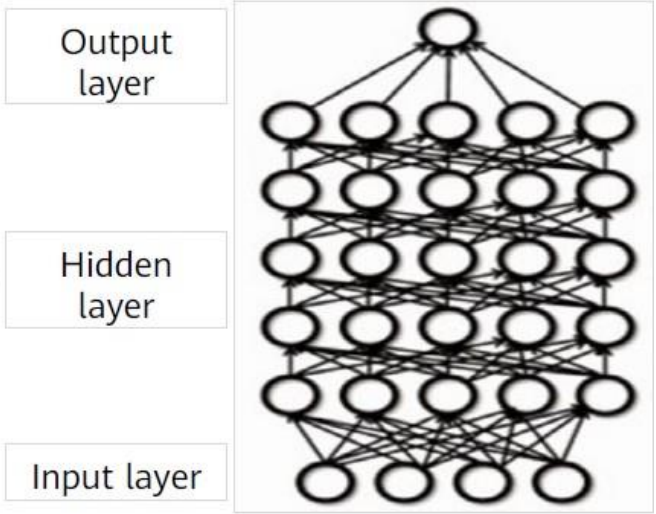
- Deep: “Deep” in “deep learning” refers to the number of layers of the neural network.
- Learning: Algorithm “learn” from data by modelling features and updating probability weights assigned to feature nodes.



Human neural network

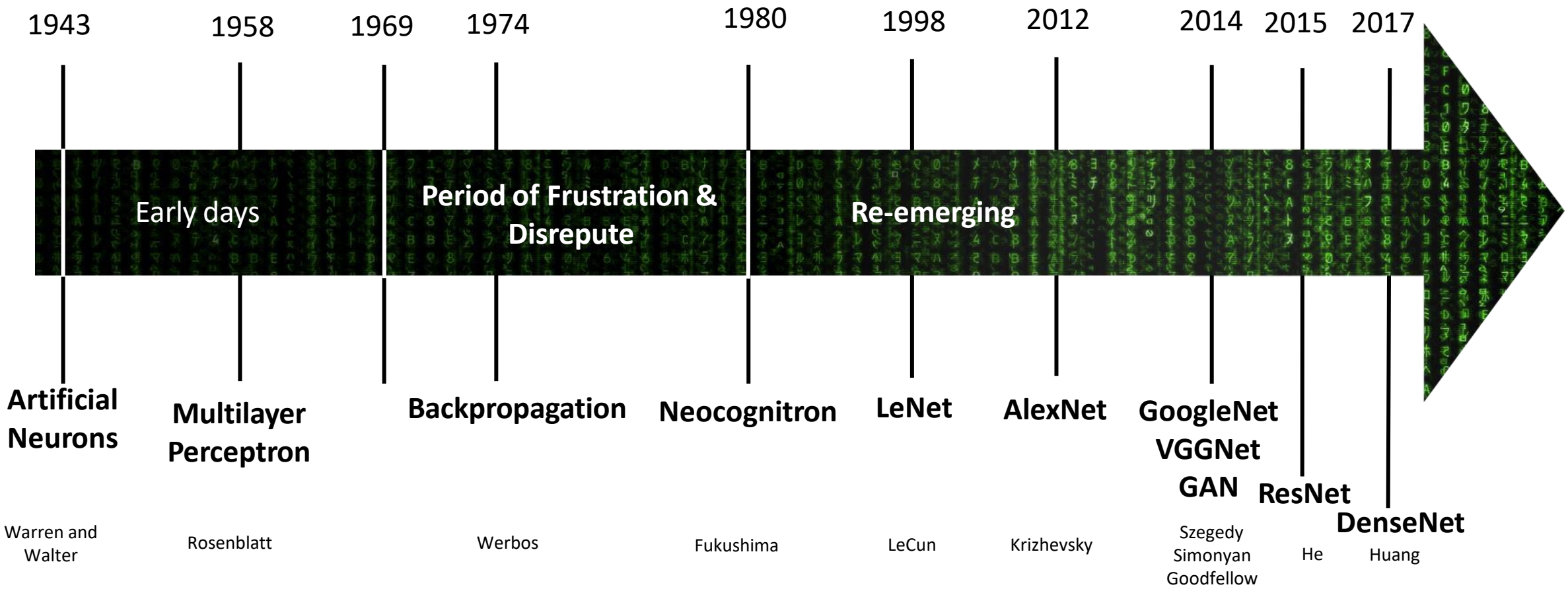


Perceptron/ single layer neural network



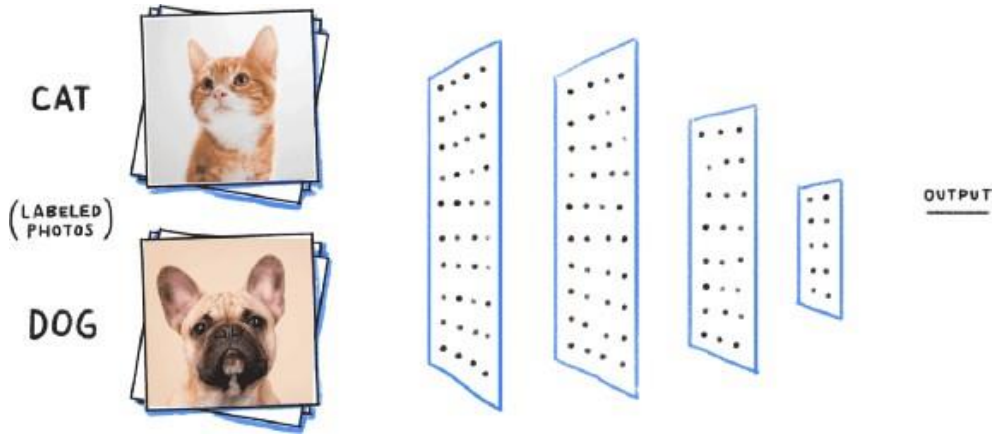
Deep Learning

Development history of Neural networks

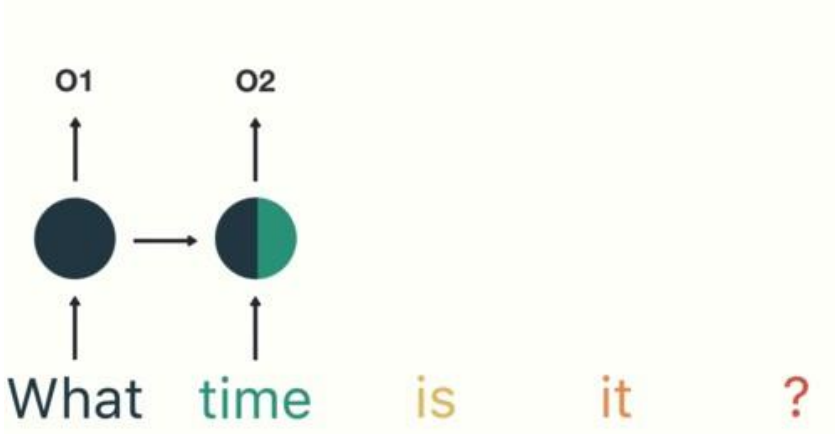


2 main types of Deep learning networks

- Convolutional neural network
  - Image classification
  - Convolve: roll up to higher levels of abstraction in feature sets.



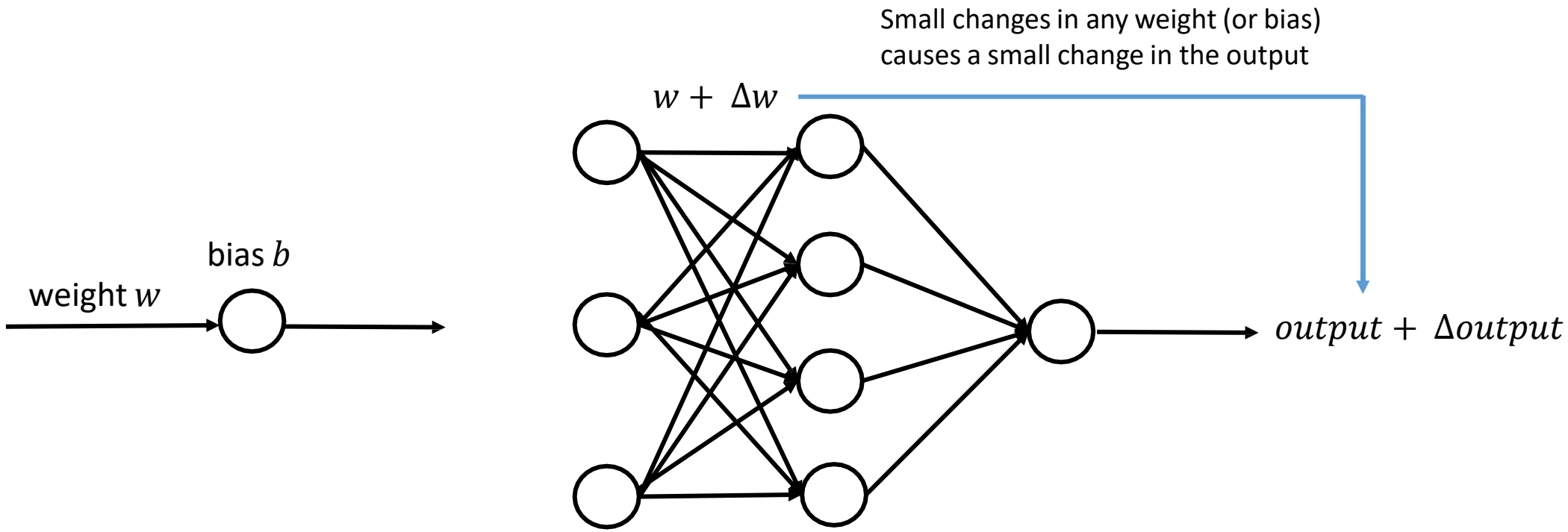
- Recurrent neural network
  - Speech, text, audio recognition
  - Recur: iterate over sequential inputs with a memory function.



https://www.analyticsvidhya.com/blog/2020/02/cnn-vs-rnn-vs-mlp-analyzing-3-types-of-neural-networks-in-deep-learning/

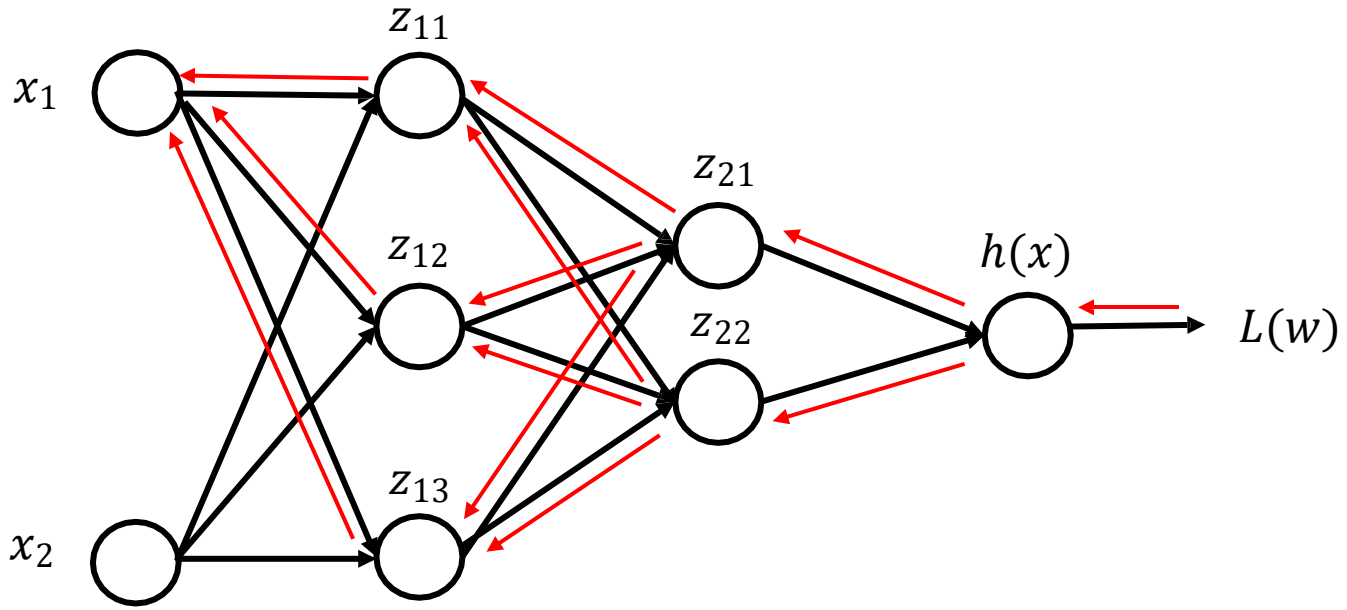
How does the neural network actually learn?

- Structural system based on cascading layers of neurons with variable parameters: weight and bias
- Vary the weights and biases to see if a better outcome is obtained
- Repeat until the network correctly classifies the data



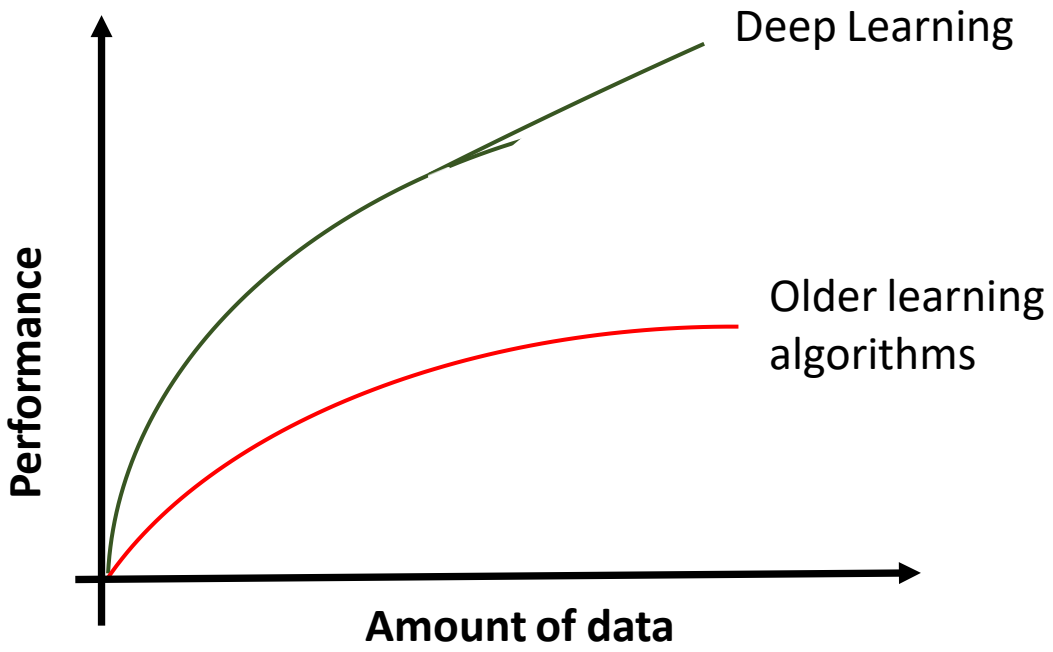
Backpropagation

- It first calculates the total error $L(w)$ and then the contribution to the error at each step going backwards.
  - Variety of error calculation methods: mean Square Error (MSE), sum of squared errors (SSE), cross Entropy (softmax)
- Aim: optimize the weights so that the neural network can learn how to correctly map arbitrary inputs to outputs.



Why do we need Deep Learning?

- A contemporary data sciences method to keep up with the growth in data, older learning algorithm no longer performing



Topics

- Introduction to Machine Learning and Deep Learning
- The Machine Learning Lifecycle
- Deep Learning Frameworks
- Applications of Machine Learning

Machine Learning Life Cycle

- The machine learning life cycle is a **sequence of steps** or stages that are followed to develop a machine learning model. These steps ensure that the model is designed, developed, and deployed effectively.
- The life cycle is **iterative**, allowing for continuous improvement and optimization of the model based on feedback and performance.
- There isn't a universal machine learning life cycle. The life cycle varies based on the organization's processes, the project's complexity, and the nature of the problem being addressed.

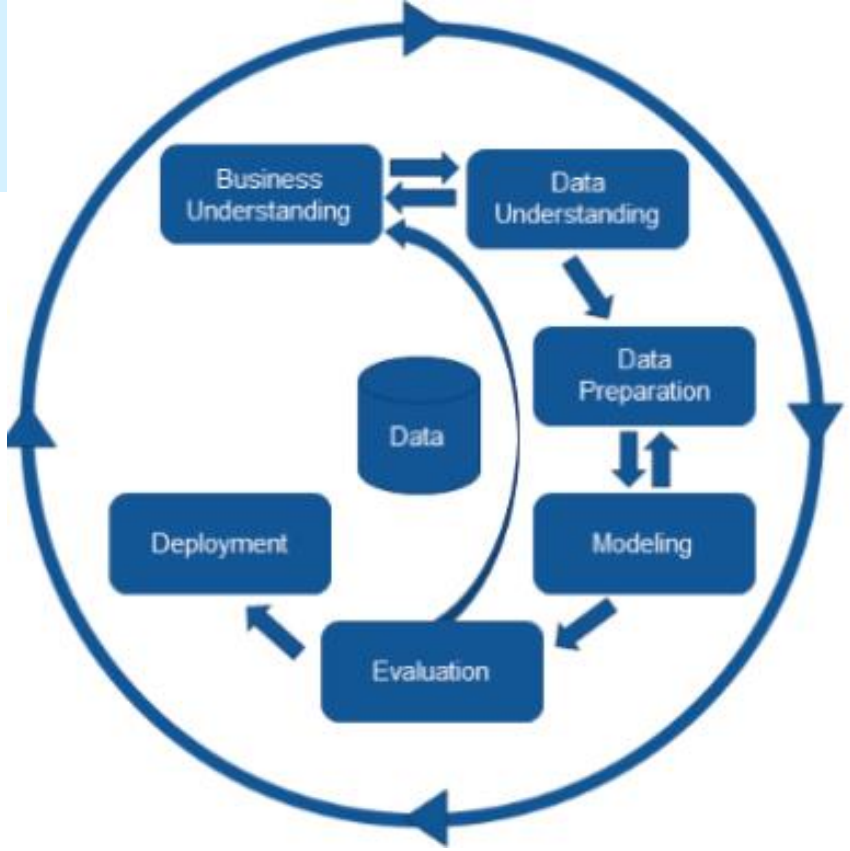
Industry-recognised Life Cycles

There are some industry-recognized frameworks:

- **CRISP-DM** (Cross-Industry Standard Process for Data Mining): A standard data mining process also used in machine learning.
- **SEMMA** (Sample, Explore, Modify, Model, Assess): Developed by SAS, this framework emphasizes the modeling aspect.
- **TDSP** (Team Data Science Process): Microsoft's agile method for enhancing team collaboration in data science.
- **KDD** (Knowledge Discovery in Databases): An older framework for extracting knowledge from databases.

These frameworks provide a foundational structure from which many of the machine learning life cycle models are derived.

Phases of CRISP-DM



- **Business Understanding**: Identify problems, goals, and success metrics.
- **Data Understanding**: Collect, explore, assess data quality.
- **Data Preparation**: Clean, construct, integrate, format data for analysis.
- **Modeling**: Select techniques, build models, adjust parameters.
- **Evaluation**: Assess model's performance, ensure business objectives alignment.
- **Deployment**: Integrate models into production for use.

Topics

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Deep Learning Frameworks

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- A deep learning framework is an interface, library or a tool which allows us to build deep learning models more easily and quickly, without getting into the details of underlying algorithms.
- Developers no longer need to compile code starting from complex neural networks and backpropagation algorithms. Instead, they can use existing models to configure parameters as required, where the model parameters are automatically trained.
- Moreover, they can add self-defined network layers to the existing models, or select required classifiers and optimization algorithms directly by invoking existing code.

Deep Learning frameworks

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Tensorflow	Google Brain, 2015 (rewritten DistBelief)
Theano	University of Montréal, 2009
Keras	François Chollet, 2015 (now at Google)
Torch	Facebook AI Research, Twitter, Google DeepMind
PyTorch	Facebook AI Research, 2016
caffe	Berkeley Vision and Learning Center (BVLC), 2013

Two Popular Frameworks

- **TensorFlow**: Developed by the Google Brain team, TensorFlow is a comprehensive, open-source framework used for machine learning and deep learning.

- **PyTorch**: Created by Facebook's AI Research lab, PyTorch is an open-source machine learning framework with a strong focus on deep learning.

TensorFlow

- TensorFlow is Google's second generation open-source software library or digital computing. The TensorFlow computing framework supports various deep learning algorithms and multiple computing platforms, ensuring high system stability.

https://www.tensorflow.org/

Features of TensorFlow

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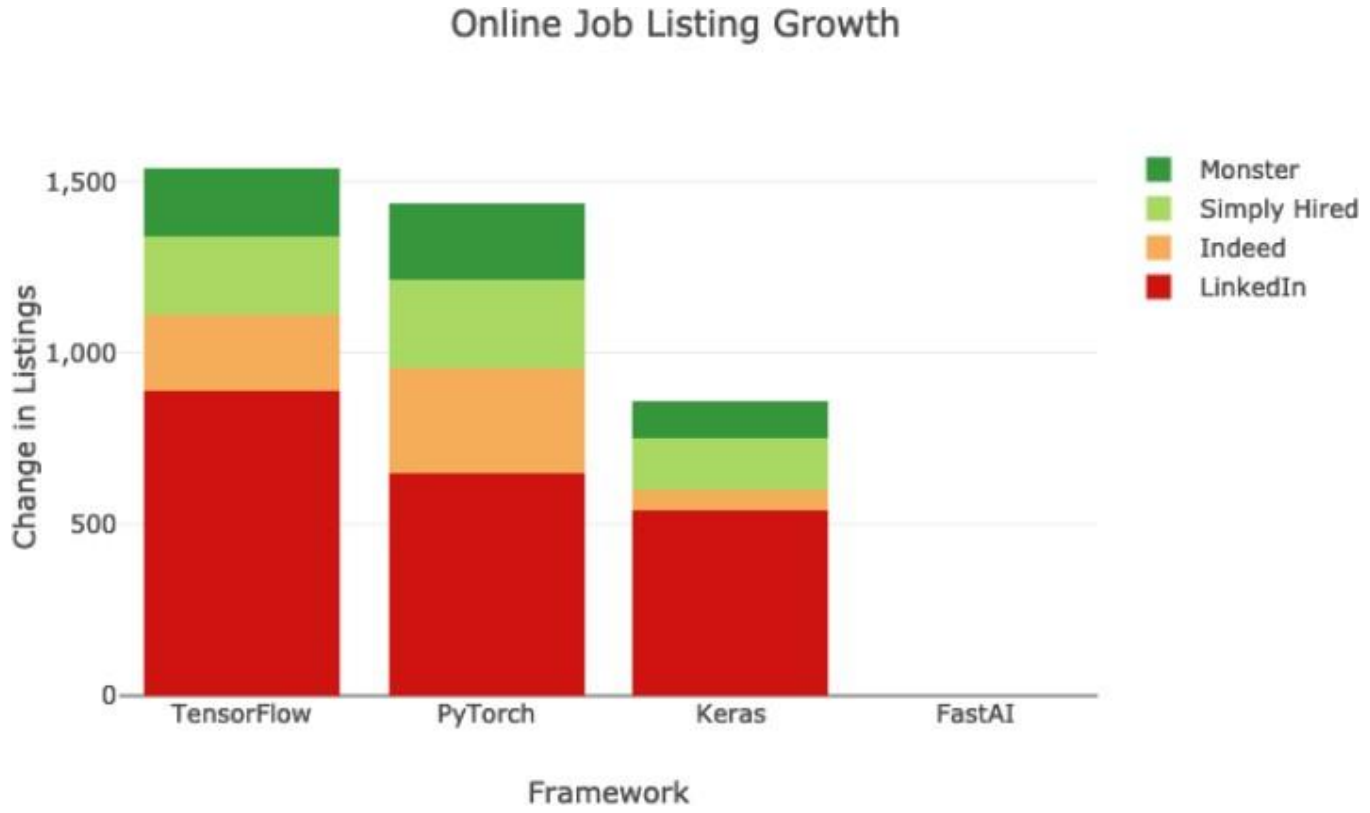
- **Scalability:** TensorFlow's tf.distribute library helps you scale your model from a single GPU to multiple GPUs and to multiple machines using simple APIs that require very few changes to your existing code.
- **GPU:** TensorFlow supports running computations on a variety of types of devices, including CPU and GPU.
- **Multi-lingual:** TensorFlow is designed to support multiple client languages. Currently, the best-supported client language is Python. Experimental interfaces for executing and constructing graphs are also available for C++, Java and Go.
- **Multi-platform:** TensorFlow is available on 64-bit Linux, macOS, Windows, and mobile computing platforms including Android and iOS.
- **Powerful computing**: TensorFlow leverages various optimization techniques to make the calculation of mathematical expressions easier and more performant.
- **Distributed:** TensorFlow can run on different computers from smartphones to computer clusters.

Why TensorFlow?

- TensorFlow appears in nearly three times the number of job listings as PyTorch or Keras.
- Keras, ranking third, is packages into and advanced API of TensorFlow 2.0, which makes TensorFlow 2.x more flexible and easier to debug.



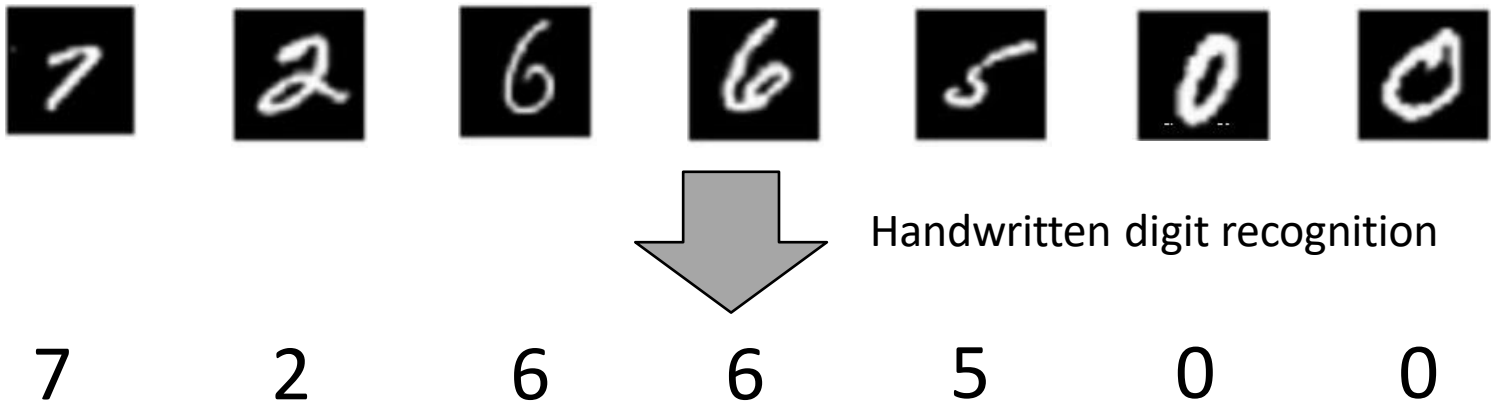
https://www.kdnuggets.com/2019/05/which-deep-learning-framework-growing-fastest.html

TensorFlow development process

- Data preparation
  - Data exploration
  - Data processing
- Network construction
  - Network structure definition
  - Network Compilation: Defining loss functions, selecting optimizers, and defining model evaluation indicators
- Model training and verification
- Model saving
- Model restoration and invoking

Example of a project

- Handwritten digit recognition is a common image recognition task where the computer recognizes text in handwritten images.
- Handwriting of different people has different sizes and styles, which makes it difficult for computers to recognize handwriting.
- This project applies deep learning and TensorFlow tools to train and build models based on the MNIST handwriting data set.

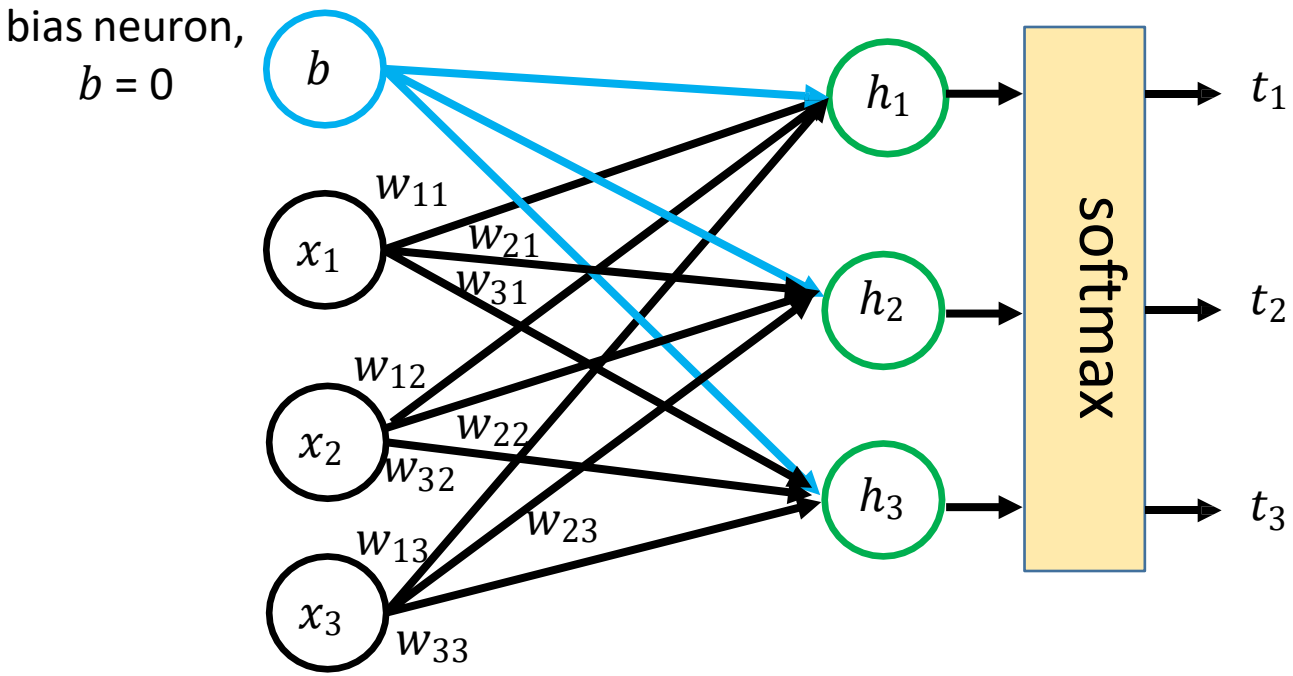


Data Preparation

- MINIST datasets
- Training set: 60,000 handwriting images and corresponding labels
- Testing set: 10,000 handwriting images and corresponding labels

Examples	Corresponding labels
	[0,0,0,0,0,0,0,1,0,0]
	[0,0,1,0,0,0,0,0,0,0]
	[1,0,0,0,0,0,0,0,0,0]

Network structure definition



- The model building process is the core process of defining the network structure.

$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{bmatrix} . \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b \\ b \\ b \end{bmatrix}$$

- Matrix multiplication and vector addition are used to express the model calculation process.

Network structure definition

- TensorFlow-based softmax regression model

```
## import tensorflow
import tensorflow as tf
##define input variables with operator symbol variables.
''' we use a variable to feed data into the graph through the placeholders X. Each input image is flattened into a 784-dimensional vector. In this case, the shape of the tensor is [None, 784], None indicates can be of any length. '''
X = tf.placeholder(tf.float32,[None,784])
''' The variable that can be modified is used to indicate the weight w and bias b. The initial values are set to 0. '''
w = tf.Variable(tf.zeros([784,10]))
b = tf.Variable(tf.zeros([10]))
''' If tf.matmul(x, w) is used to indicate that x is multiplied by w, the Soft regression equation is y = softmax(wx+b)'''
y = tf.nn.softmax(tf.matmul(x,w)+b)
```

Network compilation

- Model compilation involves the following three parts:
  - Loss function: measures how accurate the output is
  - Optimizer: measures how the model is updated
  - Metrics: monitors the training to determine when to stop

```
model.compile(optimizer=tf.train.AdamOptimizer(),
              loss=tf.keras.losses.categorical_crossentropy,
              metrics=[tf.keras.metrics.categorical_accuracy])
```

Model training

- All training data is trained through batch iteration.
- In TensorFlow, model.fit is used for training .
- An "epoch" refers to one complete pass through the entire training dataset.

```
model.fit(mnist.train.images, mnist.train.labels, epochs=5)
```

```
Epoch 1/5
55000/55000 [==============================] - 4s 74us/sample - loss: 0.3043 - categorical_accuracy: 0.9110
Epoch 2/5
55000/55000 [==============================] - 4s 73us/sample - loss: 0.1460 - categorical_accuracy: 0.9569
Epoch 3/5
55000/55000 [==============================] - 4s 79us/sample - loss: 0.1104 - categorical_accuracy: 0.9669
Epoch 4/5
55000/55000 [==============================] - 4s 74us/sample - loss: 0.0881 - categorical_accuracy: 0.9722
Epoch 5/5
55000/55000 [==============================] - 4s 73us/sample - loss: 0.0767 - categorical_accuracy: 0.9760
```

Model Evaluation

- In TensorFlow, model.evaluate is used for testing.
- It compares the predicted results with the groundtruth label to calculate the accuracy of the test set.

```
model.evaluate(mnist.test.images, mnist.test.labels)
```

```
10000/10000 [==============================] - 0s 42us/sample - loss: 0.0779 - categorical_accuracy: 0.9764
[0.07786676207473502, 0.9764]
```

Loss value

Accuracy

There are so MANY things to know

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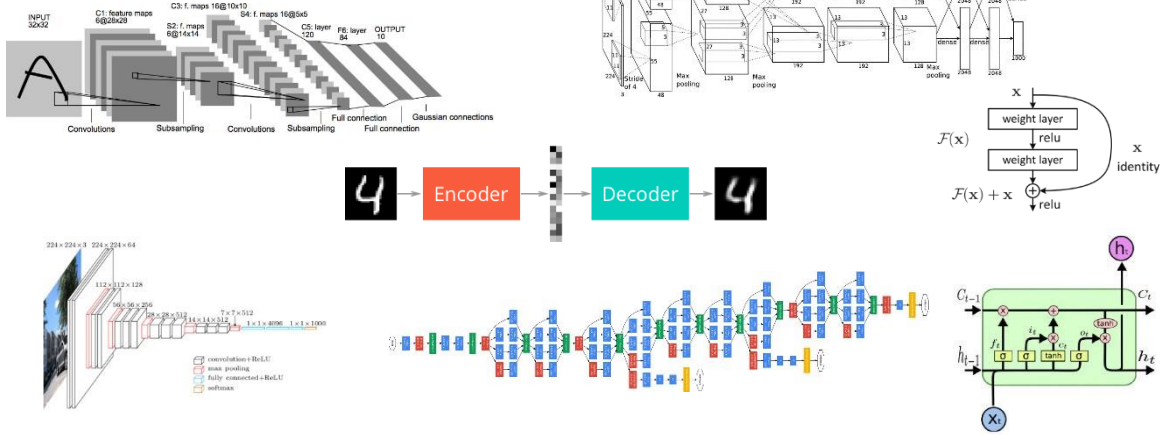
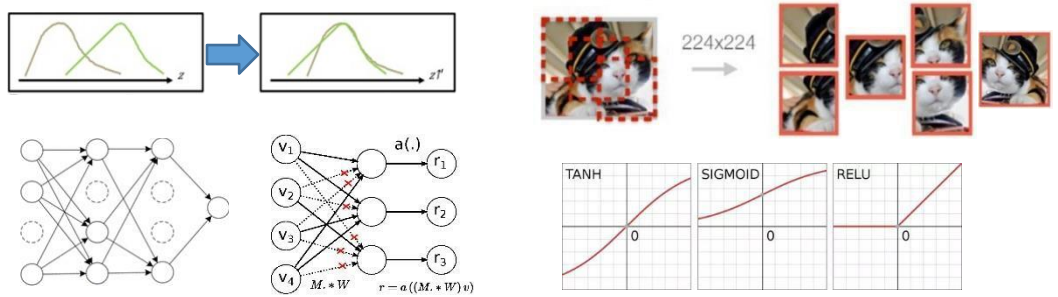
Deep Networks



Graphical Processing Units (GPUs)

Learning techniques



Deep Learning Libraries

TensorFlow
Keras
Caffe
Caffe2
Lasagne
theano
PYTORCH
Chainer
MatConvNet

Topics

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- Introduction to Machine Learning and Deep Learning
- The Machine Learning Lifecycle
- Deep Learning Frameworks
- Applications of Machine Learning

Application Areas of Machine Learning

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- Computer Vision:
  Image Recognition,
  Facial Recognition,
  Visual Surveillance
- Natural Language Processing (NLP):
  Sentiment Analysis,
  Language Translation,
  Chatbots and Virtual Assistants
- … …
- Finance:
  Fraud Detection,
  Credit Scoring,
  Algorithmic Trading
- Autonomous Vehicles and Robotics:
  Self-driving Cars,
  Robotic Process Automation

What is Computer Vision?

- How machine perceive visual information

How many people are there?

What are they doing?

What are their emotion?

Where is this happening?

What are the relation between subject?

What are the object present?

https://www.youtube.com/watch?v=nT_4Fc6uk1A

Human vision

What species does this leaf belong to?

?

q_x_hispanica

?

qacutissima

Human vision

What species does this leaf belong to?

q_x_hispanica

qacutissima

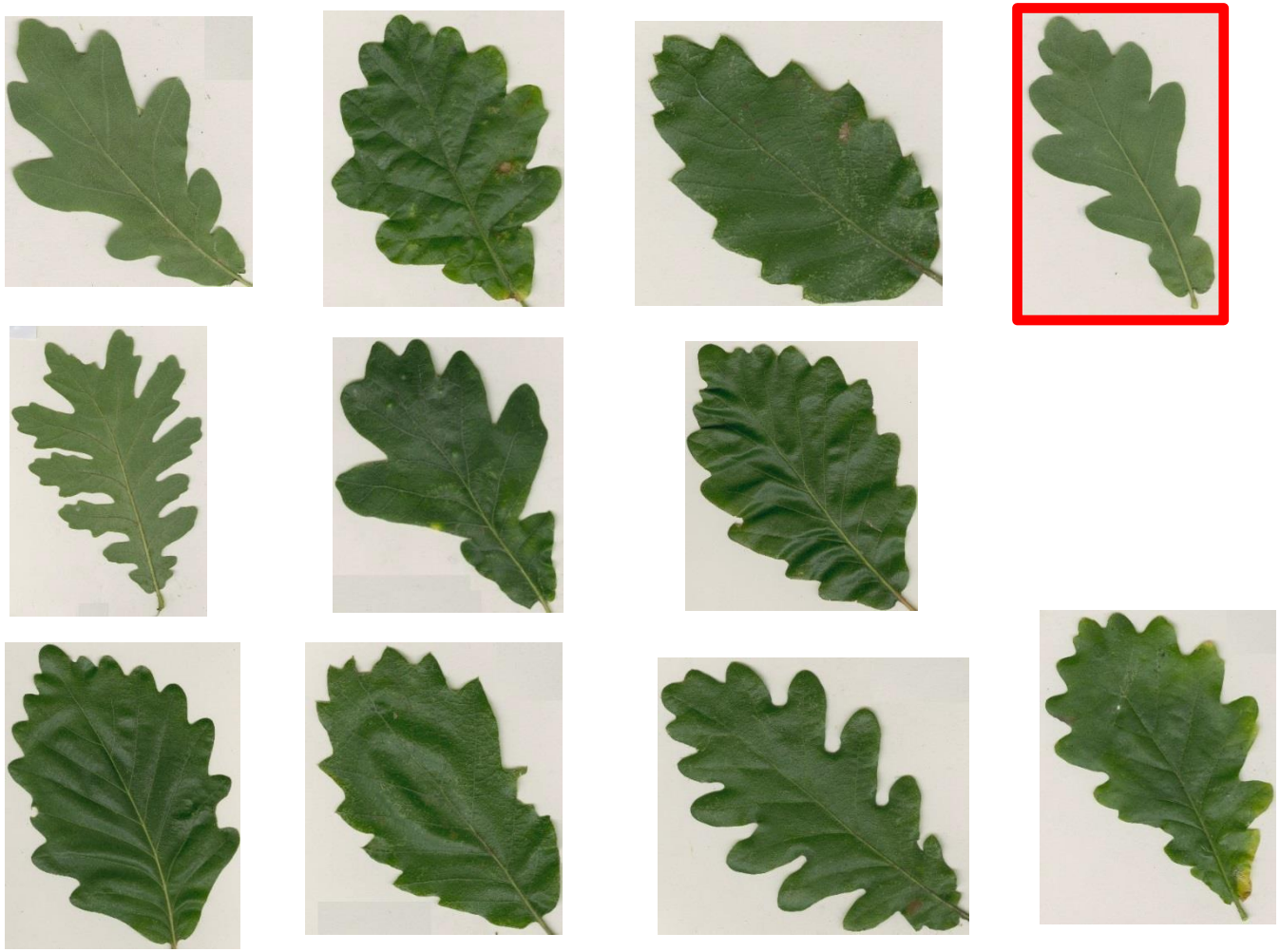
Bottlenecks

What species does this leaf belong to?

?

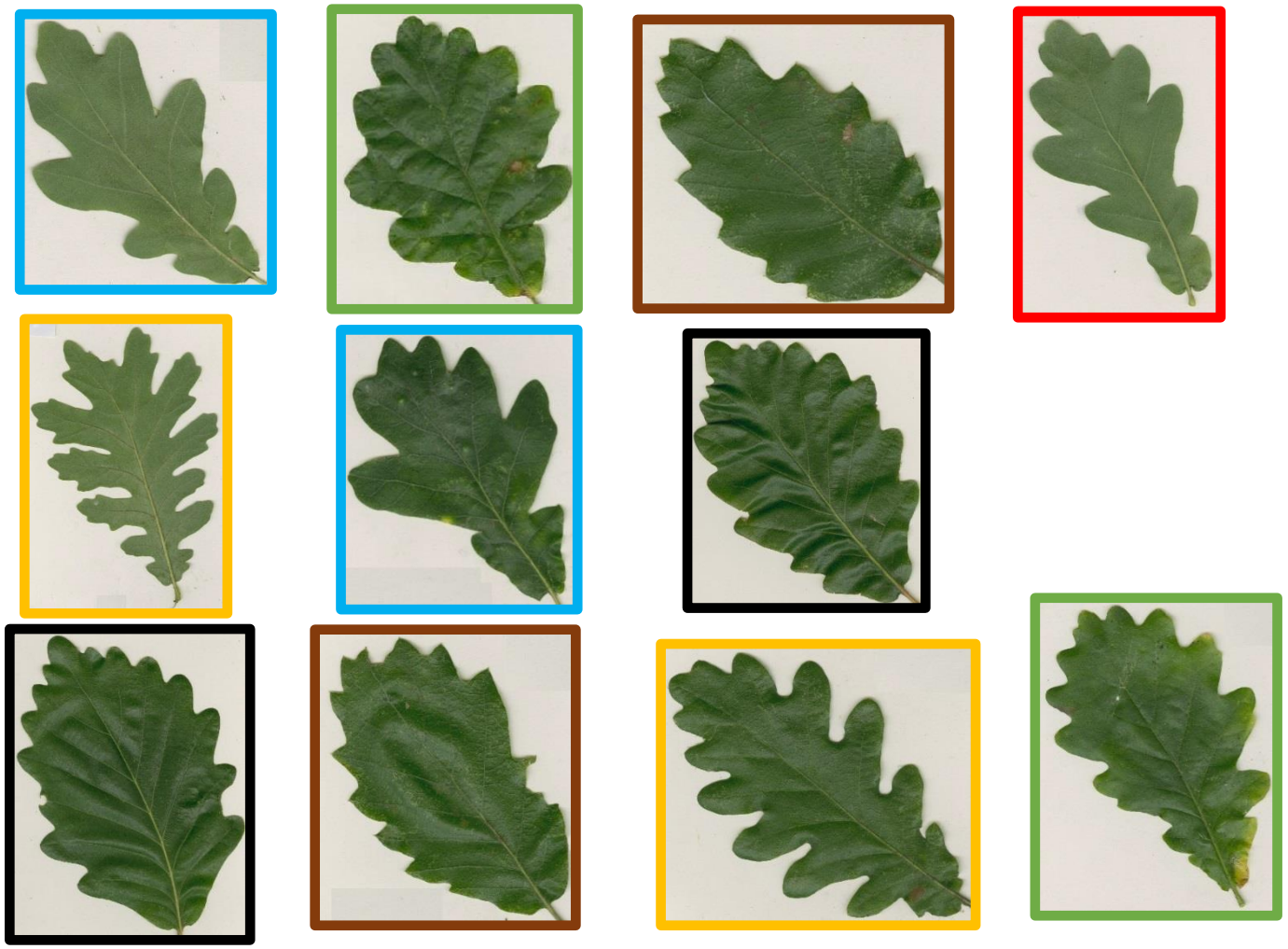
Bottlenecks

What species does this leaf belong to?



Bottlenecks

What species does this leaf belong to?



Computer Vision challenges

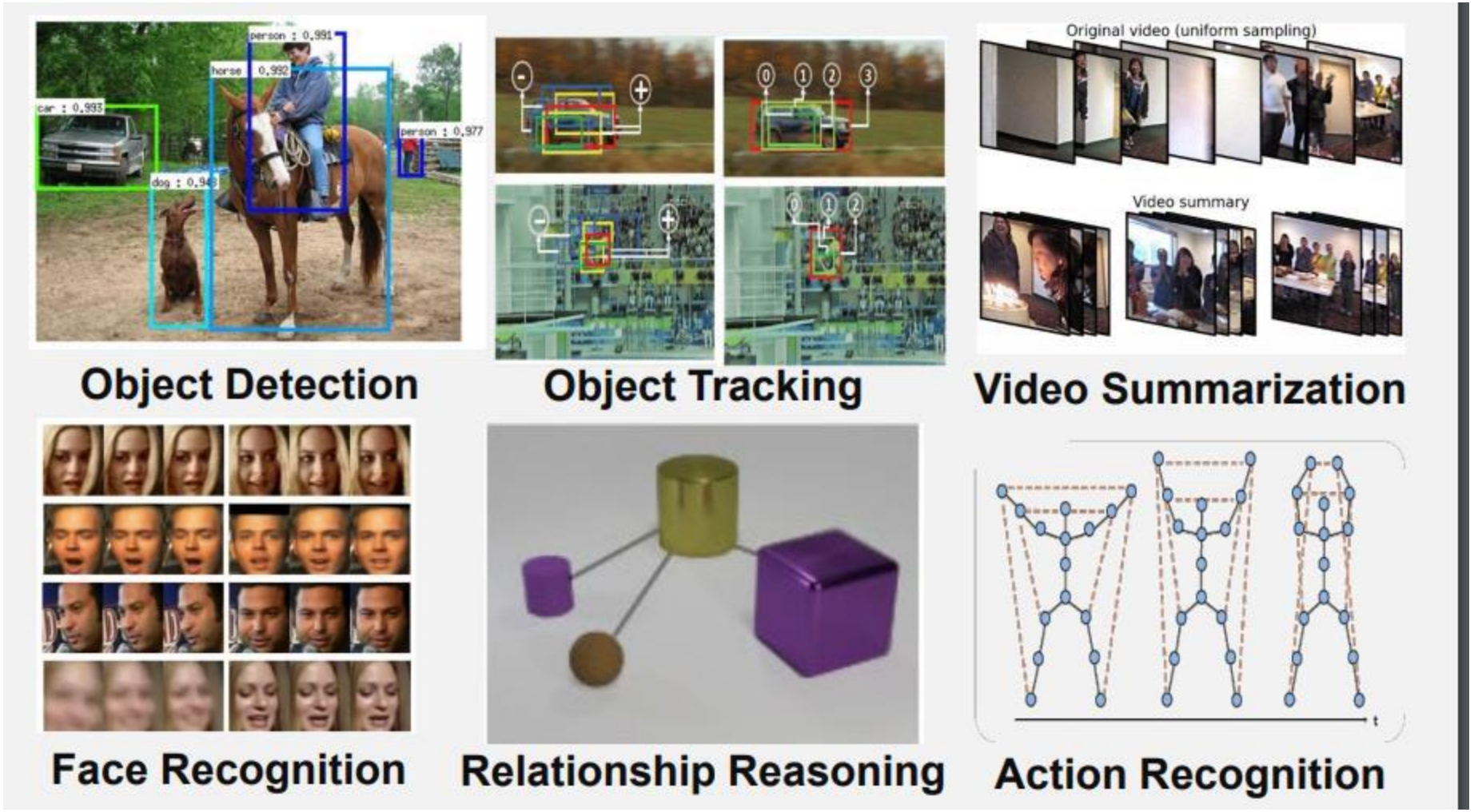
View points

Illumination

Scale

Occlusion

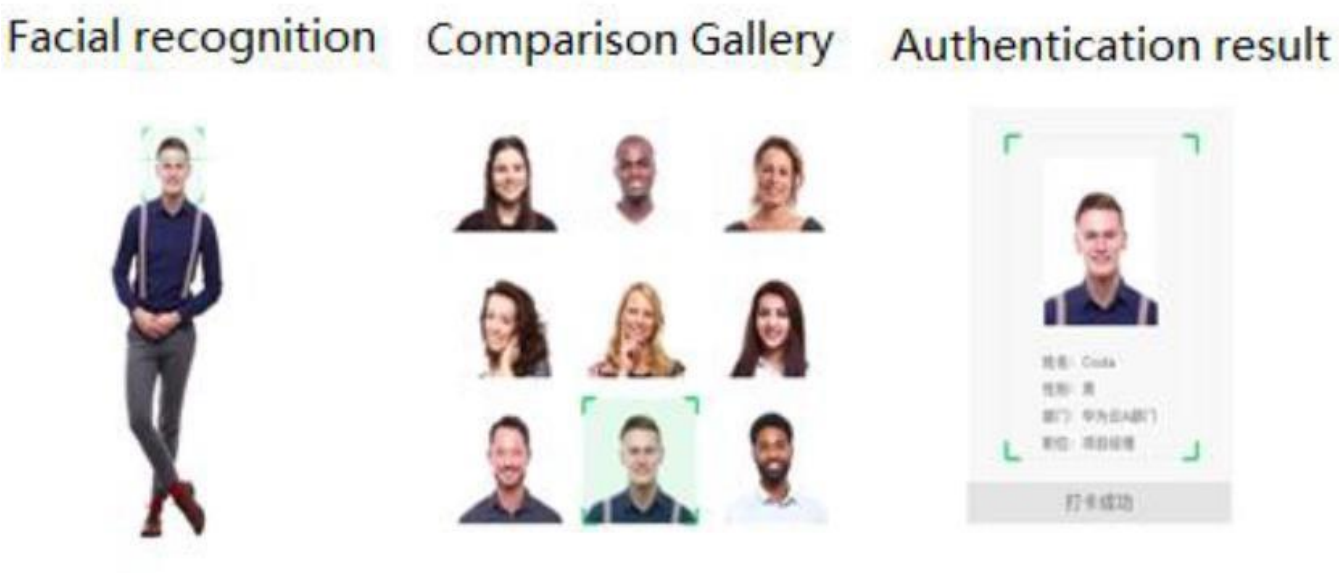
Computer Vision major areas



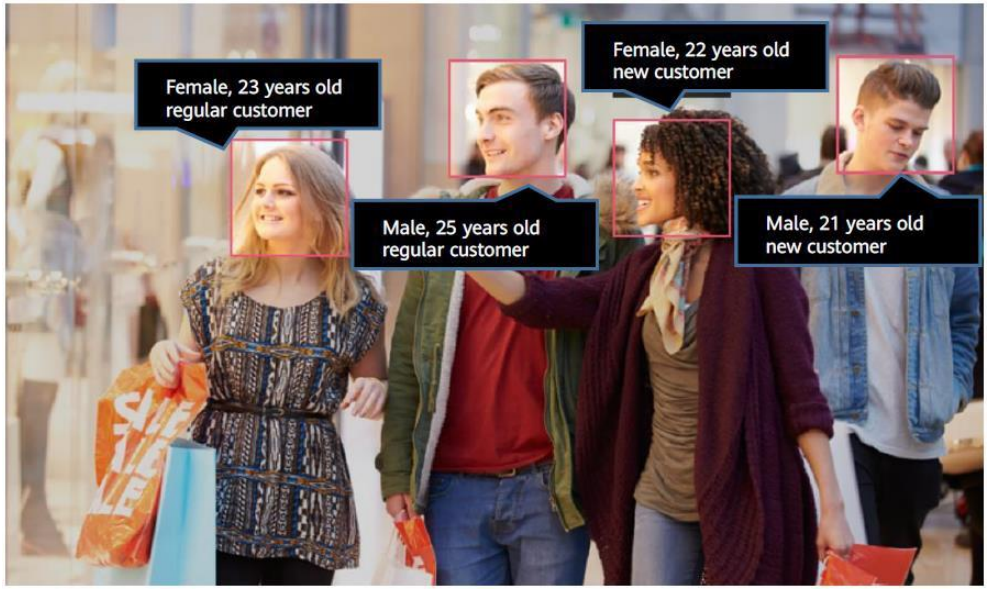
http://ivg.au.tsinghua.edu.cn/DRLCV/CVPR19_tutorial.pdf

Computer Vision application

Electronics attendance



customer analysis



Computer Vision application

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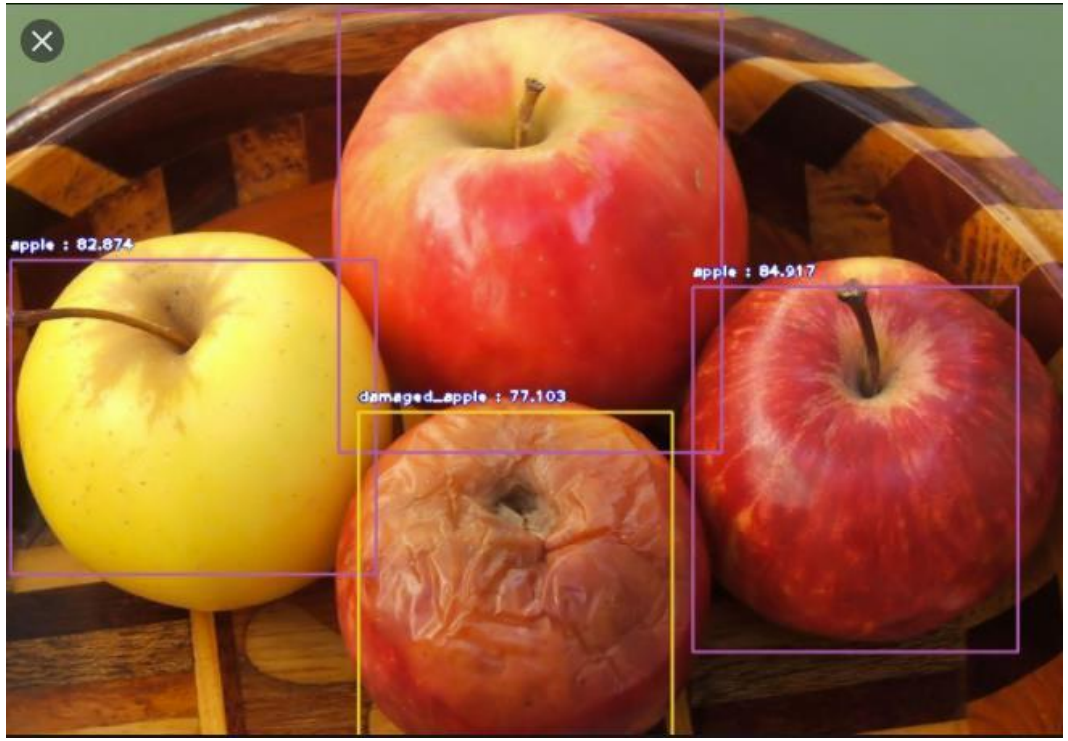
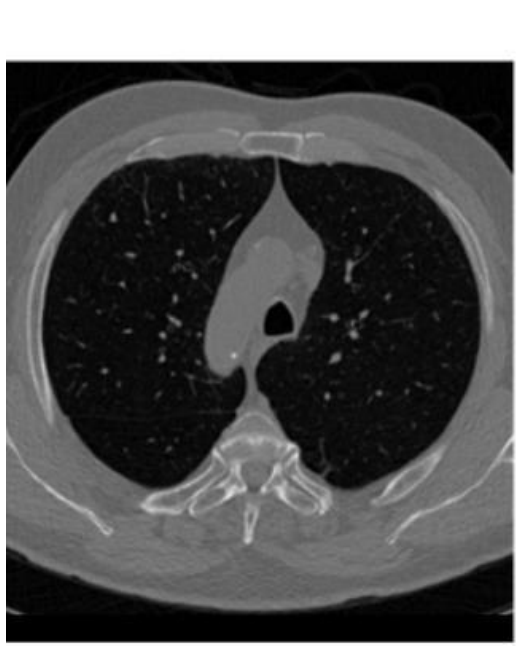
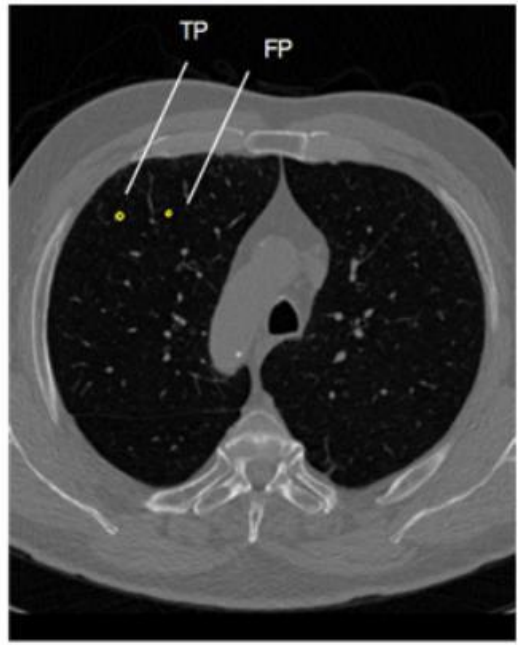
Detecting defects in Fruits



Early detection of lung cancer





Computer Vision application

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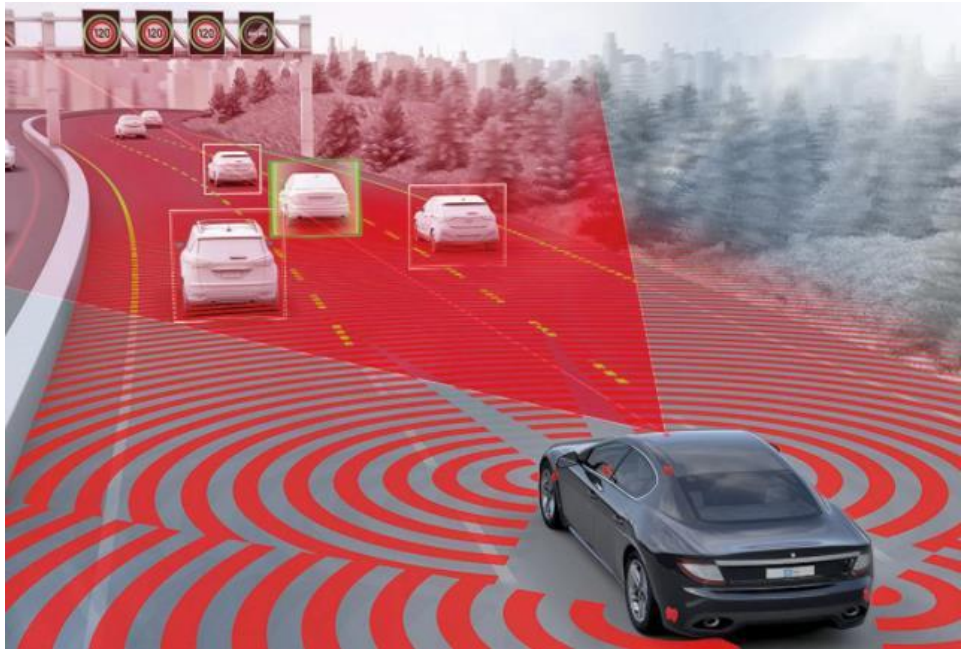
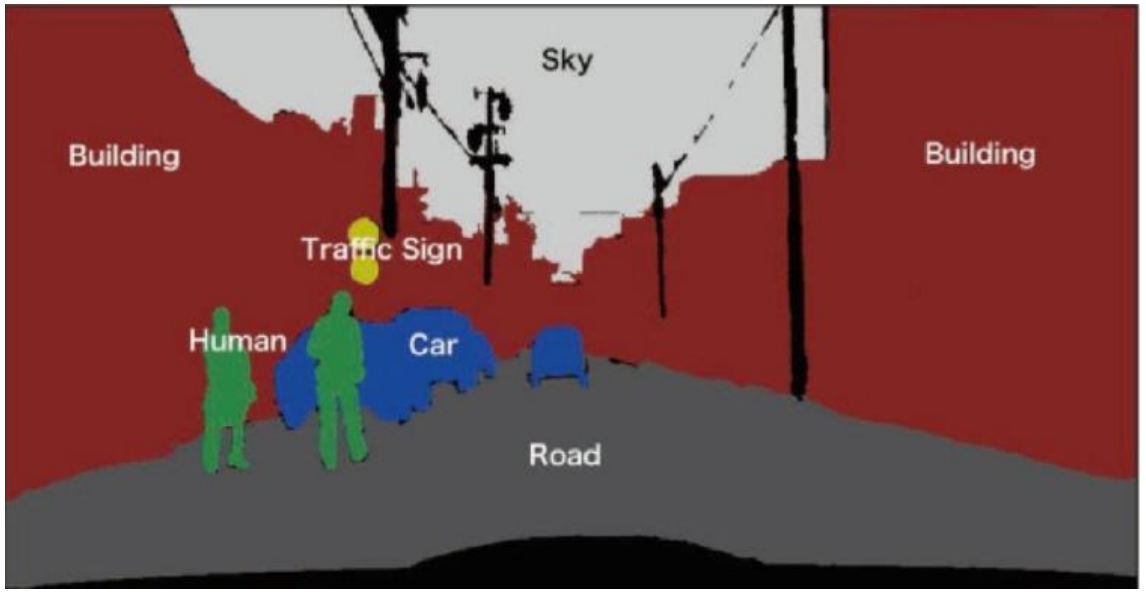
Autonomous driving

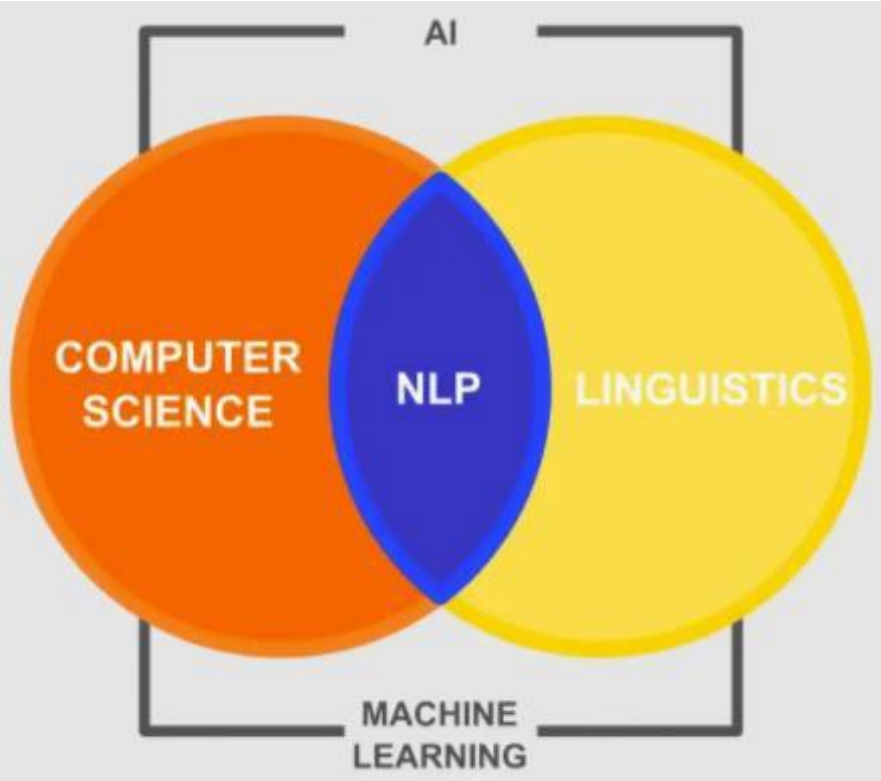


Scene parsing



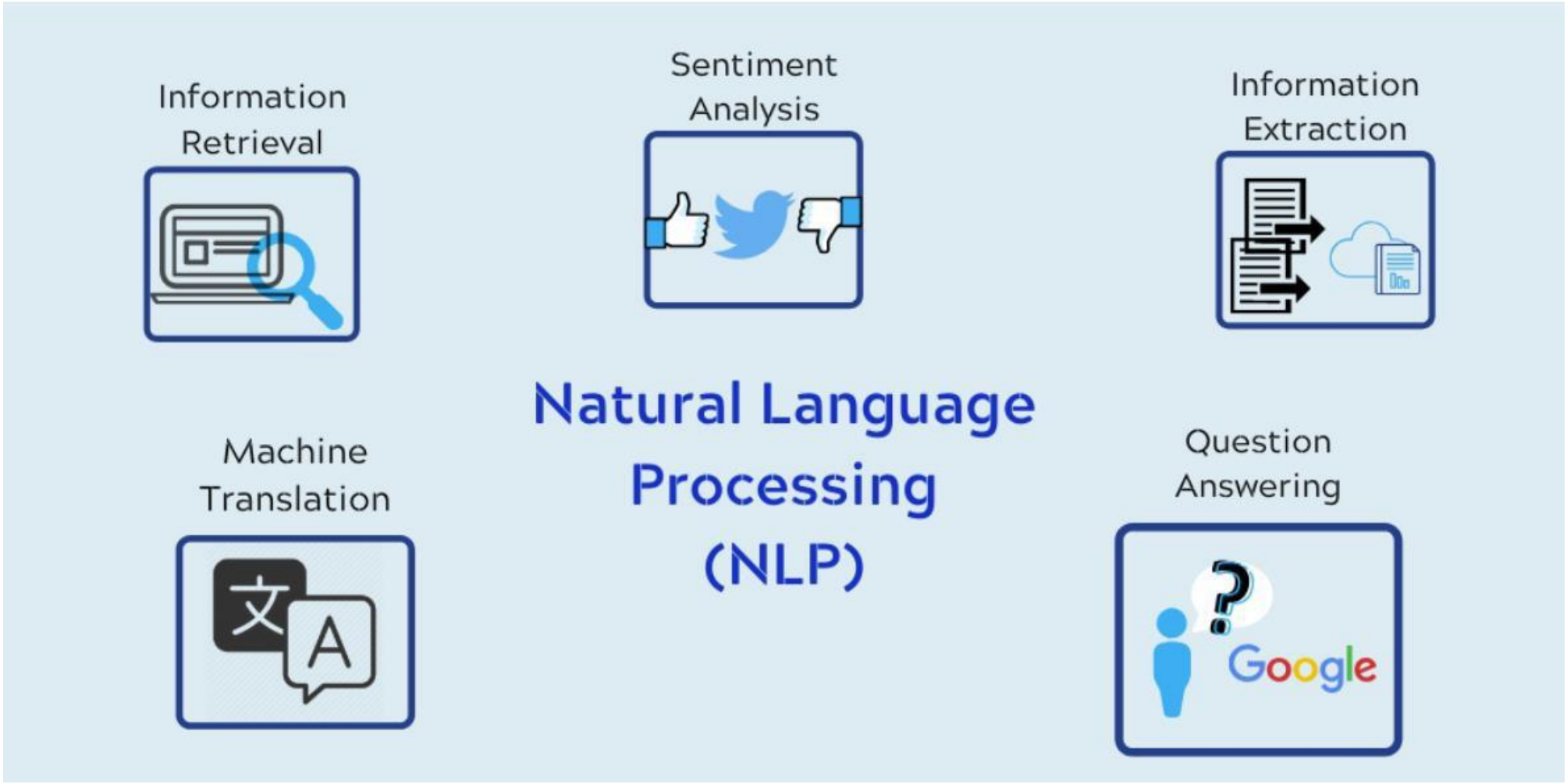
Natural Language Processing

- How to program computers to process and analyze large amounts of natural language data?



https://algorithmxlab.com/blog/natural-language-processing/

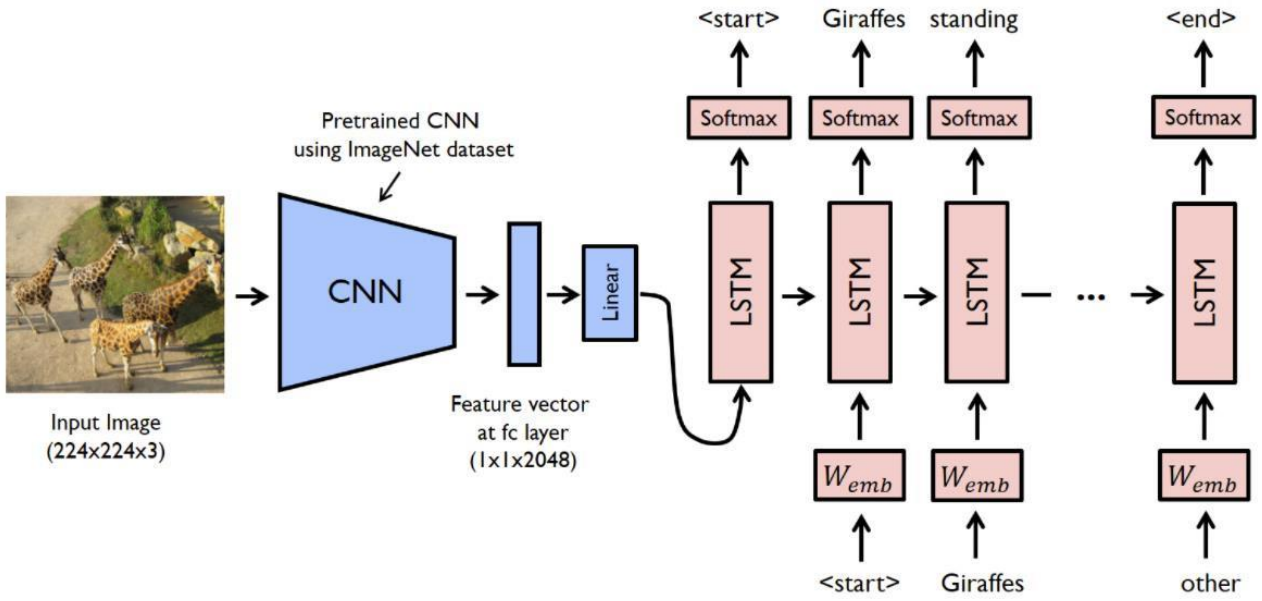
NLP application



https://www.cybiant.com/resources/natural-language-processing/

NLP and Computer Vision Integrated

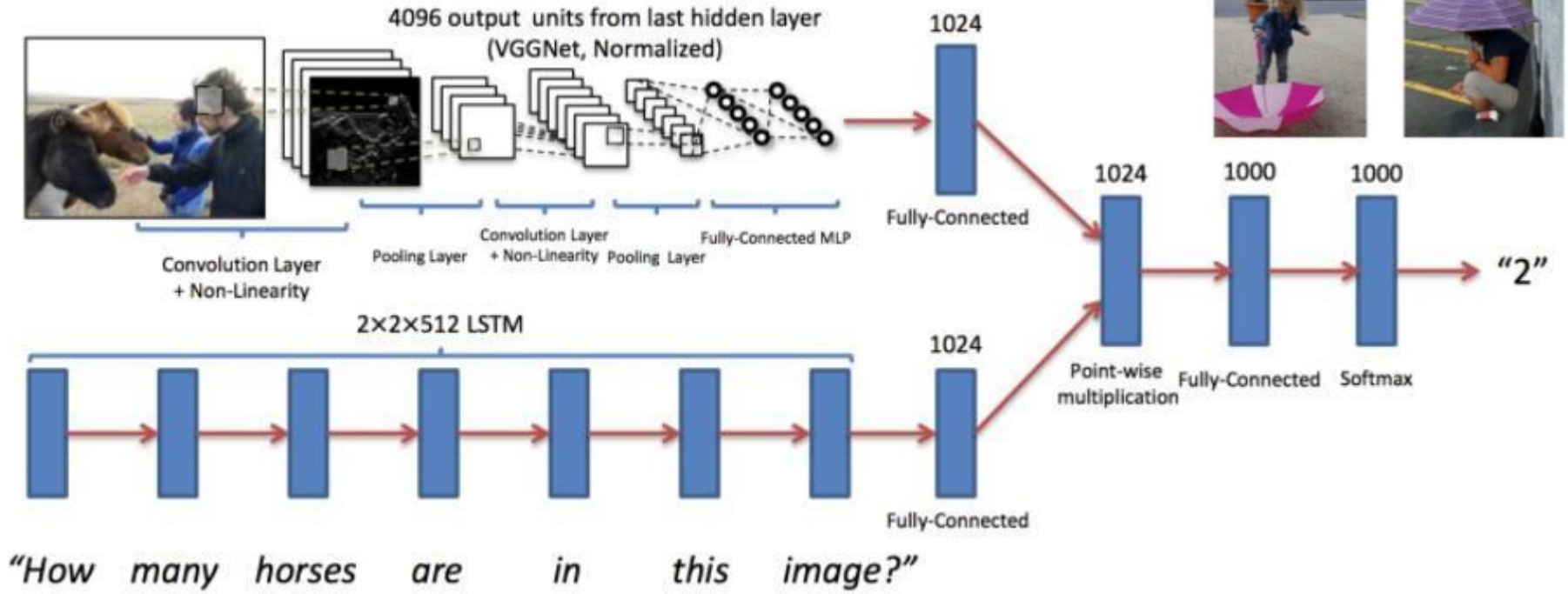
Image captioning



https://www.analyticsvidhya.com/blog/2018/04/solving-an-image-captioning-task-using-deep-learning/

NLP and Computer Vision Integrated

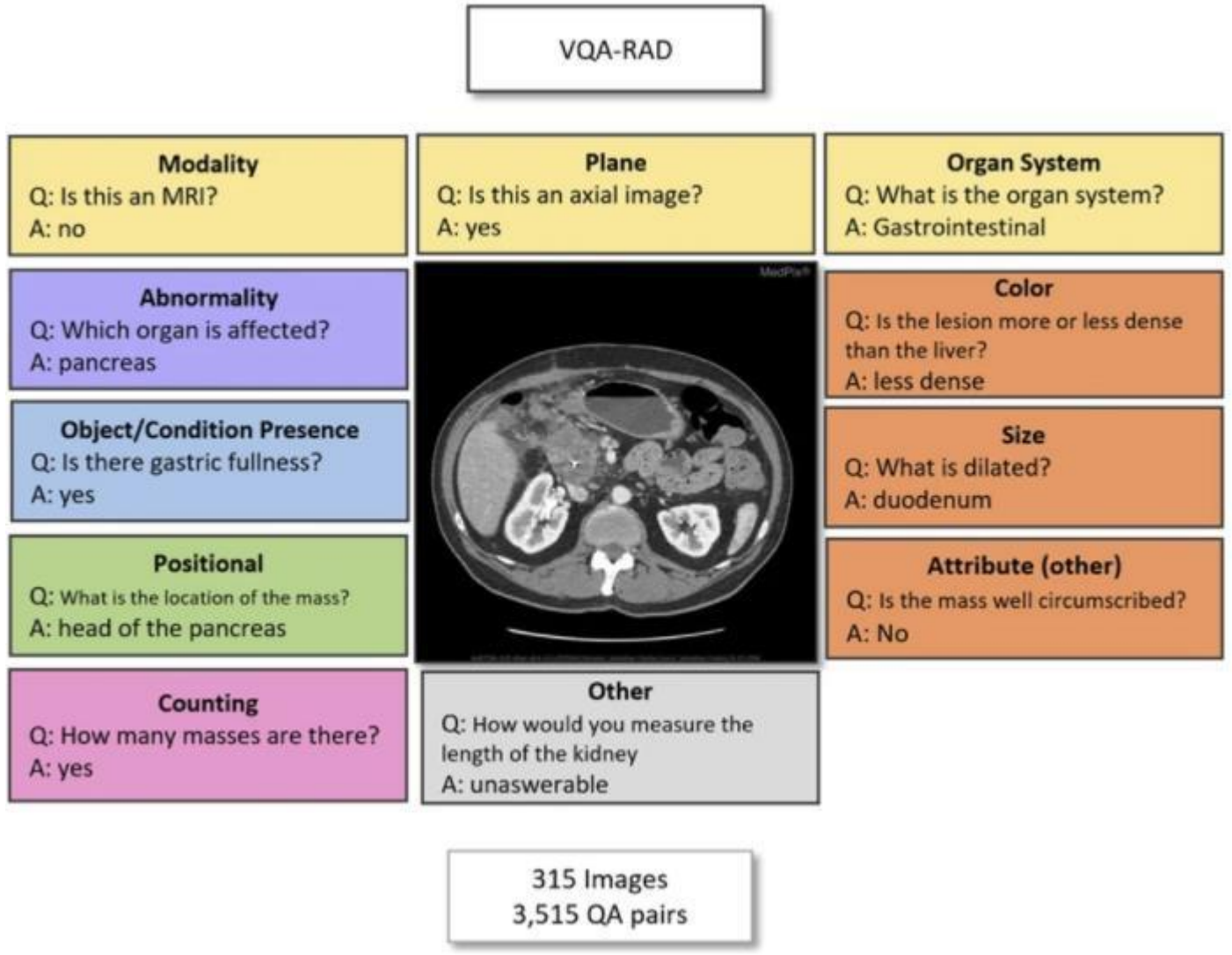
Visual question answering



https://towardsdatascience.com/deep-learning-and-visual-question-answering-c8c8093941bc

NLP + Computer Vision application

- Clinical decision support
  - Automated systems could help clinicians cope with large amounts of images by answering questions about the image contents.



Lau, J.J., Gayen, S., Abacha, A.B. and Demner-Fushman, D., 2018. A dataset of clinically generated visual questions and answers about radiology images. *Scientific data*, *5*(1), pp.1-10.

NLP + Computer Vision application

- Answering Visual Questions from Blind People

Q: Does this foundation have any sunscreen?
A: yes

Q: What is this?
A: 10 euros

Q: What color is this?
A: green

Q: Please can you tell me what this item is?
A: butternut squash red pepper soup

Q: Is it sunny outside?
A: yes

Q: Is this air conditioner on fan, dehumidifier, or air conditioning?
A: air conditioning

Gurari, D., Li, Q., Lin, C., Zhao, Y., Guo, A., Stangl, A. and Bigham, J.P., 2019. VizWiz-Priv: a dataset for recognizing the presence and purpose of private visual information in images taken by blind people. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 939-948).

NLP + Computer Vision application

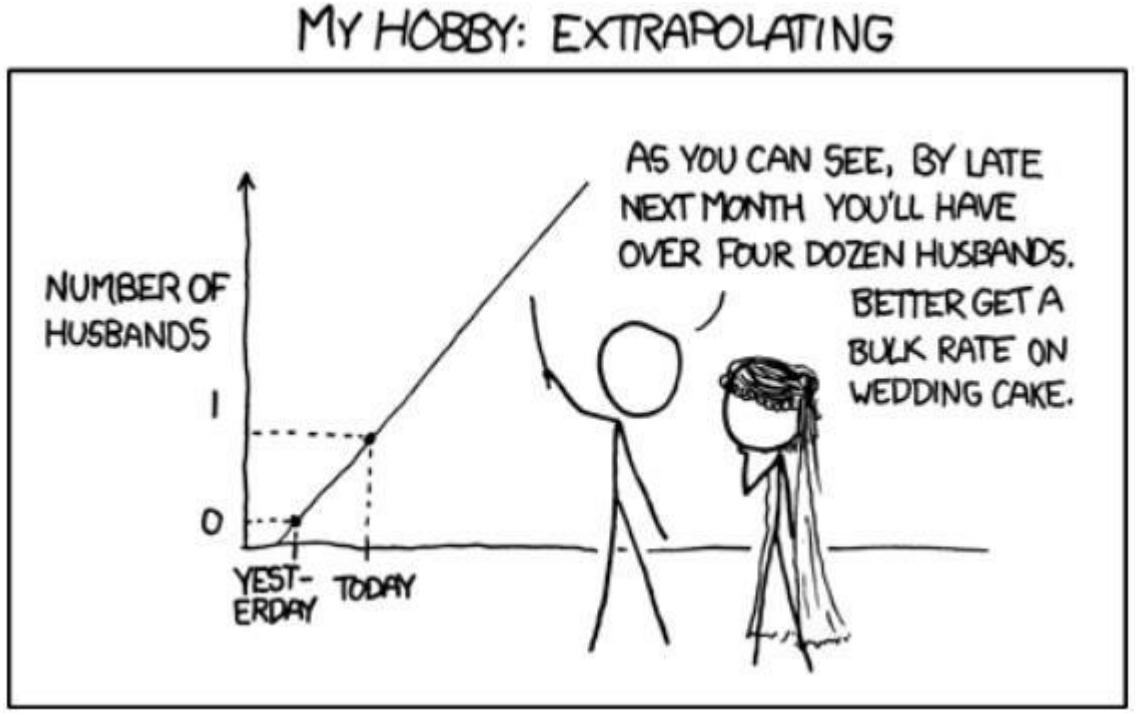
- Fashion advice
  - Individuals with and without vision impairments get fashion advice

12. Could you describe the colors of this polo shirt to me; please?

49. Does this polo shirt go with these trousers? And; if you also want to suggest what color shoes would go with this particular shade of - well; it's olive.

Next lecture

- Linear regression



https://stats.stackexchange.com/questions/423/what-is-your-favorite-data-analysis-cartoon