CS1138

Machine Learning

Lecture : Introduction, Motivation, and Applications

Arpan Gupta

What do you mean by “Learning”?

- Learning in Humans (brain)
  - knowledge acquired through study, **experience**, or being taught.

- Learning in Computers ?
  - Learning patterns

AI vs ML

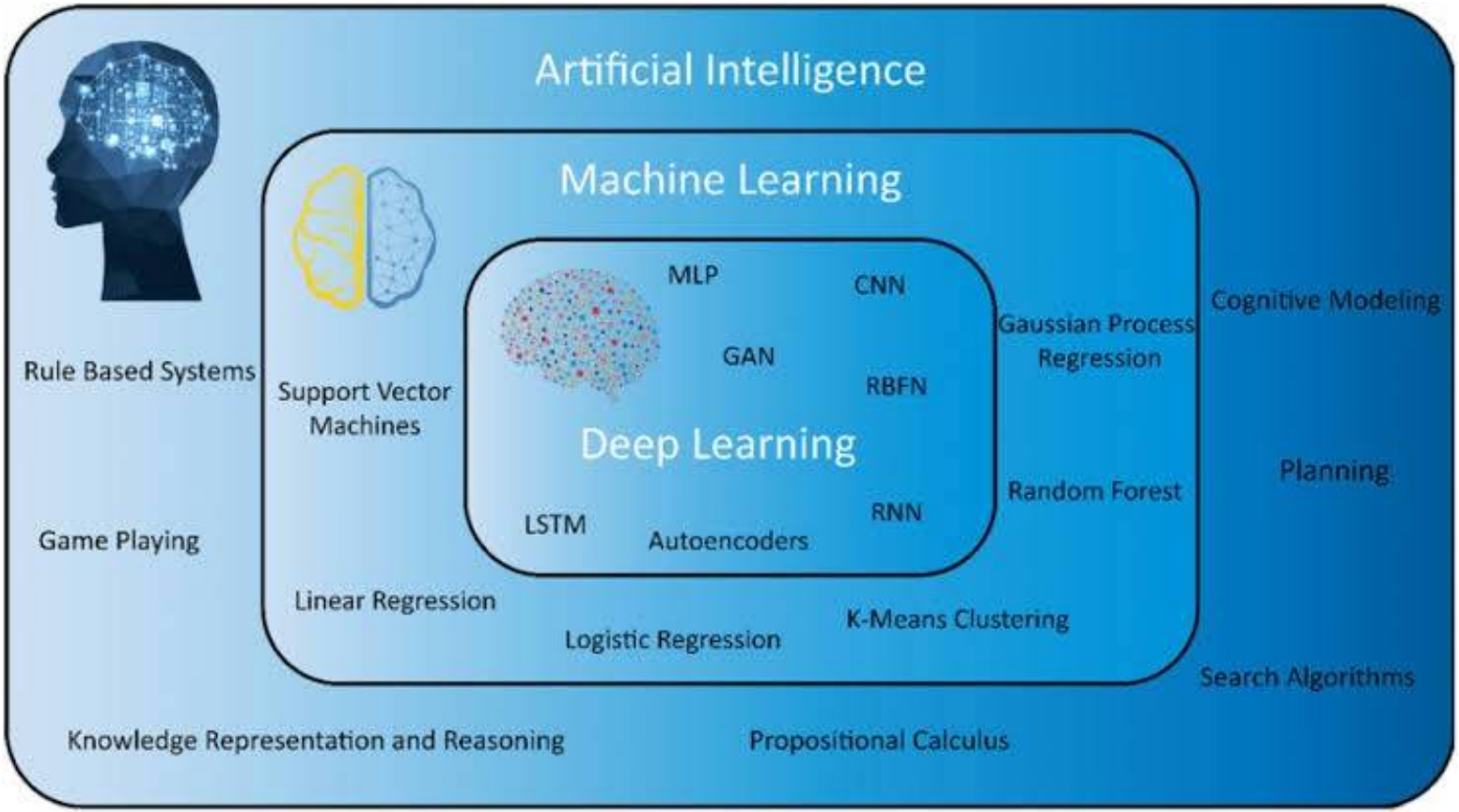
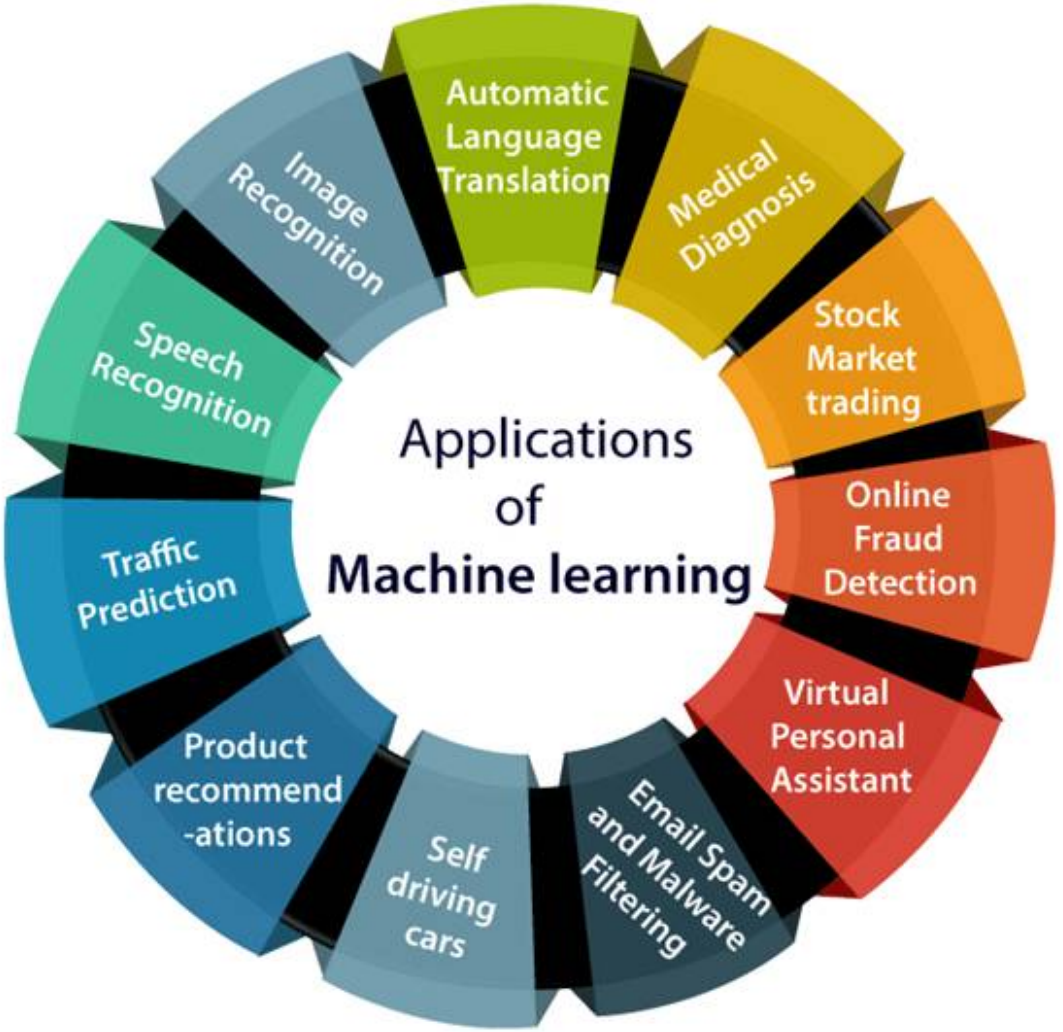


Image Credit: ResearchGate



https://www.javatpoint.com/applications-of-machine-learning

Applications

- DB Mining: Large datasets from growth of automation/web. Eg. Web click data, medical records, biology, engineering.
- AppIns. Can’t program by hand.
  - Eg. Autonomous helicopter, handwriting recognition, most of NLP, Computer Vision.
- Self-customizing programs.
  - Eg. Amazon, Netflix product recommendations.

Applications: In healthcare

- Detection and Prediction in medical imaging
  - Tumour detection
    - Cancer prediction
  - In MRI / CT images
  - Mortality prediction using ICU data.
- Diagnosis
  - Given the symptoms, predict the disease.
- In Genomics
- Etc.

NASSCOM predicts AI use in healthcare market will grow from $14.6 billion in 2023 to $102.7 billion in 2028.

- News9

Applications: Web Click data

- For Online Ad Click prediction
  - Which links are more likely to be clicked on a web page.
  - Promotions and drawing web traffic.

Applications: Product recommendations

- YouTube, Amazon and Netflix recommendations.
- Netflix Prize:
  - In October, 2006 Netflix provided a training data set of 100,480,507 ratings that 480,189 users gave to 17,770 movies and challenged the data mining, machine learning and computer science communities to develop systems that could beat the accuracy of its recommendation system, Cinematch.
  - The Netflix Prize was an open competition for the best **collaborative filtering algorithm** to **predict user ratings for films**, based on **previous ratings without any other information about the users or films**.
  - The competition was held by Netflix, a video streaming service, and was open to anyone who is neither connected with Netflix (current and former employees, agents, close relatives of Netflix employees, etc.). On September 21, 2009, the grand prize of US$1,000,000 was given to the **BellKor's Pragmatic Chaos** team which bested Netflix's own algorithm for predicting ratings by **10.06%**

https://www.cs.uic.edu/~liub/KDD-cup-2007/proceedings/The-Netflix-Prize-Bennett.pdf
https://en.wikipedia.org/wiki/Netflix_Prize

Applications: Agriculture, Weather

- Predicting the yield of a crop.
  - Detection and recognition tasks for crops, pests, etc.
  - Application of pesticides in a targeted way.
- Weather / rainfall prediction.
  - Based on historical data
  - Based on other weather features.

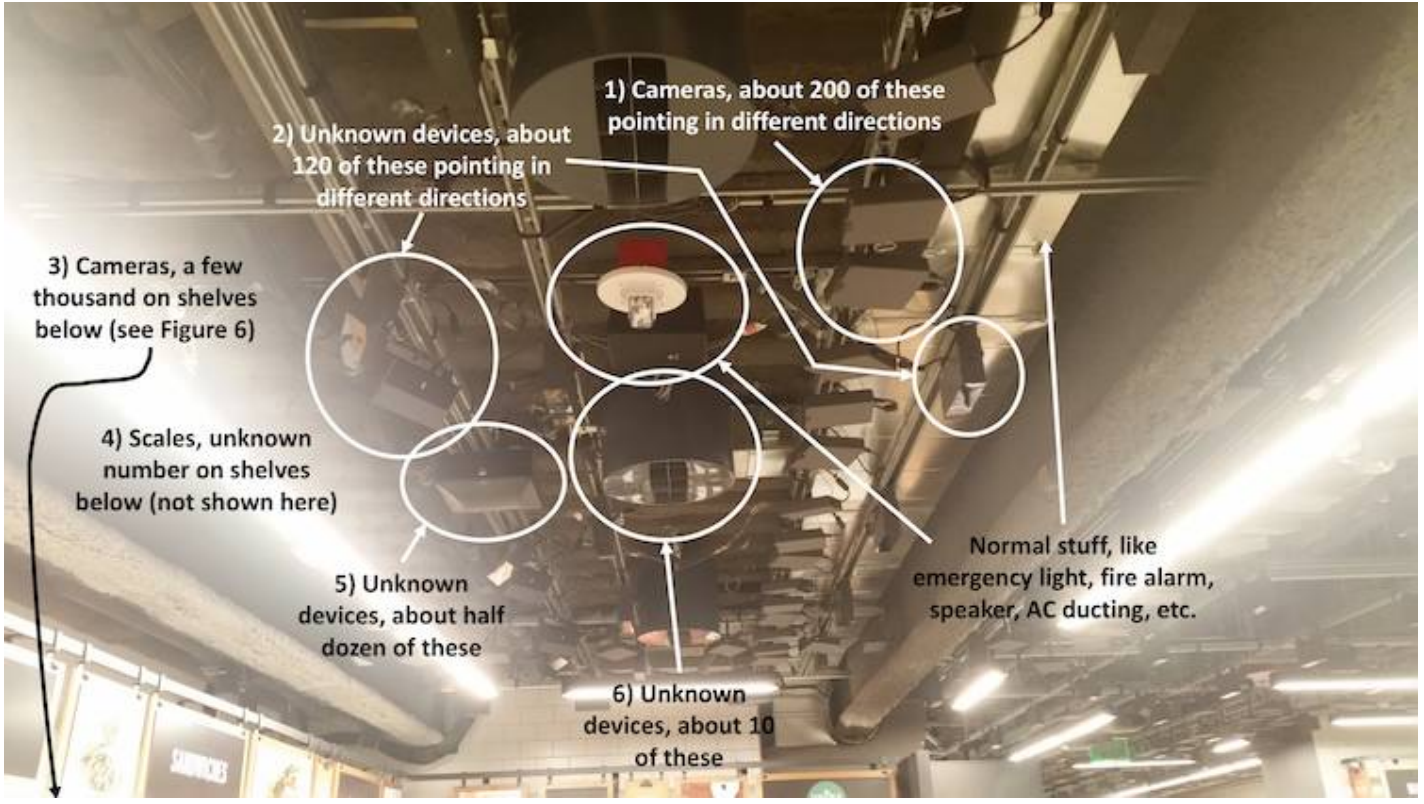
Applications: Natural Language Processing (NLP)

- Chatbots
  - To deal with text based queries
- Machine to machine Translation.
- Image captioning / commentary (subtitle) generation.
- Generative models like ChatGPT
- Social Media Analysis
  - Sentiment Analysis
- Smart Assistants
  - Alexa, Siri - Speech to text and ML
- IBM Watson: In 2011 won the quiz show *Jeopardy.*

Computer Vision Applications: Surveillance

Source: https://www.v7labs.com/blog/computer-vision-applications

Retail: Amazon Go – Automated Checkouts

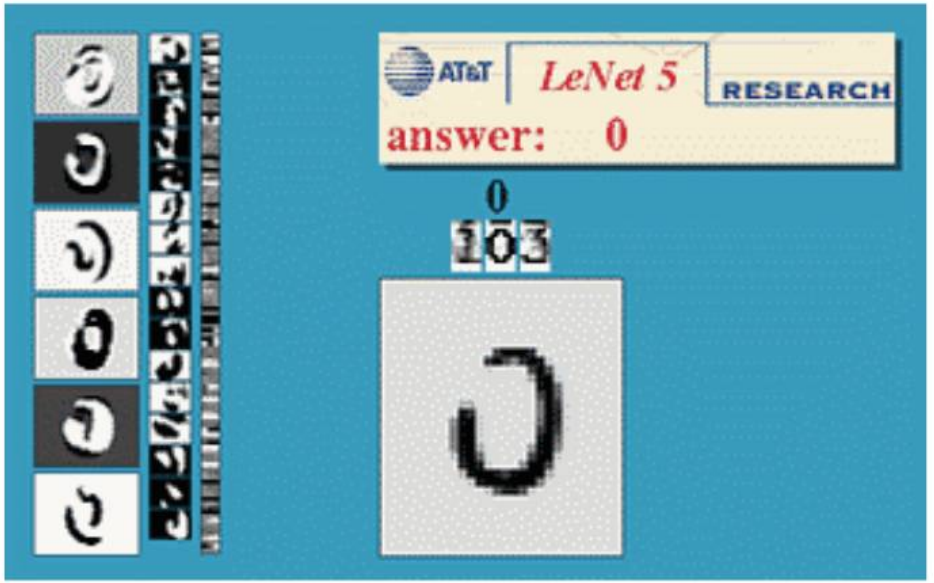


Source: https://clresearch.com/articles/amazon-go-and-the-emergence-of-sentient-buildings-how-it-works-and-what-its-impact-will-be/

Retail: Amazon Go – Automated Checkouts

Source: https://clresearch.com/articles/amazon-go-and-the-emergence-of-sentient-buildings-how-it-works-and-what-its-impact-will-be/

More CV Applications



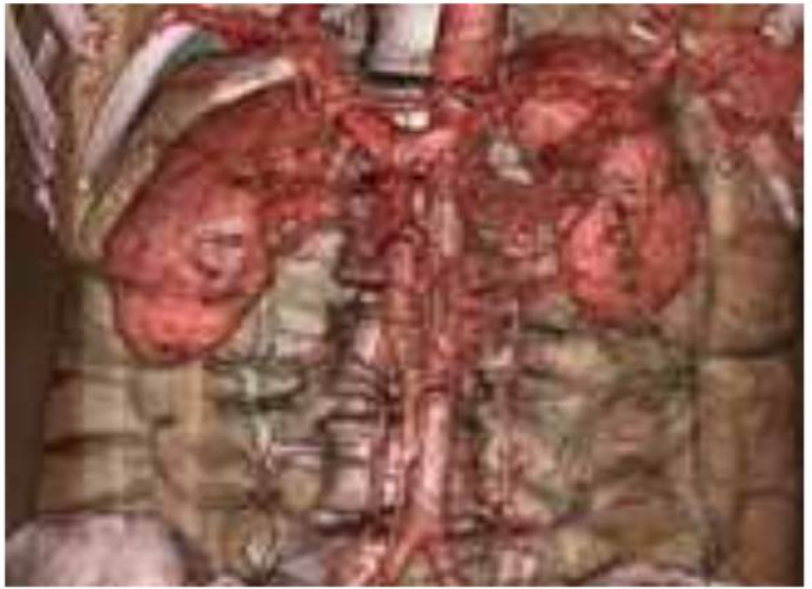
optical character recognition (OCR),
http://yann.lecun.com/exdb/lenet;

mechanical inspection,
http://www.cognitens.com;

Source: Szeliski, Computer Vision: Algorithms and Applications 2nd Edition

More CV Applications

warehouse picking,
https://covariant.ai;



Medical imaging,
http:// www.clarontech.com;

Source: Szeliski, Computer Vision: Algorithms and Applications 2nd Edition

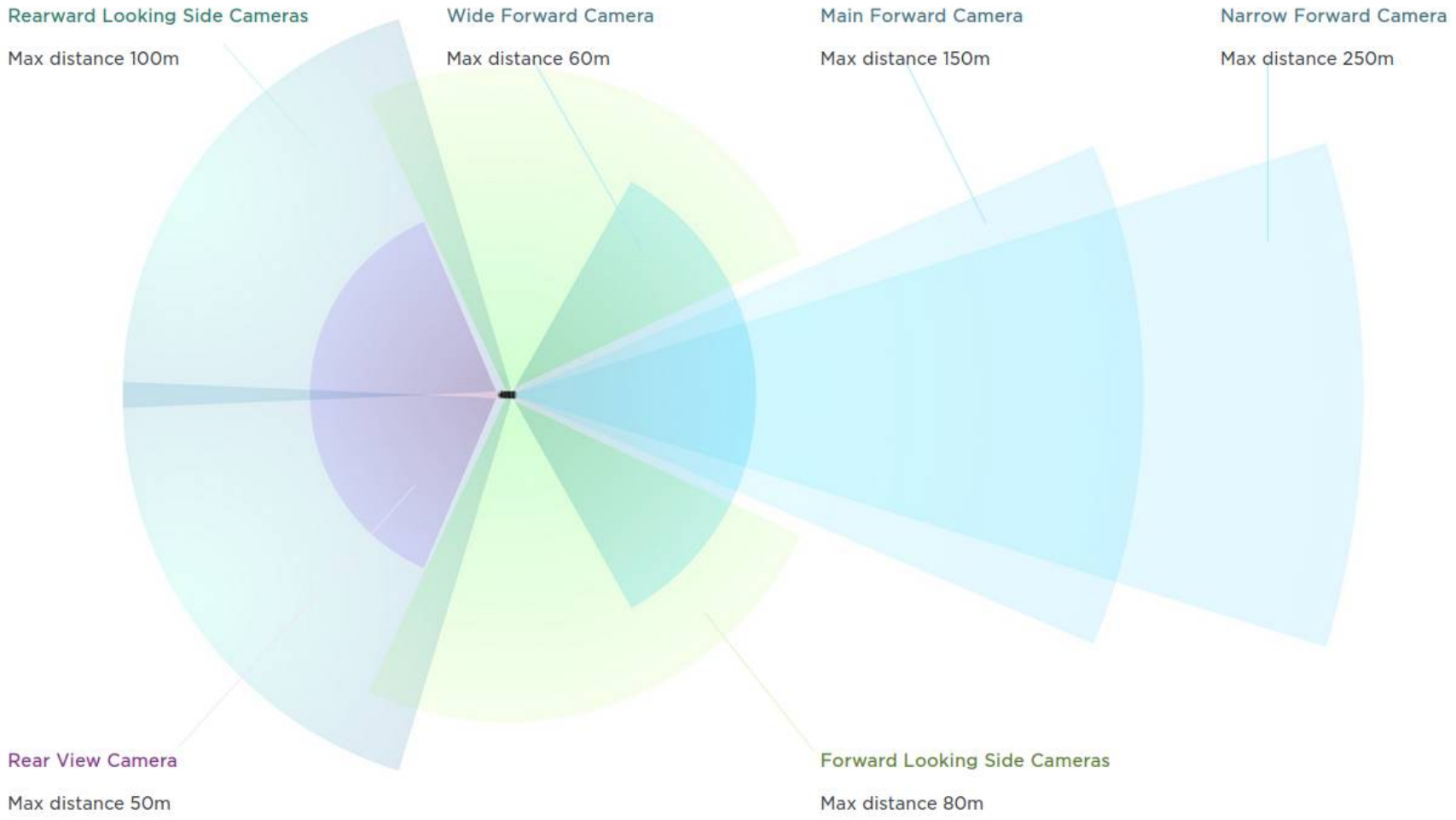
Automatic Number Plate Recognition (ANPR)

https://www.alertsystems.co.uk/security-solutions/anpr-automatic-number-plate-recognition/

Self Driving Cars Today – Tesla

- Tesla Autopilot
- https://vimeo.com/192179726

Tesla Camera Views



https://www.tesla.com/autopilot

IBM Journal, Vol. 3, No.3. July, 1959.

Some Studies in Machine Learning Using the Game of Checkers

Arthur L. Samuel

Abstract: Two machine-learning procedures have been investigated in some detail using the game of checkers. Enough work has been done to verify the fact that a computer can be programmed so that it will learn to play a better game of checkers than can be played by the person who wrote the program. Furthermore, it can learn to do this in a remarkably short period of time (8 or 10 hours of machine-playing time) when given only the rules of the game, a sense of direction, and a redundant and incomplete list of parameters which are thought to have something to do with the game, but whose correct signs and relative weights are unknown and unspecified. The principles of machine learning verified by these experiments are, of course, applicable to many other situations.

Introduction

The studies reported here have been concerned with the programming of a digital computer to behave in a way which, if done by human beings or animals, would be described as involving the process of learning. While this is not the place to dwell on the importance of machine-learning procedures, or to discourse on the philosophical aspects,[1] there is obviously a very large amount of work, now done by people, which is quite trivial in its demands on the intellect but does, nevertheless, involve some learning. We have at our command computers with adequate data-handling ability and with sufficient com-

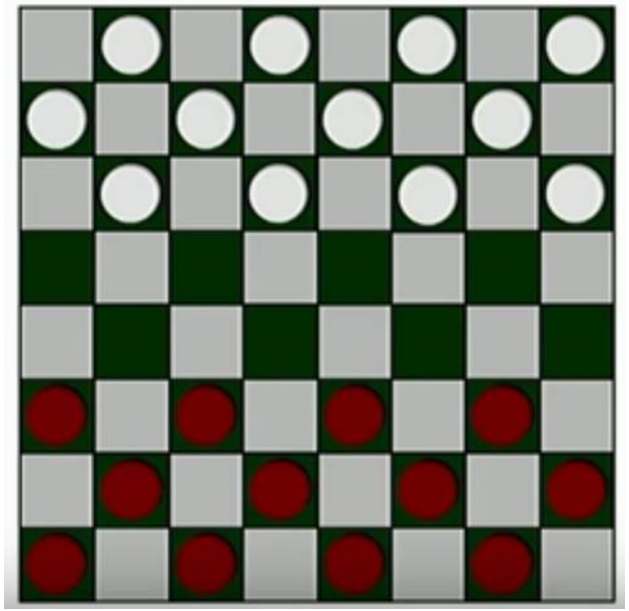
method should lead to the development of general-purpose learning machines. A comparison between the size of the switching nets that can be reasonably constructed or simulated at the present time and the size of the neural nets used by animals, suggests that we have a long way to go before we obtain practical devices.[2] The second procedure requires reprogramming for each new application, but it is capable of realization at the present time. The experiments to be described here were based on this second approach.

Refer: https://people.csail.mit.edu/brooks/idocs/Samuel.pdf

Machine Learning: Definition

- ***Def.***: Arthur Samuel (1959): Field of study that gives computers the ability to learn without being explicitly programmed.

- *"A computer can be programmed so that it will learn to play a better game of checkers than can be played by the person who wrote the program."* - 1959 paper.



Machine Learning: Definition

- ***Def.***: Tom Mitchell (1998): Well-posed learning problem. A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on task T, as measured by P , improves with experience E.
  - Sort of inductive learning. Example:
    - E – experience of program playing tons of checkers game with itself.
    - T – task of playing checkers
    - P – What is the chance of this program winning the next game of checkers it plays against the next opponent.

Inductive Learning: Going from specific examples to a general rule

Deductive Learning: General rule to specific examples

Machine Learning: Definition

- ***Def.***: Kevin P. Murphy (2012) : The goal of machine learning is to develop methods that can automatically detect patterns in data, and then to use the uncovered patterns to predict future data or other outcomes of interest.

  Machine learning is thus, closely related to the field of statistics and data mining, but differs slightly in terms of emphasis [...]

Machine Learning Vs. Statistics

- Both ML and statistics aim to “detect patterns in data” by building predictive models.
- Statistics: use this as a tool to learn something about the world (statistical inference). Focus on simple, interpretable models. Develop theoretical analysis, work out statistical guarantees under some assumptions.
- Machine Learning: use this as a tool to actually make useful predictions. Focus on complicated, competitive models. Use large datasets. Be pragmatic. Give up on inference.

- Brieman (2001) statistical modeling. The two cultures

Dmitry Kobak: https://www.youtube.com/watch?v=lWGdFeMsjzg&list

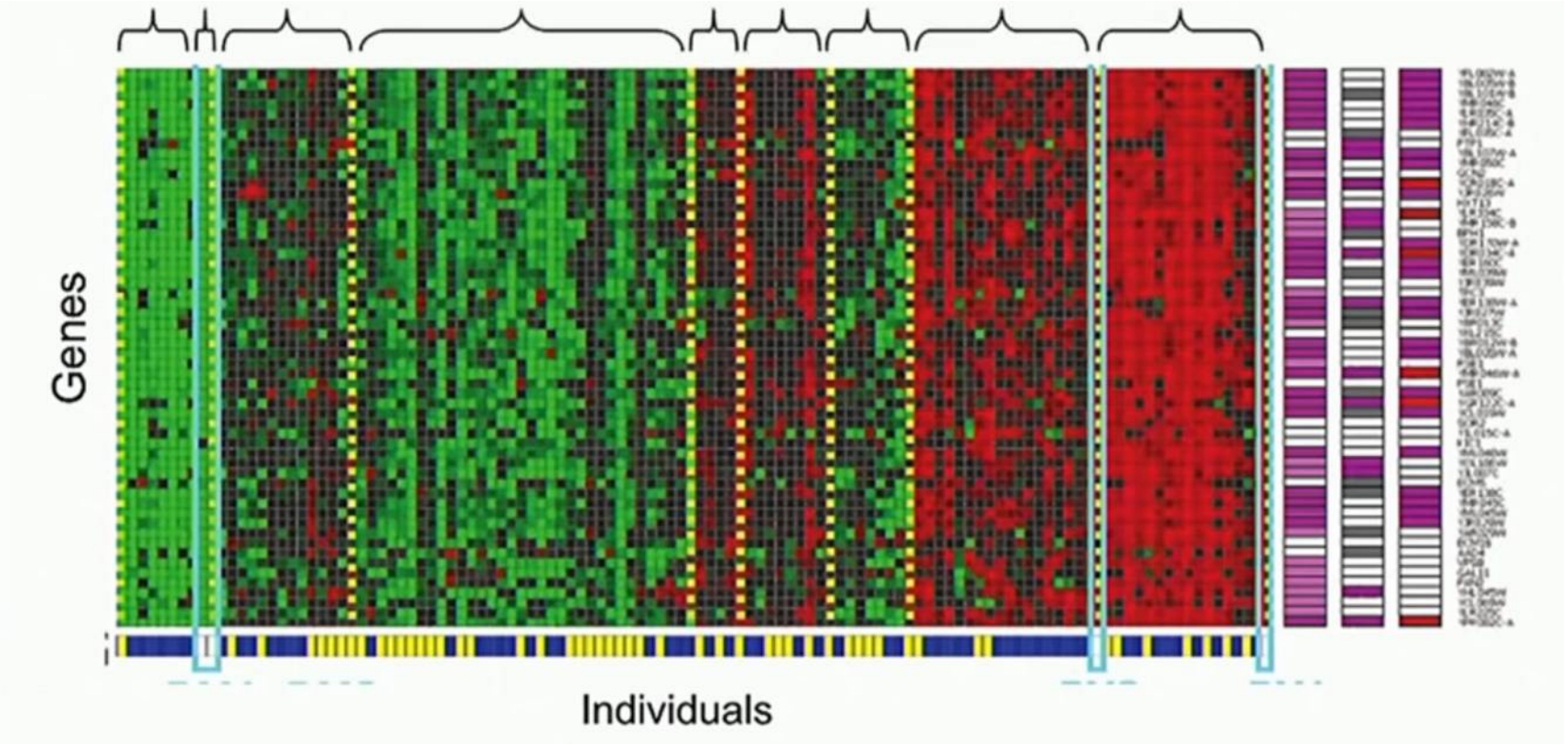
Types of Learning / ML Paradigms

- Supervised
  - Learn an input to output map
    - Regression: Continuous output
    - Classification: Categorical output
- Unsupervised
  - Discover patterns in the data
    - Clustering: cohesive grouping
    - Association: Frequent Co-occurrence
- Reinforcement Learning
  - Learning Control

Types of Learning and Performance Measures

Task	Measure
Classification	error
Regression	error
Clustering	scatter/purity
Associations	support/confidence
Reinforcement Learning	cost/reward

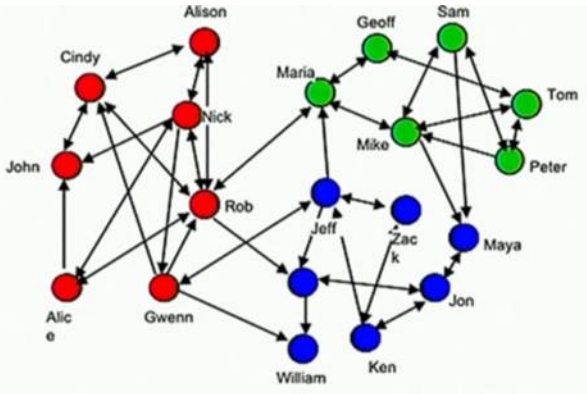
More applications: Genomics (Clustering)



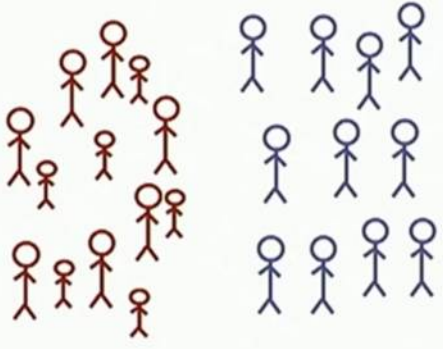
Source: Su In-Lee et al.

Clustering Applications (Contd.)

Organize computing clusters



Social network analysis



Market segmentation

Astronomical data analysis

Reinforcement Learning Applications

- Autonomous Control Systems (Robots)
- AlphaGo (Go) (Link)
- AlphaZero (Chess) (Link)
- AlphaStar (StarCraft II) (Link)
- AlphaFold (Protein Folding) (Link)

  - RL Course by David Silver from DeepMind (YouTube Link)

Quiz

- Which of the following are not machine learning tasks?
  - Recognizing malignant, or benign tumours for new patients.
  - Finding the modulus of two integers.
  - Spam filtering : Where only those messages are marked as spam, which have the words “Credit Card”, and/or “Bitcoin”.
  - Automatically detecting whether the driver is drowsy or not.
  - Realtime Defect detection in a continuously moving fabric in a manufacturing unit.

Quiz

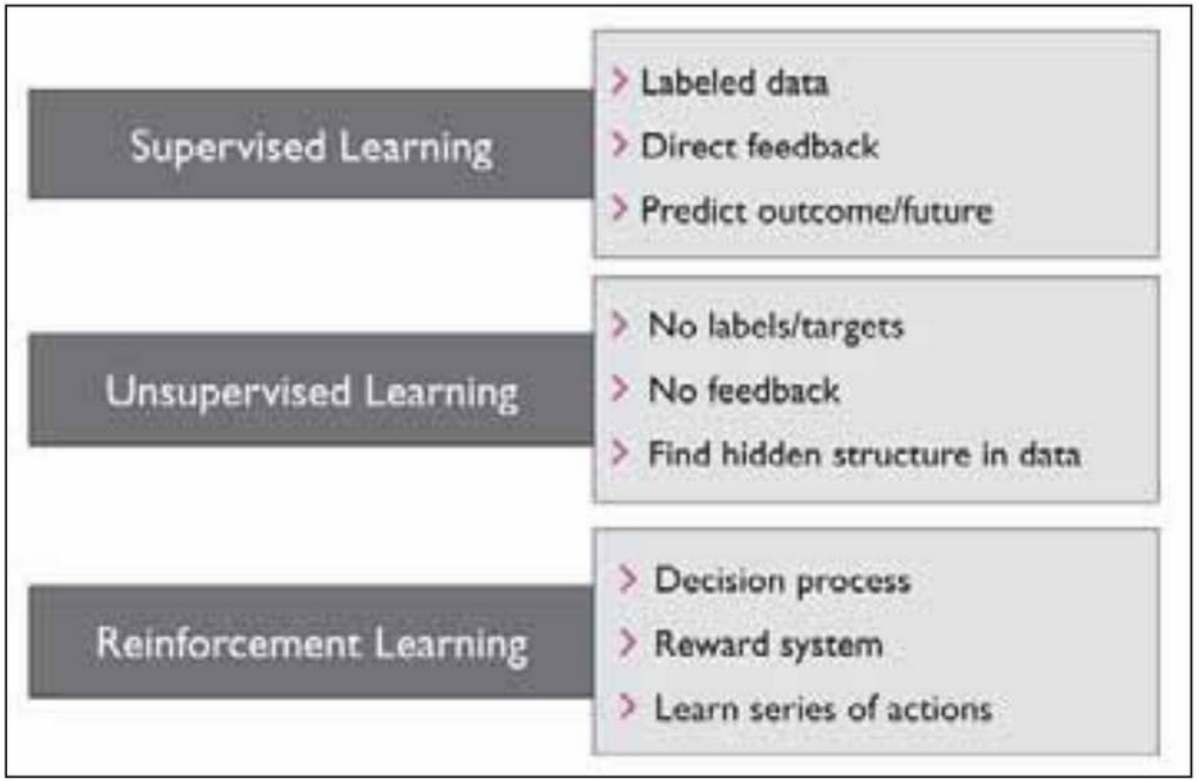
"A computer program is said to *learn* from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E."

Suppose your email program watches which emails you do or do not mark as spam, and based on that learns how to better filter spam. What is the task T in this setting?

T

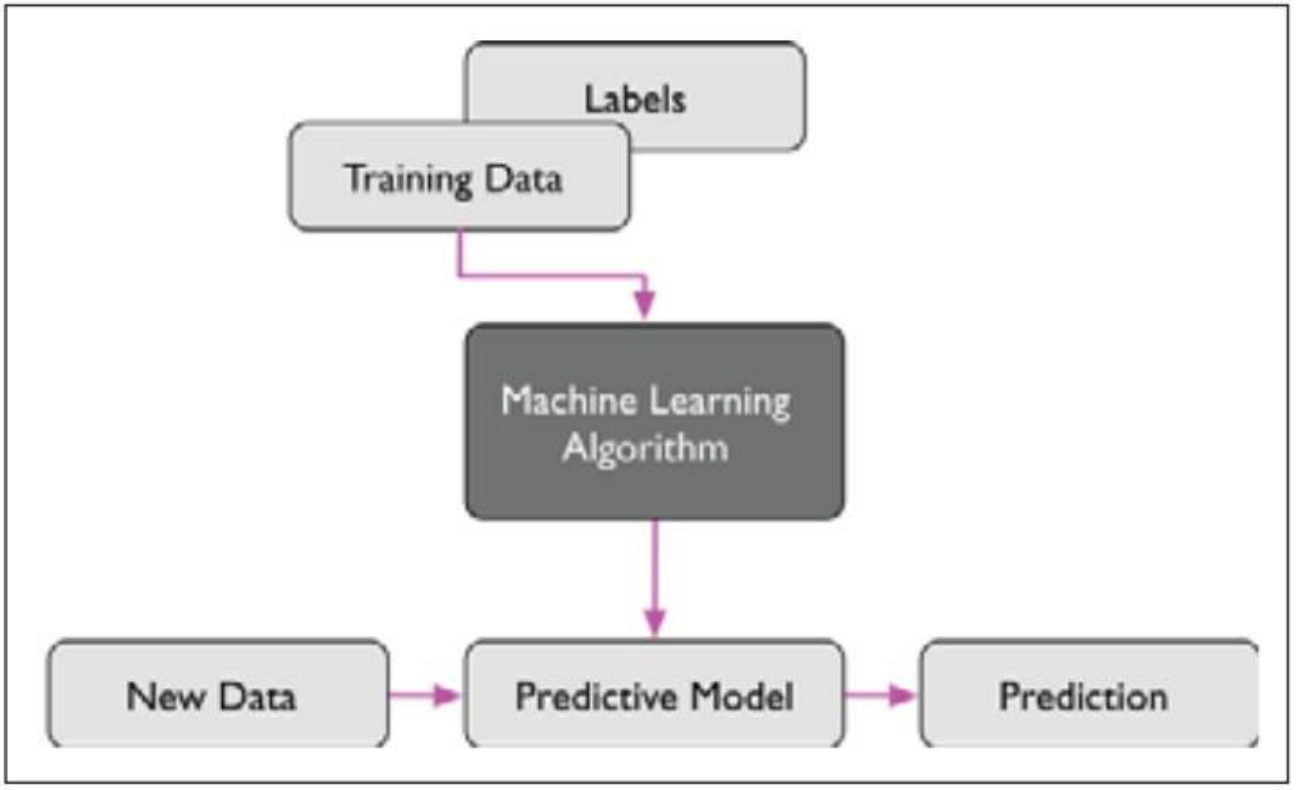
- ◯ Classifying emails as spam or not spam.
- ◯ Watching you label emails as spam or not spam.
- ◯ The number (or fraction) of emails correctly classified as spam/not spam.
- ◯ None of the above—this is not a machine learning problem.

Types of Learning / ML Paradigms



Python Machine Learning by Sebastian Raschka (Book)

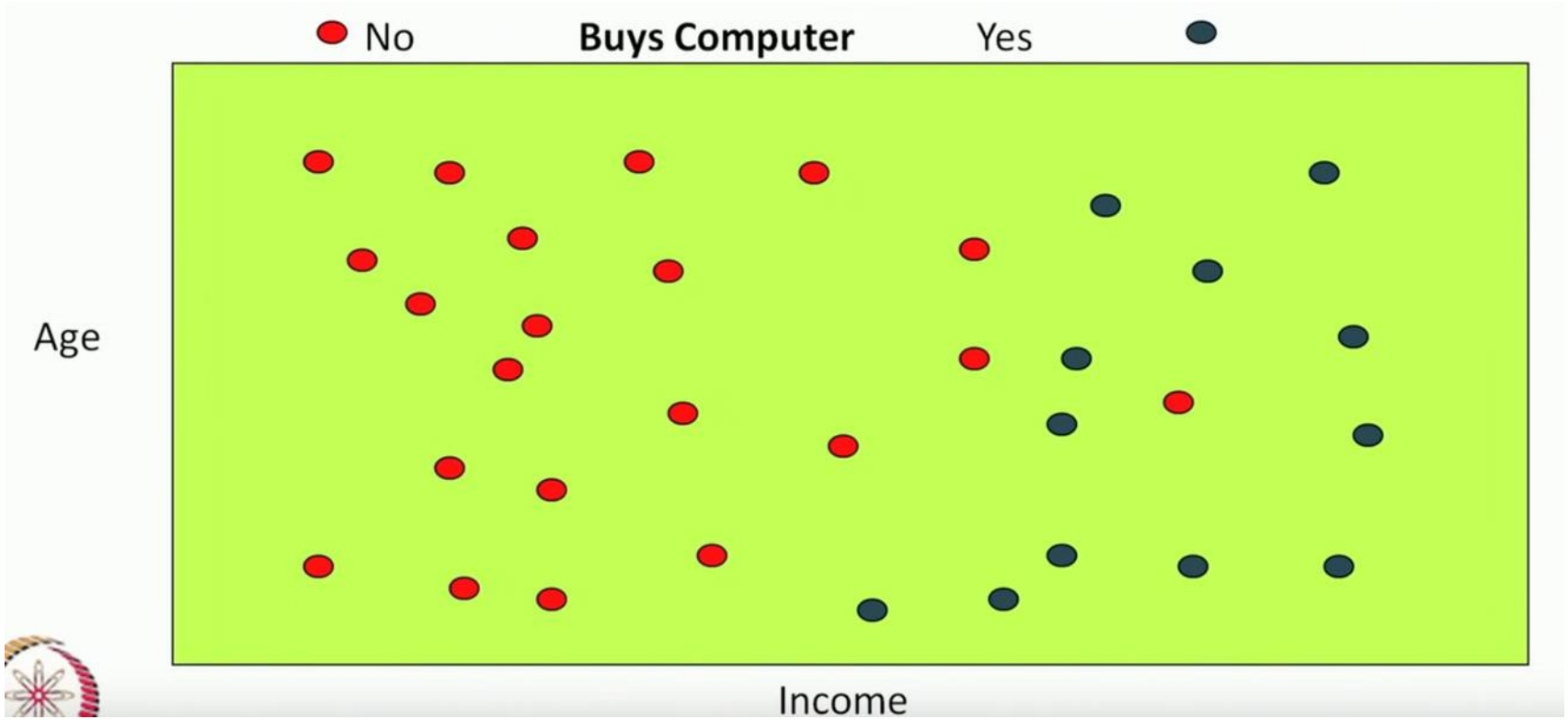
Supervised Learning



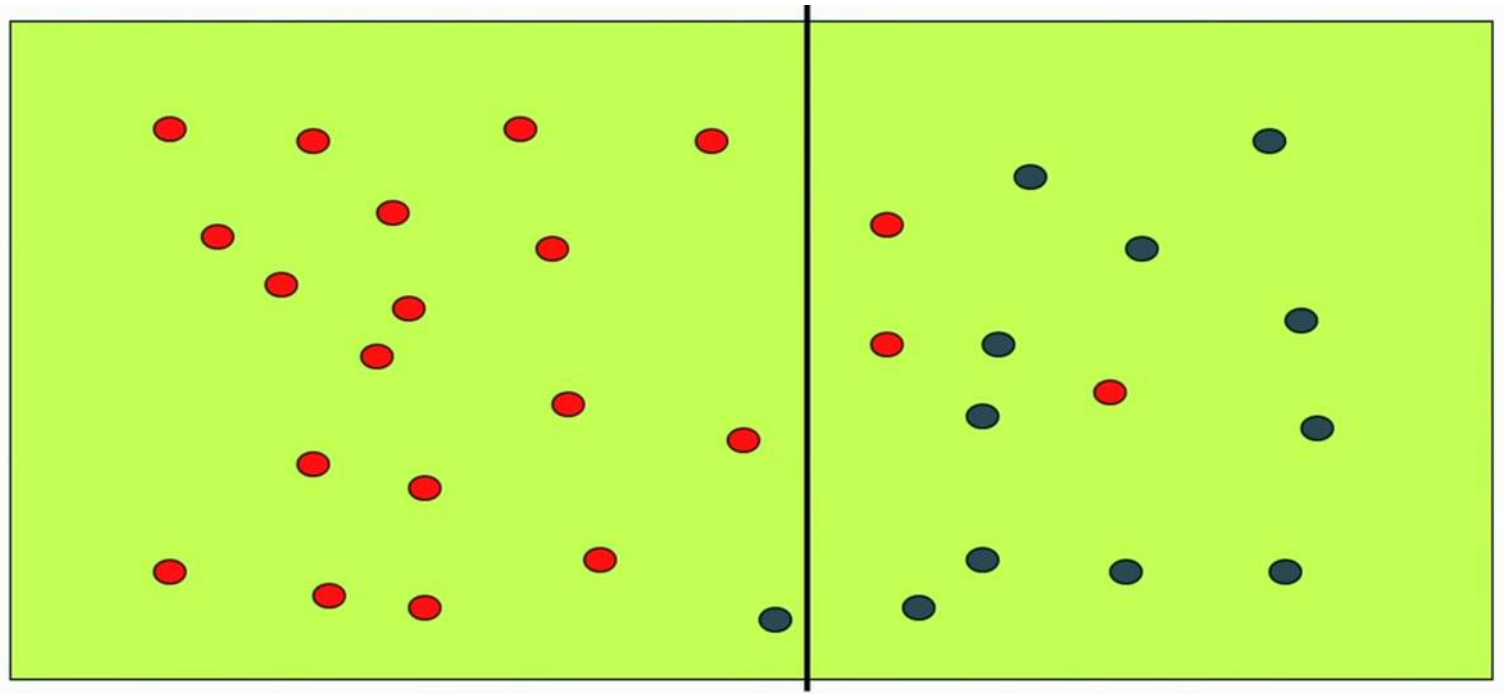
Python Machine Learning by Sebastian Raschka (Book)

Labeled Training Data: Classification

- Example: Predicting Person Who buys a PC

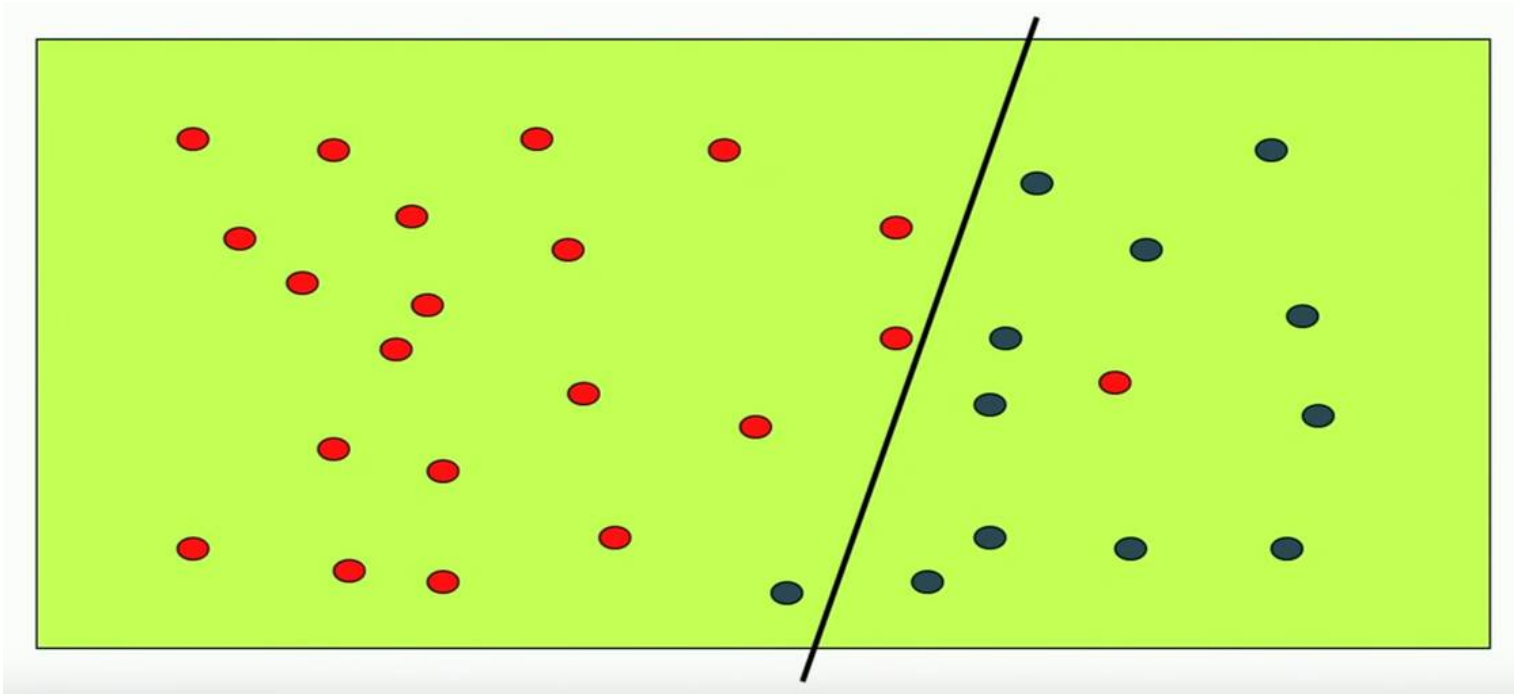


Eg.: Possible Classifier



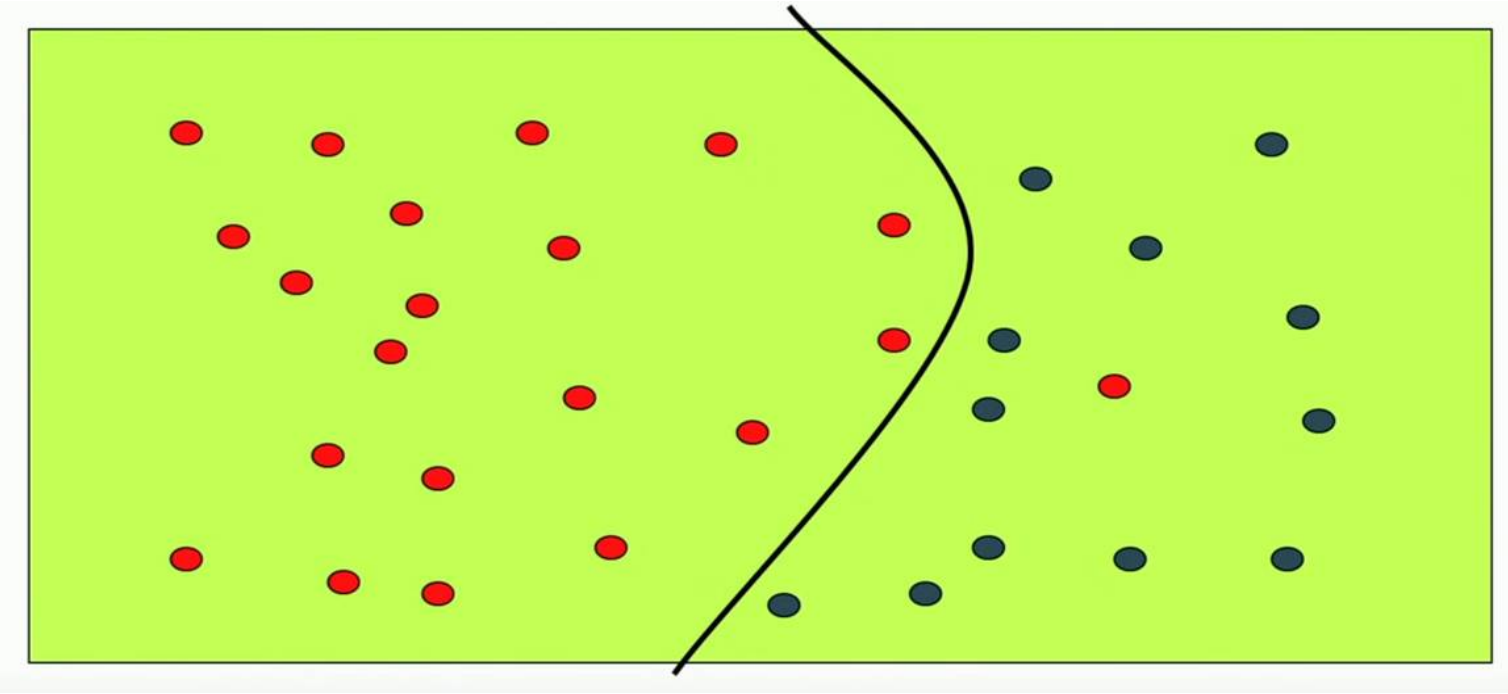
Considers only single feature (Salary) on x-axis

Eg.: Possible Classifier



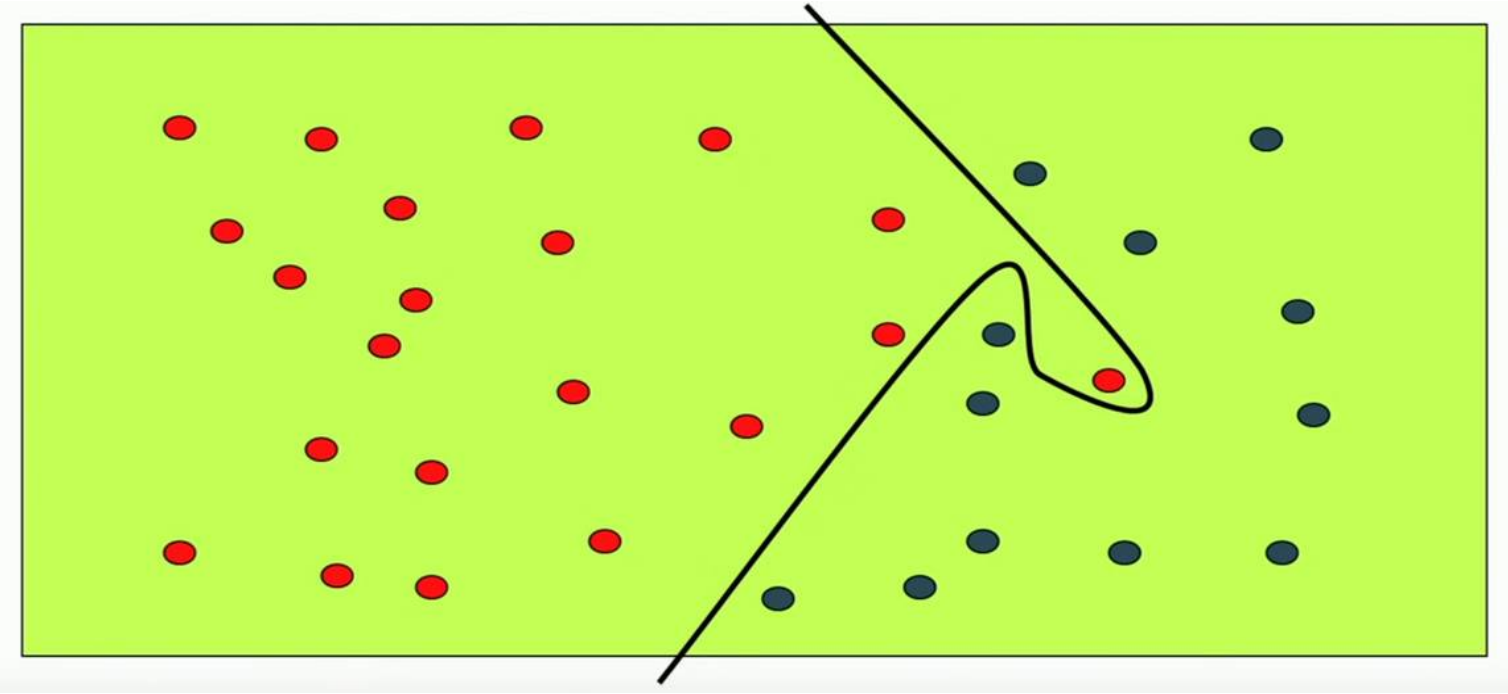
Considers both features (Salary and Age). Somewhat better.

Eg.: Possible Classifier



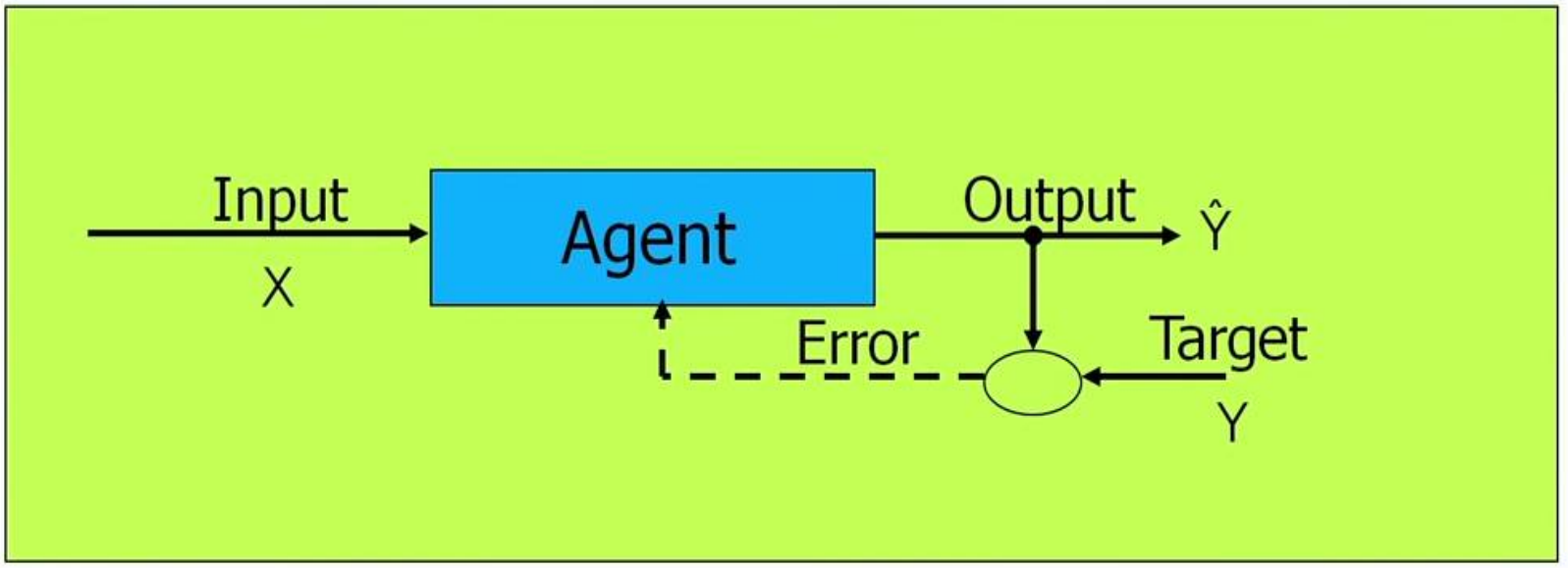
More complex. Better than previous in terms of accuracy.

Eg.: Possible Classifier



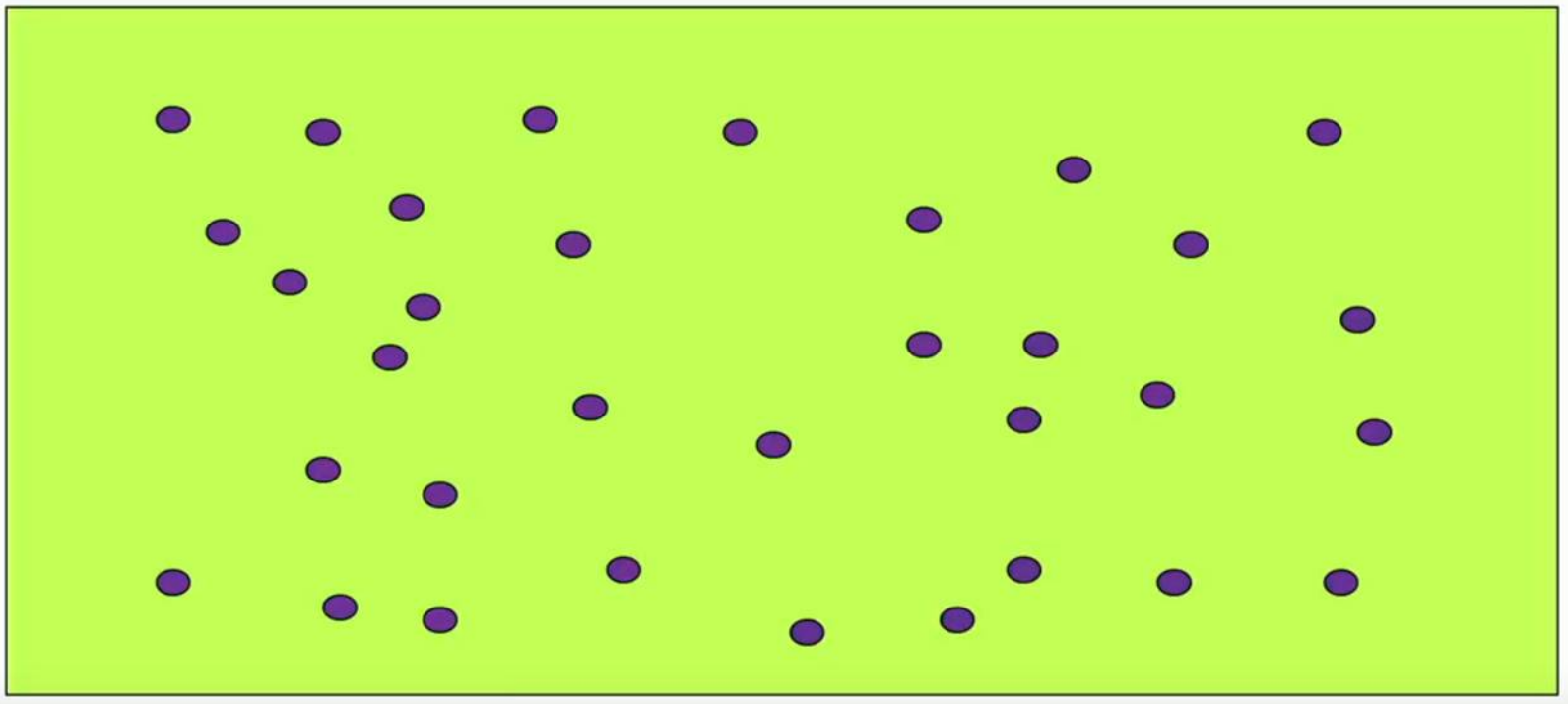
Still more complex.

Training



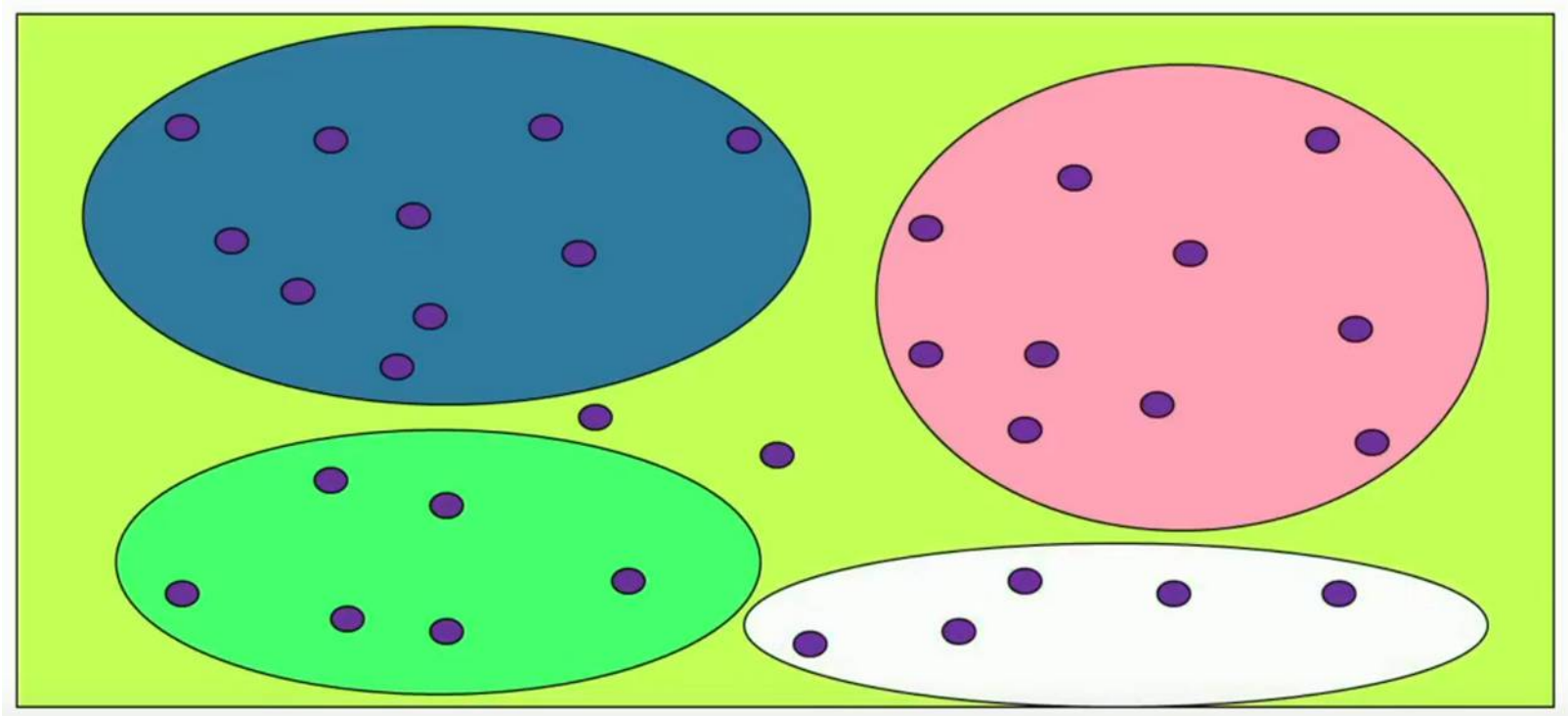
Unsupervised Learning (Clustering)

- Unlabeled training data



Unsupervised Learning (Clustering)

- Possible Clusters



More Applications of Unsupervised Learning (Clustering)

Customer Data
- Discover classes of customers

Image pixels
- Discover regions

Words
- Synonyms

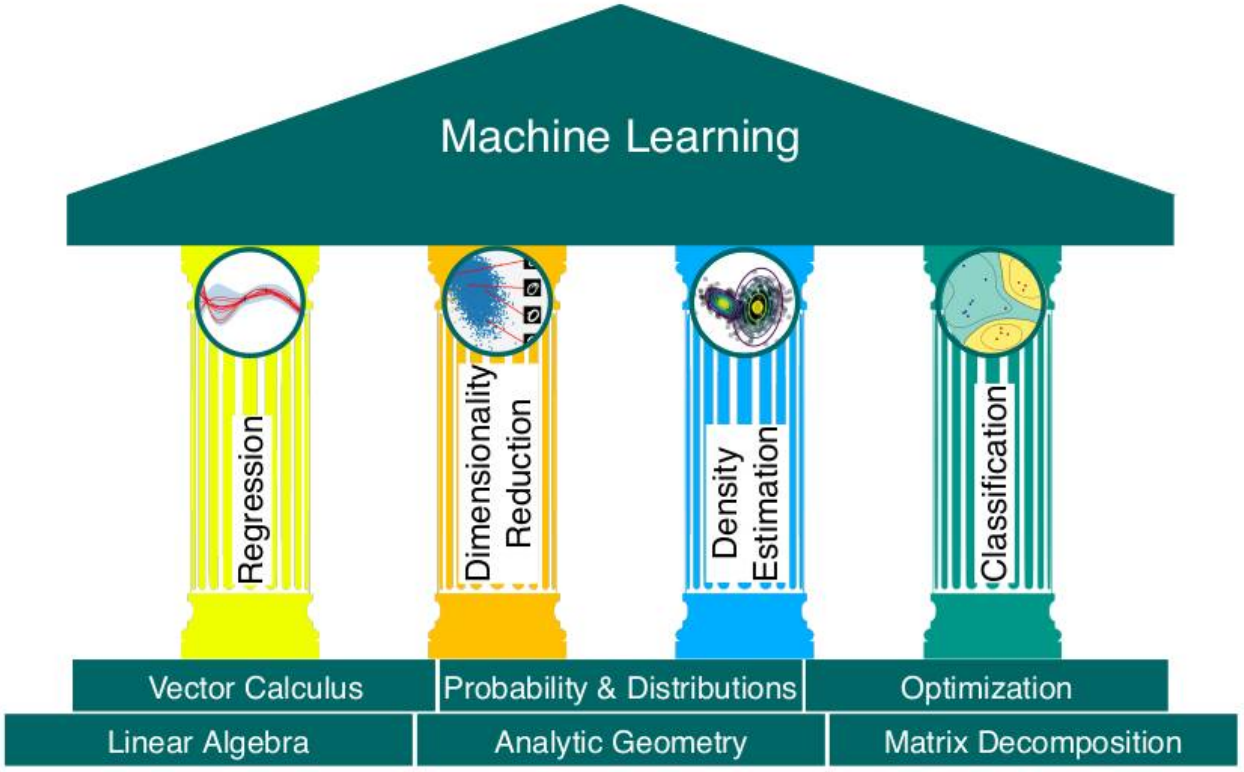
Documents
- Topics

Image Courtesy: http://cs.brown.edu/~pff/segment/

Reinforcement Learning Framework

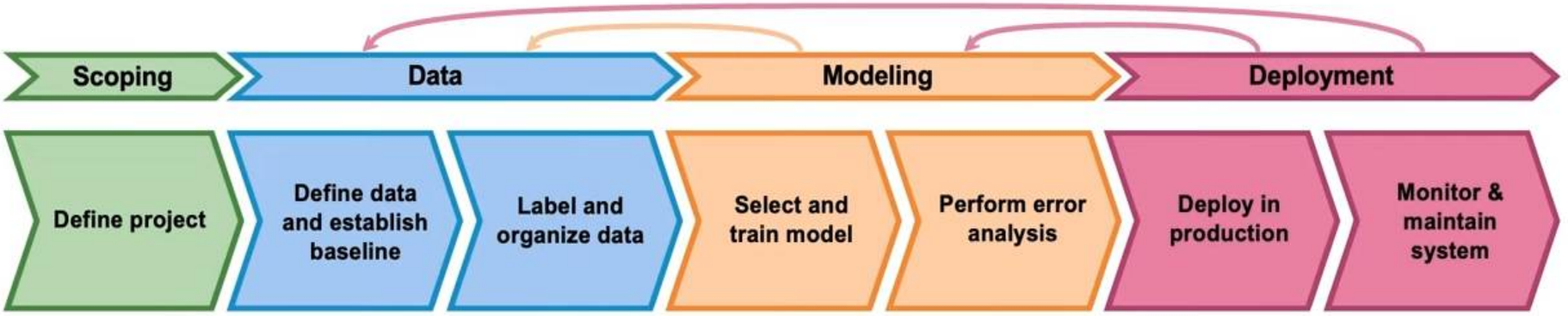
- Learn from close interaction
- Stochastic environment
- Noisy delayed scalar evaluation
- Learn a policy
  - Maximize a measure of long term performance

Foundations and 4 pillars of ML



Deisenroth : Mathematics for Machine Learning (Book)

The ML project lifecycle



Andrew Ng: Machine Learning Engineering in Production (MLOps)

Challenges

- How good is a model?
- How do I choose a model?
- Do I have enough data?
- Is the data of sufficient quality?
  - Errors in data. Ex: Age=225; noise in low resolution images
  - Missing Values
- How confident can I be of the results?
- Am I describing the data correctly?
  - Are Age and Income enough? Should I look at Gender also?

Online Video Lectures / Tutorials

- Machine Learning Course by Andrew Ng
- NPTEL MOOC Machine Learning – Prof. Balaram Ravindran
- MIT OCW course on Machine Learning

End of Lecture