MACHINE LEARNING
CSL 4107

Outline

- Course overview
- What is AI? AI superset of ML
- What is ML
- A brief history
- The state of the art

Some fundamental questions

What is **intelligence?**

What is **thinking?**

What is a **machine?**

Is the **computer** a machine?

Here on when we say machine we will mean a programmable computer system

Can a **machine** think ?

If yes are **we** machines?!

What is AI?

Some definitions of AI

- We call programs intelligent if they exhibit behaviours that would be regarded intelligent if they were exhibited by human beings.

  --Herbert Simon

- Physicists ask what kind of place this universe is and seek to characterize its behaviour systematically. Biologists ask what it means for a physical system to be living. We in AI wonder what kind of information-processing system can ask such questions.

  --Avron Barr and Edward Feigenbaum

- AI is the study of techniques for solving exponentially hard problems in polynomial time by exploiting knowledge about the problem domain.

  --Elaine Rich

- Experience translated to Knowledge
- John Locke(1632-1704), widely known as Father of Classical Liberalism.
- Locke's theory of mind is often cited as the origin of modern conceptions of identity and the self, figuring prominently in the work of later philosophers such as Hume, Rousseau and Kant.

Born 29 August 1632
Wrington, Somerset, England

He postulated the **mind** was a **blank slate** or **tabula rasa**. Contrary to pre-existing Cartesian philosophy, he maintained that we are born without innate ideas, and that **knowledge** is instead determined only by **experience** derived from sense perception

History and Philosophy of AI

Two books mentioned below give an insightful and entertaining account of the history and philosophy of AI.

--”AI: The Very Idea” by John Haugeland

http://www.philosophy.uchicago.edu/faculty/haugeland.html

--”Machines Who Think” by Pamela McCorduck

http://www.pamelamc.com/html/machines_who_think.html

Machines with Minds

- “Fundamental goal of the AI research is **not merely to mimic intelligence**”
- Not at all

- AI wants the genuine articles: **Machines with minds** in the full and literal sense.

- “The idea that **thinking and Computing** are radically the same” --”AI: The Very Idea” by John Haugeland

Some Fundamental Questions

What is **Intelligence ?**

What is **thinking ?**

What is a machine?

Is the Computer a machine?

Can a machine think?

If yes are WE machines?

Squabbles about Thinking Machines

- Human intelligence depend primarily on unconscious processes rather than conscious symbolic manipulation, and these unconscious skills can never be fully captured in formal rules.

  Herbert Dreyfus

- Chinese Room Argument. **John Searle**

- Something (quantum mechanical) goes on in our brains that current day physics cannot explain.

  Roger Penrose

- **Turing test**, originally called the **imitation game** by Alan Turing in 1950, is a test of a machine's ability to exhibit intelligent behaviour equivalent to, or indistinguishable from, that of a human.

1912-1954

The test was introduced by Turing in his 1950 paper, "Computing Machinery and Intelligence", (Turing, 1950; p. 460).

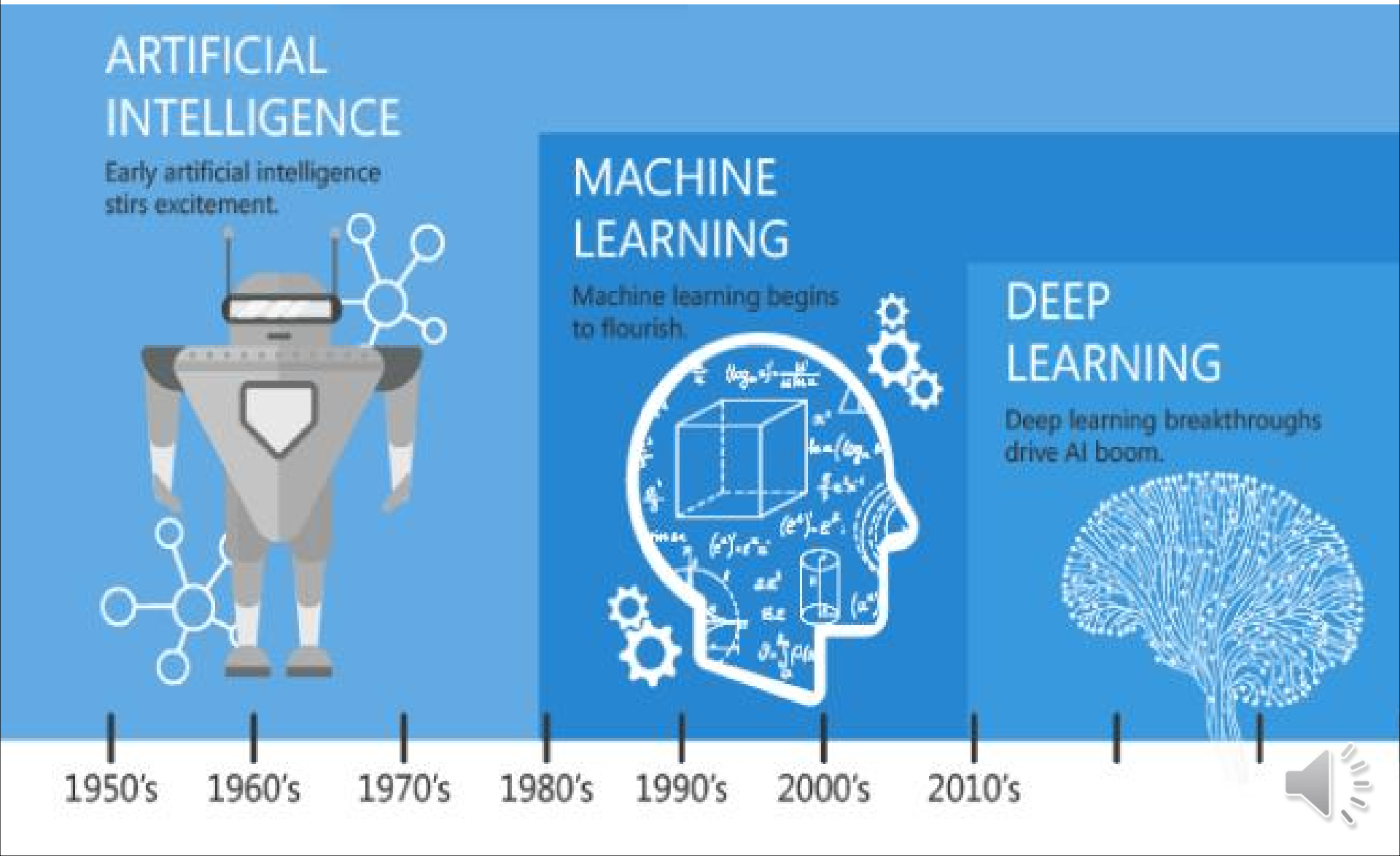
It opens with the words: "I propose to consider the question, 'Can machines think?'" Because "thinking" is difficult to define, Turing chooses to "replace the question by another.

The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence.

New York times, July 8, 1958

- **AI Personal Assistants** - Siri, Home, Alexa
  (will soon automate life)
- **AI Lawyers** - ROSS
  (90% Accuracy vs 70% for Humans)
- **AI Doctors** - IBM Watson
  (4x More Accurate than Humans)
- **AI Autonomous Drivers** - Tesla
  (Will make human drivers seem UNSAFE)
- **AI Investors** - Numerai
- **AI Facial Recognition & Analysis** - Microsoft

A Quick History of Machine Learning



ENIAC — Electronic Numerical Integrator and Computer | Image: www.computerhistory.org

AI prehistory

- Philosophy — Logic, methods of reasoning, mind as physical system foundations of learning, language, rationality
- Mathematics — Formal representation and proof algorithms, computation, (un)decidability, (in)tractability, probability
- Economics — utility, decision theory
- Neuroscience — physical substrate for mental activity
- Psychology — phenomena of perception and motor control, experimental techniques
- Control theory — design systems that maximize an objective function over time
- Linguistics — knowledge representation, grammar

History of AI

- 1943-45: The gestation of artificial intelligence- McCulloch & Pitts: Boolean circuit model of brain
- 1950 : Turing's "Computing Machinery and Intelligence"
- 1956: The birth of artificial intelligence
- 1952-69: Early enthusiasm, great expectation
- 1965: Robinson's complete algorithm for logical reasoning
- 1966-73: A dose of reality- AI discovers computational complexity Neural network research almost disappears By Herbert Simon in 1957

- 1969-79: Knowledge based systems: The key to power.
- 1980-Present: AI becomes an industry
- 1986-Present: The return of Neural Networks
- 1987-Present: AI adopts scientific method
- 1995-Present: The emergence of Intelligent Agent
- 2001-Present: The availability of very large datasets

State of the art

- Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
- Proved a mathematical conjecture (Robbins conjecture) unsolved for decades
- No hands across America (driving autonomously 98% of the time from Pittsburgh to San Diego)
- During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
- NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
- `Proverb` solves crossword puzzles better than most humans

Overview of AI application areas

- Game playing,
- Automated reasoning and theorem proving,
- Expert systems,
- Natural language understanding,
- Planning and robotics,
- Machine learning

Game Playing

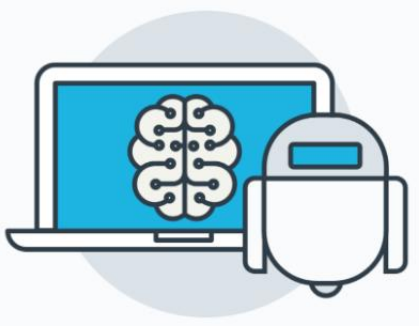
- Board configurations used in playing these games are easily represented on a computer.
- Games can generate extremely large search spaces.
- Heuristic is a useful but potentially fallible problem-solving strategy, such as checking to make sure that an unresponsive appliance is plugged in before assuming that it is broken or to castle in order to try and protect your king from capture in a chess game.

Deep Blue

- 1997: The Deep Blue chess program beats

the current world chess champion, Gary Kasparov, in a widely followed match.

What is Machine Learning (ML)**?**



- According to Arthur Samuel, Machine Learning algorithms enable the computers to learn from data, and even improve themselves, without being explicitly programmed.

- Basic premise of machine learning is to build algorithms that can receive input data and use statistical analysis to predict an output while updating outputs as new data becomes available.

What is Machine Learning (ML)**?**

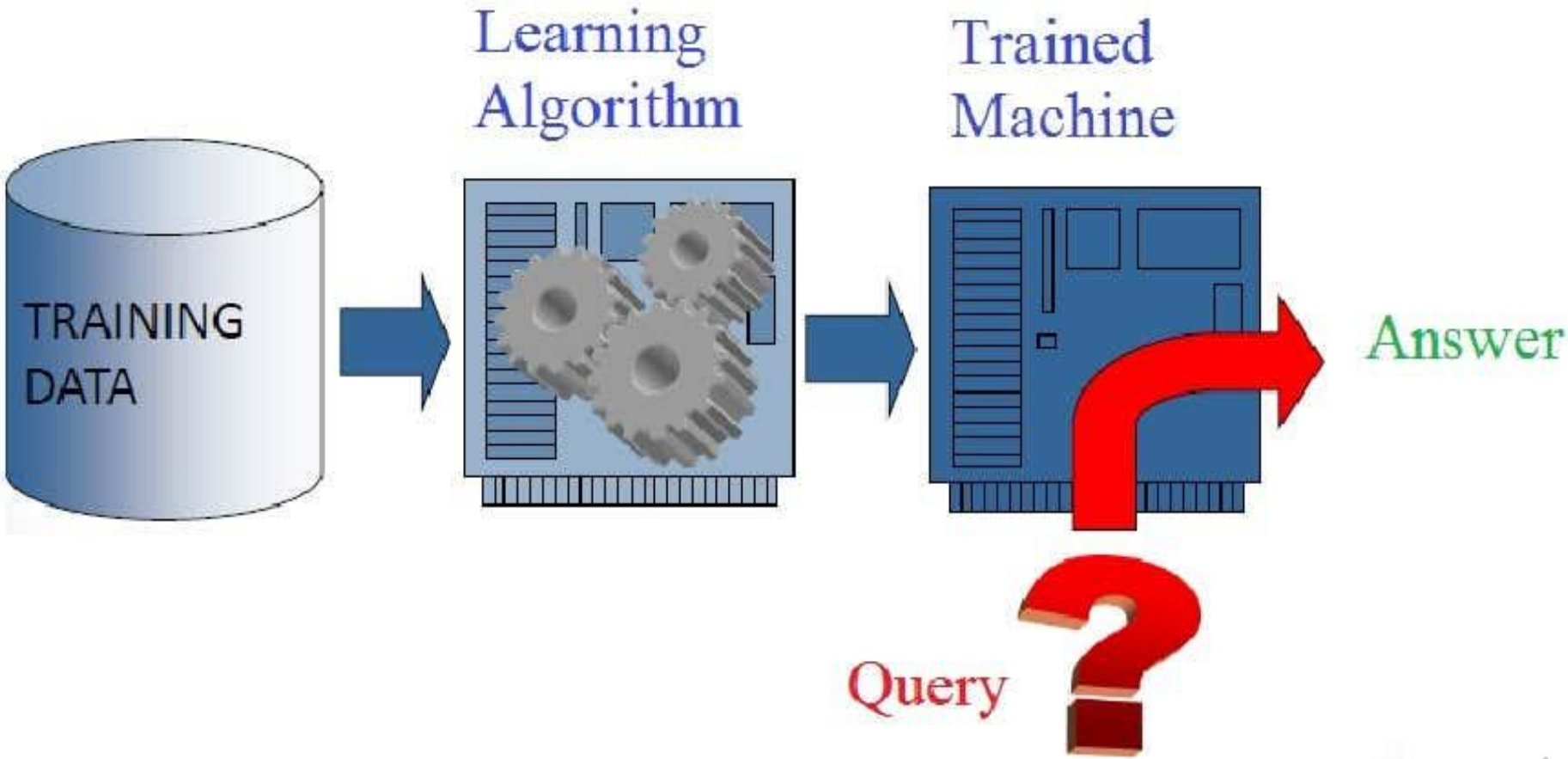
A computer program is said to learn from experience E with respect to some class of tasks ***T*** and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

Why Machine Learning?

- Develop systems that can automatically adapt and customize themselves to individual users.

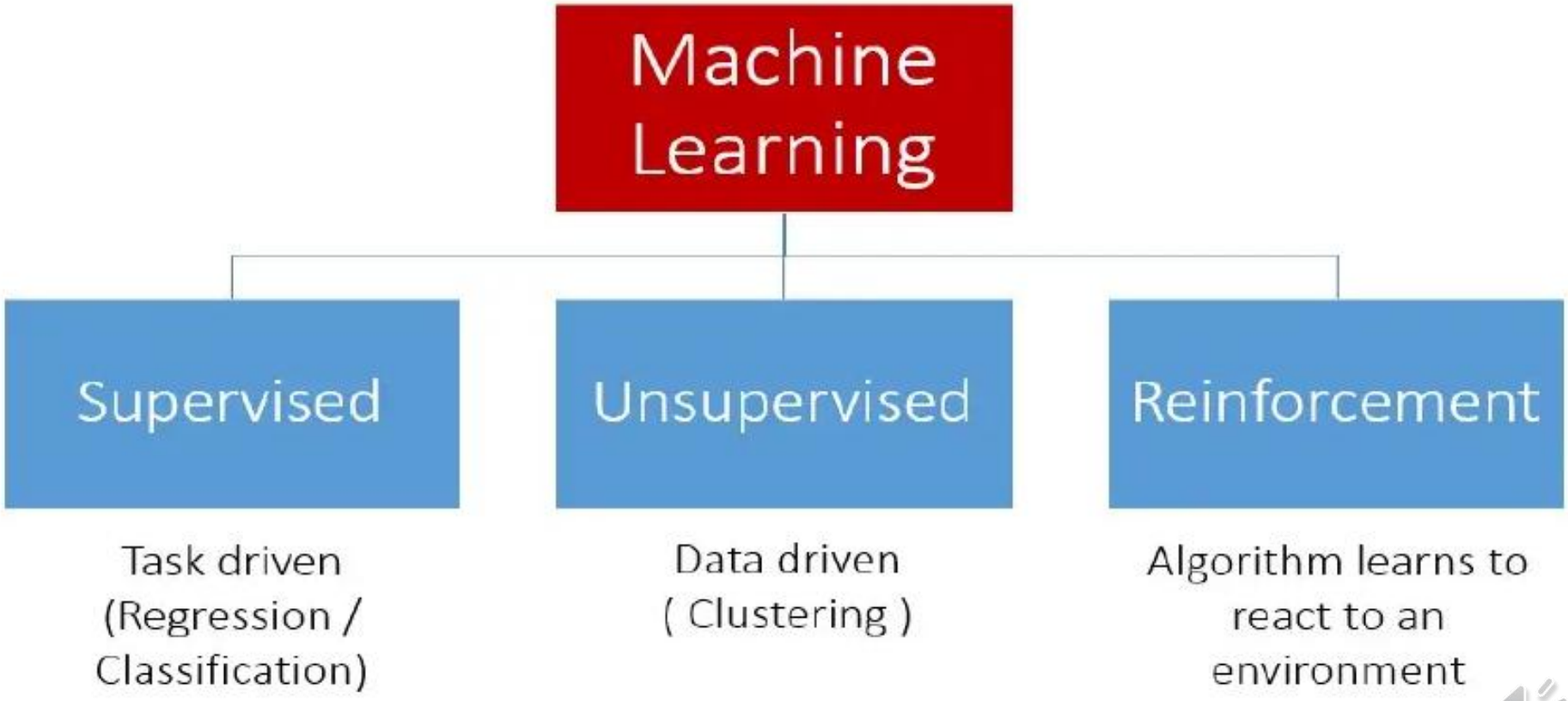
  Personalized news or mail filter
- Discover new knowledge from large databases (data mining).
  - Market basket analysis (e.g. diapers and fruits)
- Ability to mimic human and replace certain monotonous task require some intelligence.
  - like recognizing handwritten characters

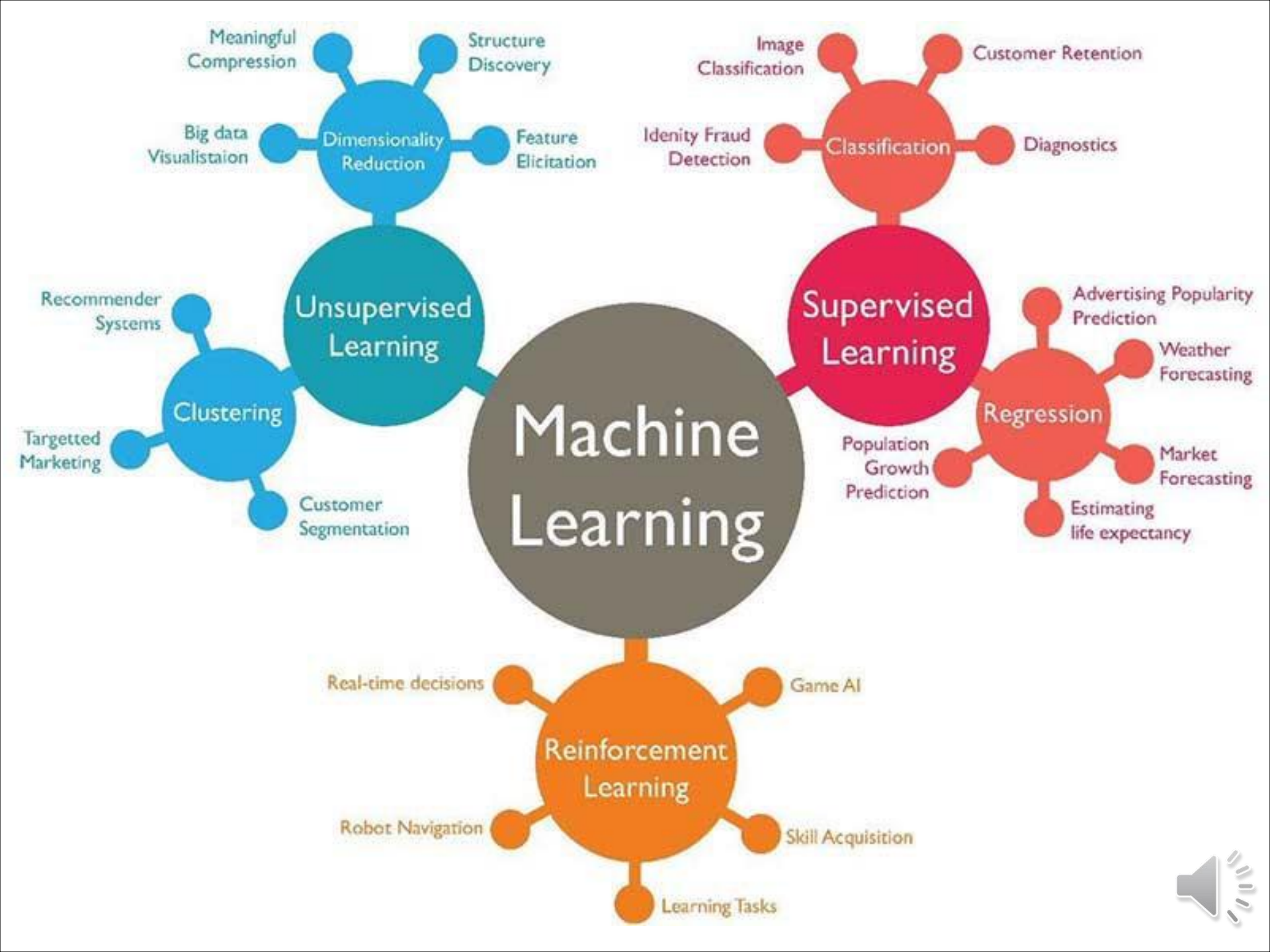
Machine Learning



Types of Machine Learning?

- Machine learning can be classified into 3 types of algorithms.




Machine Learning
Unsupervised Learning
Dimensionality Reduction
Meaningful Compression
Structure Discovery
Big data Visualistaion
Feature Elicitation
Clustering
Recommender Systems
Targetted Marketing
Customer Segmentation
Supervised Learning
Classification
Image Classification
Customer Retention
Idenity Fraud Detection
Diagnostics
Regression
Advertising Popularity Prediction
Weather Forecasting
Population Growth Prediction
Market Forecasting
Estimating life expectancy
Reinforcement Learning
Real-time decisions
Game AI
Robot Navigation
Skill Acquisition
Learning Tasks

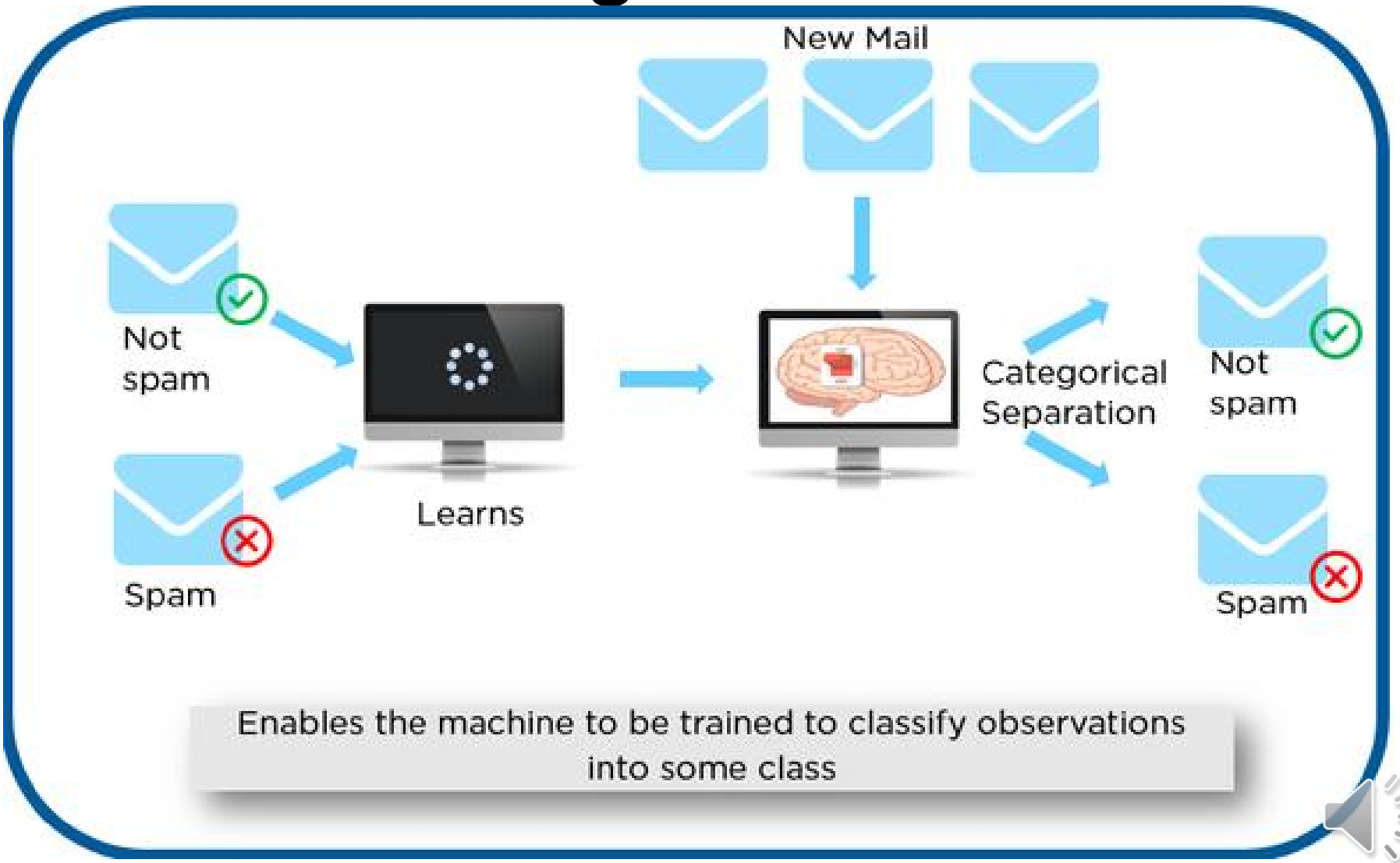
Machine Learning Tasks

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

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?
  - How should I represent age? As a number, or as young, middle age, old?

Overview of Supervised Learning Algorithm

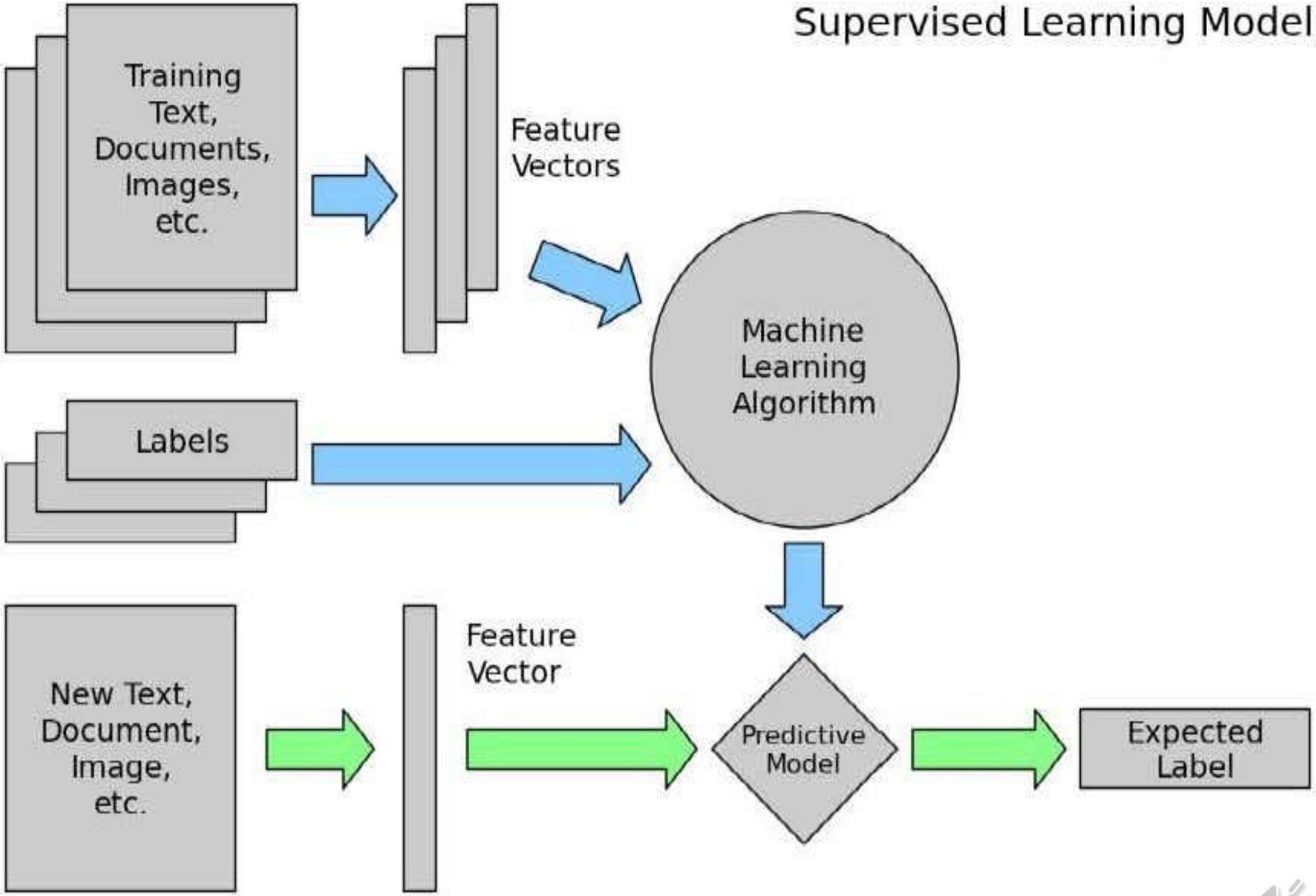


Types of Supervised learning

- **Classification**: A classification problem is when the output variable is a category, such as “red” or “blue” or “disease” and “no disease”.

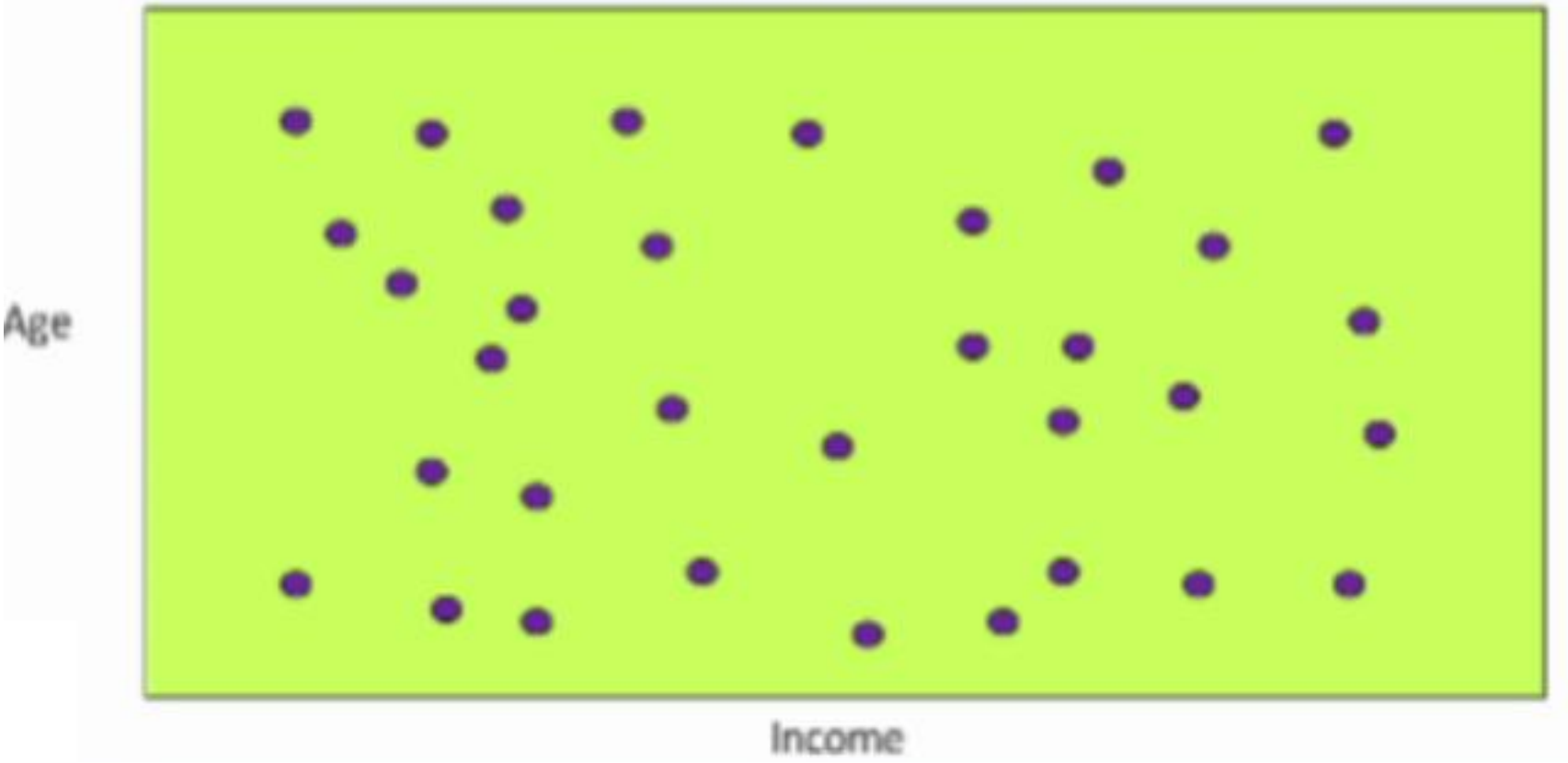
- **Regression**: A regression problem is when the output variable is a real value, such as “dollars” or “weight”.

Supervised Learning Model

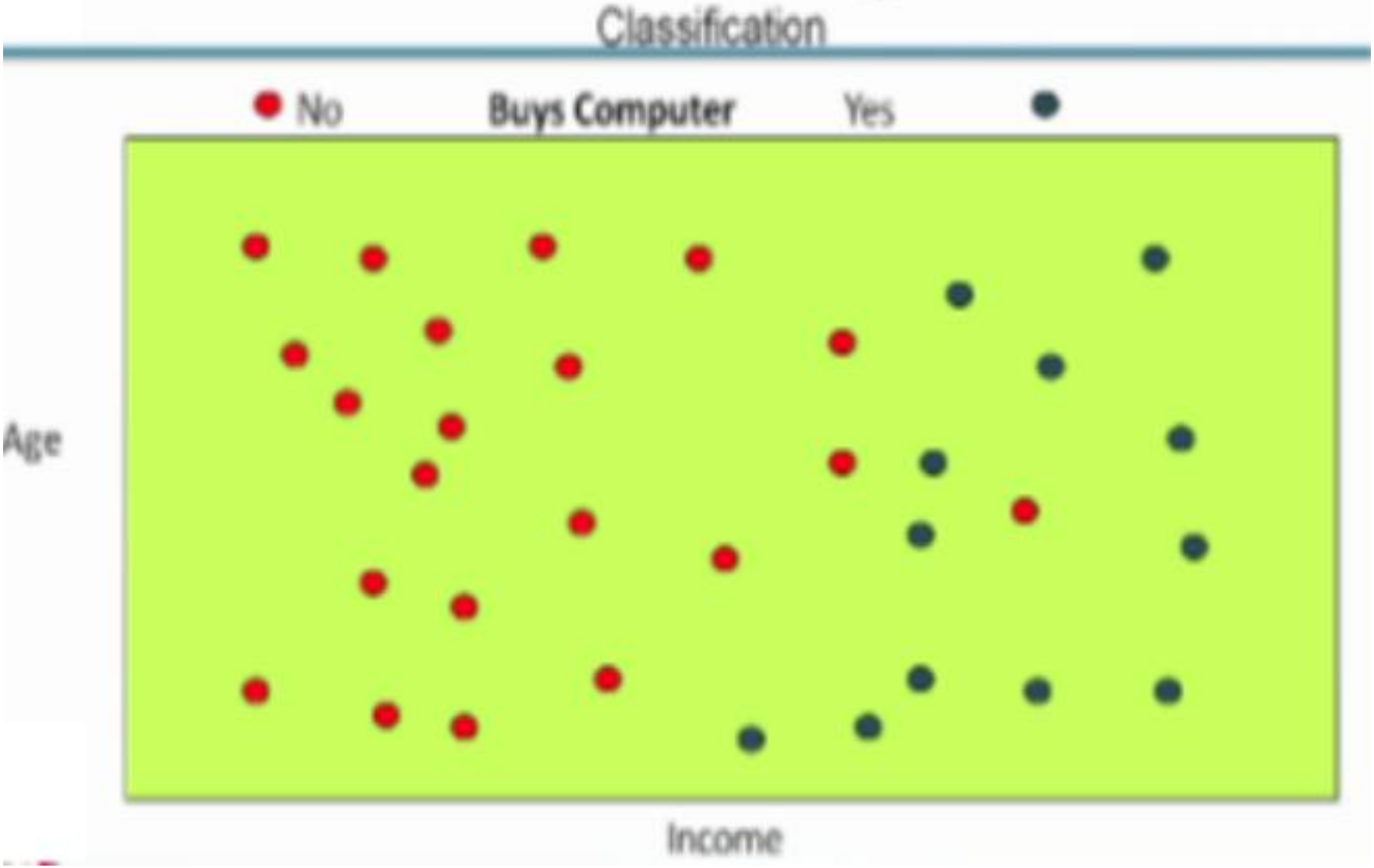


Experience

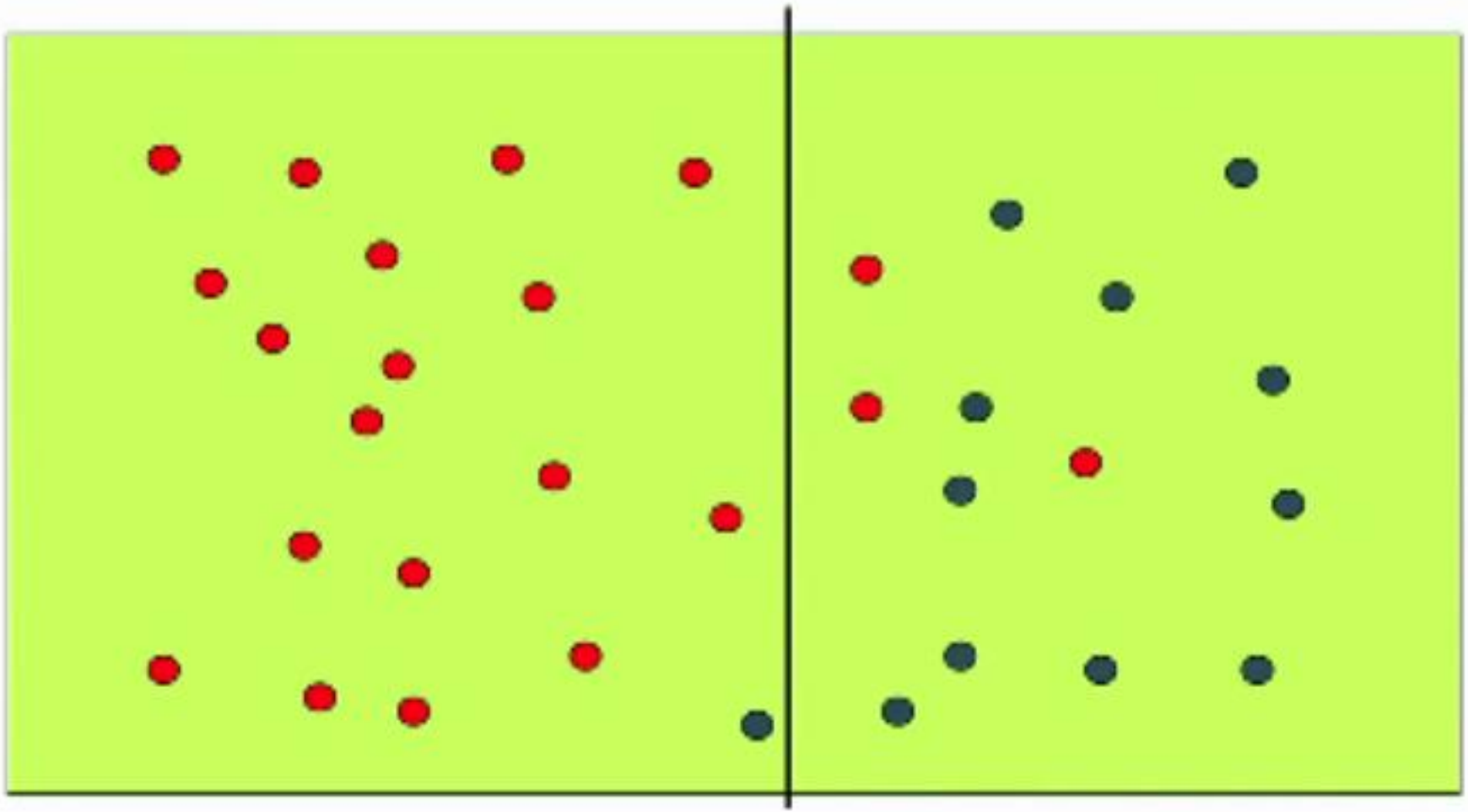
Training Data



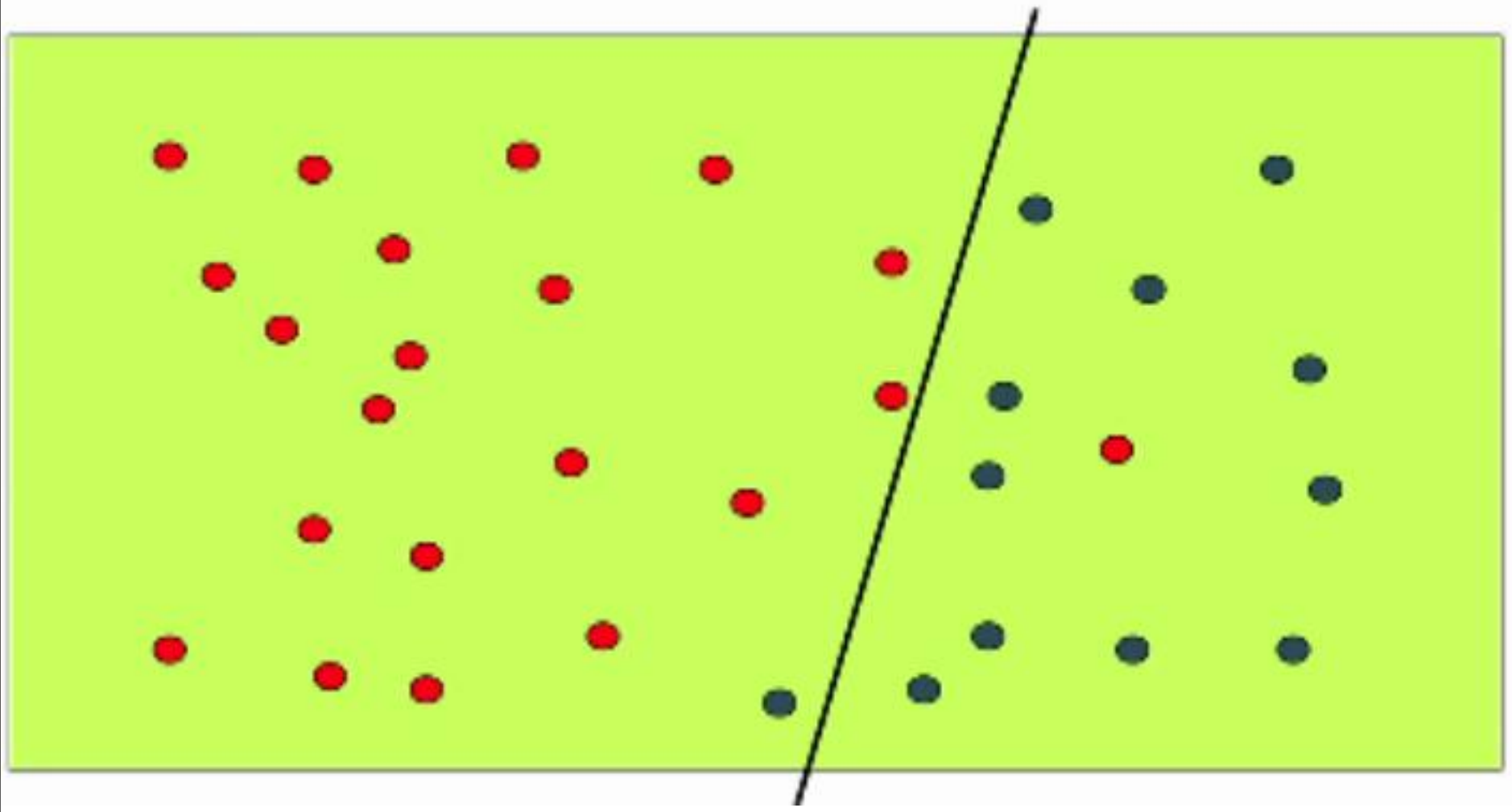
Labeled Training Data



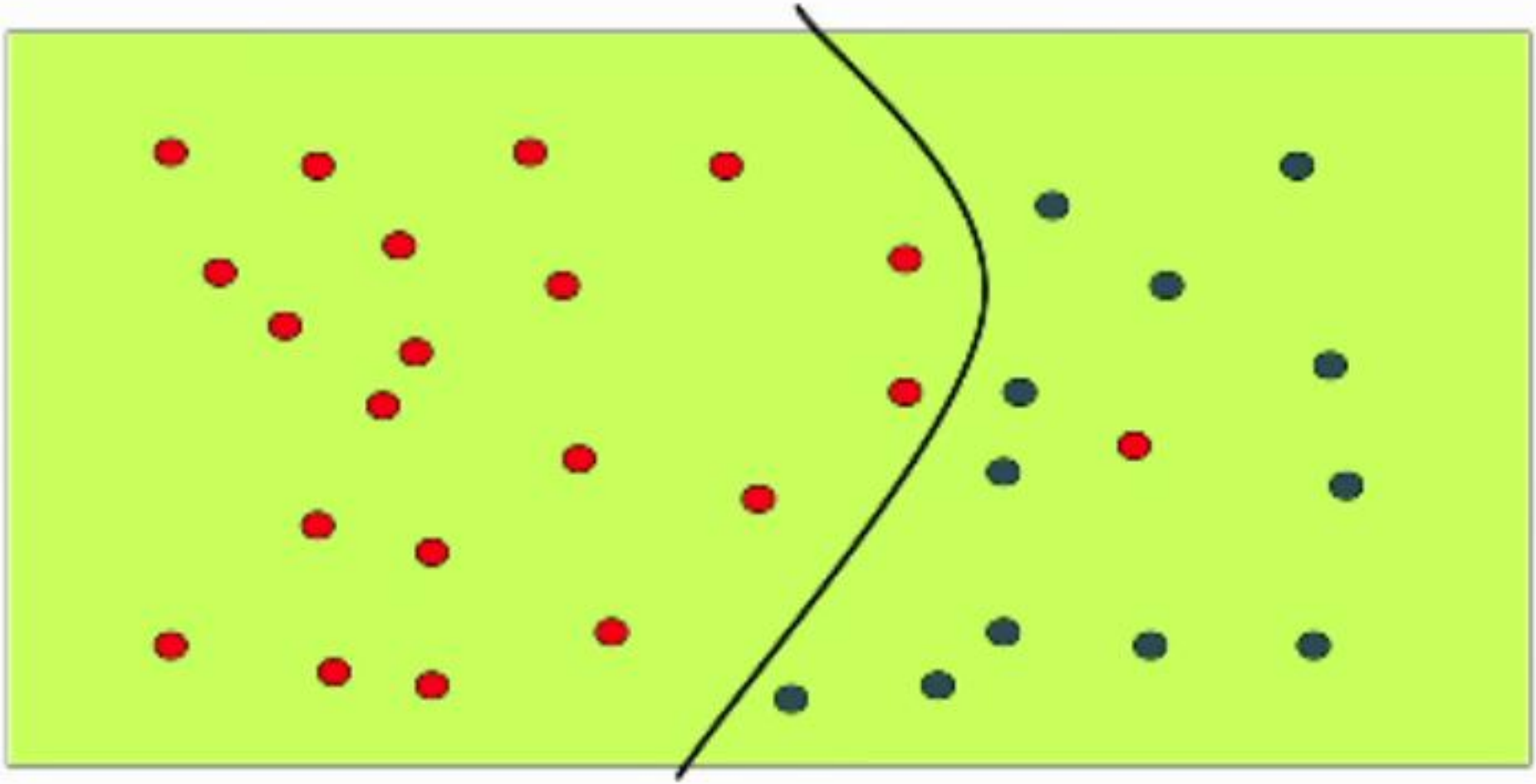
Possible Classifiers



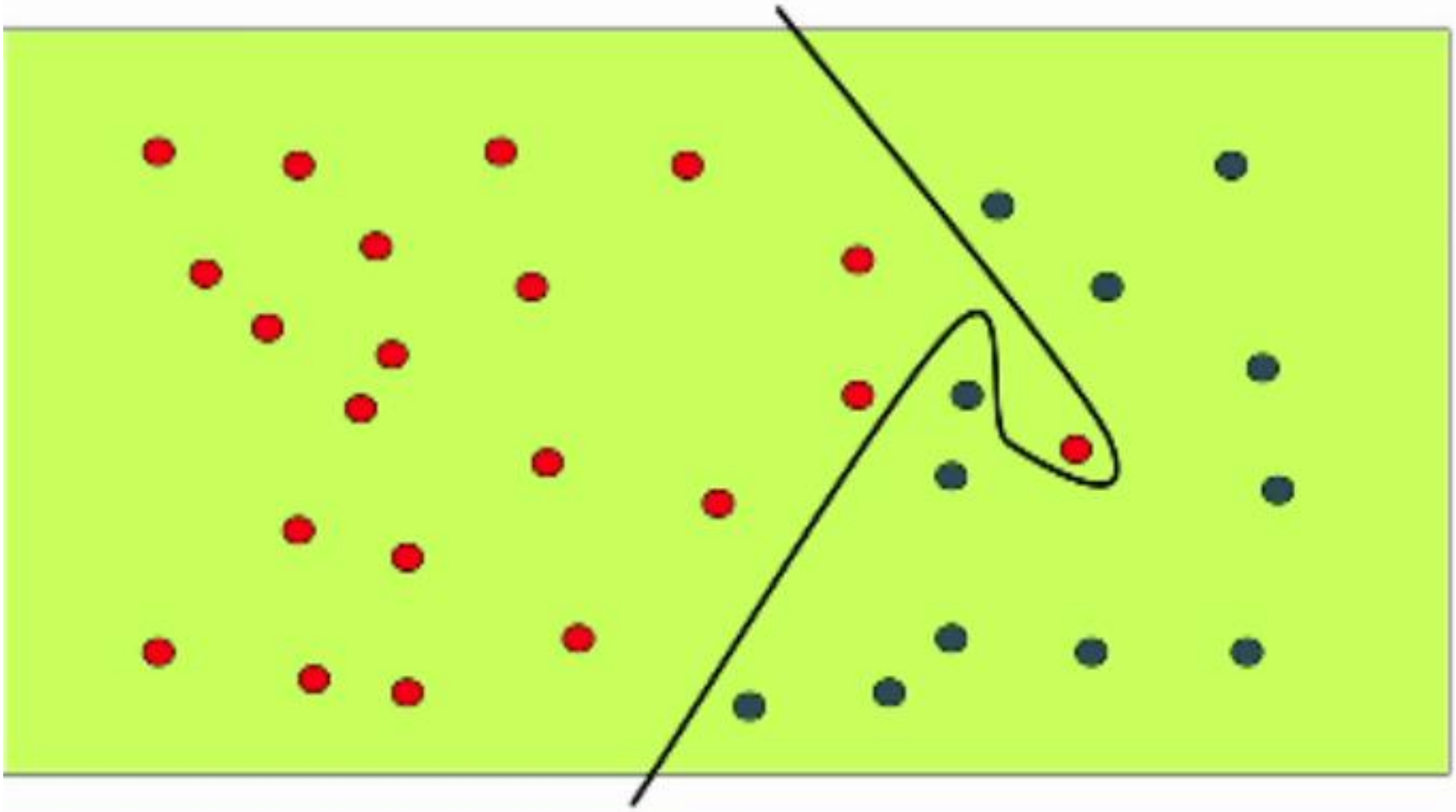
Possible Classifiers



Possible Classifiers



Possible Classifiers

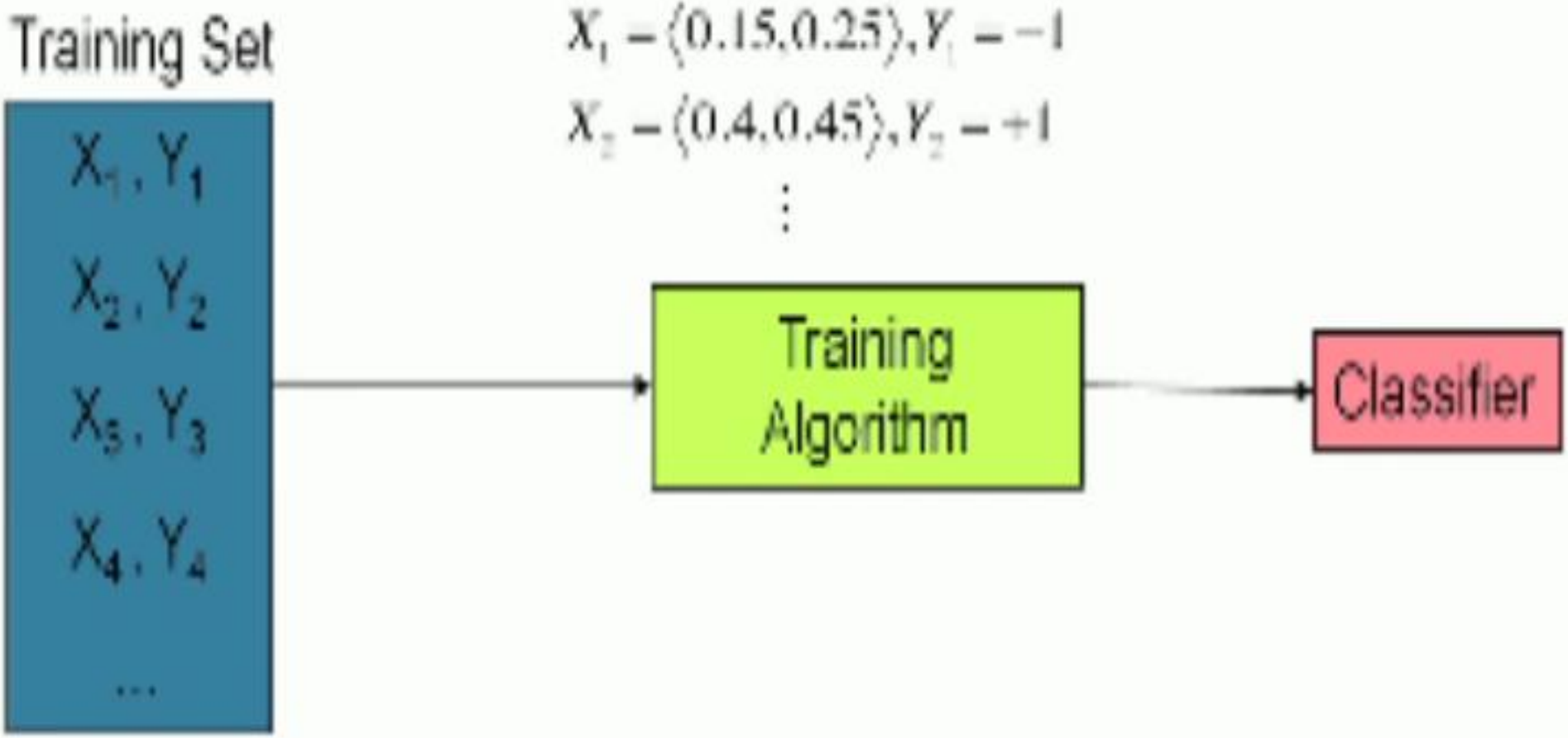


Inductive Bias

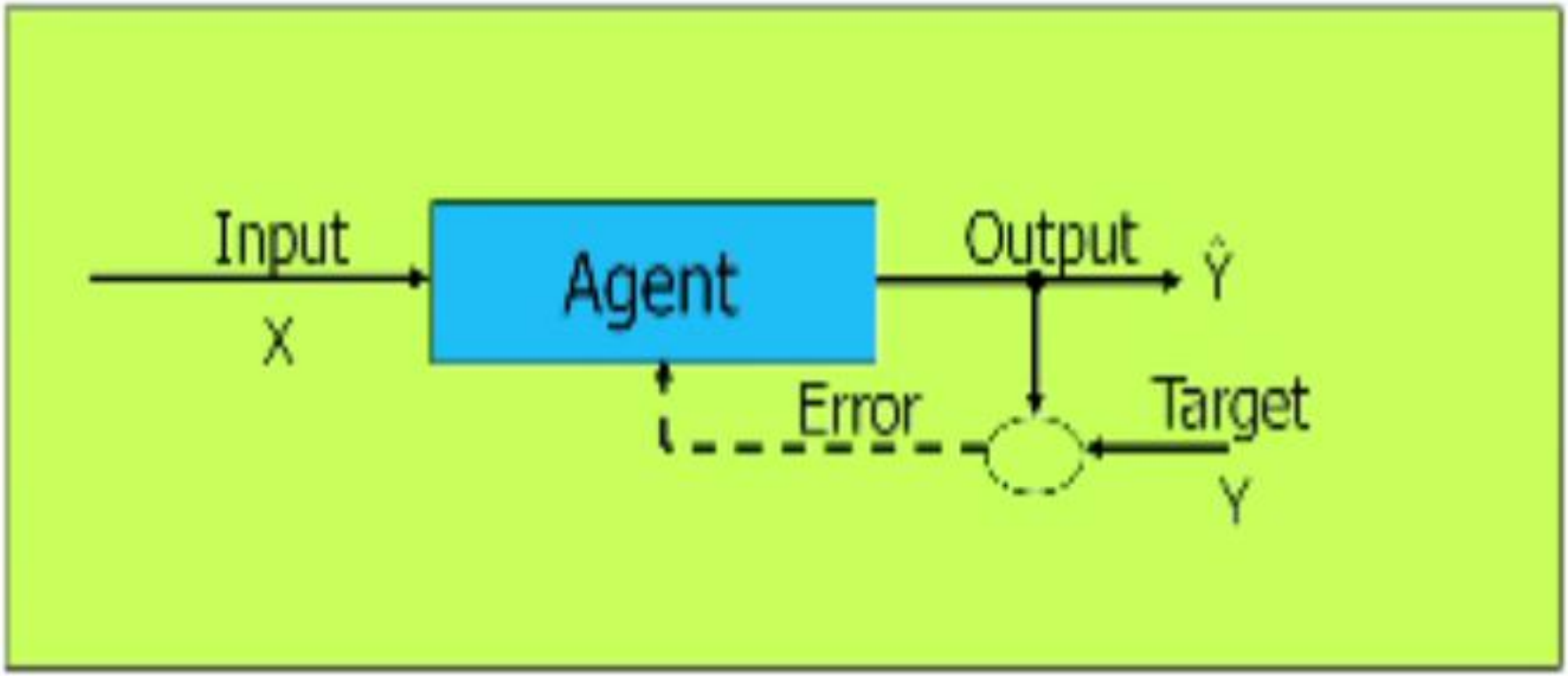
- Need to generalize → Assumptions about lines!

- In general, Inductive bias
  - Language bias
  - Search bias

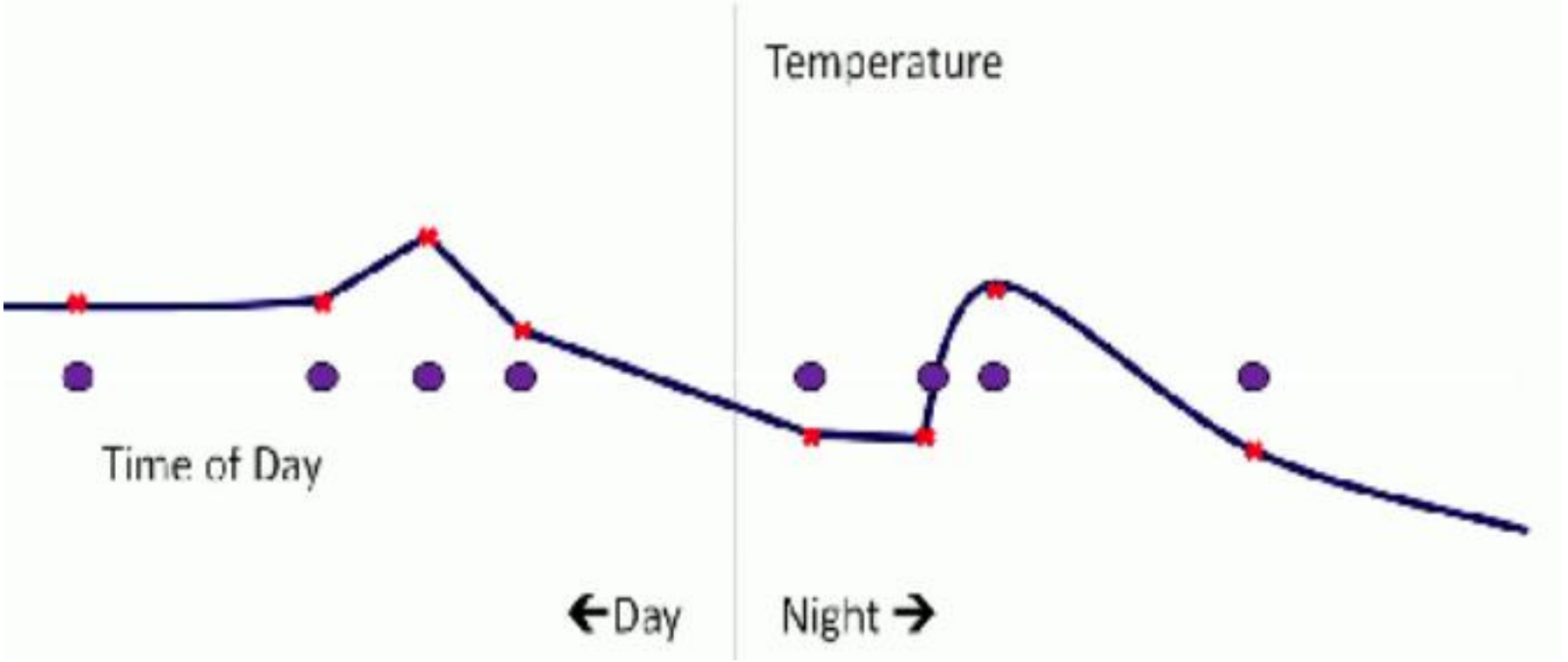
The Process


Training Set
X_1, Y_1
X_2, Y_2
X_3, Y_3
X_4, Y_4
...
$X_1 = (0.15, 0.25), Y_1 = -1$
$X_2 = (0.4, 0.45), Y_2 = +1$
Training Algorithm
Classifier

Training



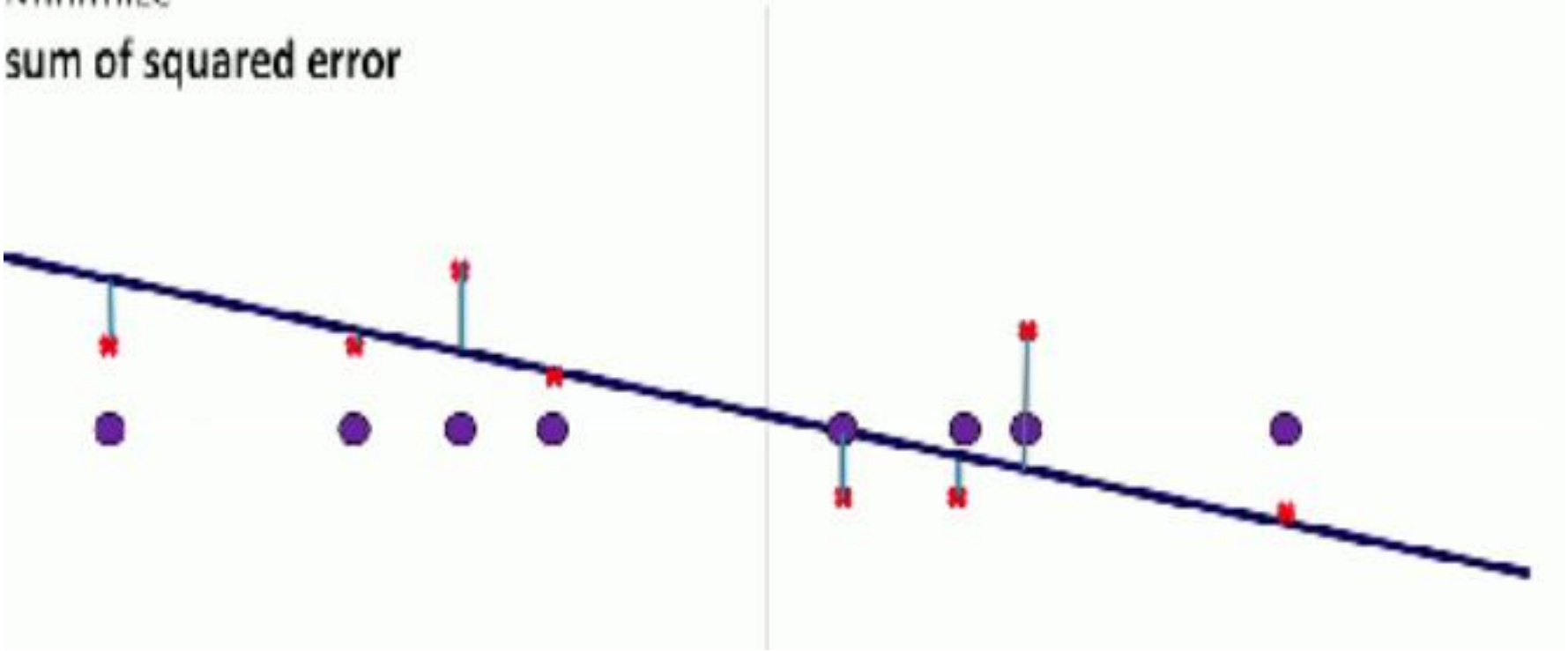
Prediction or Regression



Linear Regression

Minimize

sum of squared error



Linear Regression

- Minimize sum squared error
- With sufficient data simple enough
- With many dimensions, challenge is to avoid over fitting
  - Regularization
- Higher order functions?
  - Basis transformations
  - Ex: $(x_1, x_2) \rightarrow (x_1^2, x_2^2, x_1x_2, x_1, x_2)$

Applications

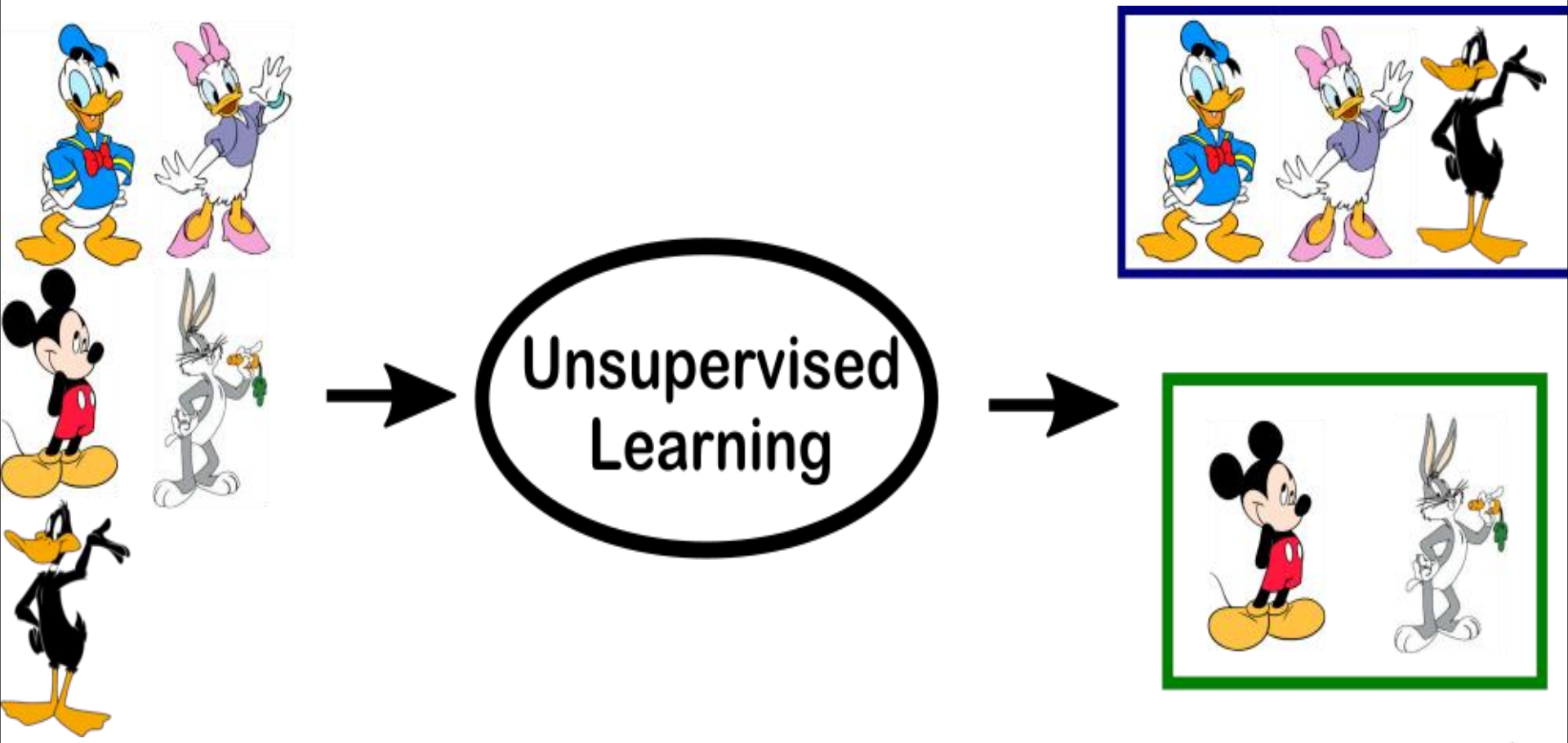
- Time series predictions
  - Rainfall in a certain region
  - Spend on voice calls
- Classification!
- Data reduction
- Trend analysis
  - Linear or exponential
- Risk factor analysis
  - Factors contributing most to output

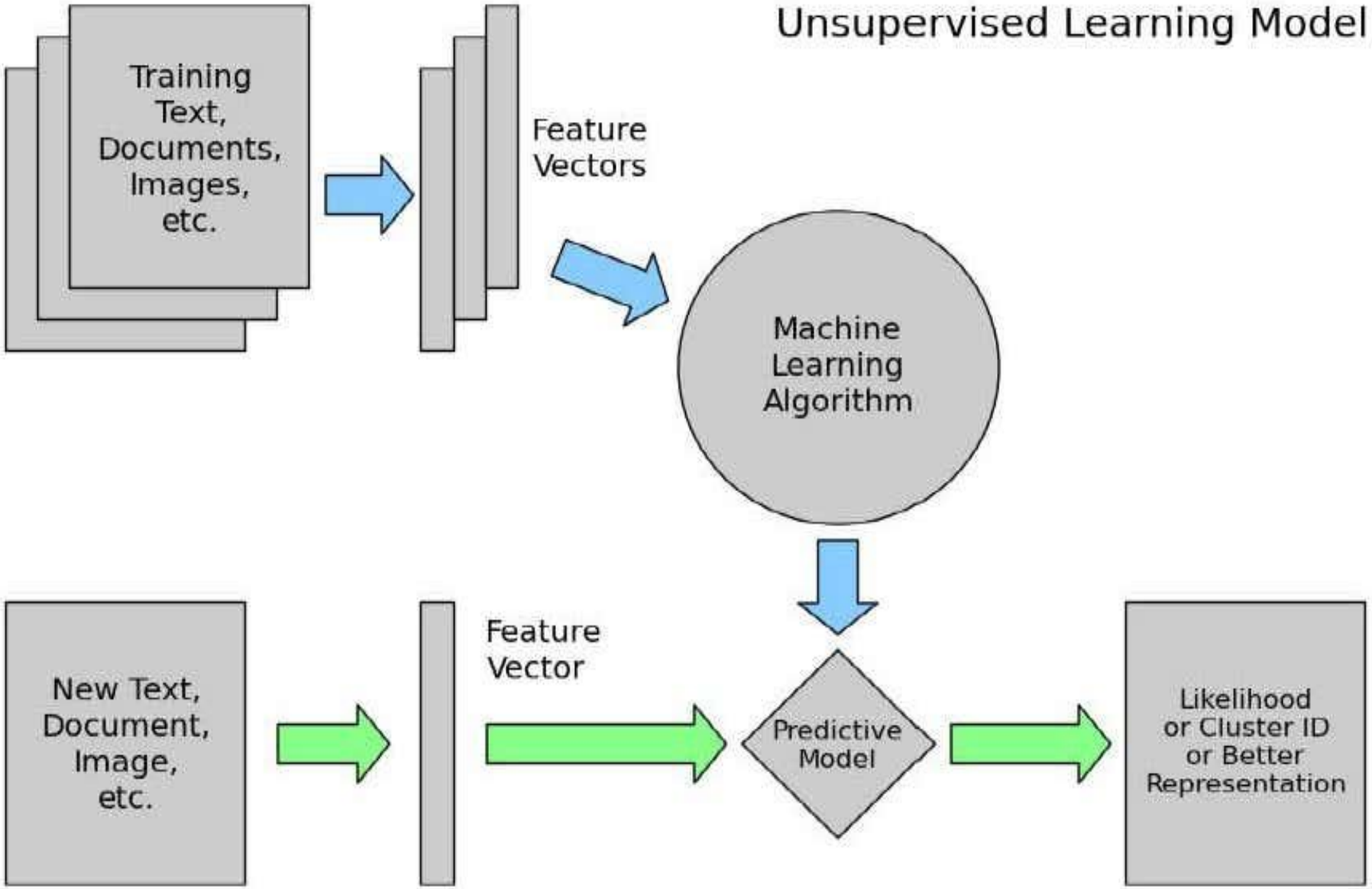
Overview of Unsupervised Learning Algorithm

Types of Unsupervised learning

- **Clustering**: A clustering problem is where you want to discover the inherent groupings in the data, such as grouping customers by purchasing behavior.
- **Association**: An association rule learning problem is where you want to discover rules that describe large portions of your data, such as people that buy X also tend to buy Y.

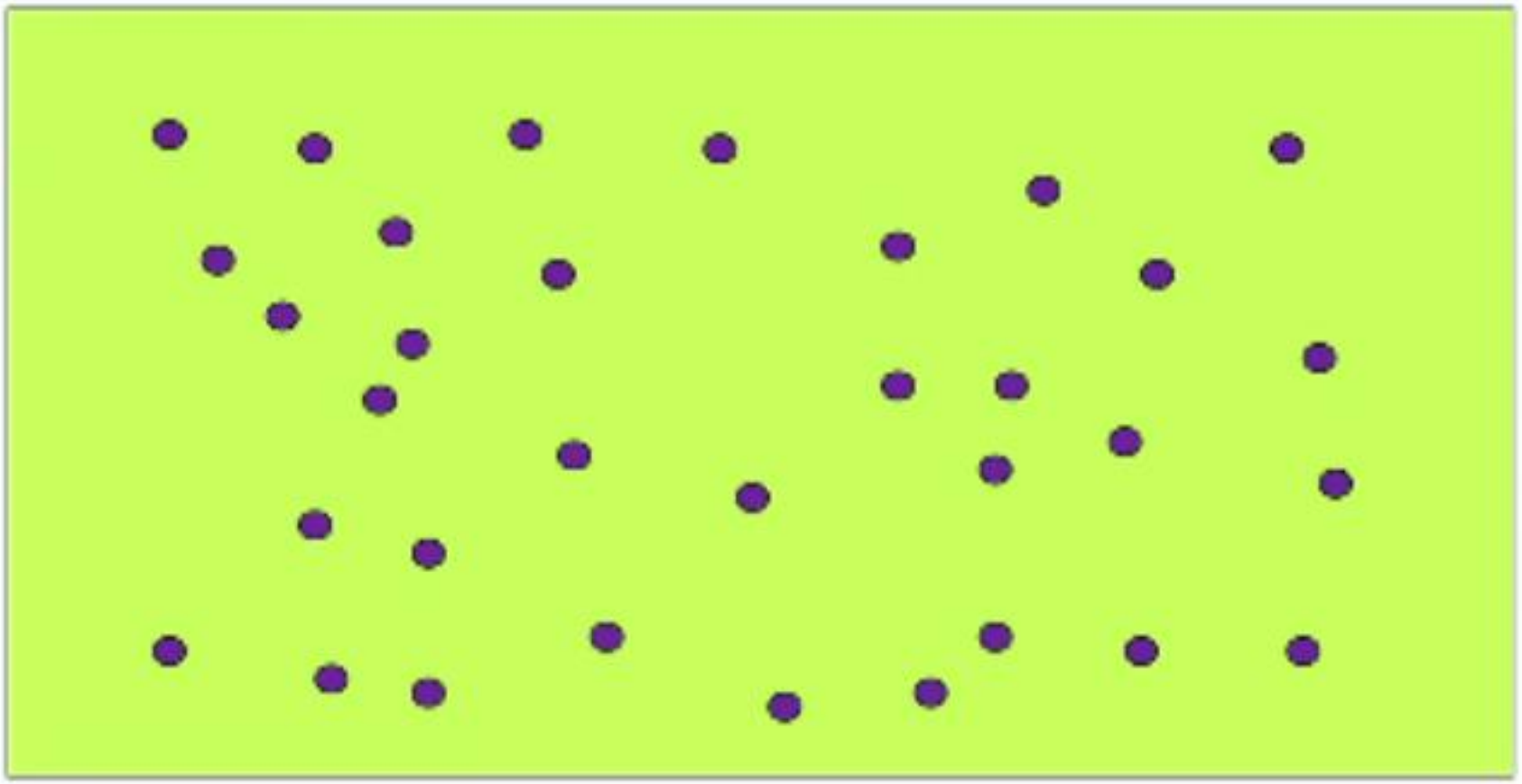
Overview of Unsupervised Learning Algorithm




Unsupervised Learning Model
Training Text, Documents, Images, etc.
Feature Vectors
Machine Learning Algorithm
New Text, Document, Image, etc.
Feature Vector
Predictive Model
Likelihood or Cluster ID or Better Representation

Unlabelled Training Data

Clustering



Applications

- Customer Data
  - Discover classes of customers
- Image pixels
  - Discover regions
- Words
  - Synonyms
- Documents
  - Topics

Image Courtesy: http://ai.brown.edu/~pf/segment/

Association Rule Mining

- Mining frequent patterns and rules
- Association rules: conditional dependencies
- Two stages
  - Find frequent patterns
  - Derive associations ($A \Rightarrow B$) from frequent patterns
- Find patterns in
  - Sequences (time series data, fault analysis)
  - Transactions (market basket data)
  - Graphs (social network analysis)

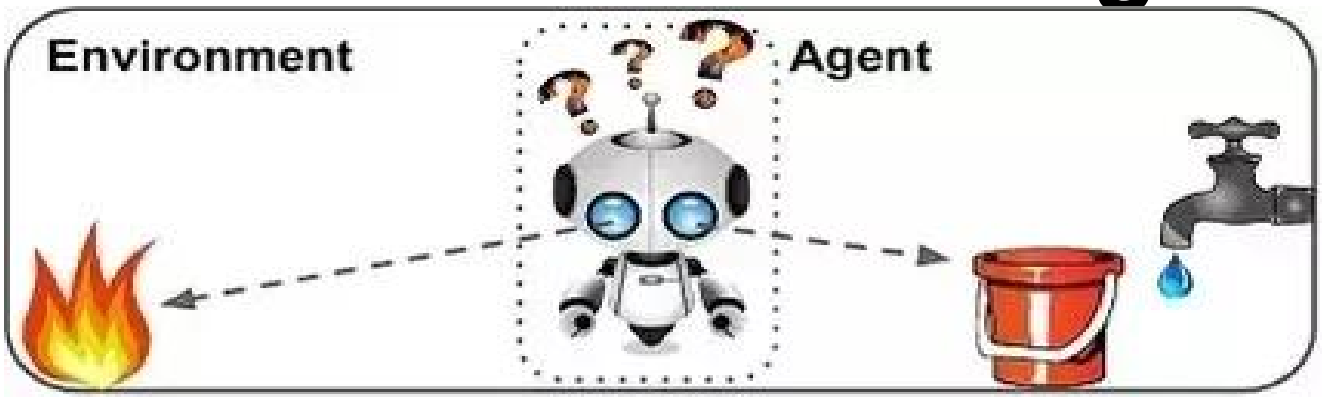
Mining Transactions

- Transaction is a collection of items bought together
  - A (sub)set of items is called an itemset
- Find frequent itemsets
- Itemset A $\Rightarrow$ Itemset B, if both A and A U B are frequent itemsets.

Applications

- Predicting co-occurrence
- Market Basket analysis
- Time series analysis!
  - Trigger Events

Overview of Reinforcement Learning



1. Observe
2. Select action using policy
3. Action!
4. Get reward or penalty
5. Update policy (learning step)
6. Iterate until an optimal policy is found

Learning to Control

- Popular models of machine learning
  - Supervised: Classification, Regression, etc.
  - Unsupervised: Clustering, Frequent patterns, etc.

- How did you learn to cycle?
  - Neither of the above
  - Trial and error!
  - Falling down hurts!

RL Framework

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

Applications of RL

- Game playing
  - Backgammon – world's best player!
  - Atari games from scratch
- Autonomous agents
  - Robot navigation
- Adaptive control
  - Helicopter pilot!
- Combinatorial optimization
  - VLSI placement
- Intelligent Tutoring Systems

Basic steps used in Machine Learning

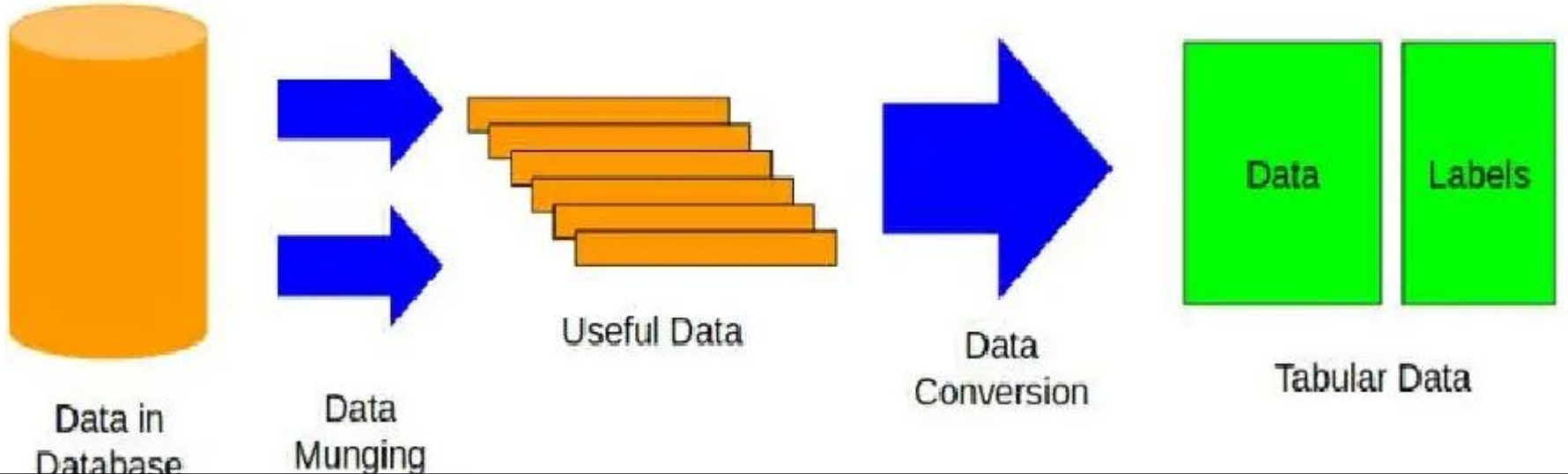
Five basic steps used to perform a machine learning task:

Collecting data

- Be it the raw data from excel, access text files etc. this step (gathering past data) forms the foundation of the future learning.

Preparing the data

- Any analytical process thrives on the quality of the data used like missing values imputation, cleaning etc.



- **Training a model**
  - Choosing the appropriate algorithm and representation of data in the form of the model.
  - Cleaned data is split into two parts-train and test.
    - First part (training data) is used for developing the model.
    - Second part (test data) is used as a reference
- **Evaluating the model**
  - Determines the precision in the choice of the algorithm based on the outcome
- **Improving the performance**
  - Involve choosing a different model altogether or introducing more variables to augment the efficiency