COS30082
Applied Machine Learning

Lecture 1

Introduction to Machine Leaning

Aims

This unit equips students with essential skills to implement applied machine learning projects. It focuses on techniques and methods for solving complex real-world problems rather than on machine learning theories and statistics.

Learning Objectives

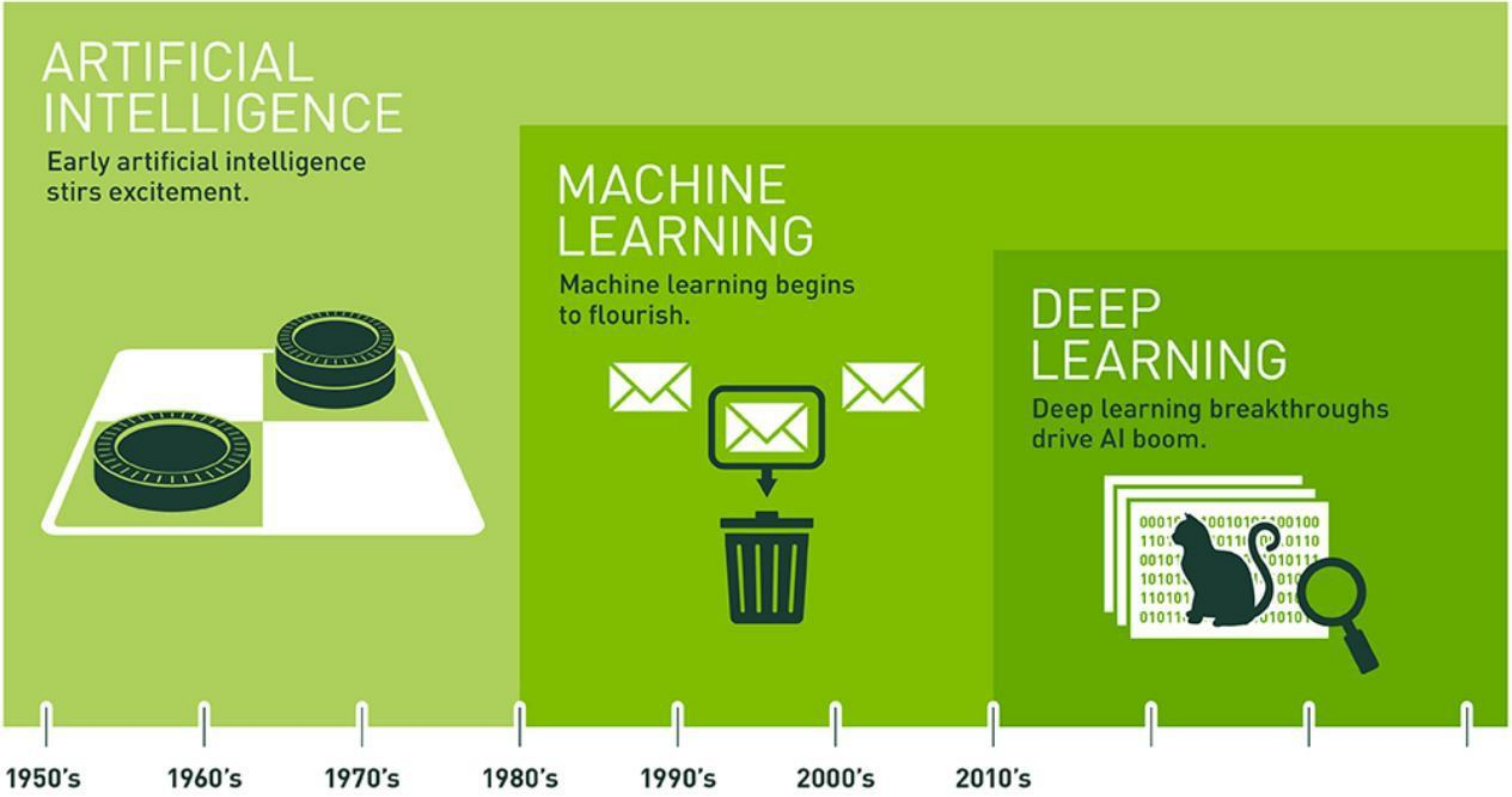
Students who successfully complete this unit will be able to:

- Explain the machine learning lifecycle.
- Apply appropriate data engineering techniques for data preparation.
- Analyse and apply advanced machine learning algorithms to solve complex real-world problems.
- Evaluate, deploy, and optimise machine learning solutions for given problems.
- Interpret and effectively communicate machine learning project outcomes to domain-specific users.

Topics

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

The development of AI



ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.

MACHINE LEARNING

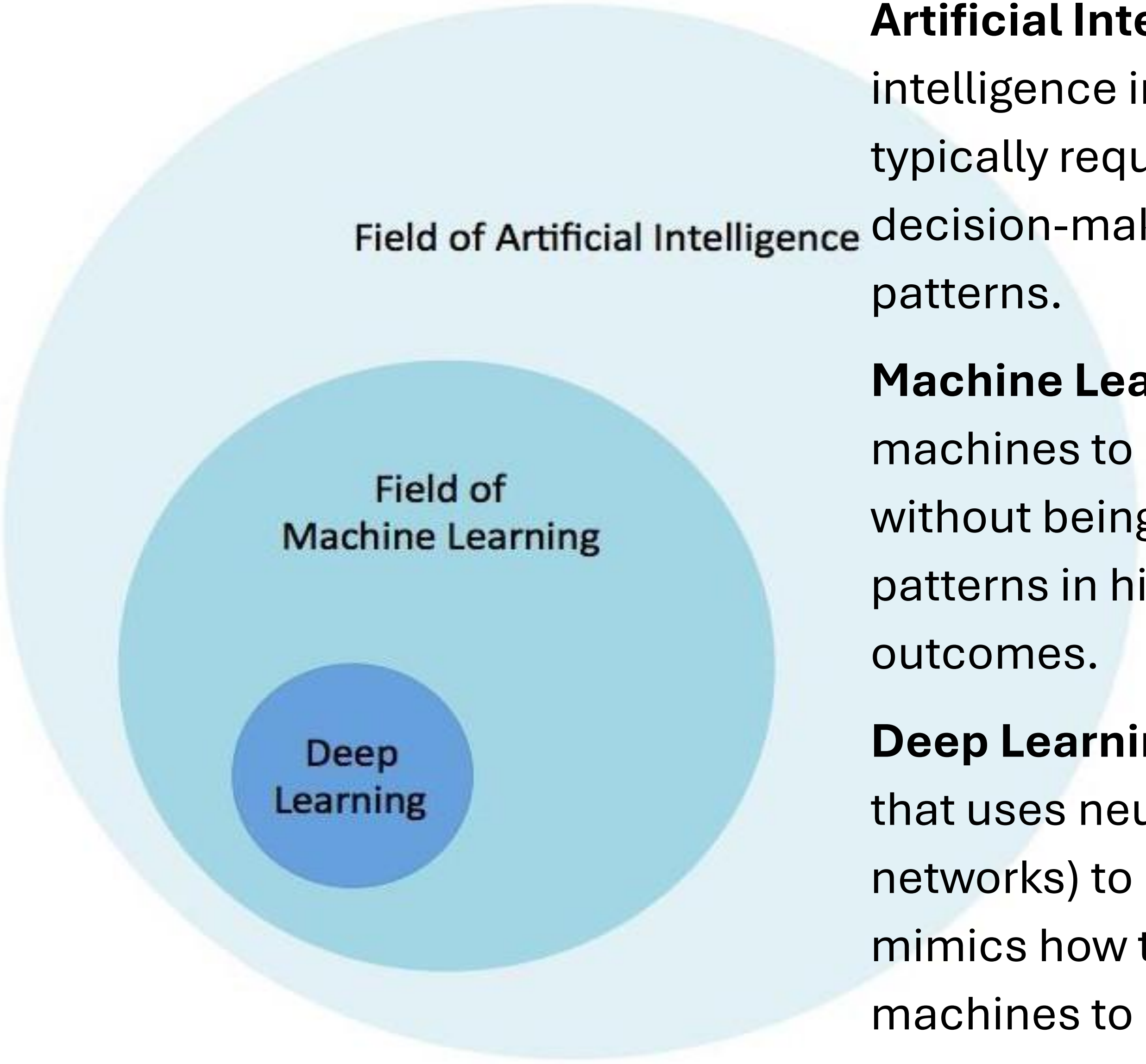
Machine learning begins to flourish.

DEEP LEARNING

Deep learning breakthroughs drive AI boom.

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 (AI) refers to the simulation of human intelligence in machines, enabling them to perform tasks that typically require human cognition, such as problem-solving, decision-making, understanding language, and recognising patterns.

Machine Learning (ML) is a subset of AI that involves training machines to learn from data and make predictions or decisions without being explicitly programmed. ML algorithms analyse patterns in historical data and use them to predict future outcomes.

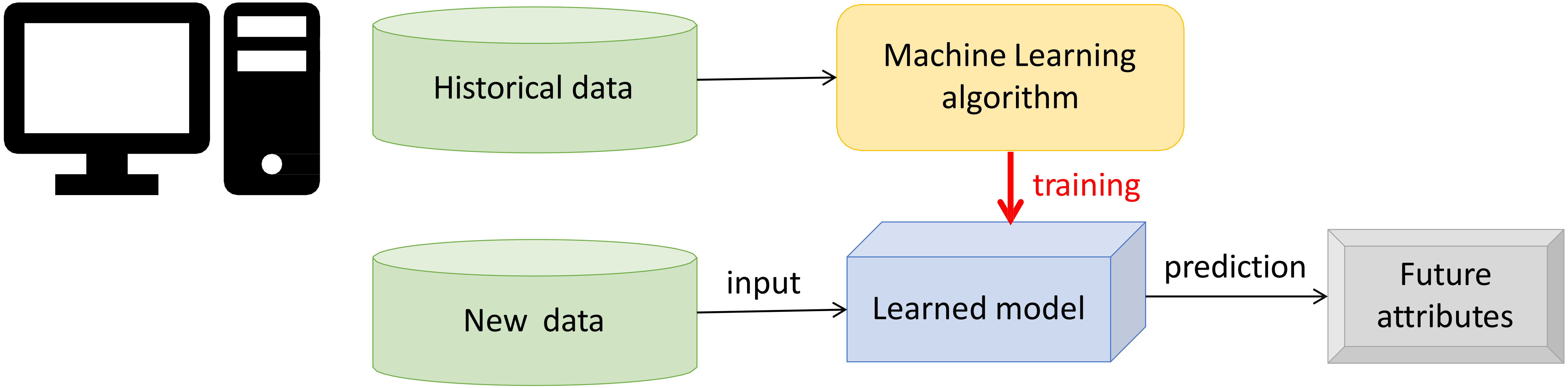
Deep Learning (DL) is a specialized branch of machine learning that uses neural networks with multiple layers (deep neural networks) to model complex patterns in data. Deep learning mimics how the human brain processes information, enabling machines to perform tasks like image recognition, speech processing, and natural language understanding.

What is Machine Learning?

"*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?

- Machine learning (ML) is the process of training a software program, called a model, to analyse a dataset and make useful predictions.
- Once trained, the model can generate predictions for new, unseen data. These predictions help automate decision-making.
- For example, if the system predicts that a user will enjoy a particular video, it automatically recommends that video to them.



Historical data

Machine Learning algorithm

training

New data

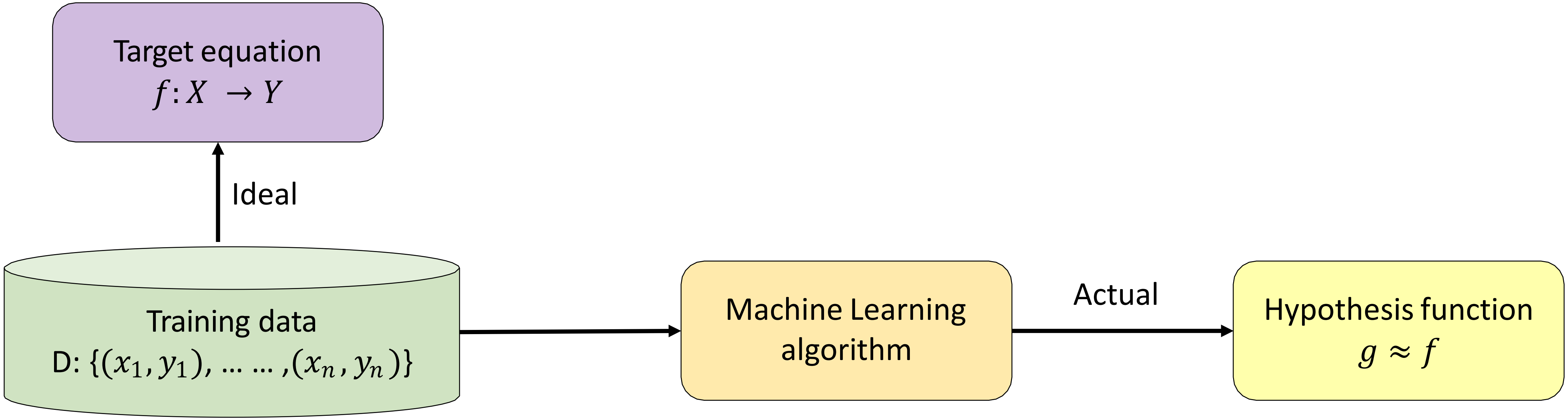
input

Learned model

prediction

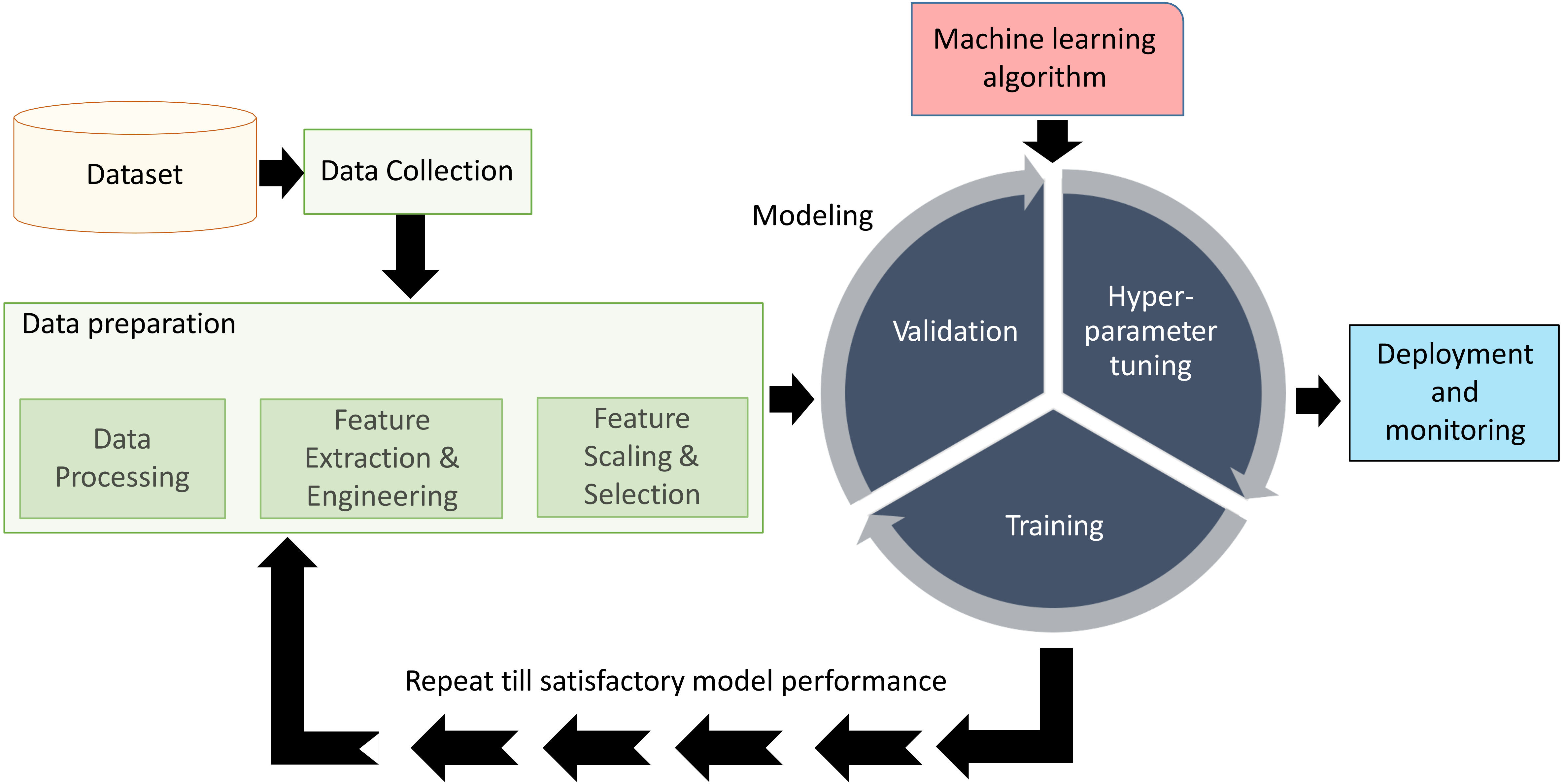
Future attributes

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


Machine learning algorithm
Dataset
Data Collection
Modeling
Data preparation
Data Processing
Feature Extraction & Engineering
Feature Scaling & Selection
Validation
Hyper-parameter tuning
Training
Deployment and monitoring
Repeat till satisfactory model performance

ML & Rule-based system differences

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 analyses 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		**Machine learning**
Human involved in all aspects		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

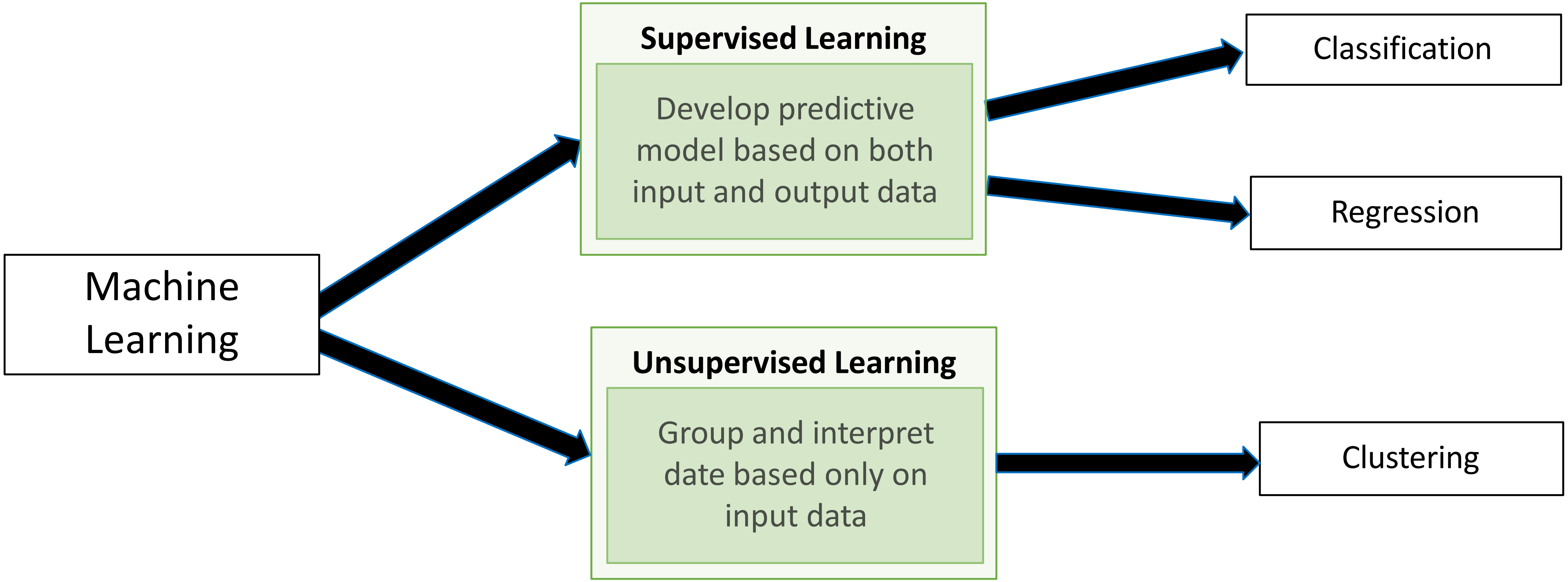
When to use rule-based system?

- 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



Machine Learning

Supervised Learning

Develop predictive model based on both input and output data

Classification

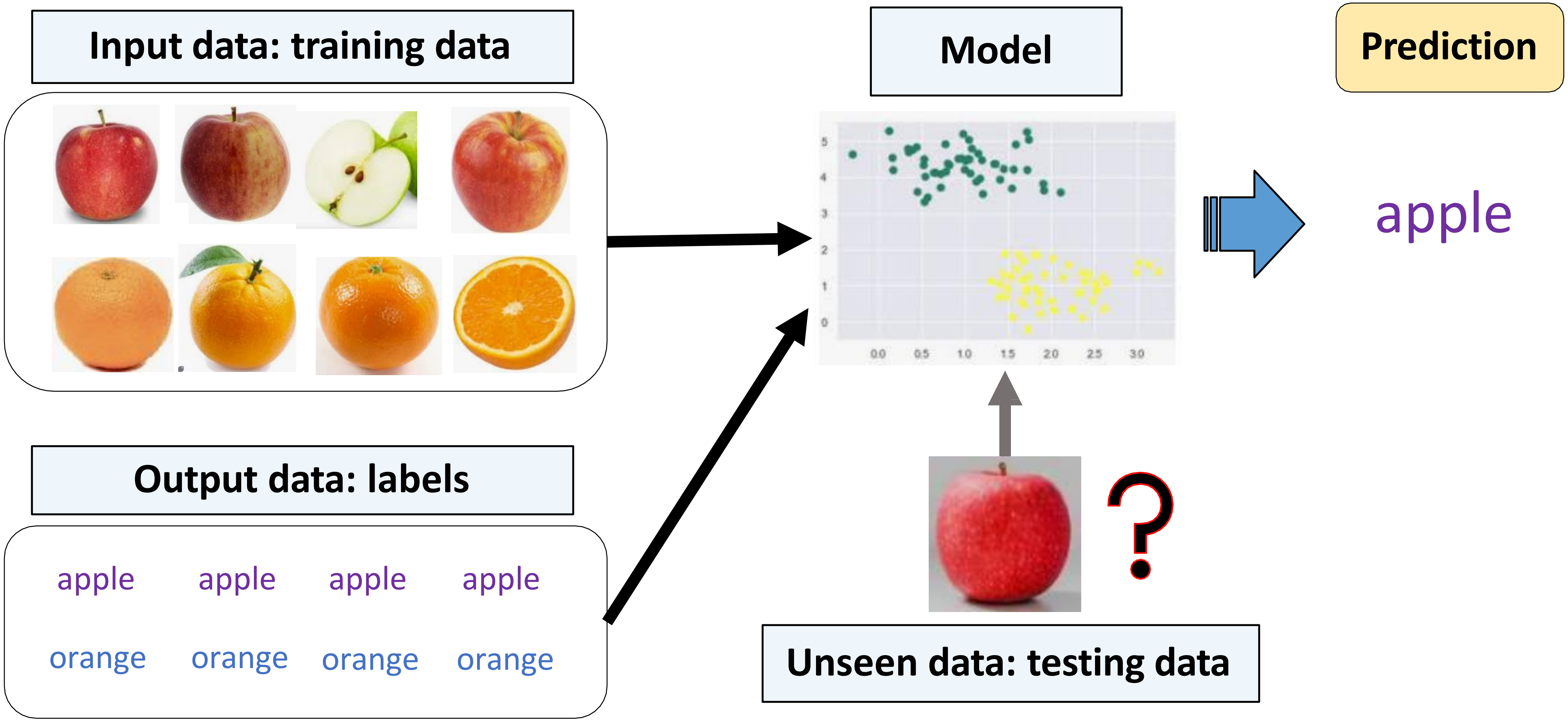
Regression

Unsupervised Learning

Group and interpret date based only on input data

Clustering

Supervised learning



Input data: training data

Output data: labels

apple apple apple apple

orange orange orange orange

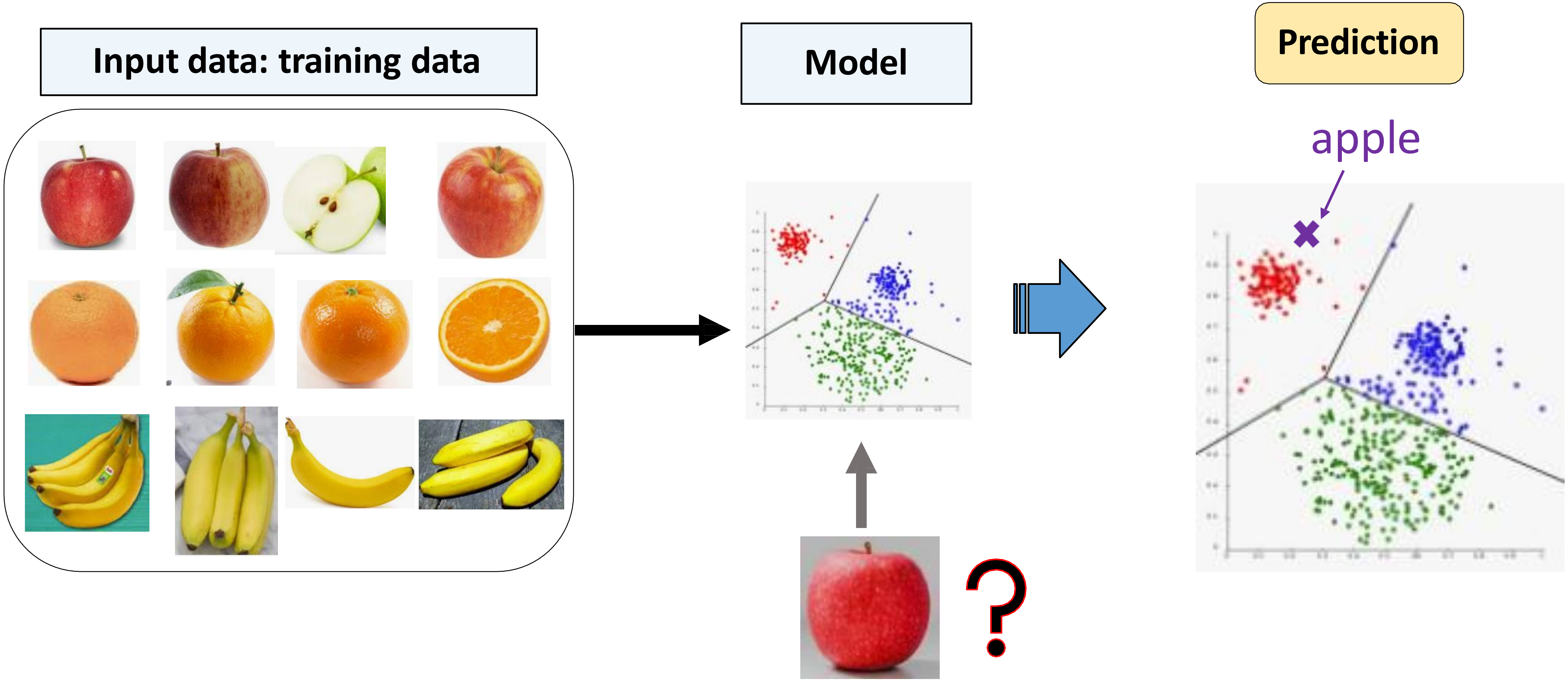
Model

Prediction

apple

Unseen data: testing data

Unsupervised learning



Input data: training data

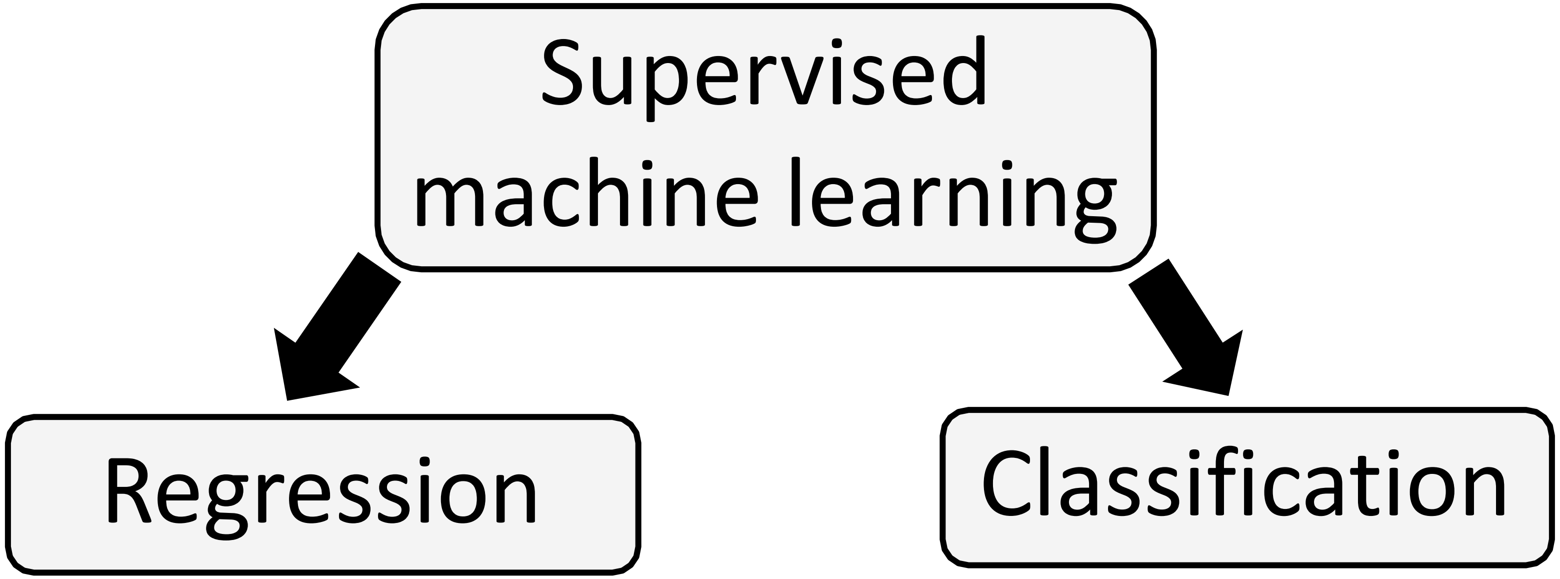
Model

Prediction

apple

?

Supervised learning



Supervised machine learning

Regression

Classification

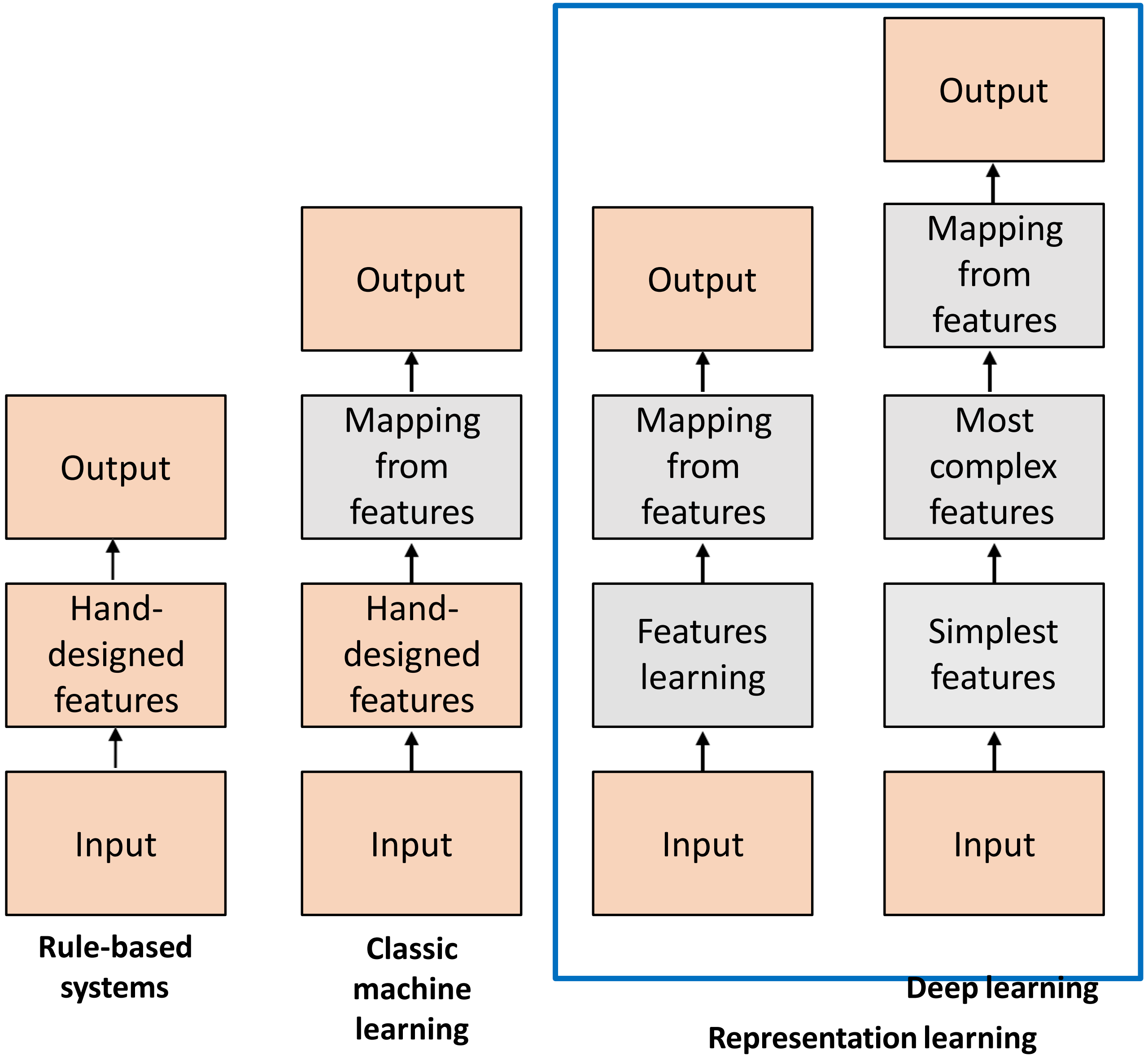
Supervised learning - Regression

- 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?

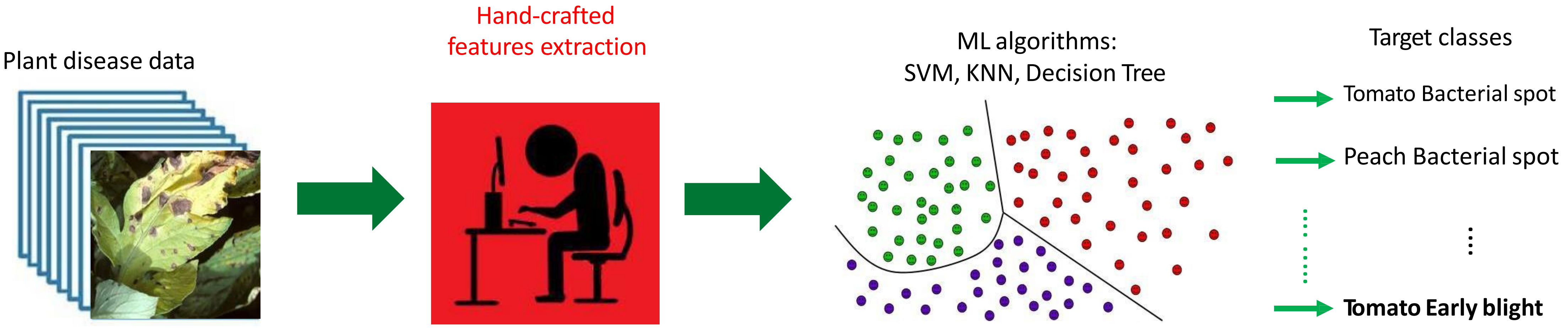
What is Deep learning?



- 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

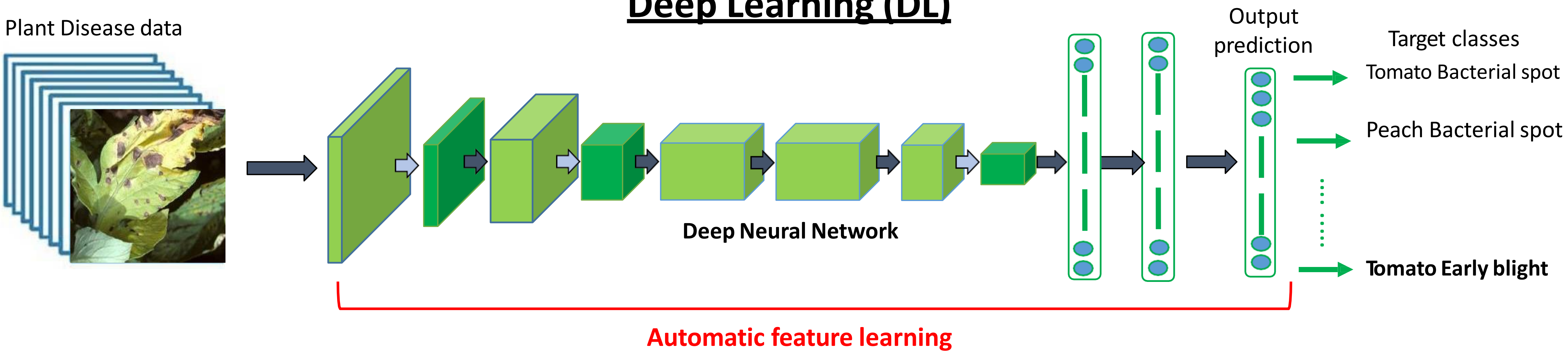
Tomato Bacterial spot

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

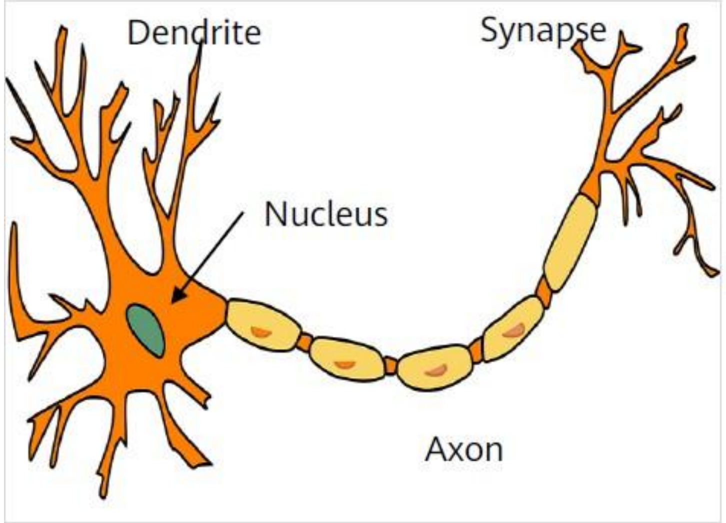
Automatic feature learning

Traditional ML vs. Deep Learning

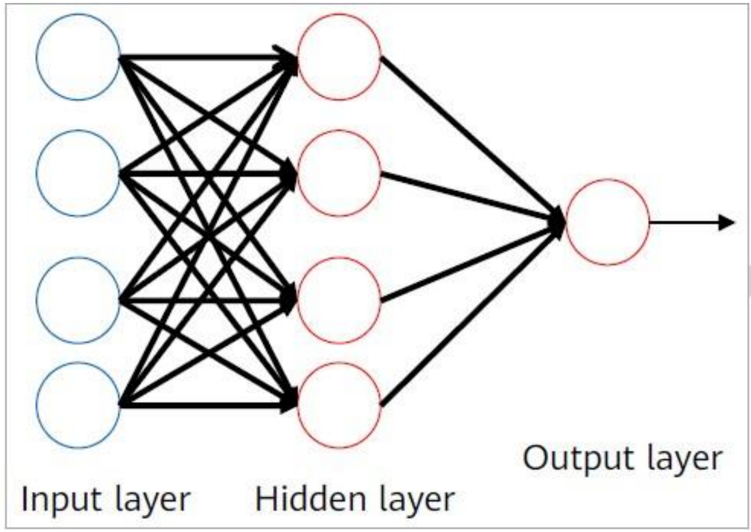
Classic Machine Learning	Deep Learning
Low hardware requirements: Given the limited computing amount, the computer does not need a GPU for parallel computing generally	**High hardware requirements:** To execute matrix operation on massive data, the computer needs GPU to perform parallel computing
Applicable 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?

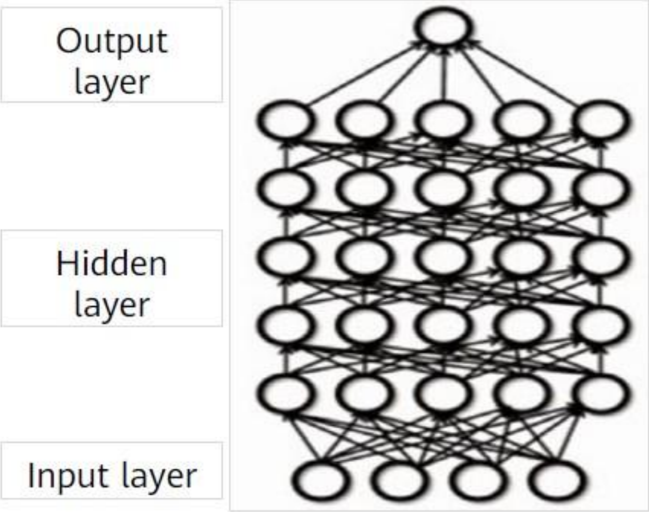
- Deep: “Deep” in “deep learning” refers to the number of layers of the neural network.
- Learning: Algorithm “learn” from data by modelling features and updating probability weights assigned to feature nodes.



Human neural network

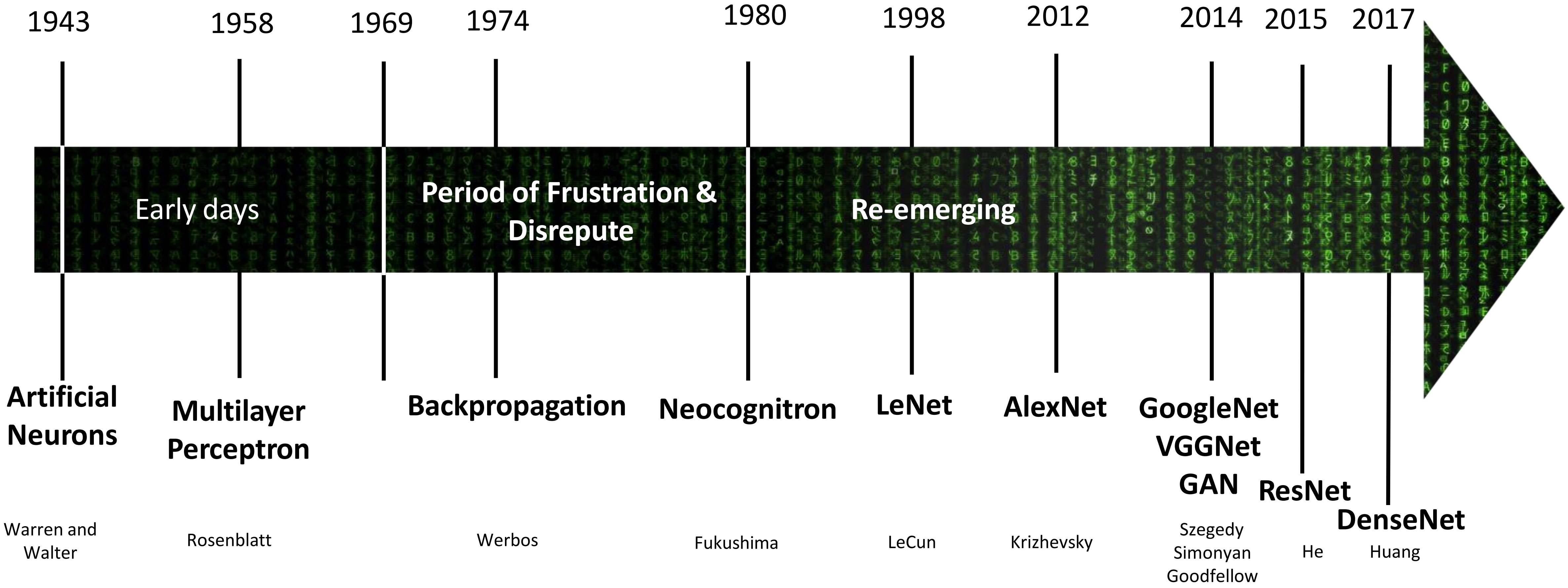


Perceptron/ single layer neural network



Deep Learning

Development history of Neural networks



Early days

Period of Frustration & Disrepute

Re-emerging

1943
Artificial Neurons
Warren and Walter

1958
Multilayer Perceptron
Rosenblatt

1969

1974
Backpropagation
Werbos

1980
Neocognitron
Fukushima

1998
LeNet
LeCun

2012
AlexNet
Krizhevsky

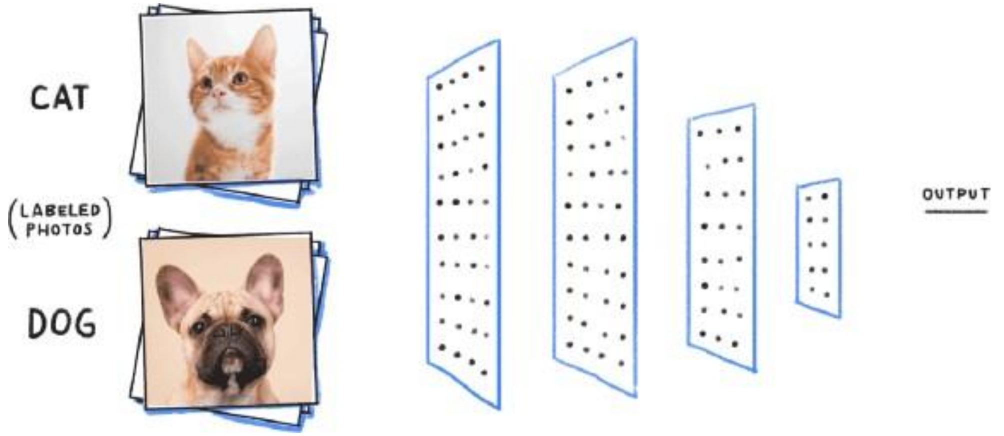
2014
GoogleNet
VGGNet
GAN
Szegedy
Simonyan
Goodfellow

2015
ResNet
He

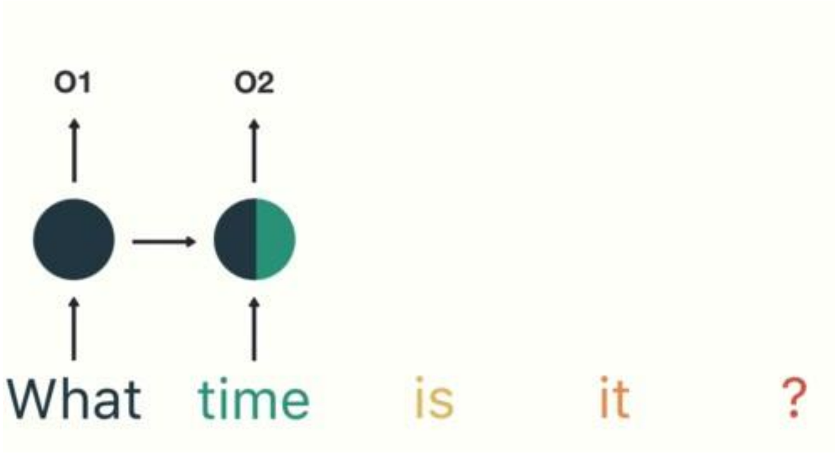
2017
DenseNet
Huang

2 main types of Deep learning networks

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



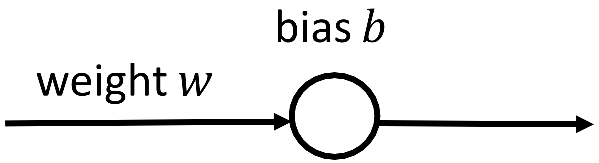
- Recurrent neural network
  - Speech, text, audio recognition
  - Recur: iterate over sequential inputs with a memory function.



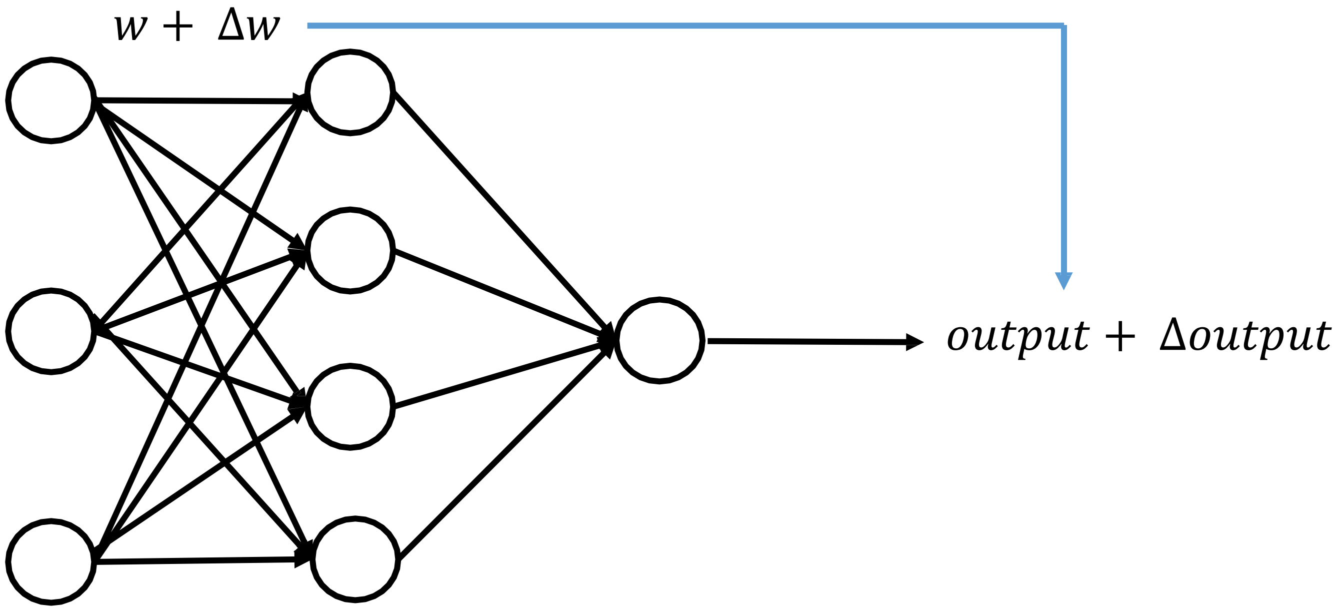
https://www.analyticsvidhya.com/blog/2020/02/cnn-vs-rnn-vs-mlp-analyzing-3-types-of-neural-networks-in-deep-learning/

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

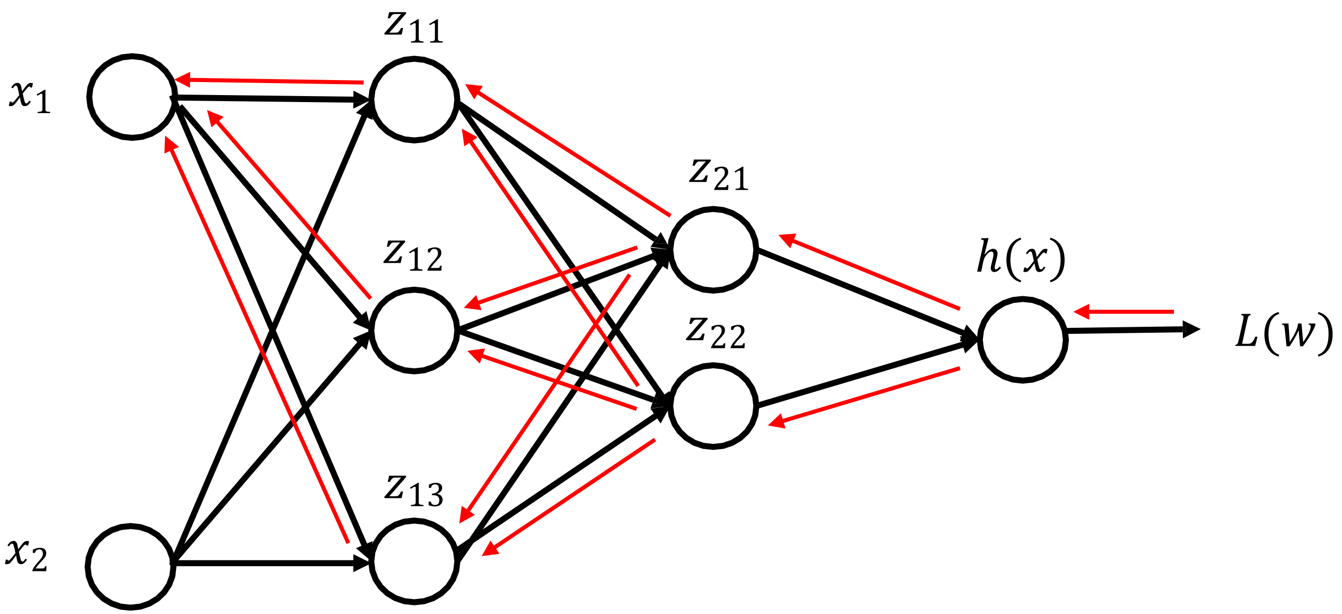


Small changes in any weight (or bias) causes a small change in the output



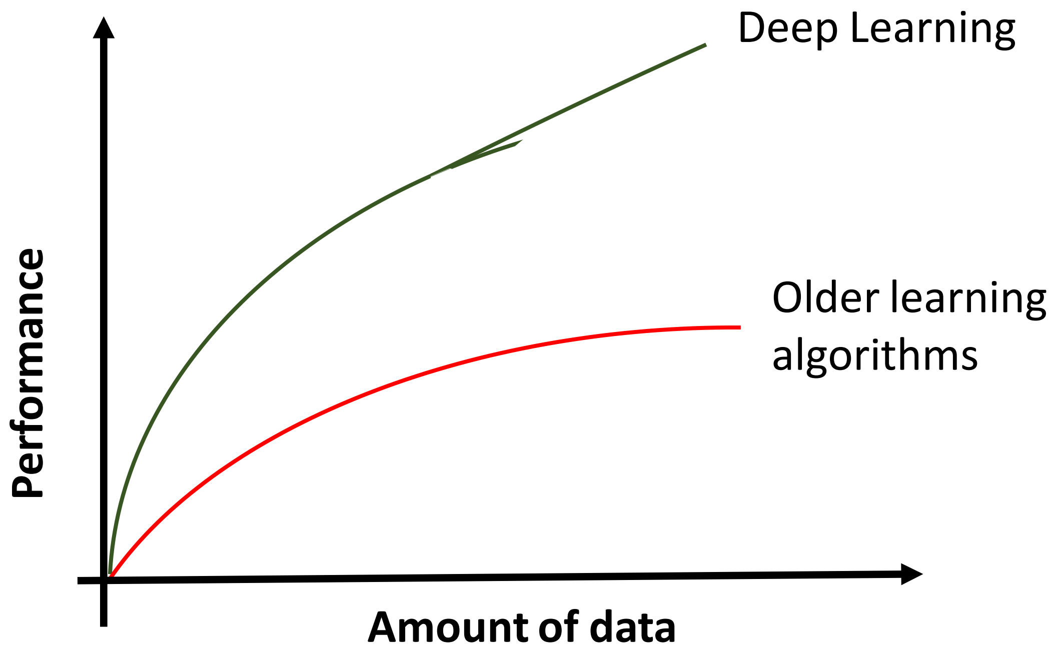
Backpropagation

- 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
- ✓ 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 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 optimisation of the model based on feedback and performance.
- There isn’t a universal machine learning life cycle; it varies based on an organisation’s processes, the project's complexity, and the nature of the problem being addressed.

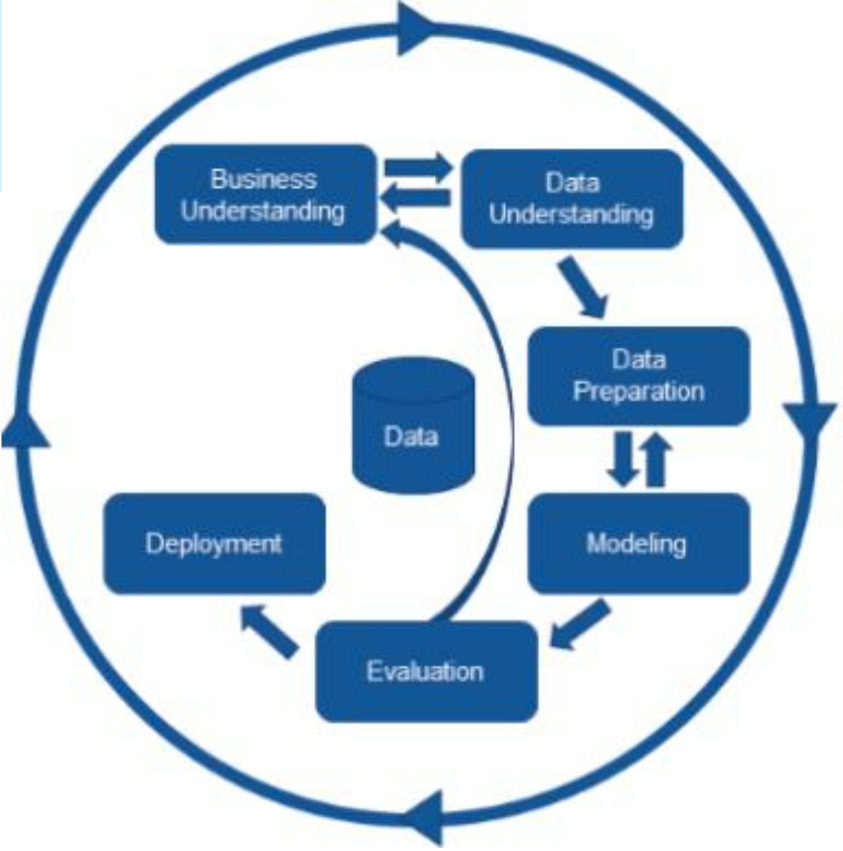
Industry-recognised Life Cycles

There are several 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 emphasises 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 machine learning life cycle models are derived.

Phases of CRISP-DM



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

Topics

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

Deep Learning Frameworks

- A deep learning framework is an interface, library or a tool that allows us to build deep learning models more easily and quickly, without delving into the details of underlying algorithms.
- Developers no longer need to compile code from scratch using 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 custom network layers to the existing models, or directly select required classifiers and optimization algorithms by invoking existing code.

Deep Learning frameworks

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 for machine learning and deep learning.

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

Features of TensorFlow

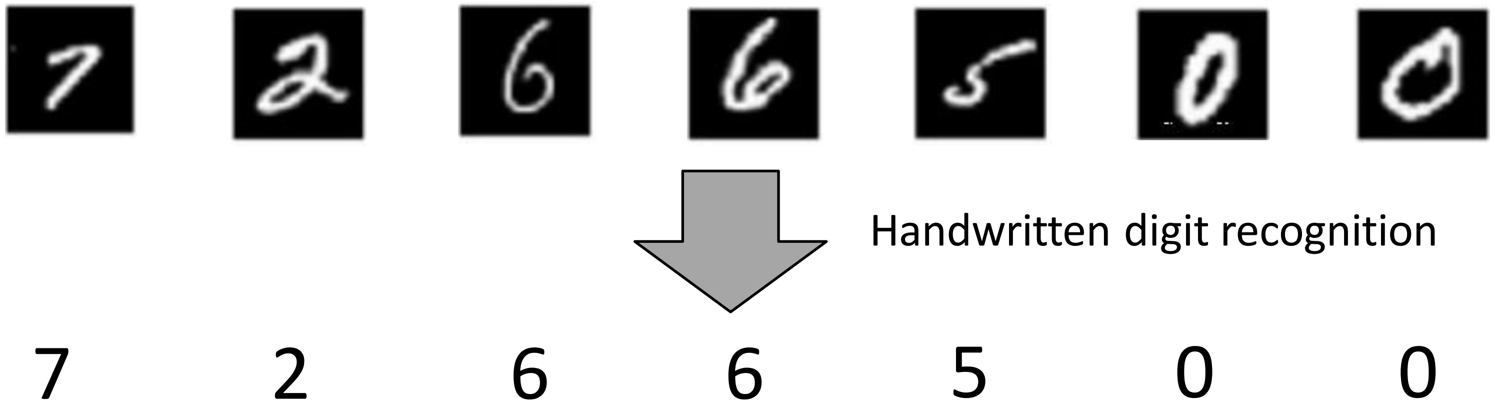
- **Scalability**: TensorFlow has library helps scale your model from a single GPU to multiple GPUs and even across multiple machines using simple APIs that require minimal changes to your existing code.
- **GPU Support**: TensorFlow supports running computations on various types of devices, including CPUs and GPUs.
- **Multi-lingual**: TensorFlow is designed to support multiple client languages. Currently, Python is the best-supported client language. Experimental interfaces for executing and constructing graphs are also available in C++, Java, and Go.
- **Multi-platform**: TensorFlow is available on 64-bit Linux, macOS, and Windows, as well as mobile platforms such as Android and iOS.
- **Powerful Computing**: TensorFlow leverages various optimisation techniques to simplify and enhance the performance of mathematical computations.
- **Distributed**: TensorFlow can run on a wide range of devices, from smartphones to large-scale computer clusters.

Why TensorFlow?

- Easy to Learn with Keras – TensorFlow 2.x integrates Keras, making model building simple with minimal code.
- Pre-Trained Models & GPU Support – Use TensorFlow Hub for transfer learning and leverage GPU acceleration for faster training.
- Strong Community & Resources – Extensive tutorials, documentation, and support from Google.
- … …

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.

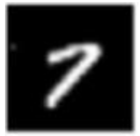
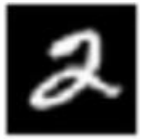
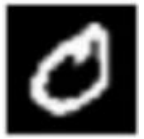


Handwritten digit recognition

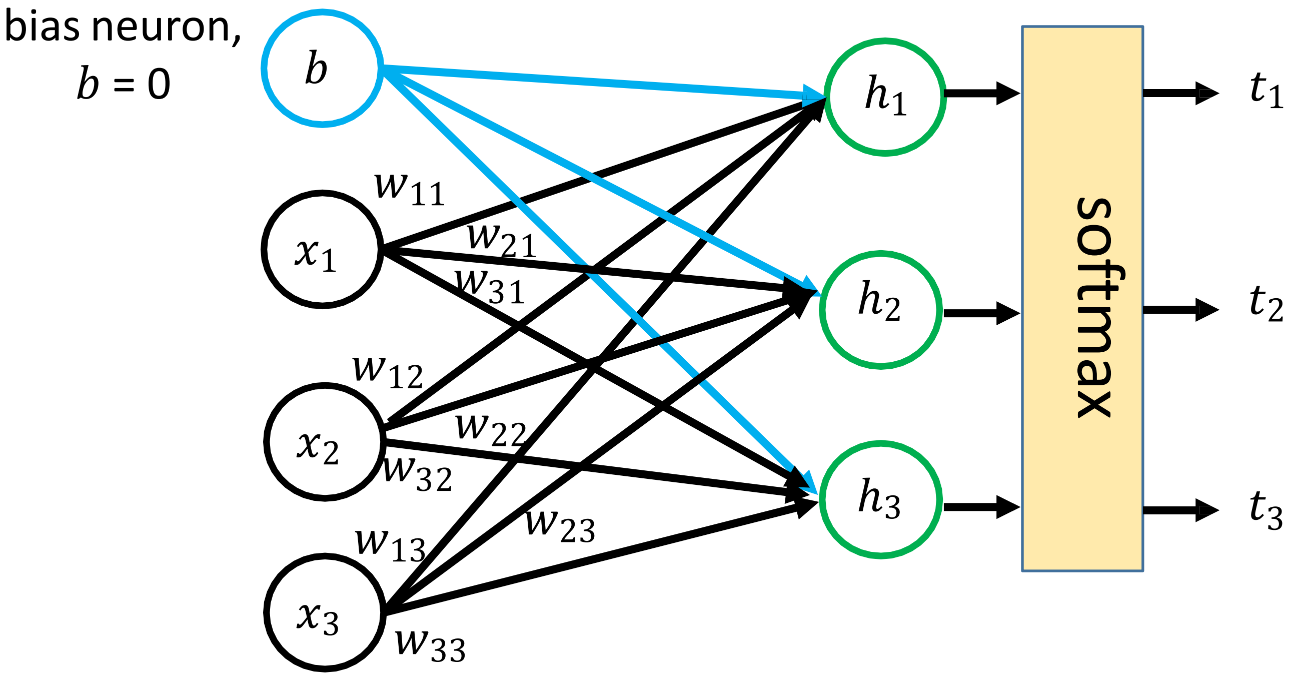
7 2 6 6 5 0 0

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



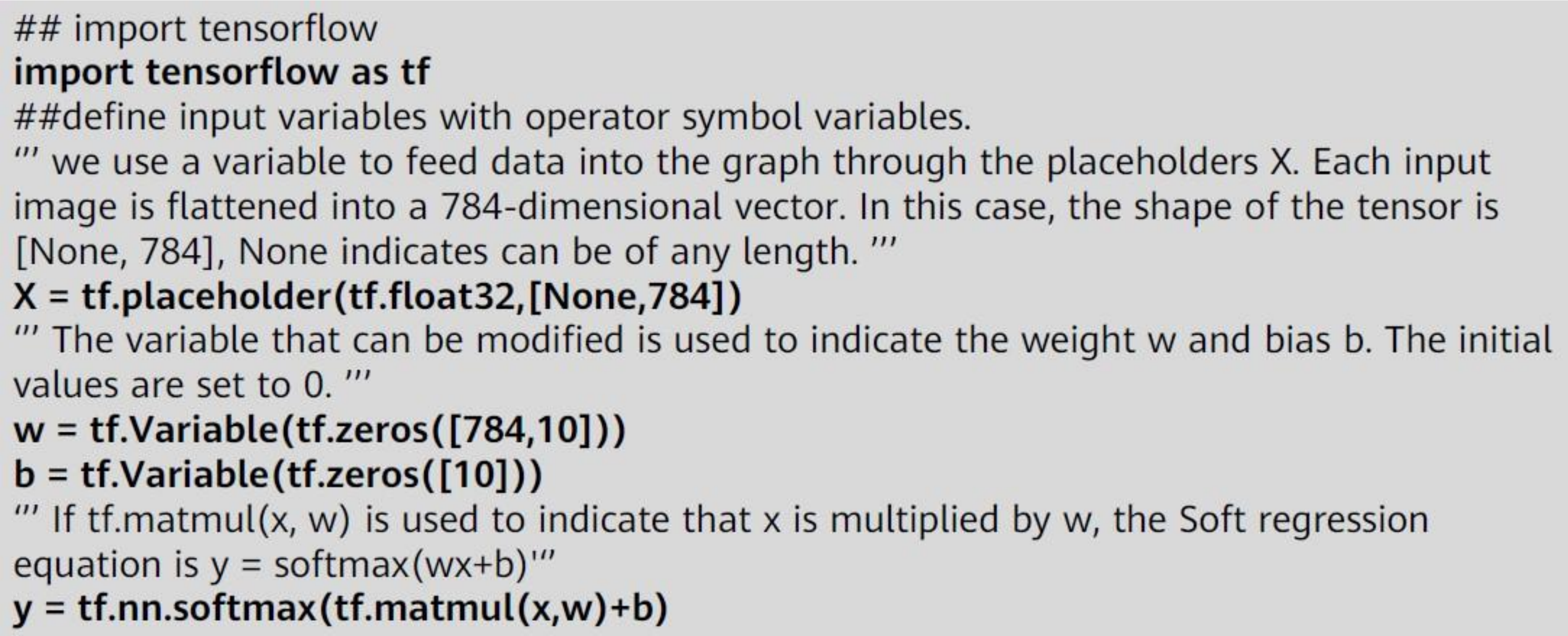
$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{bmatrix} . \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b \\ b \\ b \end{bmatrix}$$

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

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

Network structure definition

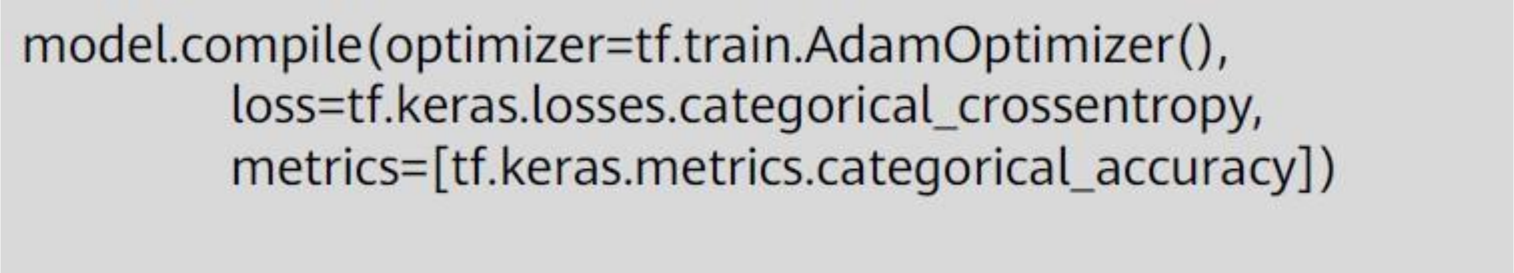
- TensorFlow-based softmax regression model



```
## 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

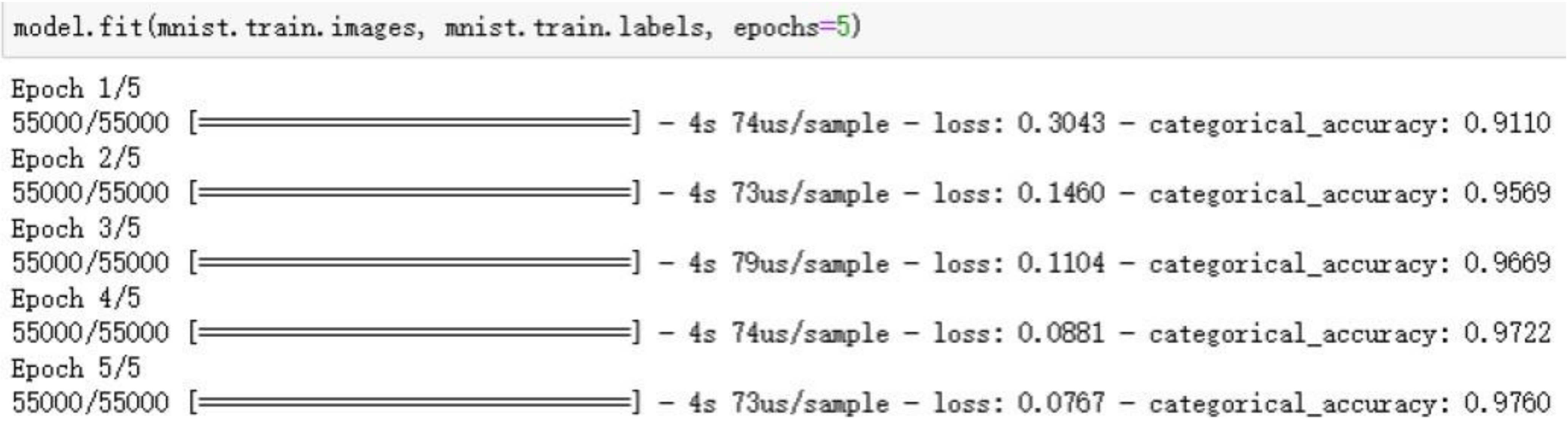
- Model compilation involves the following three parts:
  - Loss function: measures how accurate the output is
  - Optimizer: measures how the model is updated
  - Metrics: monitors the training to determine when to stop



```
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.

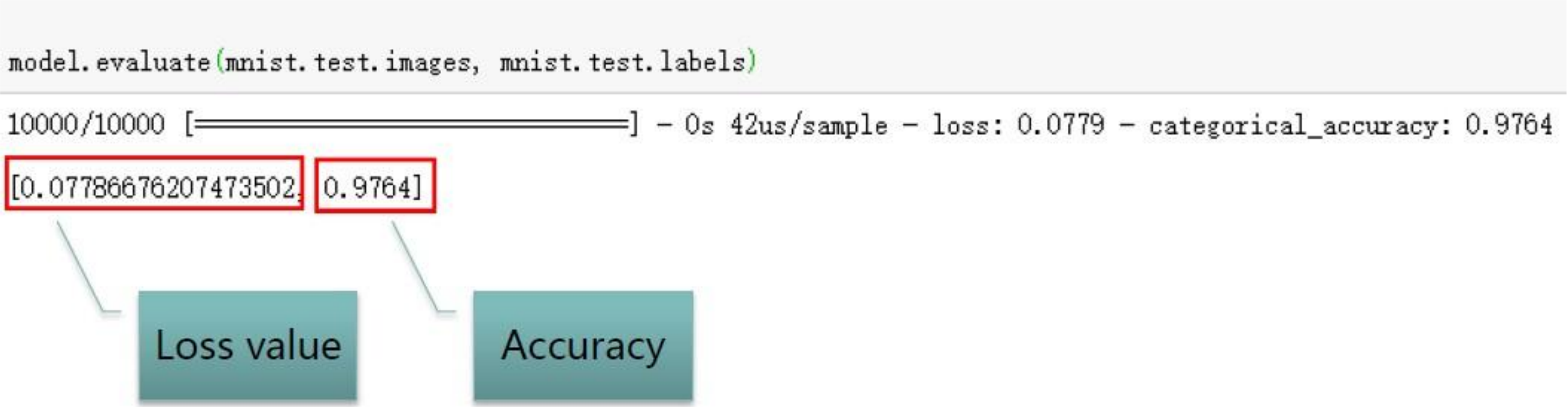


```
model.fit(mnist.train.images, mnist.train.labels, epochs=5)
```

```
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)
```

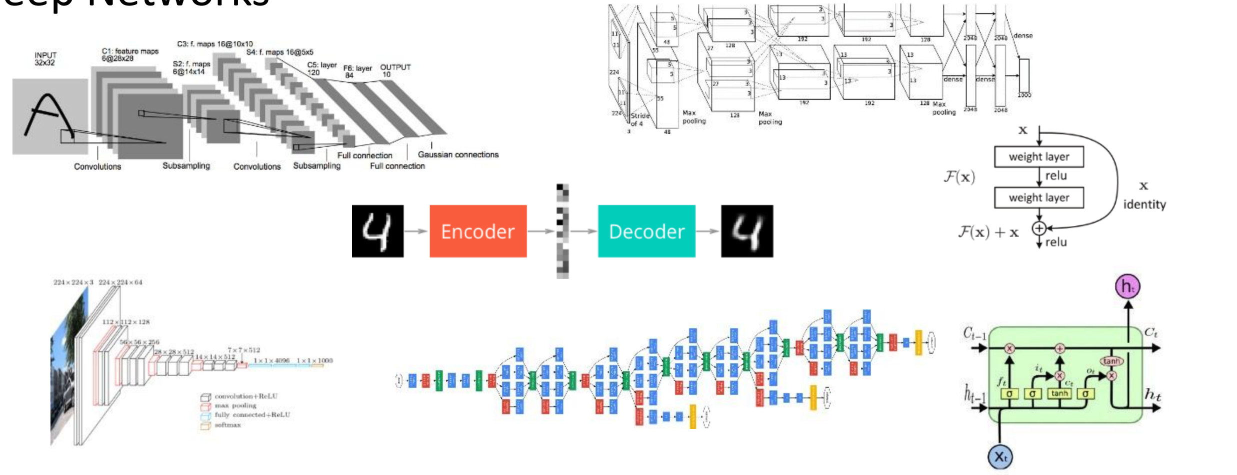
```
10000/10000 [==============================] - 0s 42us/sample - loss: 0.0779 - categorical_accuracy: 0.9764
[0.07786676207473502, 0.9764]
```

Loss value

Accuracy

There are so MANY things to know

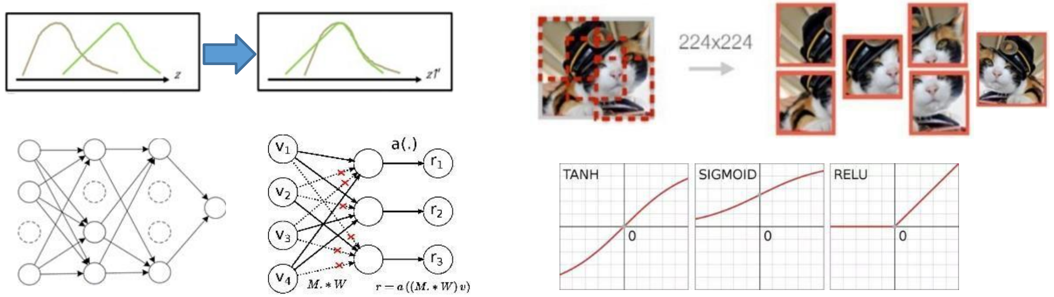
Deep Networks



Graphical Processing Units (GPUs)

● ● ●

Learning techniques



Deep Learning Libraries

TensorFlow

Keras

Caffe

Lasagne

Caffe2

theano

Chainer

PYTORCH

MatConvNet

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Topics

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

Application Areas of Machine Learning

- Computer Vision
- Natural Language Processing (NLP)
- Autonomous Systems & Robotics
- Generative AI & Creativity
- Predictive Analytics & Decision Making
- … …

Application Areas of Machine Learning

Computer Vision

- Image Recognition – Identifying objects, people, text, or scenes in images.
- Facial Recognition – Detecting and verifying faces in security, biometrics, and authentication.
- Object Detection – Identifying and locating multiple objects in an image or video.
- Medical Imaging – Detecting anomalies in MRIs, X-rays, and CT scans.
- Optical Character Recognition (OCR) – Extracting text from scanned documents/images.
- Autonomous Navigation – Assisting self-driving cars and robots in real-time scene understanding.

Application Areas of Machine Learning

Natural Language Processing (NLP)

- Speech Recognition – Converting spoken language into text.
- Machine Translation – Translating text across languages.
- Chatbots & Virtual Assistants – AI-powered conversation agents.
- Sentiment Analysis – Understanding emotions/opinions from text (used in reviews, social media).
- Text Summarization – Generating concise summaries of long articles.
- Question Answering (QA) – Extracting precise answers from a text or knowledge base.
- Text Generation – AI-generated articles, summaries, and creative writing.

Application Areas of Machine Learning

Autonomous Systems & Robotics

- Self-driving Vehicles – Cars, trucks, and drones using AI for navigation.
- Industrial Robots – AI-driven robotic arms in manufacturing.
- Drones – AI-powered navigation and mapping for drones.

Application Areas of Machine Learning

Generative AI & Creativity

- AI-Generated Art & Images – Creating new images using AI.
- Text-to-Speech (TTS) & Speech Synthesis – Generating human-like voices.
- Music & Video Generation – AI-generated music, videos, and animations.
- Code Generation & Auto-completion – AI-assisted programming.

Application Areas of Machine Learning

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Predictive Analytics & Decision Making

- Anomaly Detection – Identifying fraud, cybersecurity threats, and manufacturing defects.
- Risk Assessment – Evaluating risks in credit scoring, insurance, and finance.
- Predictive Maintenance – Forecasting equipment failures in factories and infrastructure.
- Market Forecasting – Predicting stock trends, sales, and economic fluctuations.

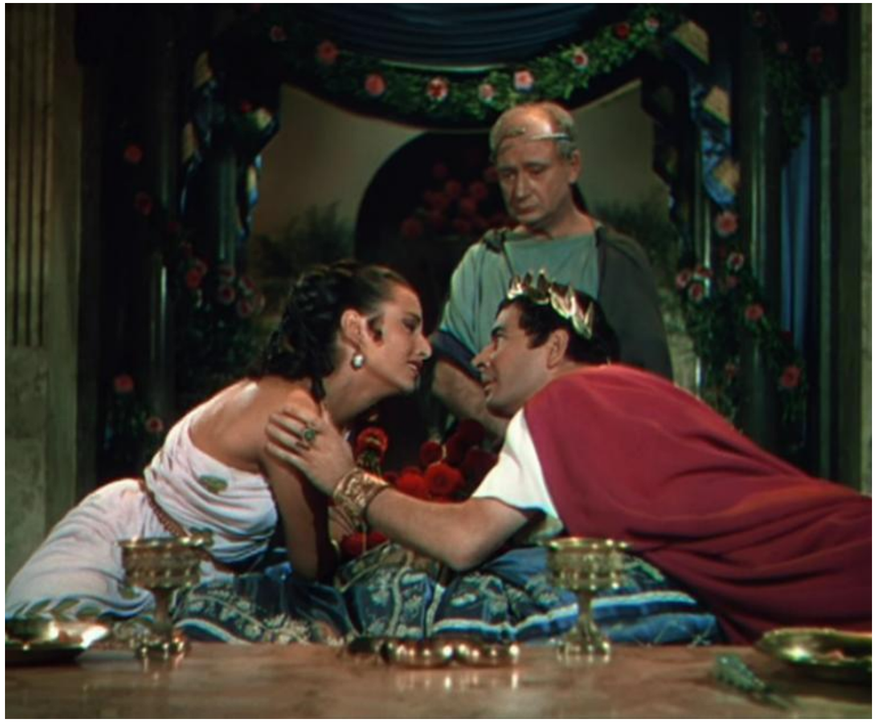
What is Computer Vision?

- How machine perceive visual information

How many people are there?

What are they doing?

What are their emotion?



Where is this happening?

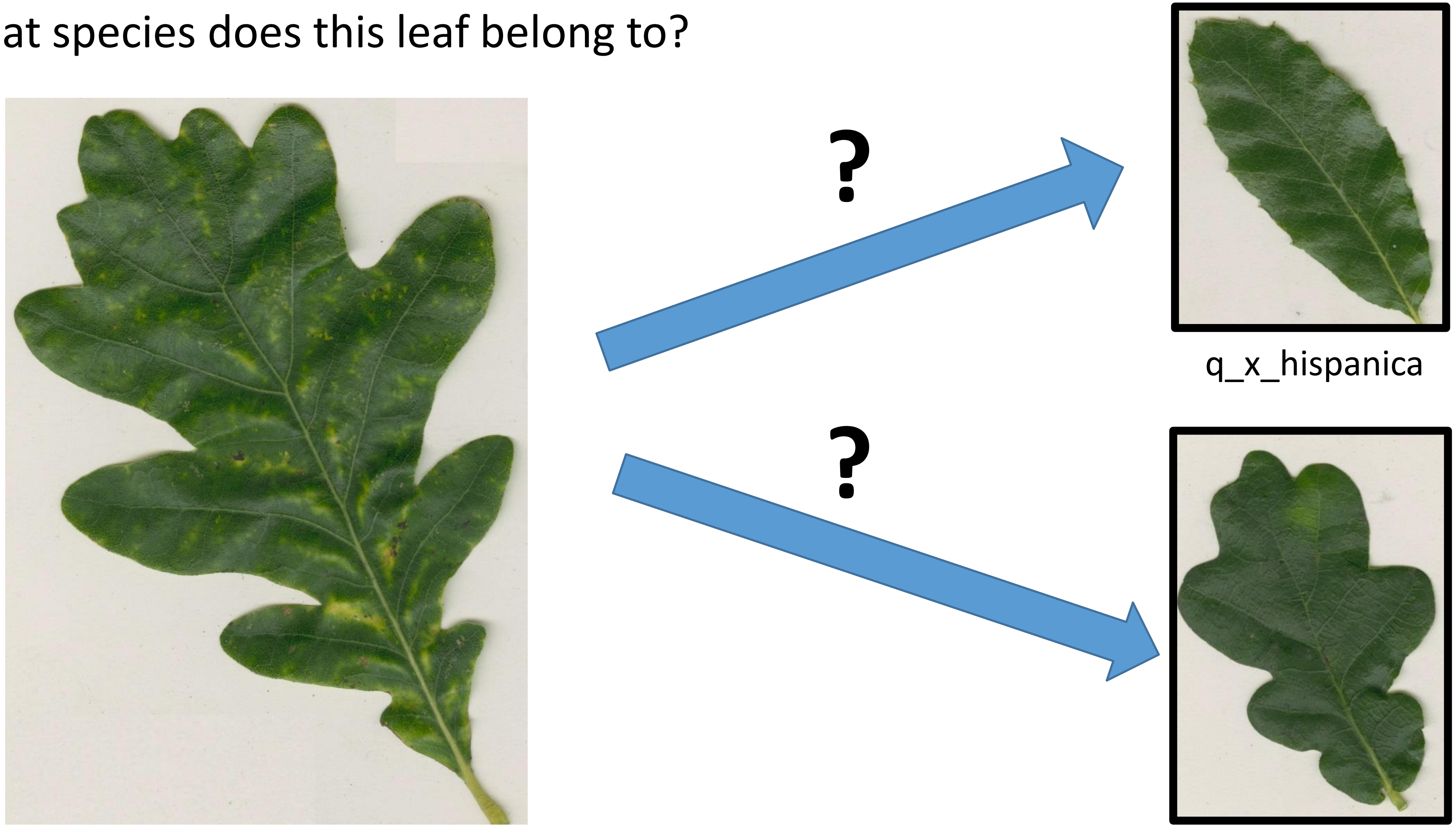
What are the relation between subject?

What are the object present?

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

Human vision

What species does this leaf belong to?



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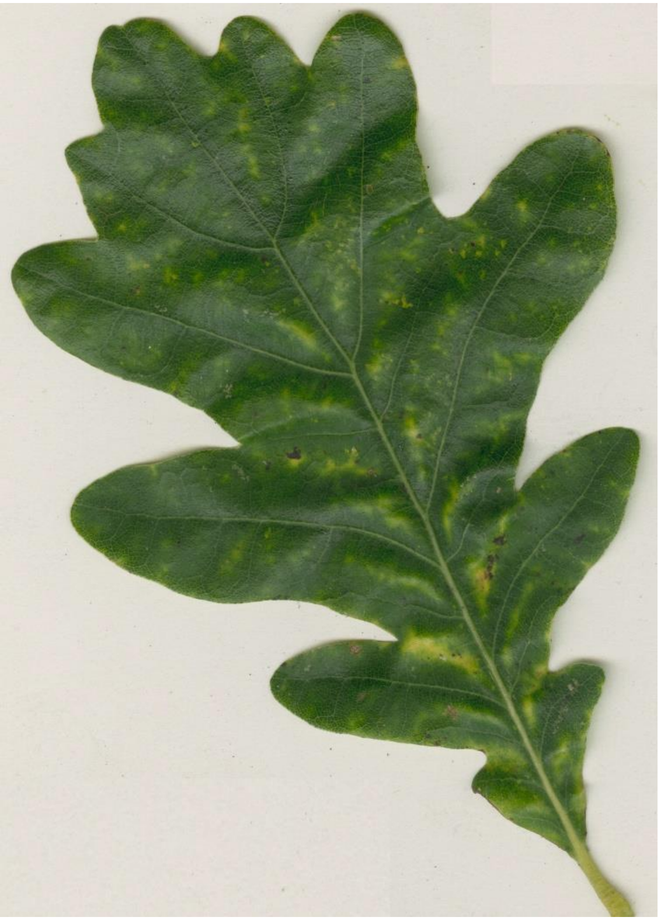
q_x_hispanica

qacutissima

Human vision

What species does this leaf belong to?



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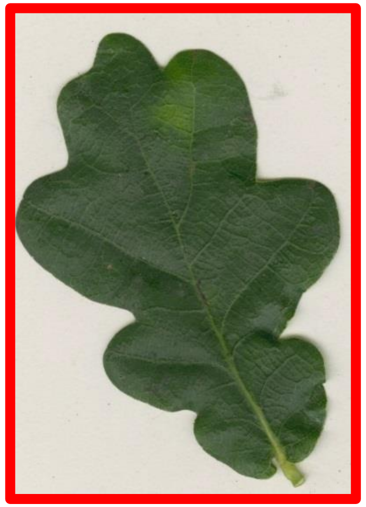
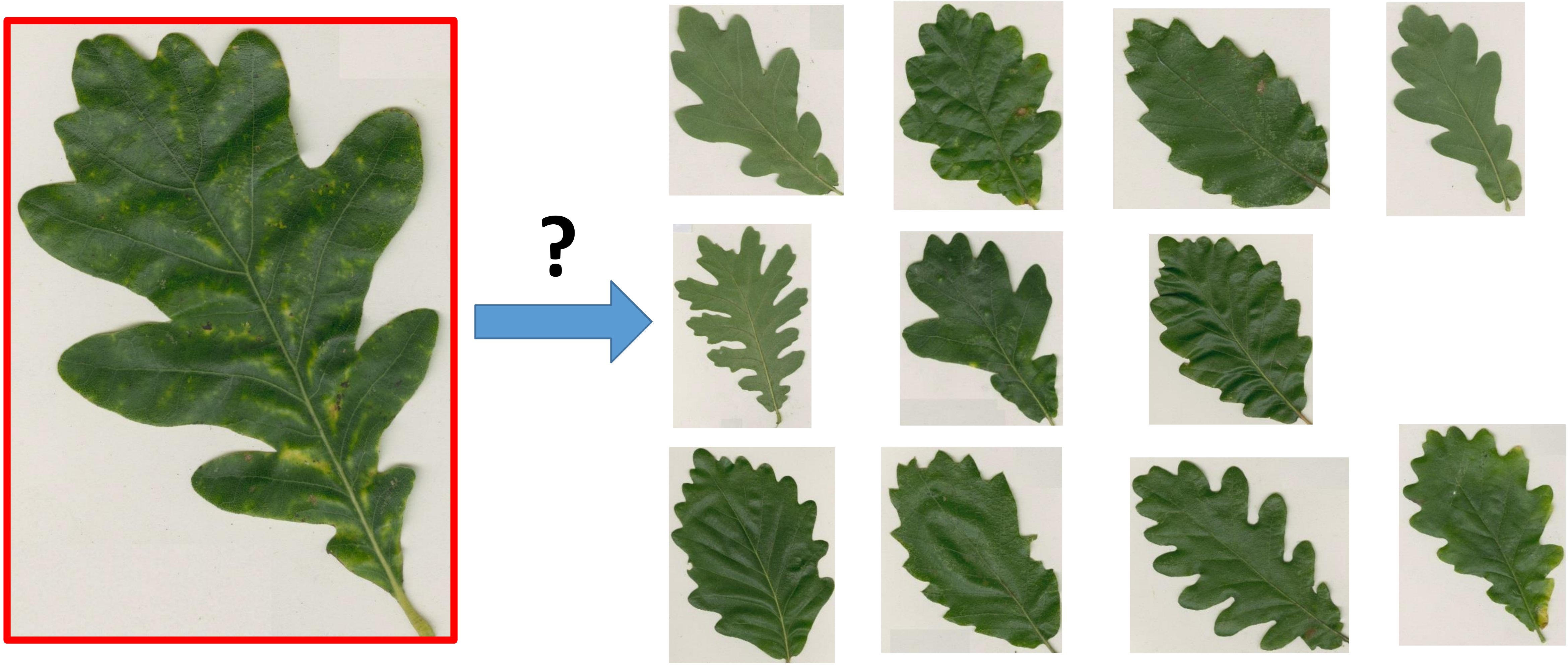


qacutissima

Bottlenecks

What species does this leaf belong to?



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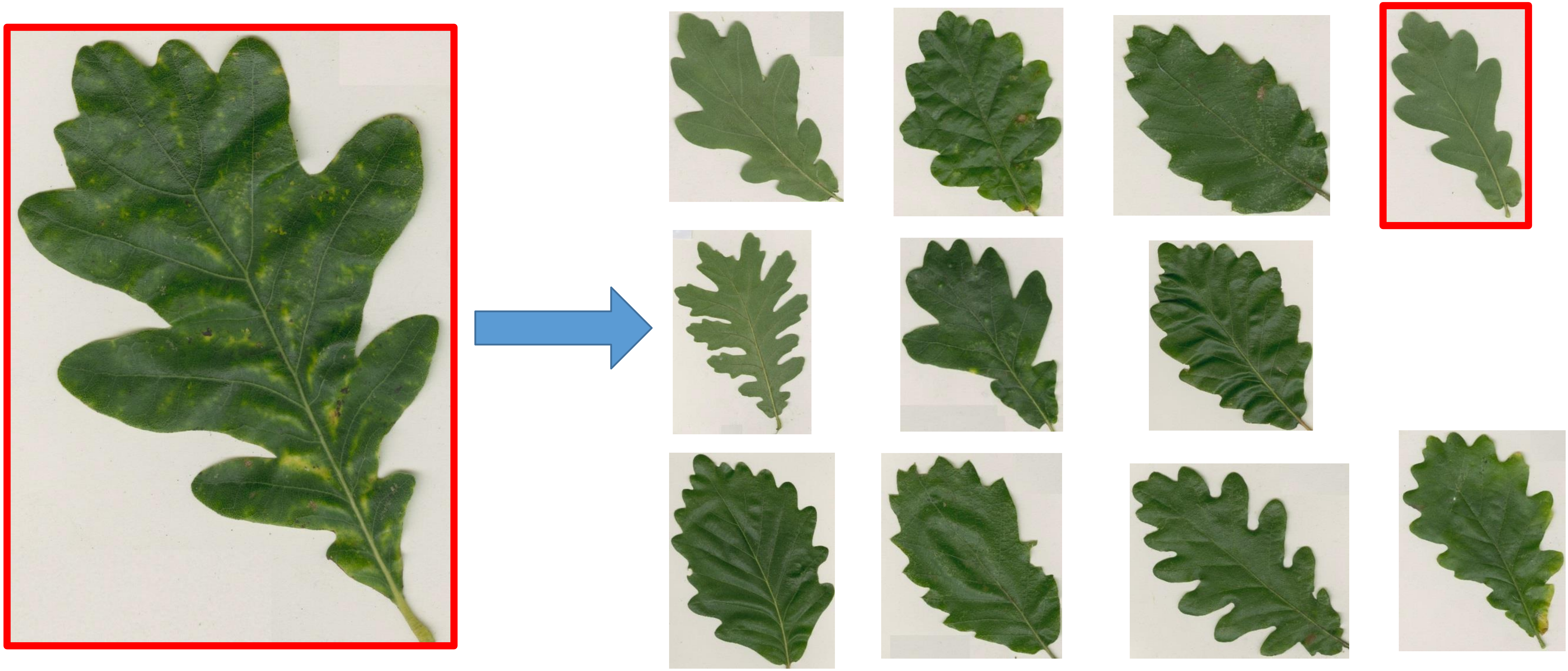

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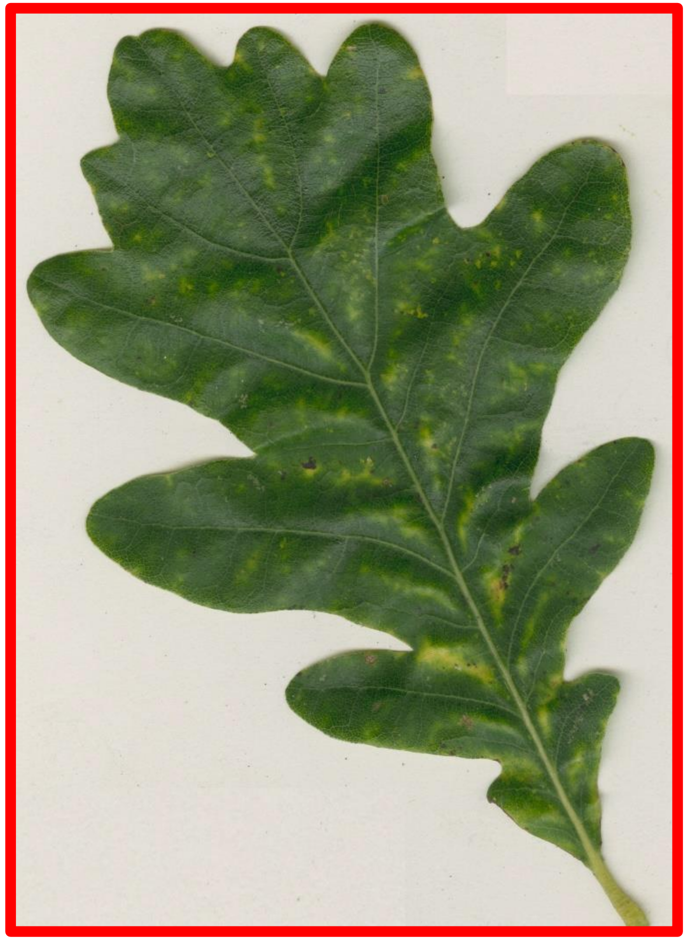
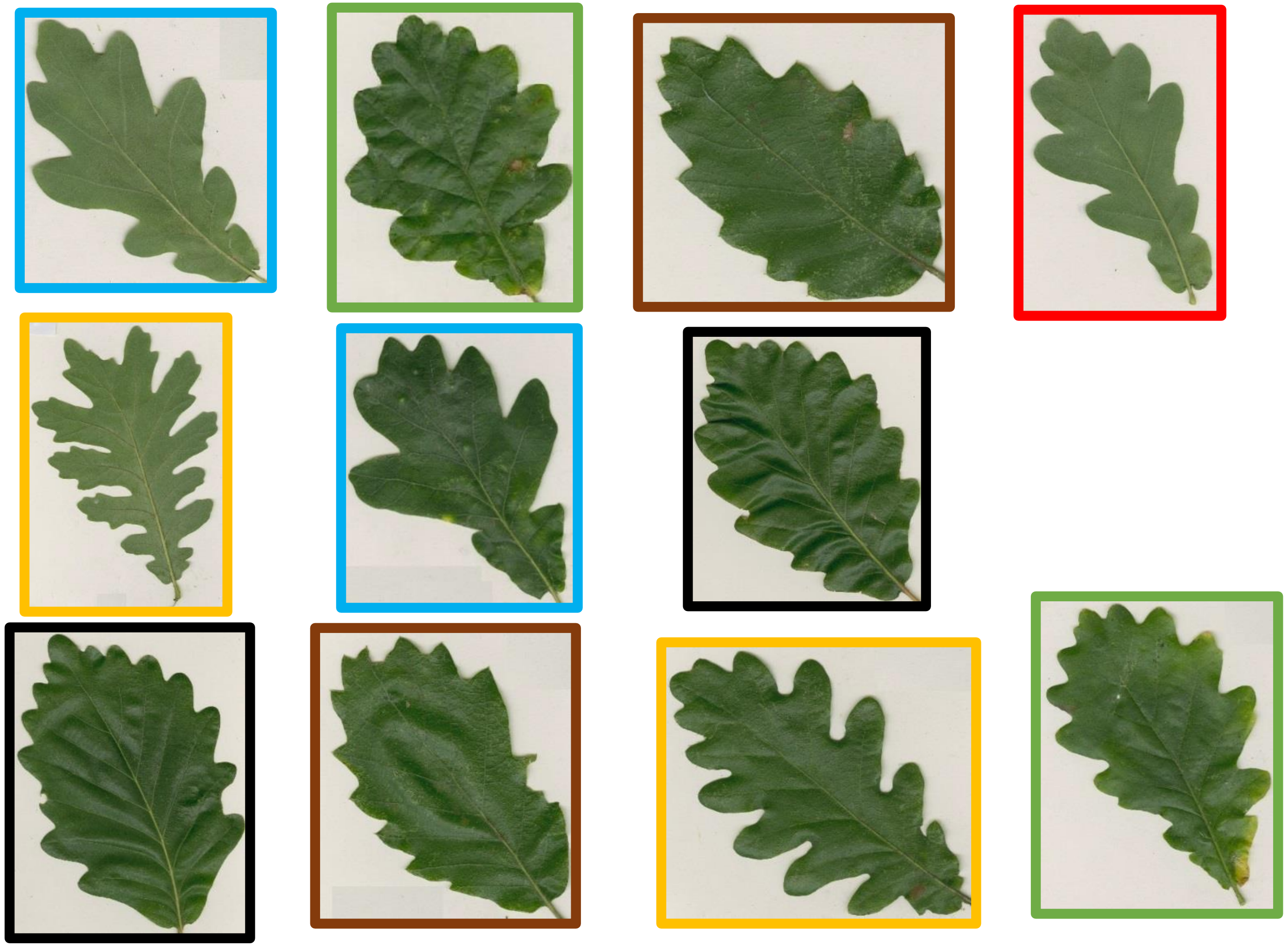




Computer Vision challenges

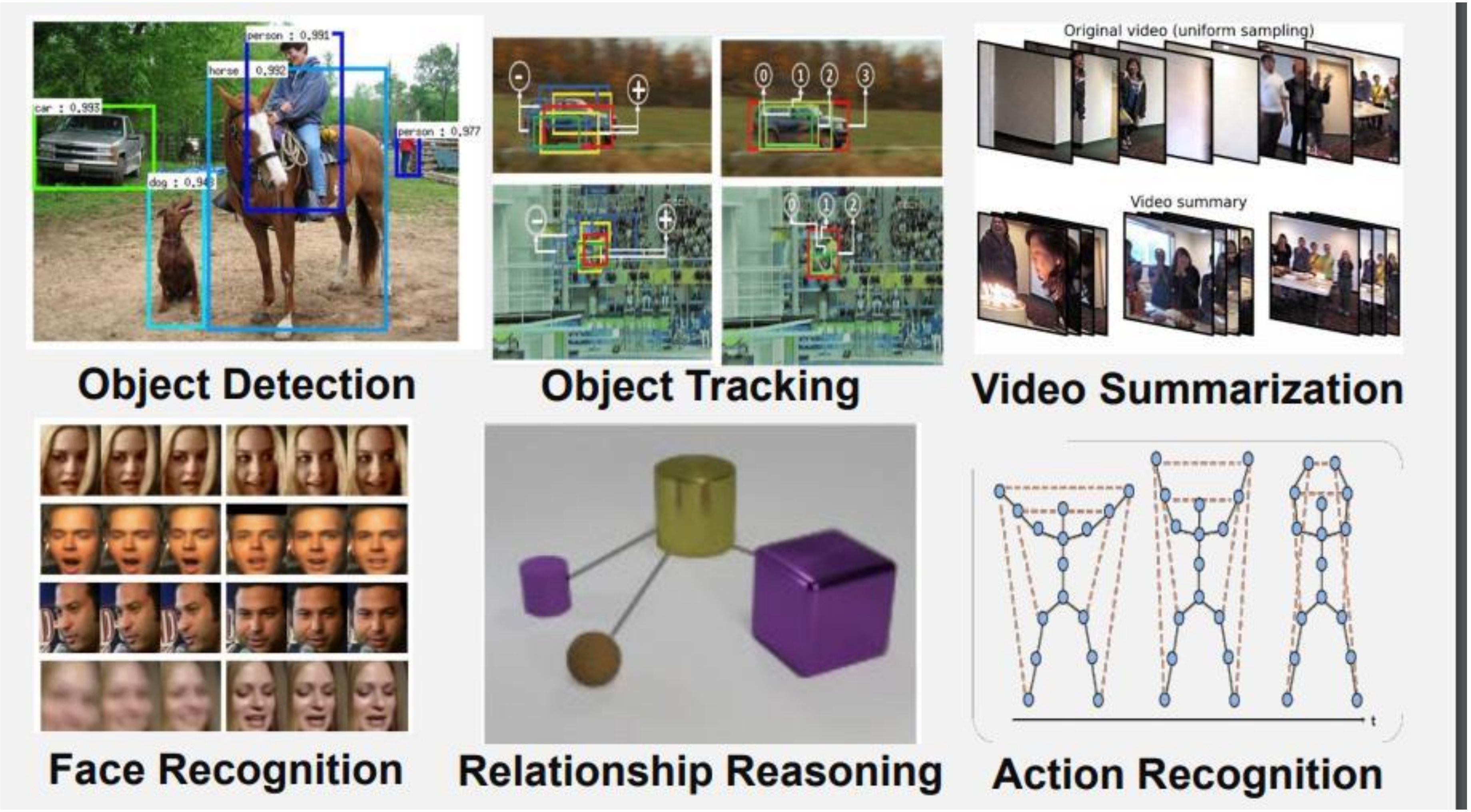
View points

Illumination

Scale

Occlusion

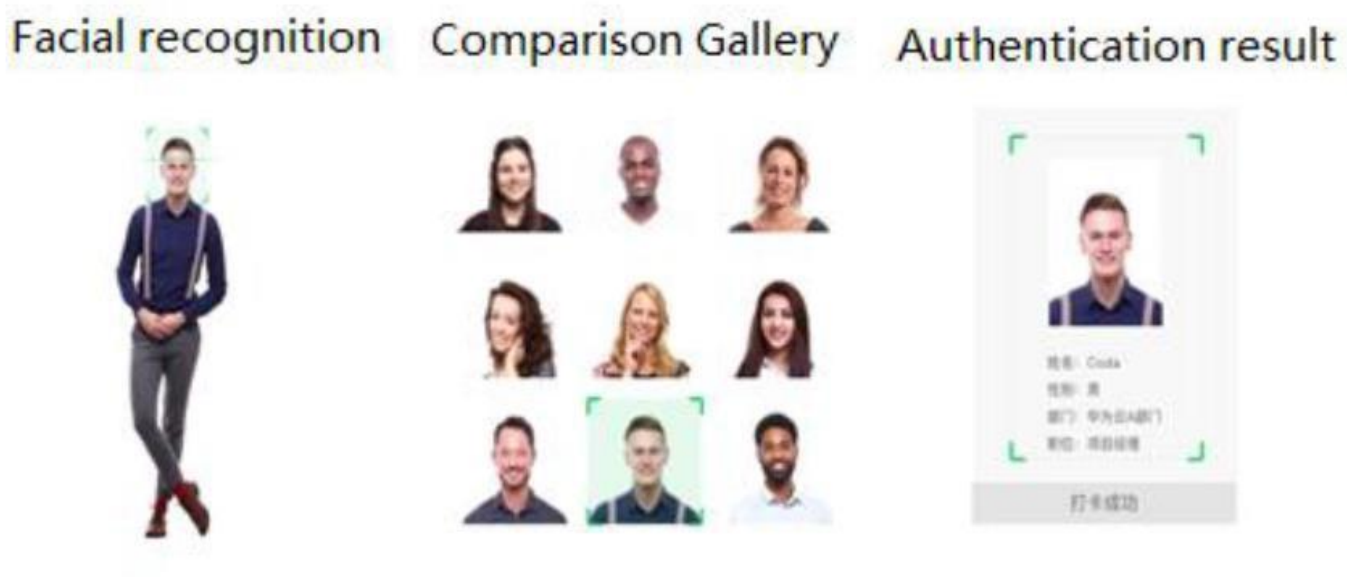
Computer Vision major areas



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

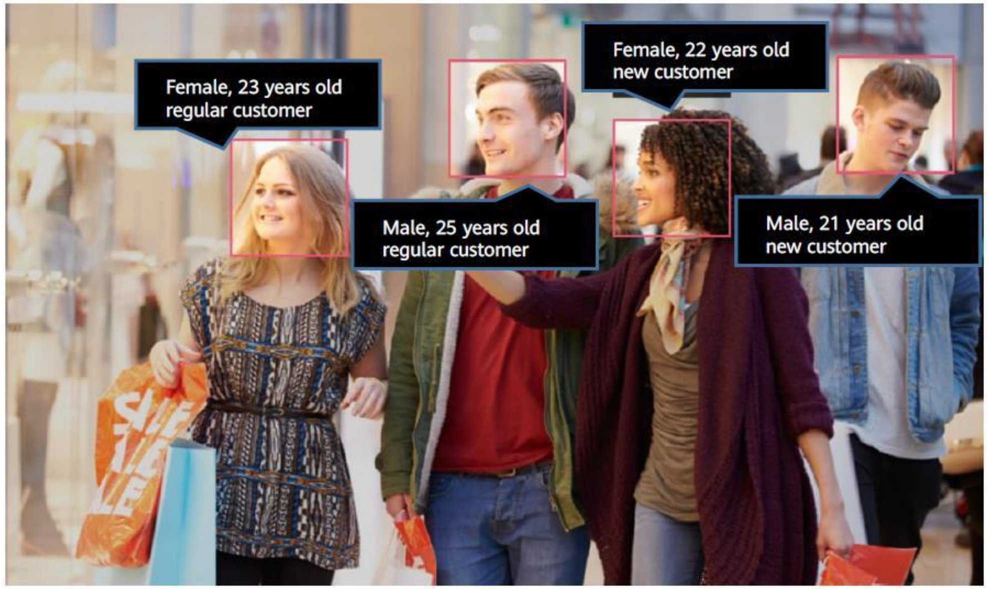
Computer Vision application

Electronics attendance



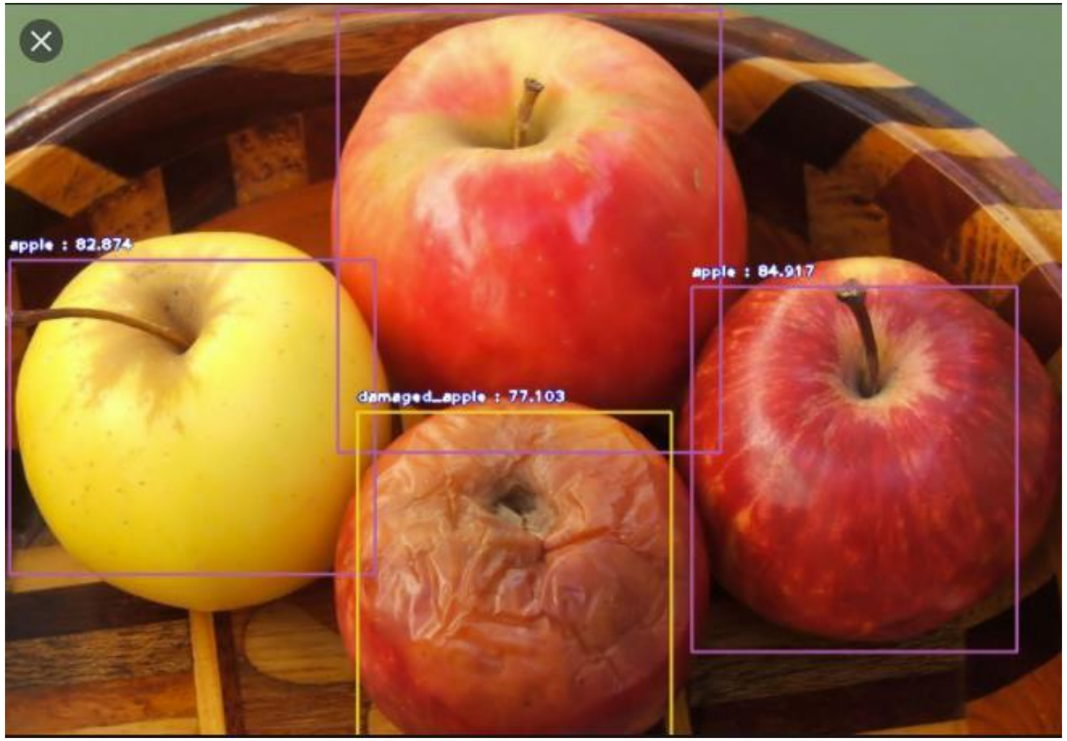
姓名: Coda
性别: 男
部门: 华为云AI部门
职位: 项目经理

customer analysis

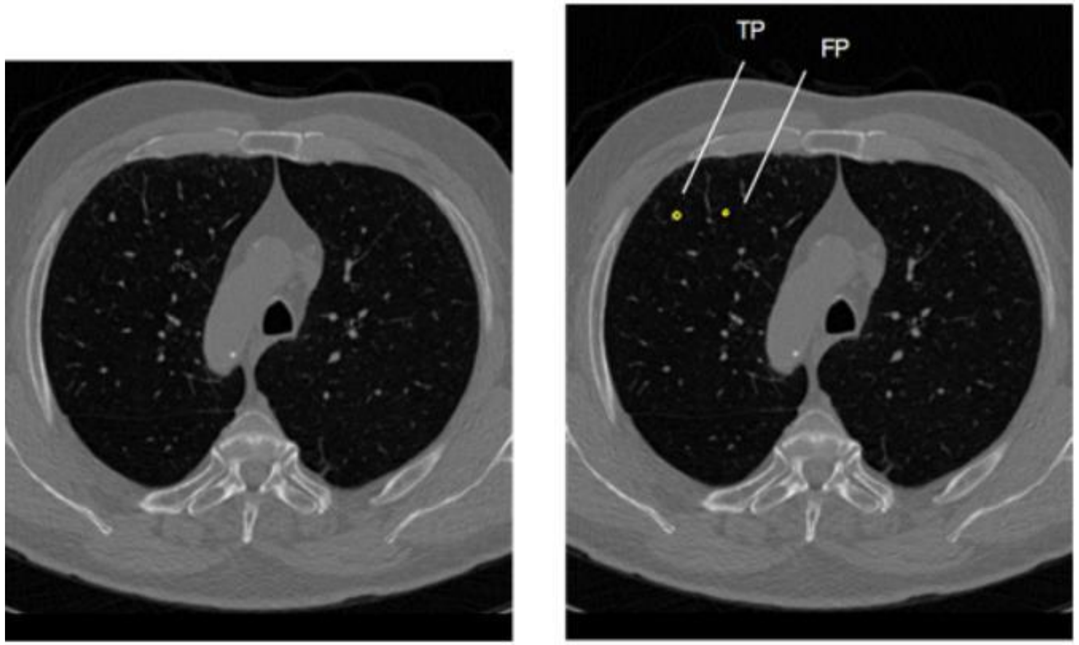


Computer Vision application

Detecting defects in Fruits

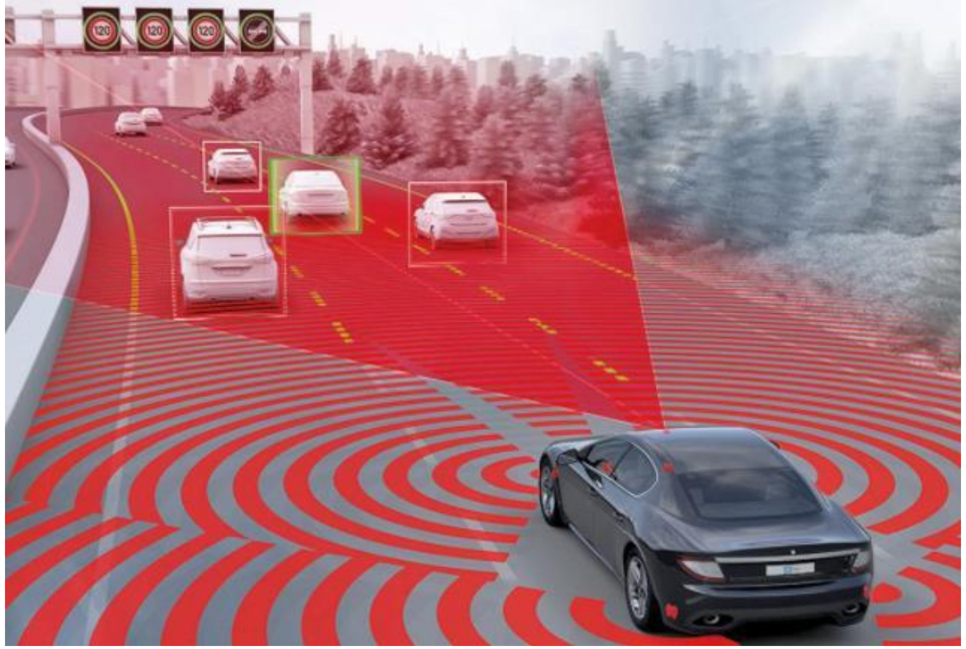


Early detection of lung cancer

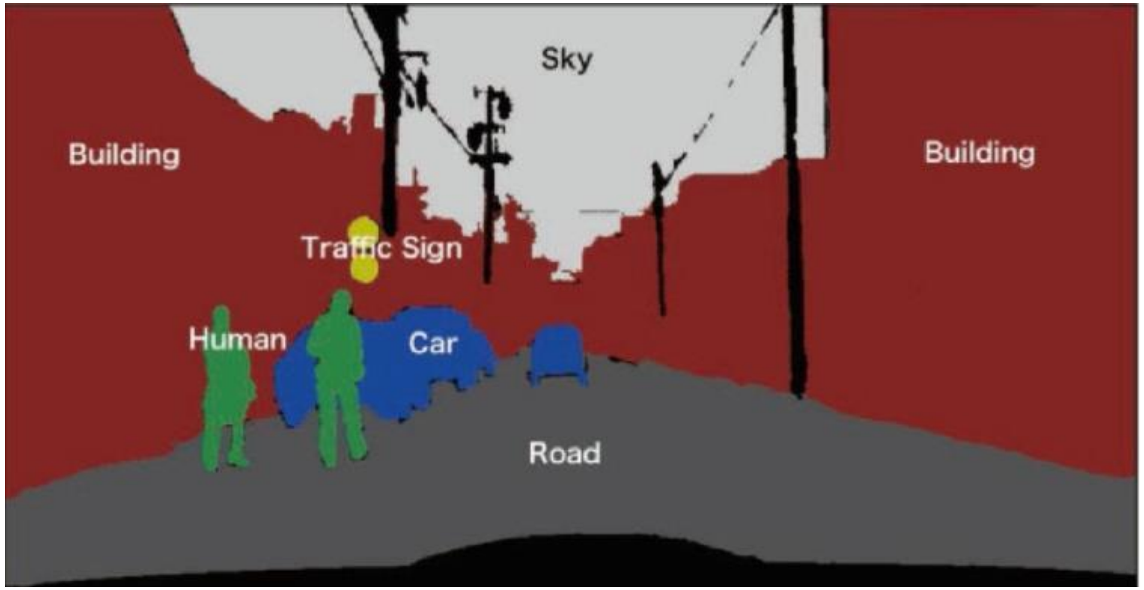


Computer Vision application

Autonomous driving

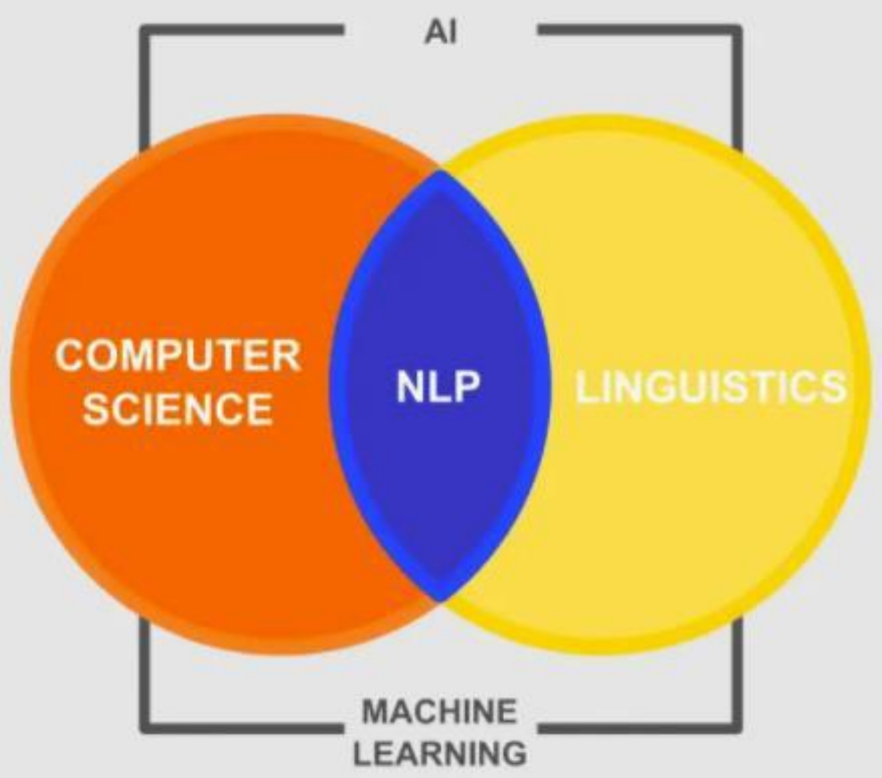


Scene parsing



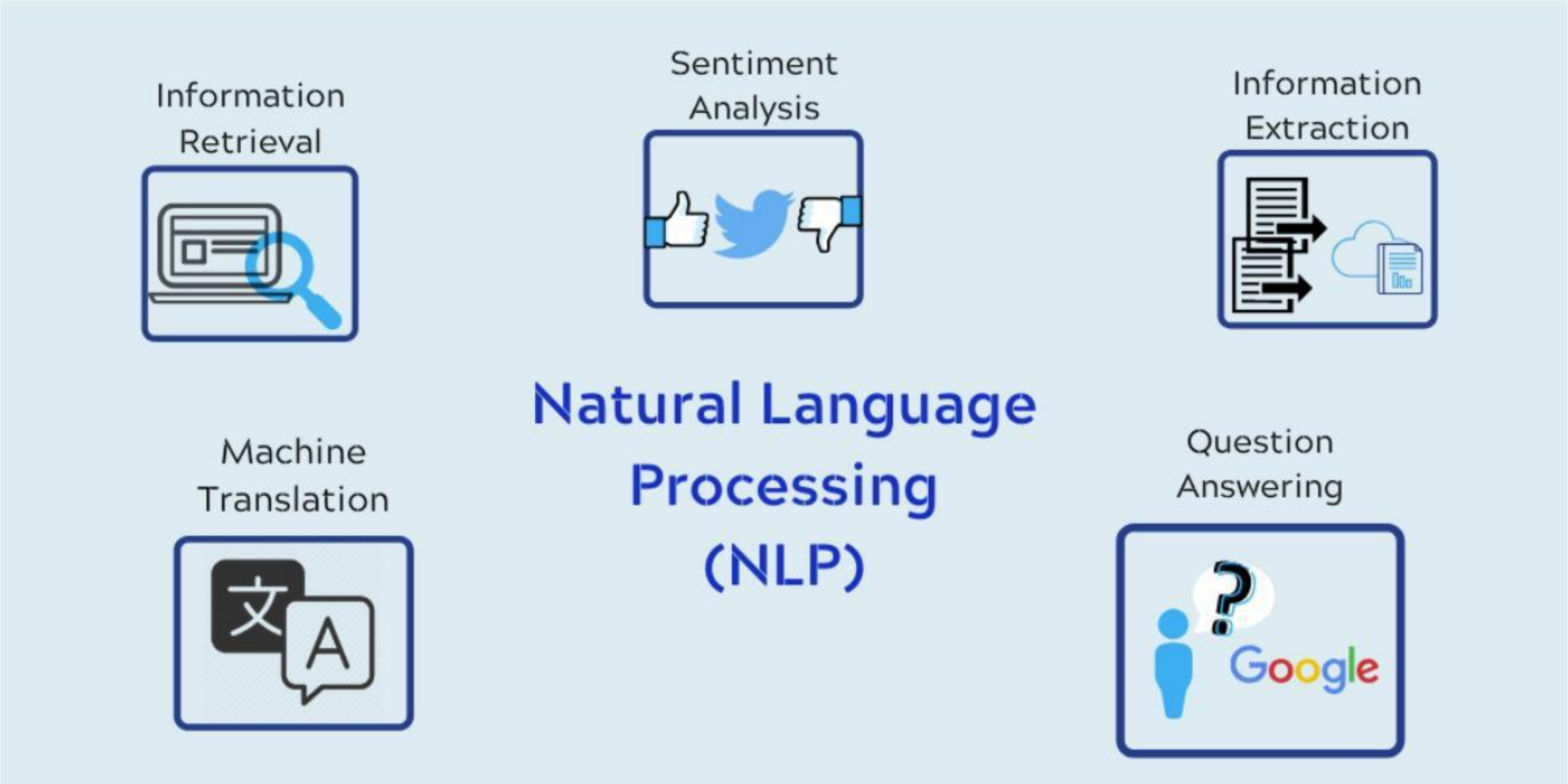
Natural Language Processing

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



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

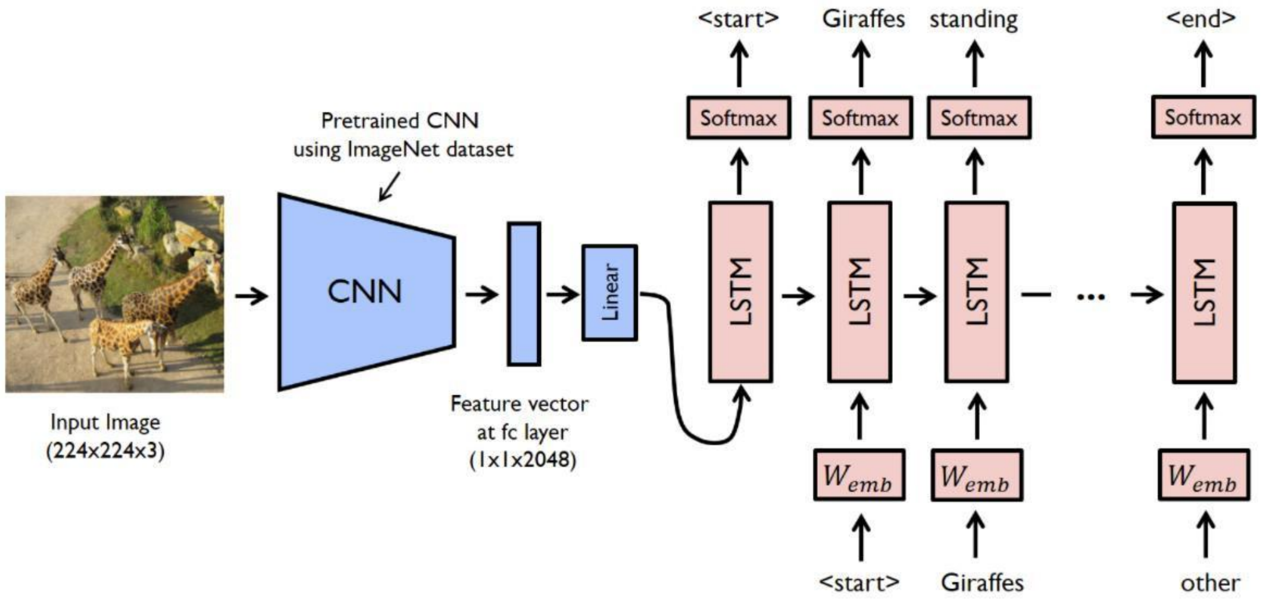
NLP application

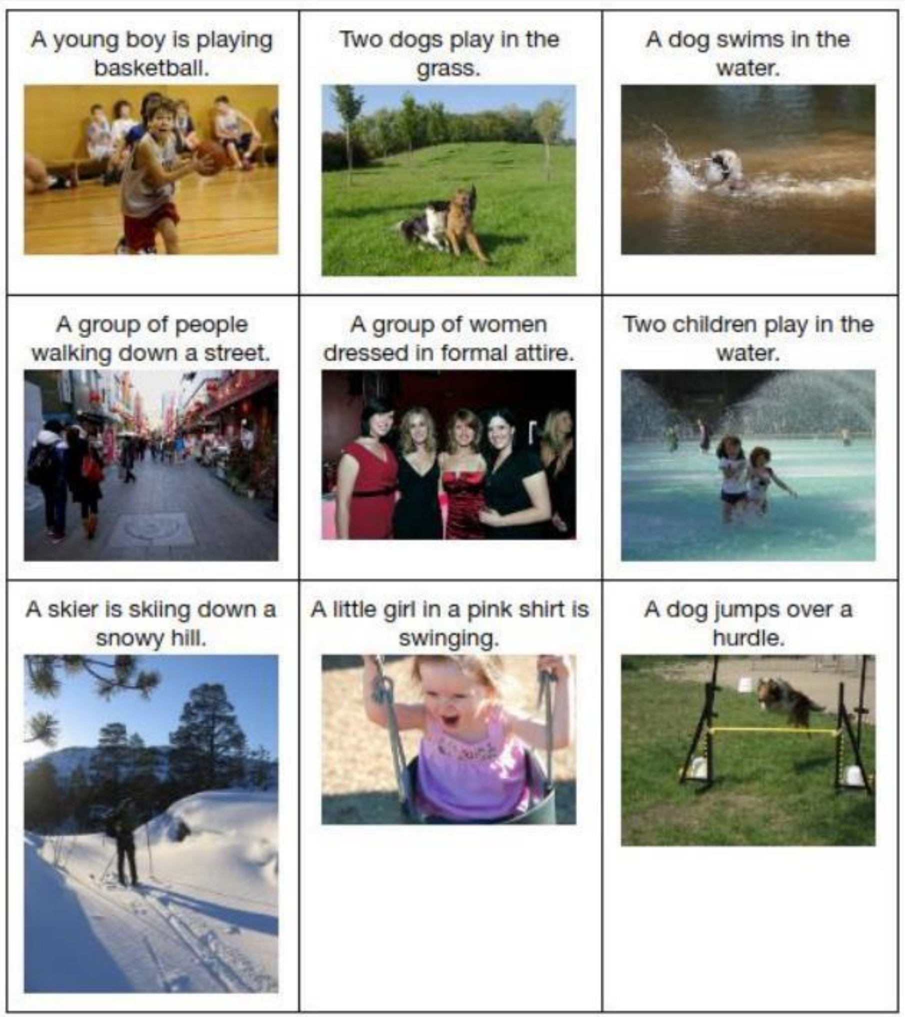


https://www.cybiant.com/resources/natural-language-processing/

NLP and Computer Vision Integrated

Image captioning





A young boy is playing basketball.

Two dogs play in the grass.

A dog swims in the water.

A group of people walking down a street.

A group of women dressed in formal attire.

Two children play in the water.

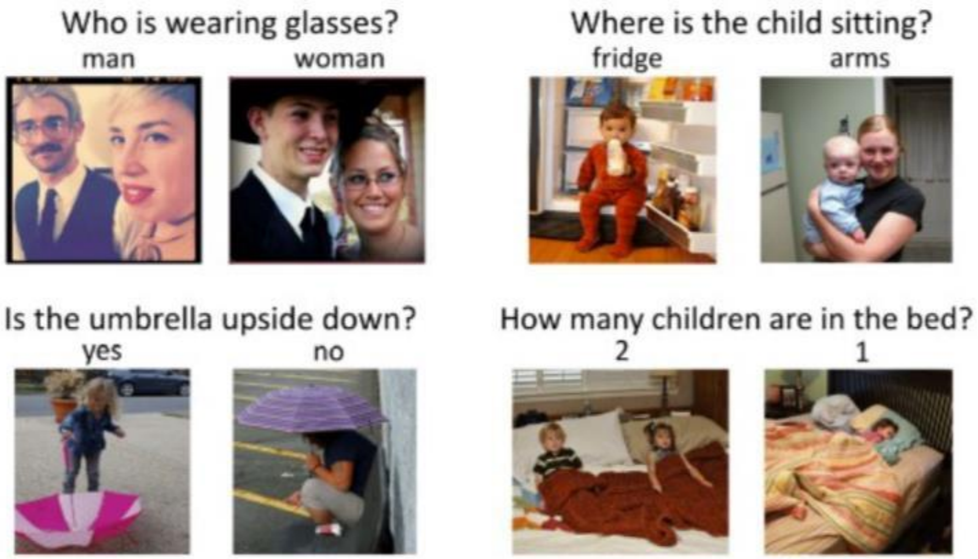
A skier is skiing down a snowy hill.

A little girl in a pink shirt is swinging.

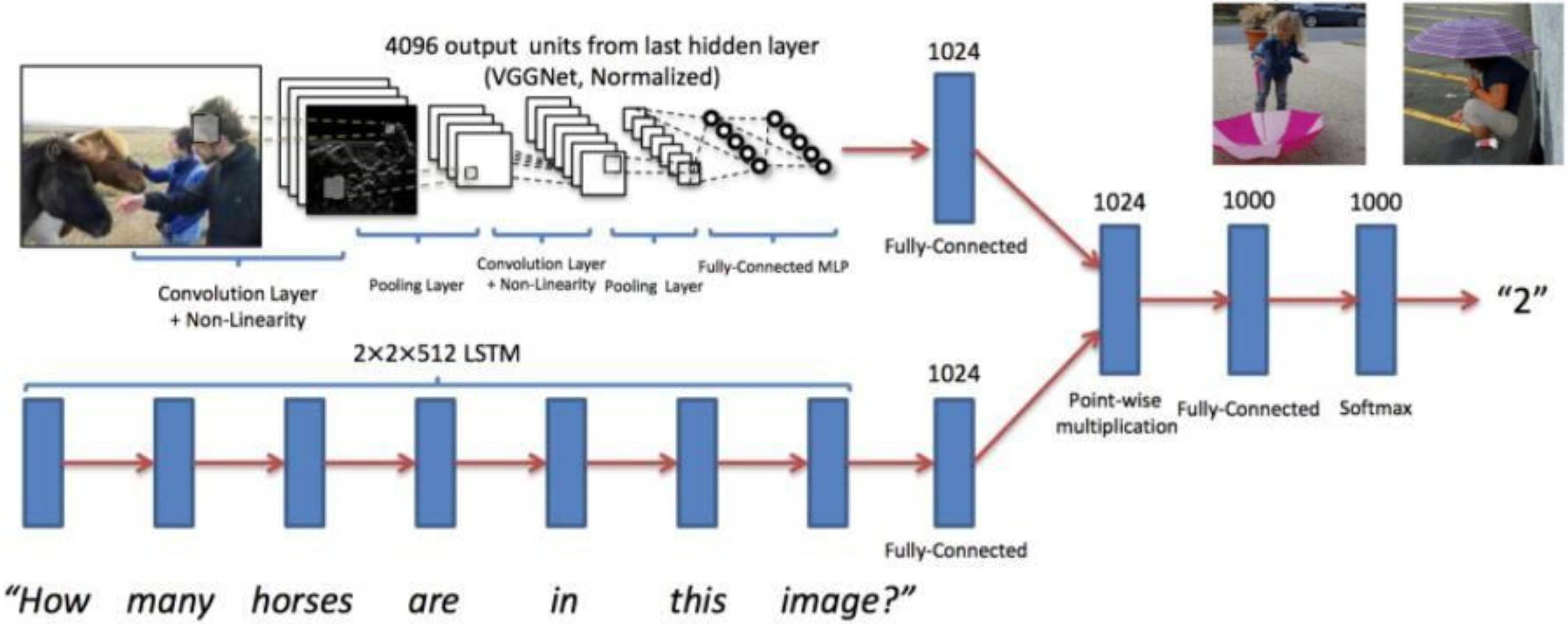
A dog jumps over a hurdle.

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

NLP and Computer Vision Integrated


Who is wearing glasses?
man
woman
Where is the child sitting?
fridge
arms
Is the umbrella upside down?
yes
no
How many children are in the bed?
2
1

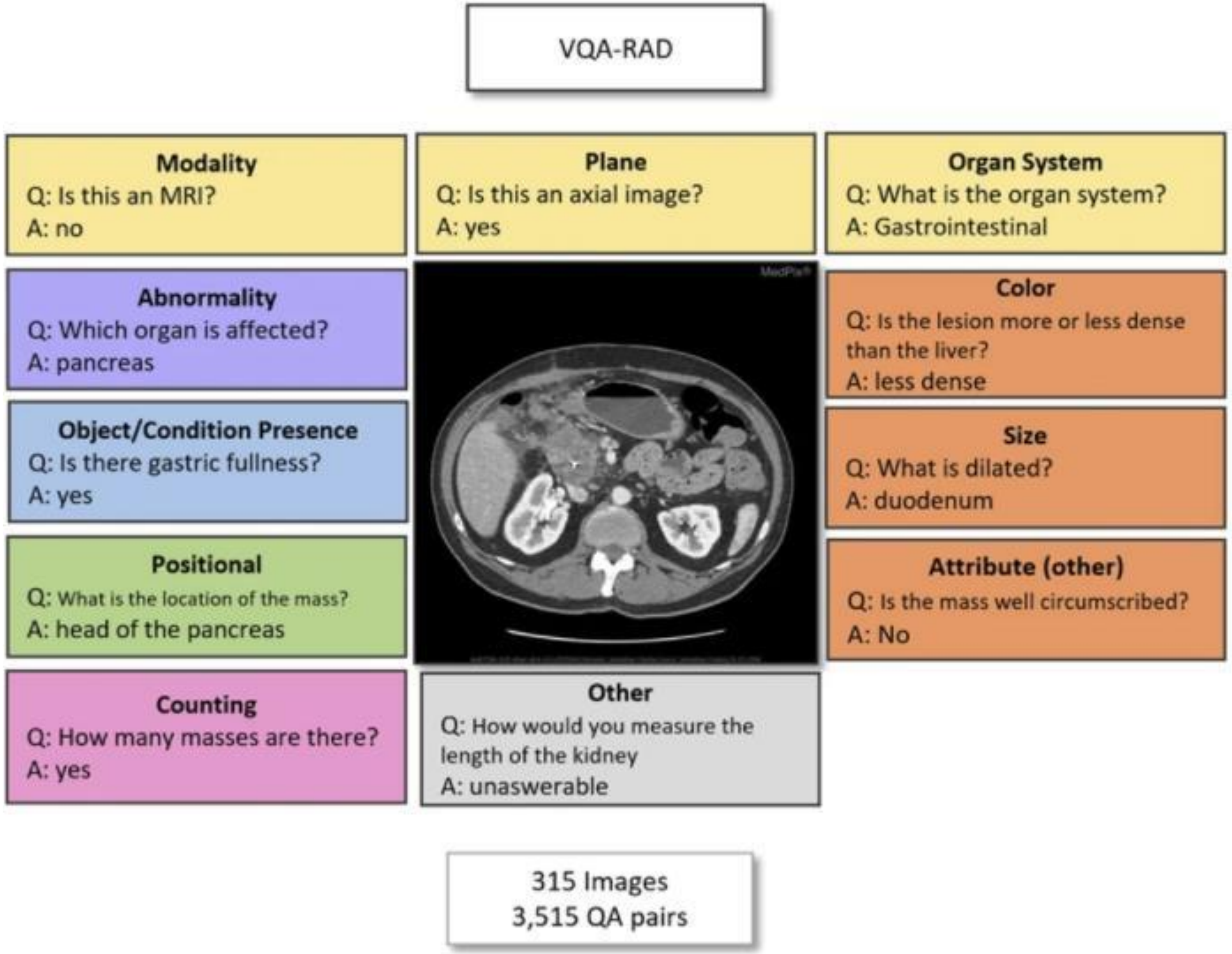
Visual question answering



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.



VQA-RAD

Modality
Q: Is this an MRI?
A: no

Plane
Q: Is this an axial image?
A: yes

Organ System
Q: What is the organ system?
A: Gastrointestinal

Abnormality
Q: Which organ is affected?
A: pancreas

Color
Q: Is the lesion more or less dense than the liver?
A: less dense

Object/Condition Presence
Q: Is there gastric fullness?
A: yes

Size
Q: What is dilated?
A: duodenum

Positional
Q: What is the location of the mass?
A: head of the pancreas

Attribute (other)
Q: Is the mass well circumscribed?
A: No

Counting
Q: How many masses are there?
A: yes

Other
Q: How would you measure the length of the kidney
A: unaswerable

315 Images
3,515 QA pairs

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

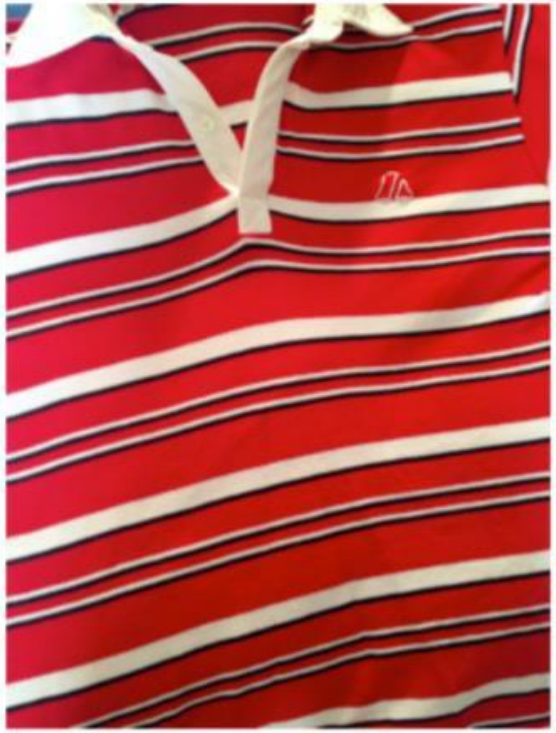
Q: Is this air conditioner on fan, dehumidifier, or air conditioning?

A: air conditioning

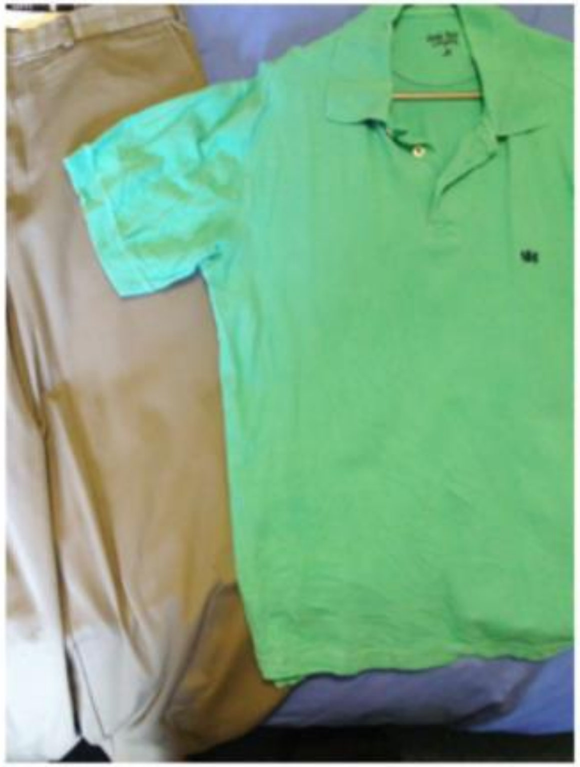
Gurari, D., Li, Q., Lin, C., Zhao, Y., Guo, A., Stangl, A. and Bigham, J.P., 2019. VizWiz-Priv: a dataset for recognizing the presence and purpose of private visual information in images taken by blind people. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 939-948).

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.

Endless Possibilities with AI

There are endless possibilities with AI—let your creativity and imagination guide you. Explore new ideas, push boundaries, and innovate to create something amazing!

Next lecture

- Linear regression