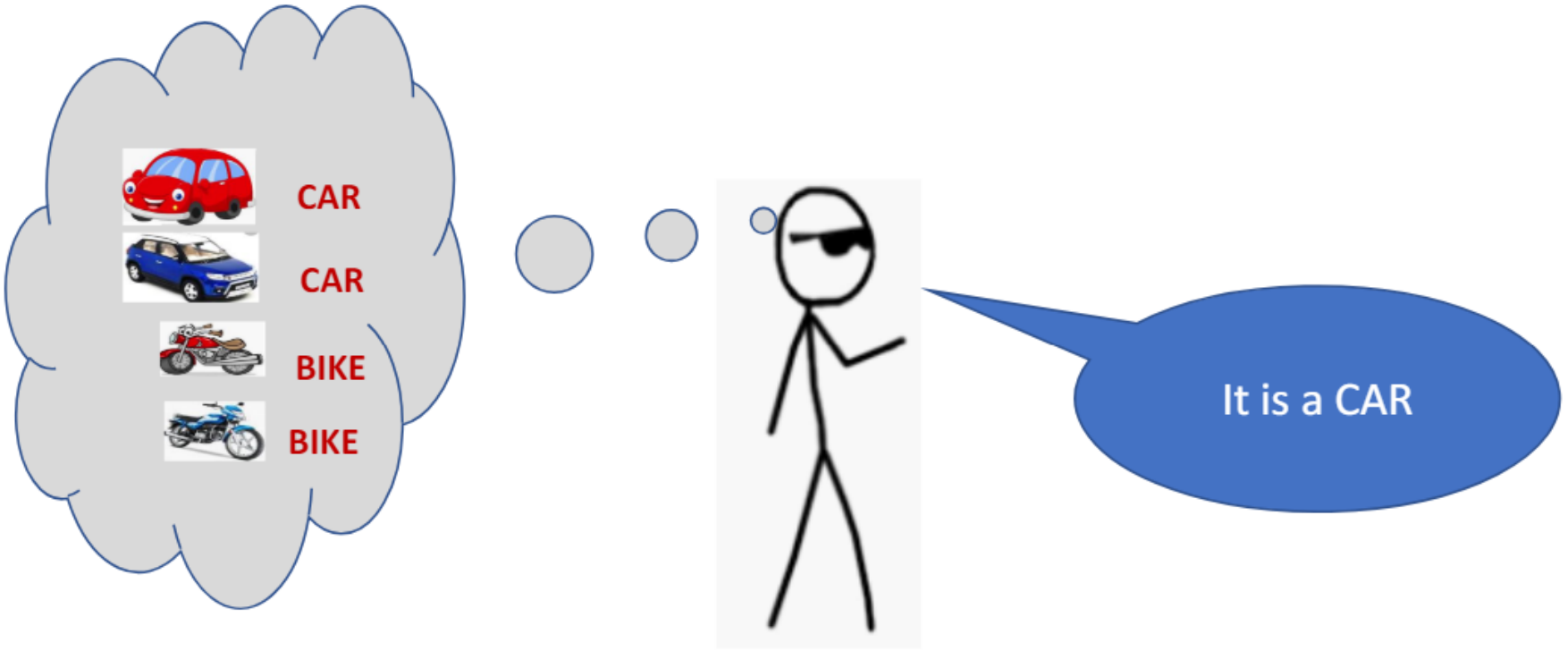
Introduction to Machine Learning

What is this object?

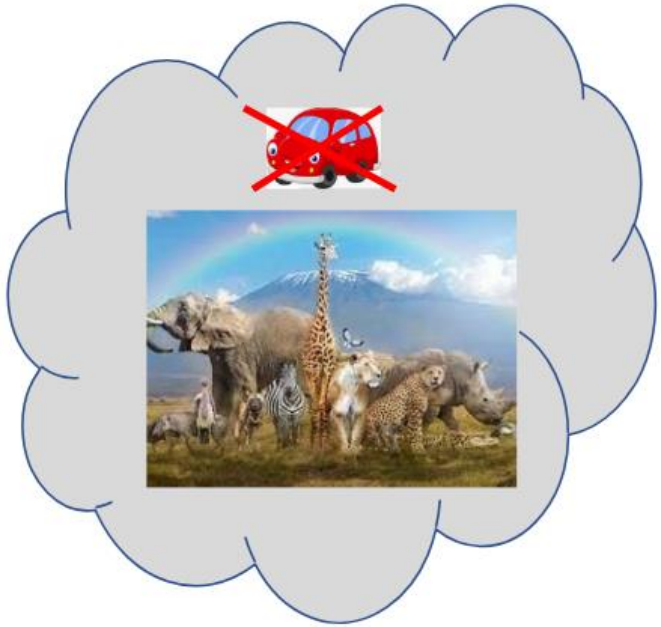
Human can learn from past experience
and make decision of its own

What is this object?



Let us ask the same question to him

What is this object?



[But, he is a human being. He can observe and learn]

Let us make him learn

show him

CAR

CAR

BIKE

BIKE

Let us ask the same question now

What is this object?

CAR

CAR

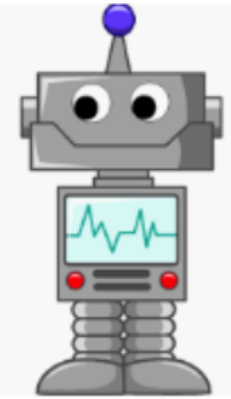
CAR

BIKE

BIKE

Past experience

What about a Machine ?



We can ask a machine

- To perform an arithmetic operations such as
  - Addition
  - Multiplication
  - Division

Machines follow instructions

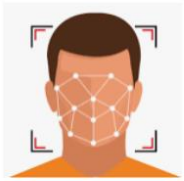
[It can not take decision of its own]

But

[We want a machine to act like a human]

What is Machine Learning?

[to identify this object.]

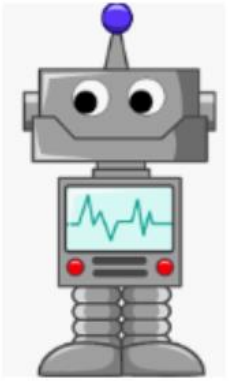


recognize face

Price in 2025?

[predict the price in future]

What is Machine Learning?



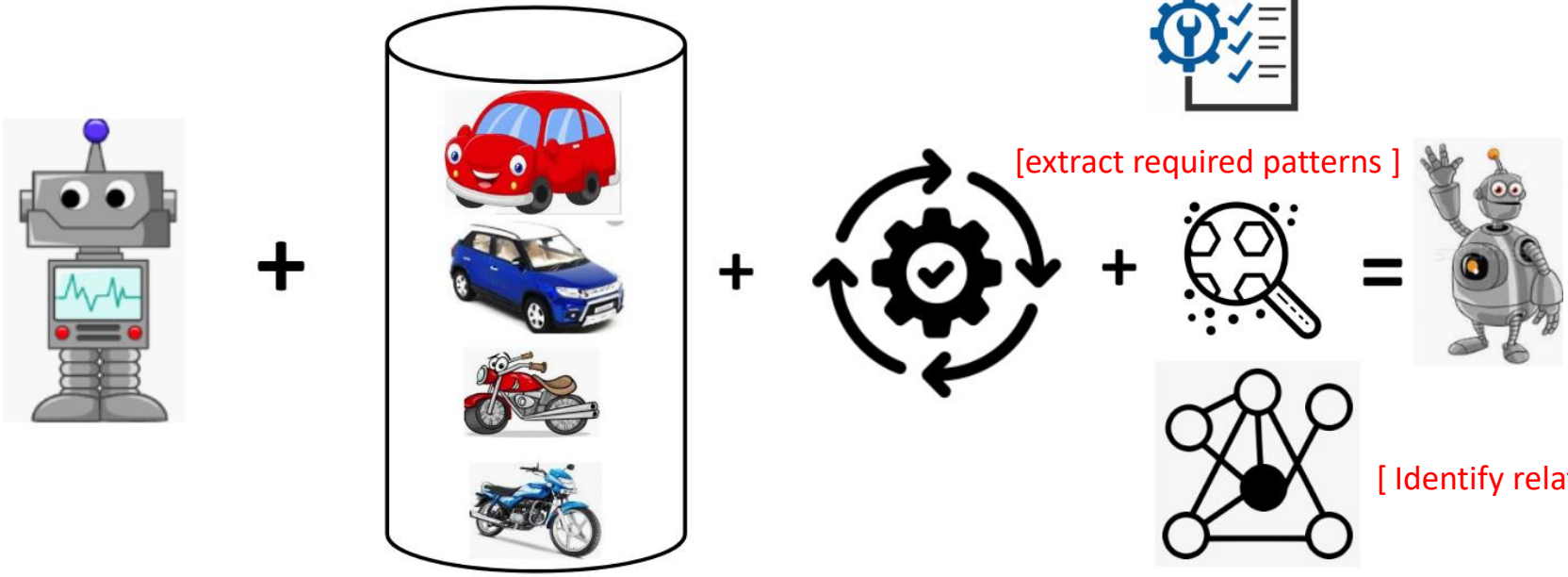
+

Dataset

[
This what we called as Data or Training dataset

So, we first need to provide training dataset to the machine
]

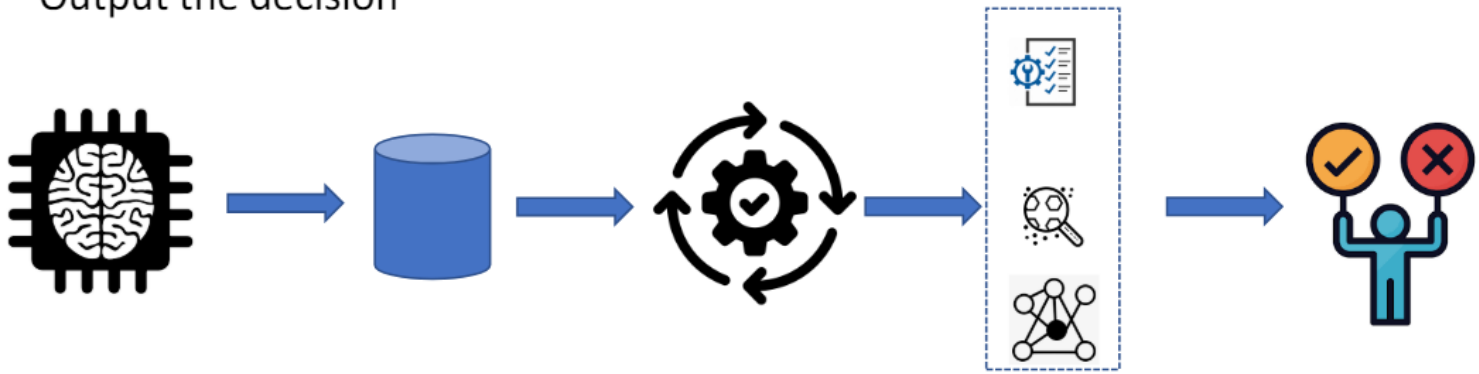
What is Machine Learning?



In summary, what is machine learning?

Given a machine learning problem

- Identify and create the appropriate dataset
- Perform computation to learn
  - Required rules, pattern and relations
- Output the decision



What is Machine Learning?

"Learning is any process by which a system improves performance from experience."

- Herbert Simon

Definition by Tom Mitchell (1998):

Machine Learning is the study of algorithms that

- improve their performance *P*
- at some task *T*
- with experience *E*.

A well-defined learning task is given by <*P*, *T*, *E*>.

Defining the Learning Task

Improve on task T, with respect to performance metric P, based on experience E

T: Playing checkers
P: Percentage of games won against an arbitrary opponent
E: Playing practice games against itself

T: Recognizing hand-written words
P: Percentage of words correctly classified
E: Database of human-labeled images of handwritten words

T: Driving on four-lane highways using vision sensors
P: Average distance traveled before a human-judged error
E: A sequence of images and steering commands recorded while observing a human driver.

T: Categorize email messages as spam or legitimate.
P: Percentage of email messages correctly classified.
E: Database of emails, some with human-given labels

When Do We Use Machine Learning?

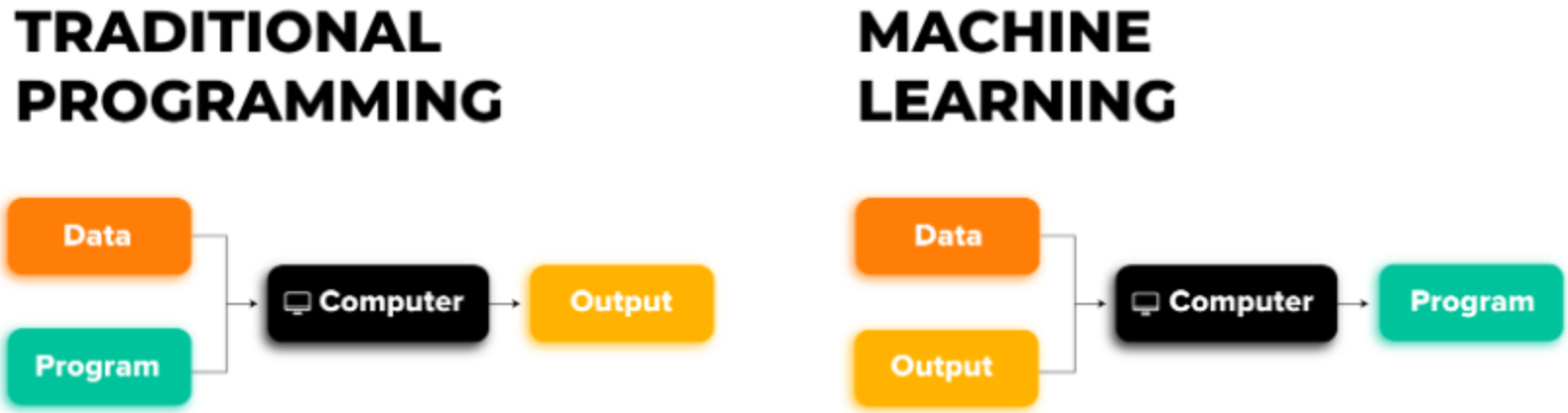
ML is used when:

- Human expertise does not exist (navigating on Mars)
- Humans can't explain their expertise (speech recognition)
- Models must be customized (personalized medicine)

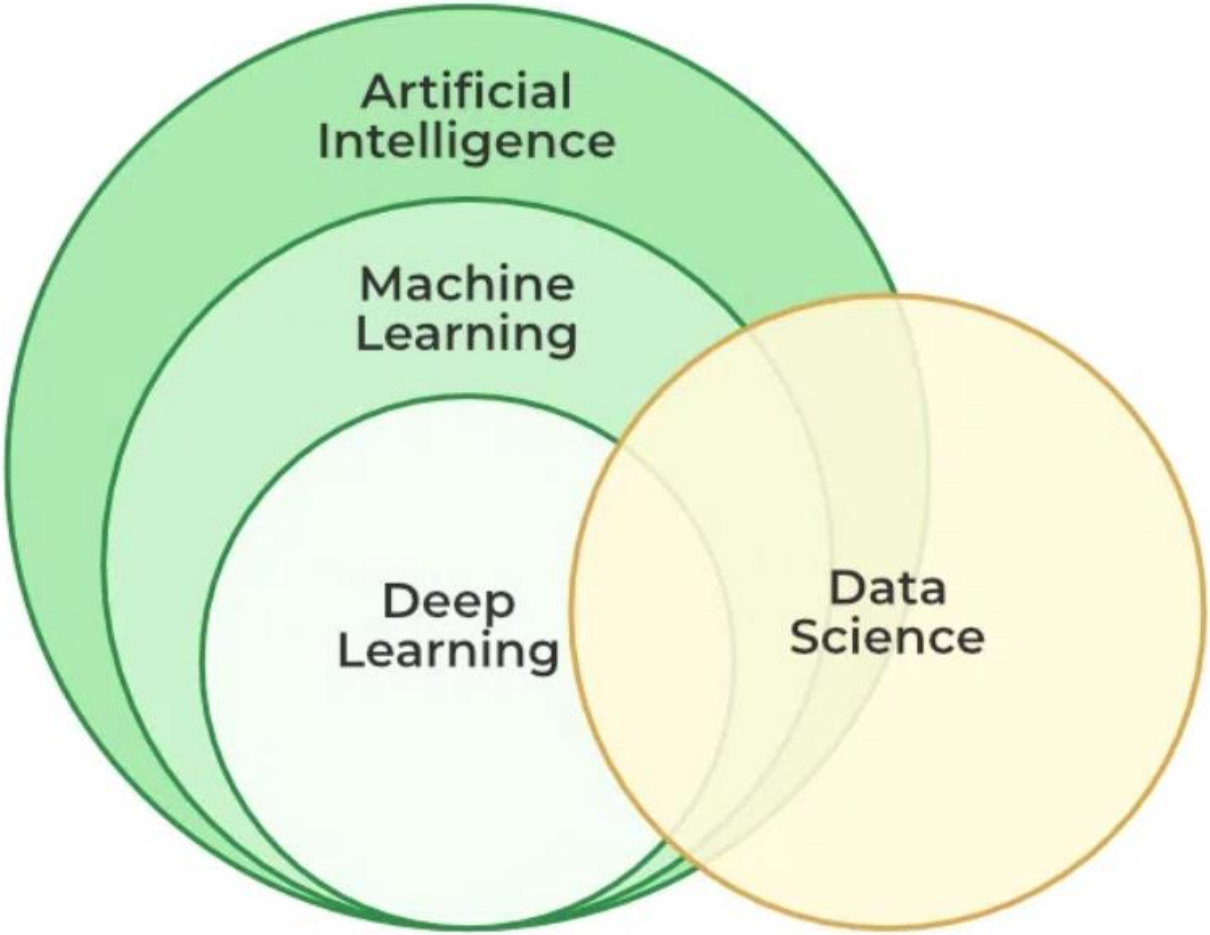
Learning isn't always useful:

- There is no need to "learn" to calculate payroll

Traditional programming vs Machine Learning?

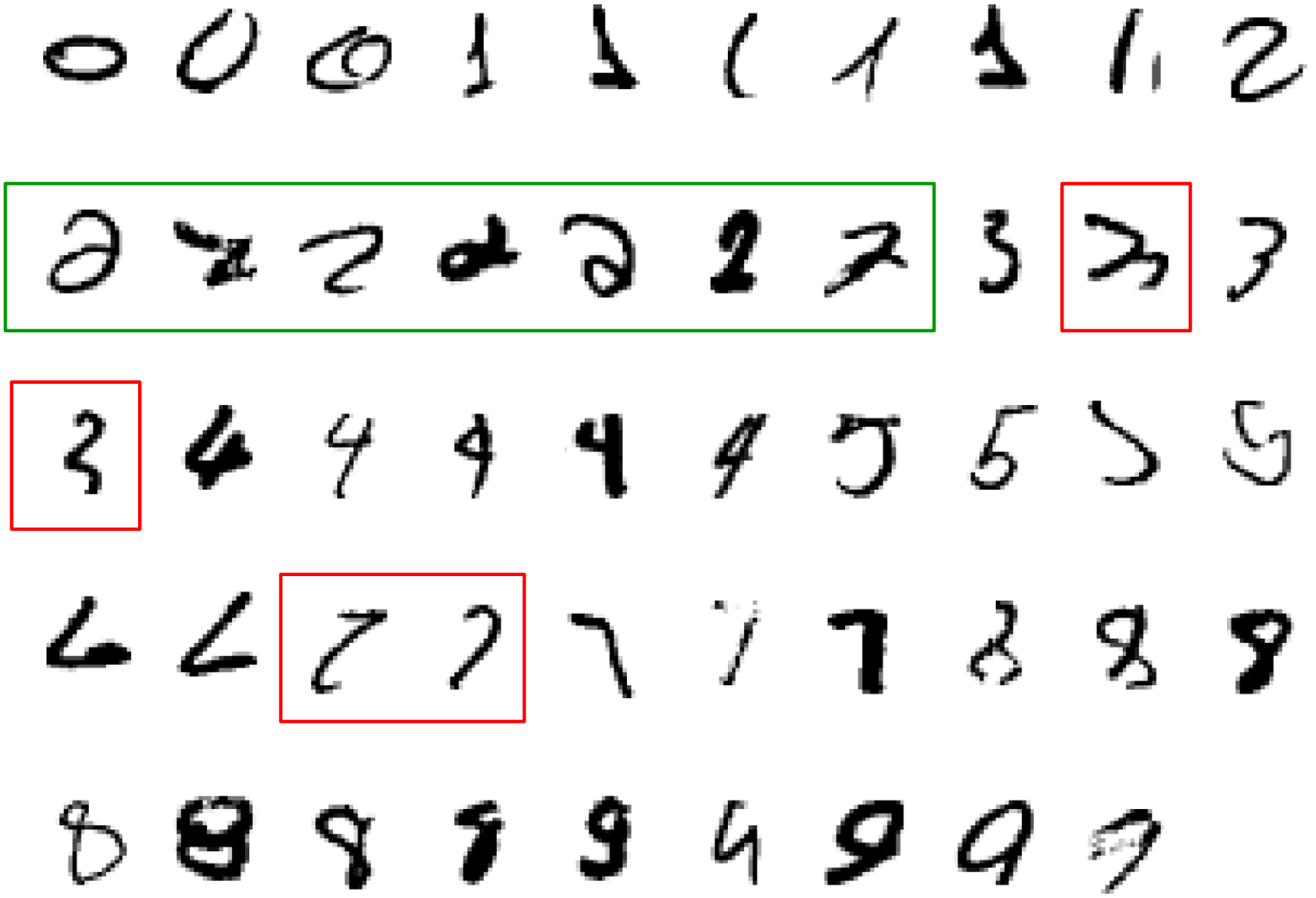


Data Science vs AI, ML, DL

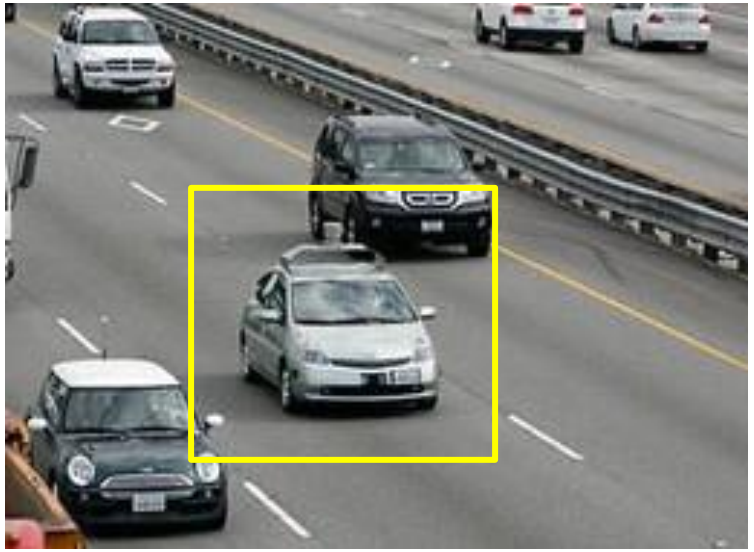


State of the Art Applications of Machine Learning

A classic example of a task that requires machine learning:
It is very hard to say what makes a 2



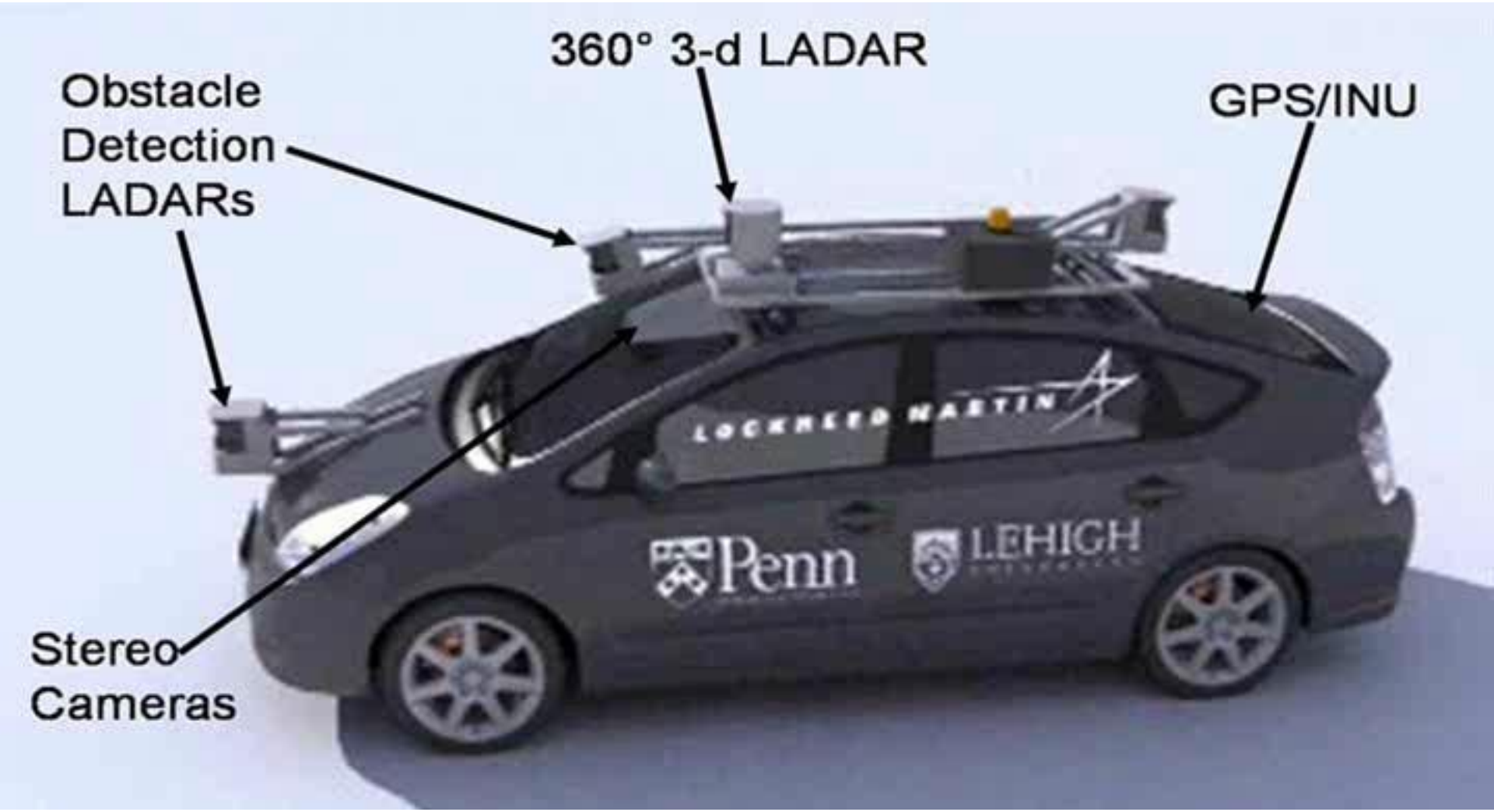
Autonomous Cars



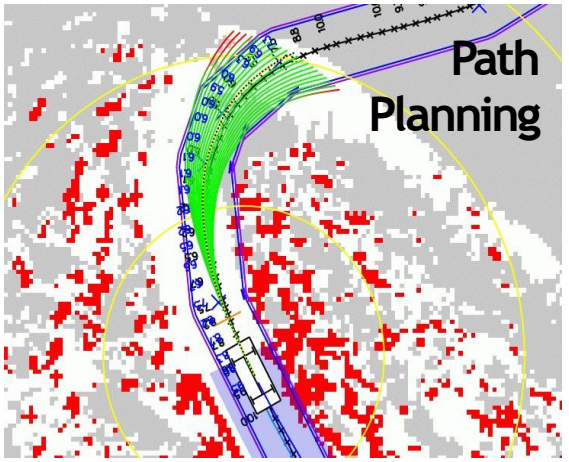
- Nevada made it legal for autonomous cars to drive on roads in June 2011
- As of 2013, four states (Nevada, Florida, California, and Michigan) have legalized autonomous cars

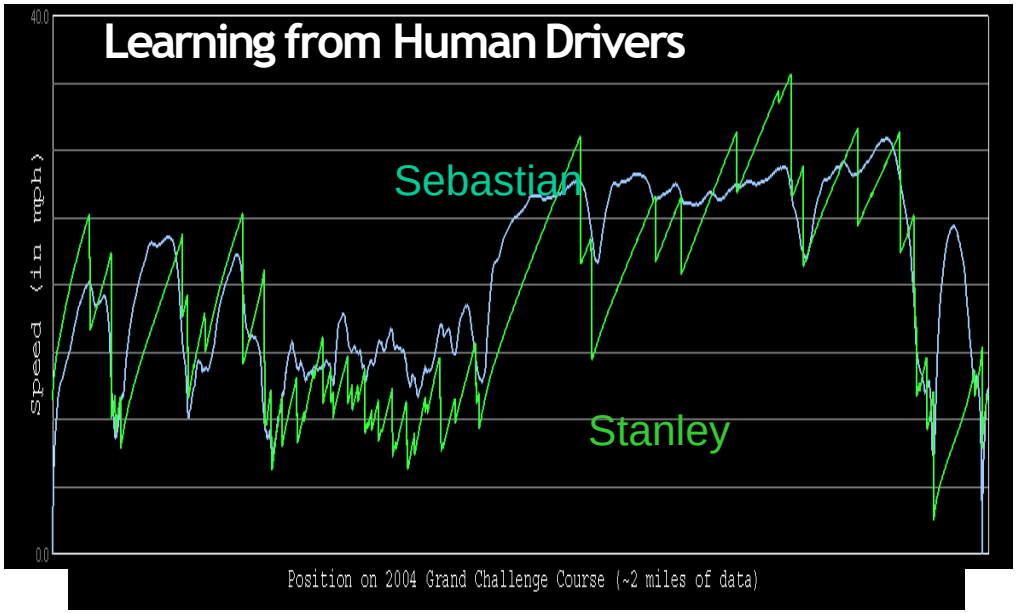
Penn's Autonomous Car →
(Ben Franklin Racing Team)

Autonomous Car Sensors



Autonomous Car Technology

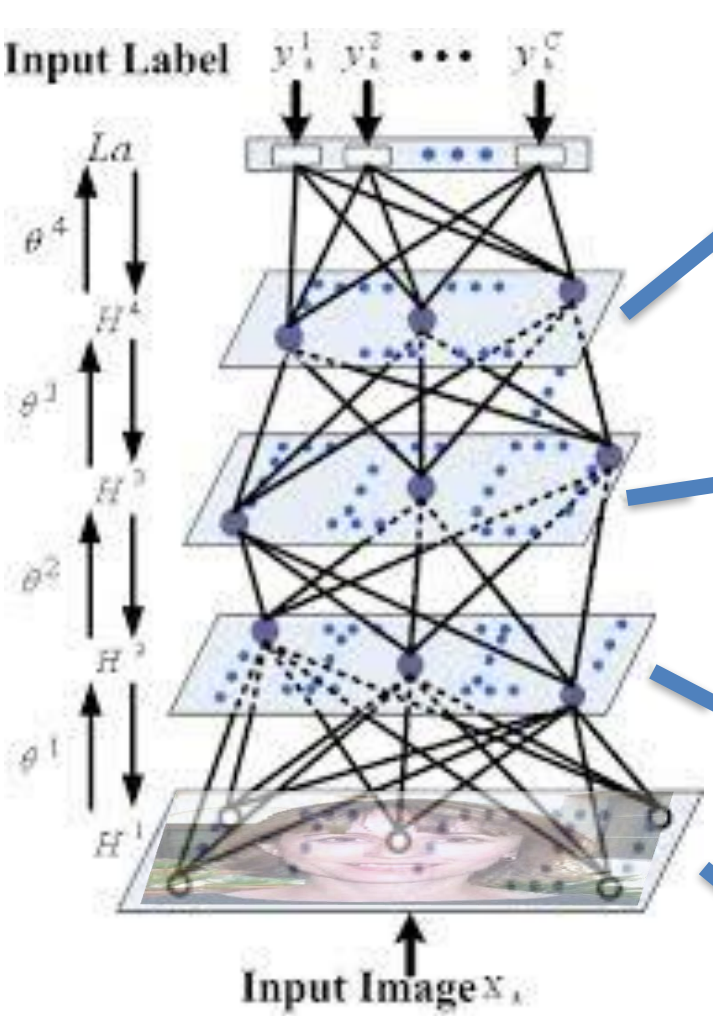


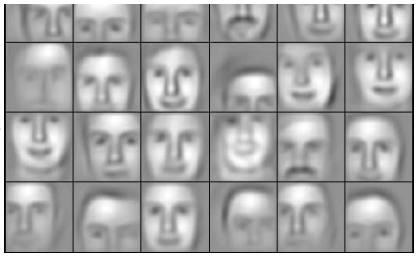


ML Application: Face Detection

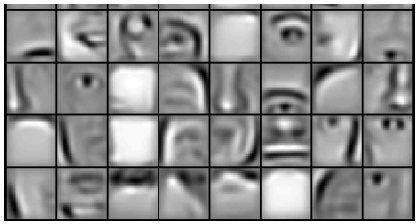
- Objects – image patches
- Classes – “face” and “not face”

Deep Belief Net on Face Images

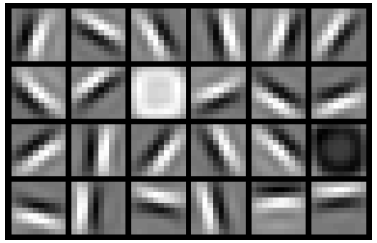




object models



object parts (combination of edges)



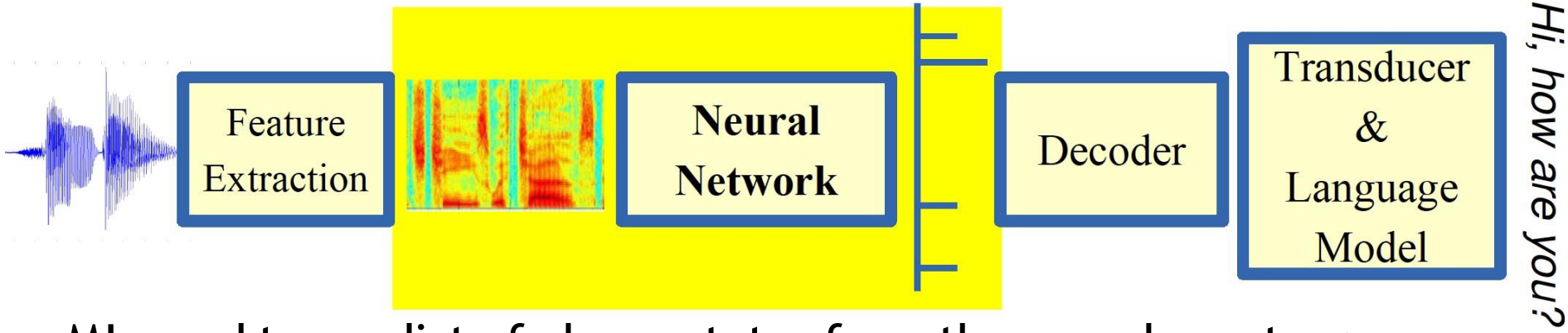
edges

pixels

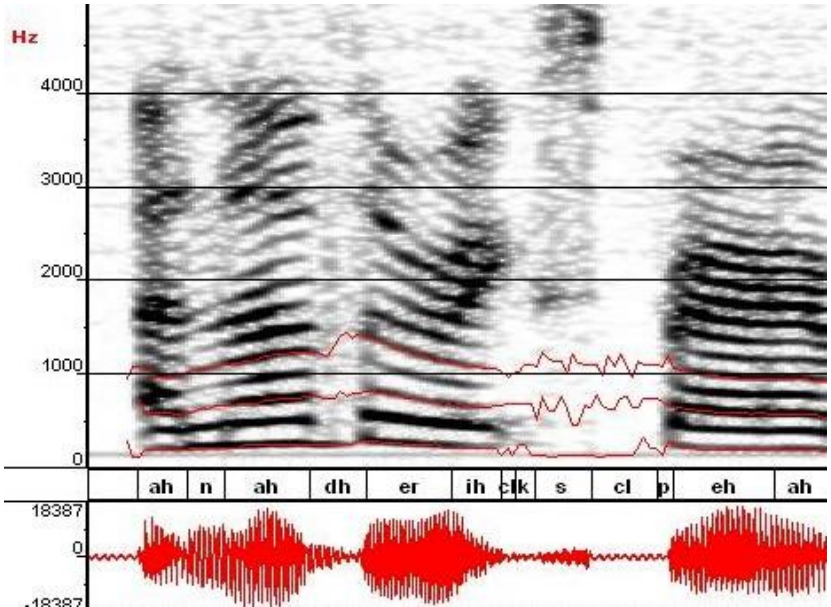
Scene Labeling via Deep Learning

Machine Learning in Automatic Speech Recognition

A Typical Speech Recognition System



ML used to predict of phone states from the sound spectrogram



Deep learning has state-of-the-art results

# Hidden Layers	1	2	4	8	10	12
Word Error Rate%	16.0	12.8	11.4	10.9	11.0	11.1

Baseline GMM performance = 15.4%

Types of Learning

Types of Learning

- **Supervised (inductive) learning**
  - Given: training data + desired outputs (labels)
- **Unsupervised learning**
  - Given: training data (without desired outputs)
- **Semi-supervised learning**
  - Given: training data + a few desired outputs
- **Reinforcement learning**
  - Rewards from sequence of actions

What is Supervised Learning?


CAR


CAR

+


BIKE


BIKE

Samples Labels

= **Training Dataset**

Identify the features which can represent the objects

$$F = \{f_1 f_2 f_3 \dots f_k\}$$

Feature set={ #Wheel Height Weight Color }

[In supervised learning, we need some thing called a Labelled Training Dataset]

What is Supervised Learning?


CAR


CAR


BIKE


BIKE

Samples Labels

= **Training Dataset**

$f($  $,\quad\quad)=$

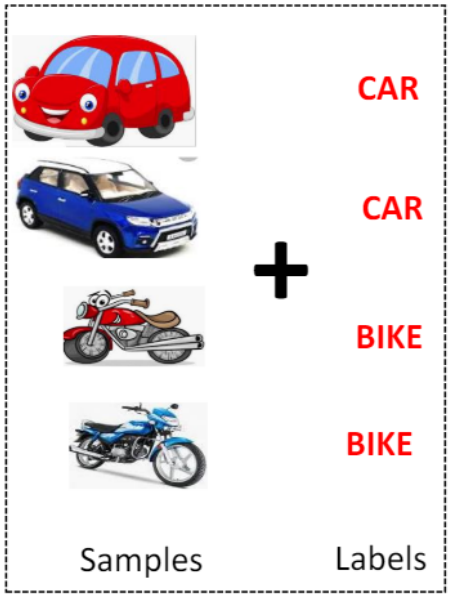
$f($   $)=$ CAR

Classification

[Given a labelled dataset, the task is to devise a function which takes the dataset, and a new sample, and produces an output value.]

[If the possible output values of the function are predefined and discrete/categorical, it is called Classification

What is Supervised Learning?



= **Training Dataset**

Classification

$f($  ,  $)=$ CAR

[Predefined classes means, it will produce output only from the labels defined in the dataset. For example, even if we input a bus, it will produce either CAR or BIKE]

Supervised Learning: Classification

- Objects – people
- Classes – “approve”, “deny”

	income	debt	married	age	approve	deny
John Smith	200,000	0	yes	80		☑
Peter White	60,000	1,000	no	30	☑	
Ann Clark	100,000	10,000	yes	40	☑	
Susan Ho	0	20,000	no	25		☑

Classification: Applications

- Face recognition: Pose, lighting, occlusion (glasses, beard), make-up, hair style

- Character recognition: Different handwriting styles.

- Speech recognition: Temporal dependency.
  - Use of a dictionary or the syntax of the language.
  - Sensor fusion: Combine multiple modalities; eg, visual (lip image) and acoustic for speech

- Medical diagnosis: From symptoms to illnesses

Regression

Dataset

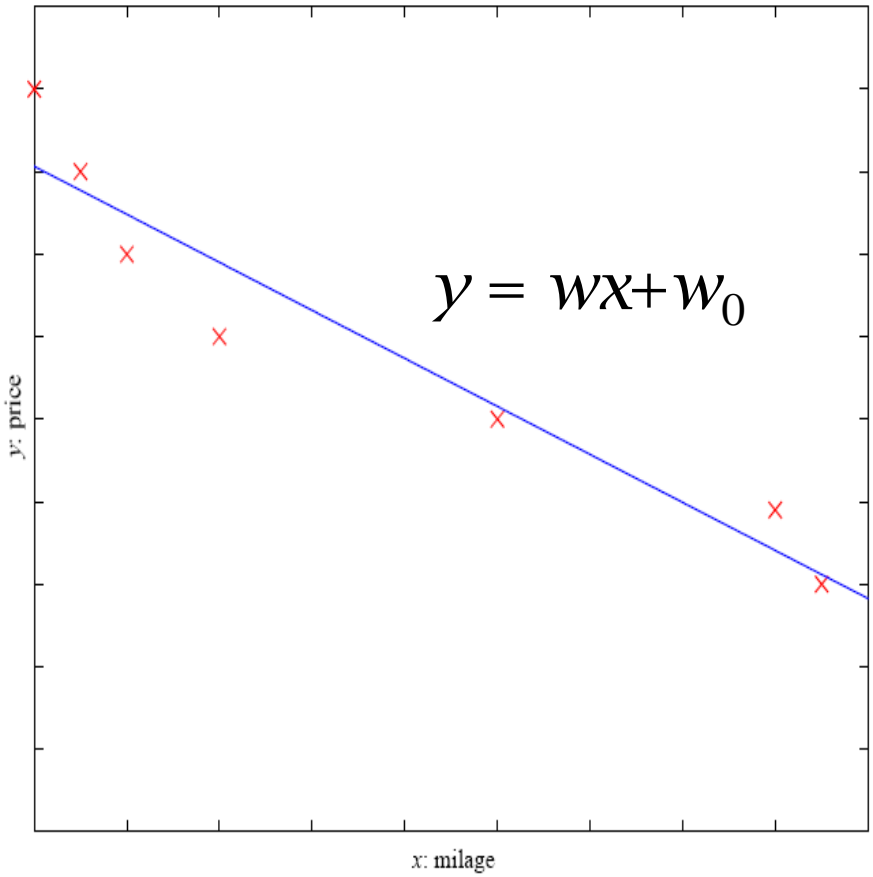
Regression

$f($  $)= 20500.50$

[If the possible output values of the function are continuous real values, then it is called Regression

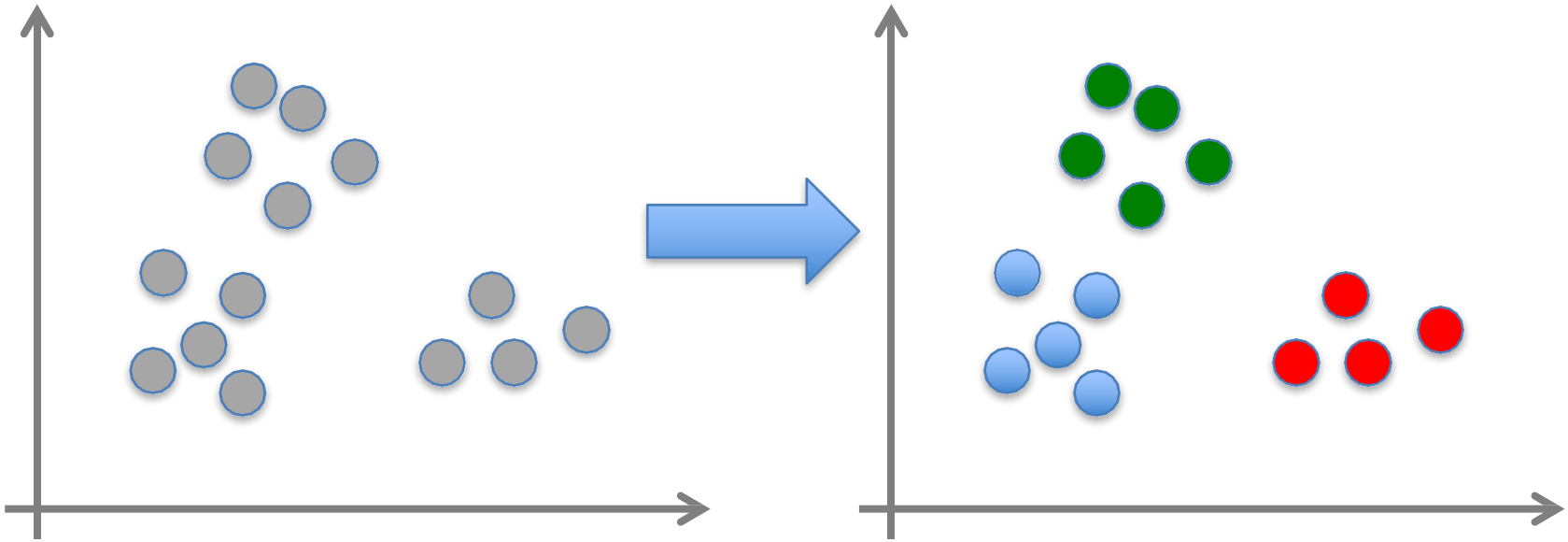
Regression :

Example: Price of a used car
***x* : car attributes**
***y* : price**
***y* = *g* (*x* | *θ*)**
***g* ( ) model,**
***θ* parameters**



Unsupervised Learning

- Given $x_1, x_2, \ldots, x_n$ (without labels)
- Output hidden structure behind the x's
  - E.g., clustering



What is Unsupervised Learning


~~CAR~~


~~CAR~~


~~BIKE~~


~~BIKE~~

Dataset

[In the unsupervised learning, we do not need to know the labels or Ground truth values]

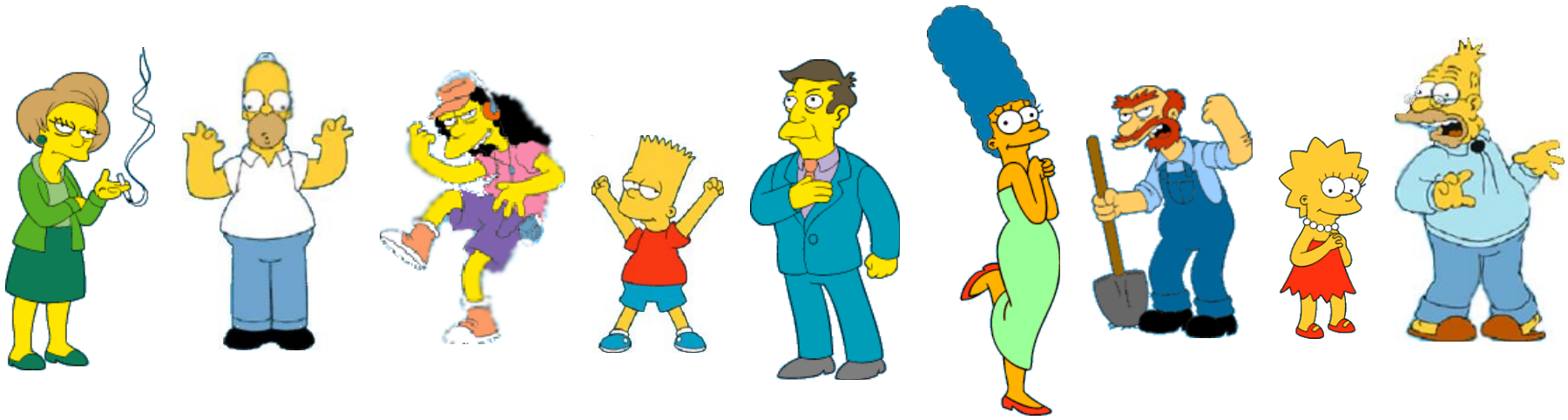
What is Unsupervised Learning

Dataset

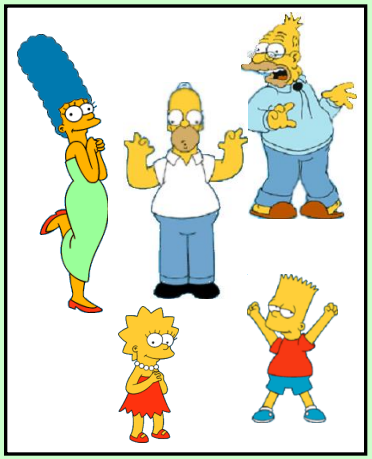
Clustering

[The task is to identify the patterns like group the similar objects together]

What is a natural grouping among these objects?

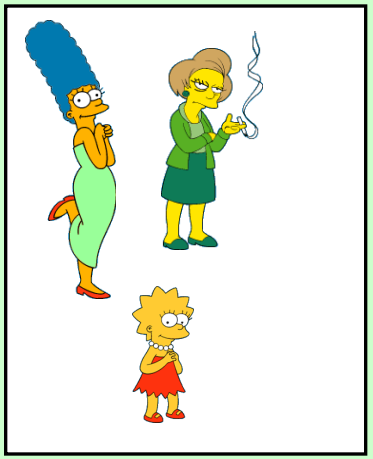


Clustering is subjective



Simpson's Family

School Employees

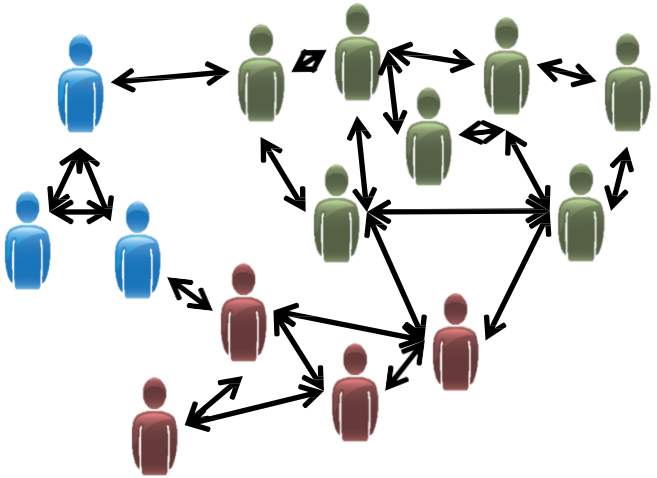


Females

Males

Unsupervised Learning

Organize computing clusters



Social network analysis

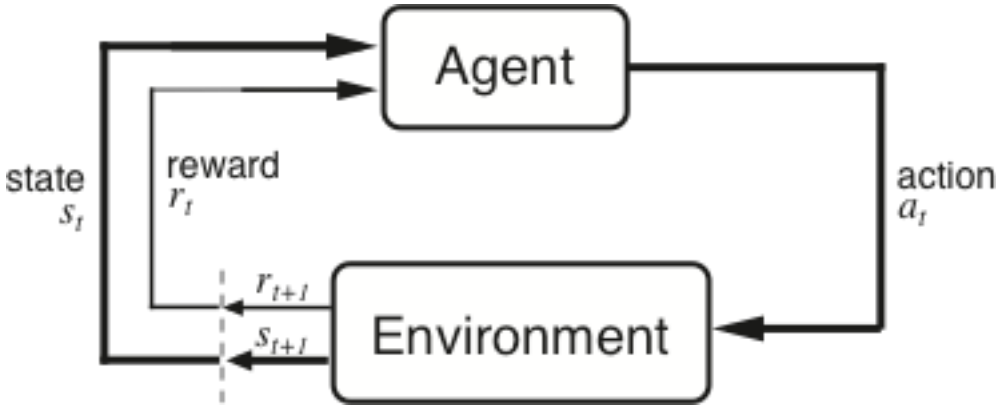
Market segmentation

More Example Unsupervised Learning

Reinforcement Learning

- Given a sequence of states and actions with (delayed) rewards, output a policy
  - Policy is a mapping from states → actions that tells you what to do in a given state
- Examples:
  - Credit assignment problem
  - Game playing
  - Robot in a maze
  - Balance a pole on your hand

The Agent-Environment Interface



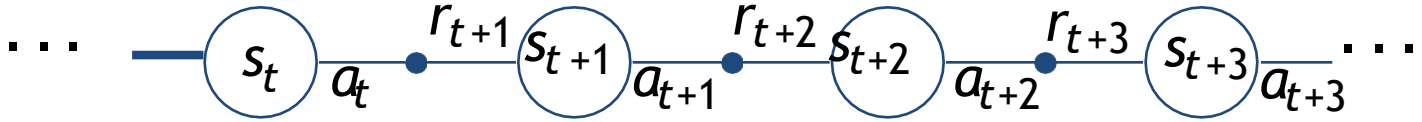
Agent and environment interact at discrete time steps : $t = 0, 1, 2, \mathrm{K}$

Agent observes state at step t : $s_t \in S$

produces action at step t : $a_t \in A(s_t)$

gets resulting reward : $r_{t+1} \in \Re$

and resulting next state : s_{t+1}

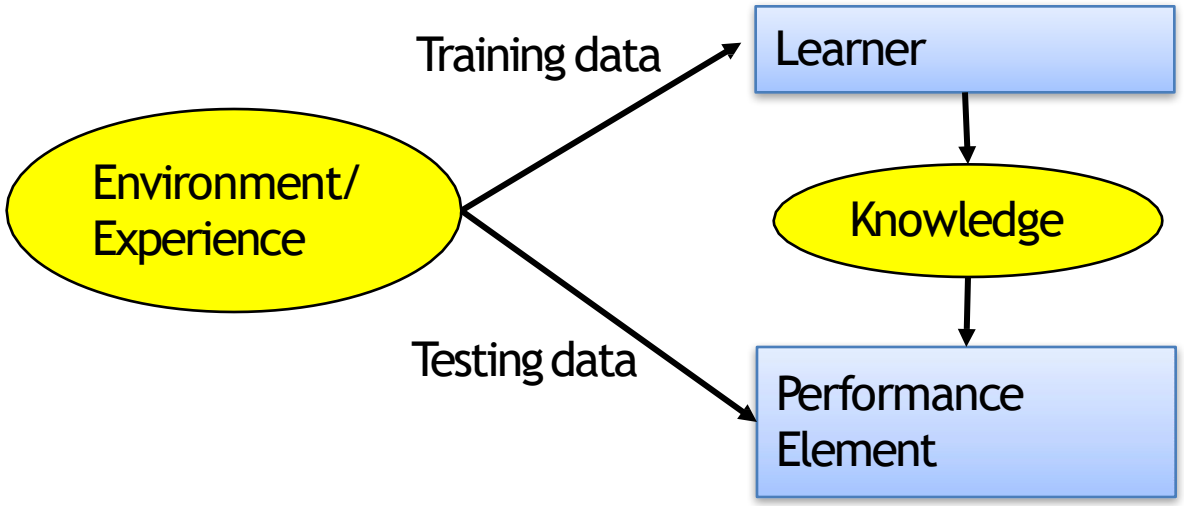


Reinforcement Learning

https://www.youtube.com/watch?v=4cgWya-wjgY

Designing a Learning System

- Choose the training experience
- Choose exactly what is to be learned
  - i.e. the ***target function***
- Choose how to represent the target function
- Choose a learning algorithm to infer the target function from the experience



A Brief History of Machine Learning

History of Machine Learning

- 1950s
  - Samuel's checker player
  - Selfridge's Pandemonium
- 1960s:
  - Neural networks: Perceptron
  - Pattern recognition
  - Learning in the limit theory
  - Minsky and Papert prove limitations of Perceptron
- 1970s:
  - Symbolic concept induction
  - Winston's arch learner
  - Expert systems and the knowledge acquisition bottleneck
  - Quinlan's ID3
  - Michalski's AQ and soybean diagnosis
  - Scientific discovery with BACON
  - Mathematical discovery with AM

History of Machine Learning (cont.)

- 1980s:
  - Advanced decision tree and rule learning
  - Explanation-based Learning (EBL)
  - Learning and planning and problem solving
  - Utility problem
  - Analogy
  - Cognitive architectures
  - Resurgence of neural networks (connectionism, backpropagation)
  - Valiant's PAC Learning Theory
  - Focus on experimental methodology
- 1990s
  - Data mining
  - Adaptive software agents and web applications
  - Text learning
  - Reinforcement learning (RL)
  - Inductive Logic Programming (ILP)
  - Ensembles: Bagging, Boosting, and Stacking
  - Bayes Net learning

History of Machine Learning (cont.)

- 2000s
  - Support vector machines & kernel methods
  - Graphical models
  - Statistical relational learning
  - Transfer learning
  - Sequence labeling
  - Collective classification and structured outputs
  - Computer Systems Applications (Compilers, Debugging, Graphics, Security)
  - E-mail management
  - Personalized assistants that learn
  - Learning in robotics and vision
- 2010s
  - Deep learning systems
  - Learning for big data
  - Bayesian methods
  - Multi-task & lifelong learning
  - Applications to vision, speech, social networks, learning to read, etc.
  - ……

What We'll Cover in this Course

- **Supervised learning**
  - Decision tree induction
  - Linear regression
  - Logistic regression
  - Support vector machines & kernel methods
  - Model ensembles
  - Bayesian learning
  - Neural networks & deep learning
  - Learning theory
- **Unsupervised learning**
  - Clustering
  - Dimensionality reduction
- **Reinforcement learning**
  - Temporal difference learning
- **Evaluation**
- **Applications**

Our focus will be on applying machine learning to real applications