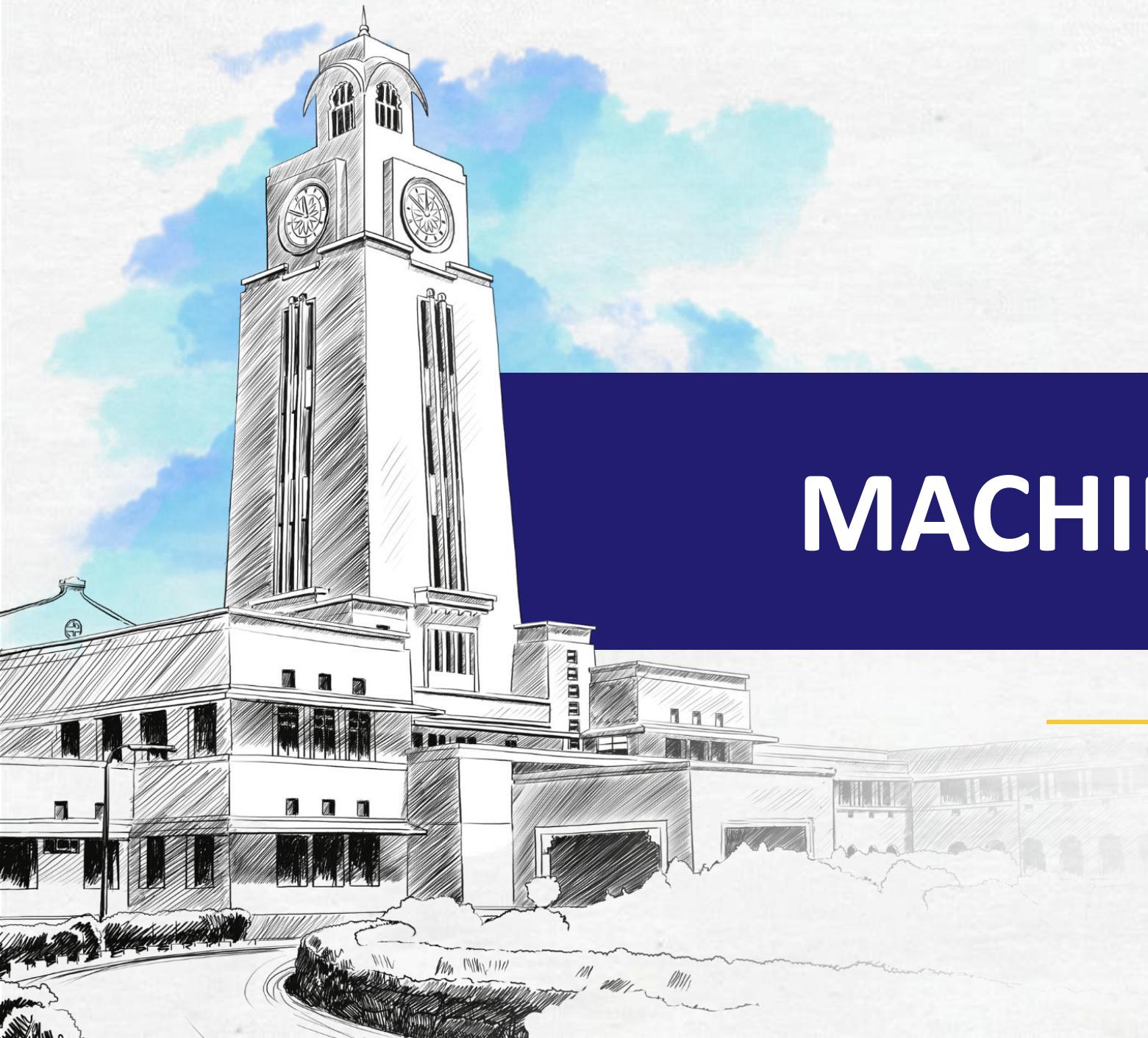




**BITS Pilani**  
Pilani | Dubai | Goa | Hyderabad

# MACHINE LEARNING

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# **Session 1**

## **(27<sup>th</sup> July 2025)**

# Faculty Details- AIML

Course Instructor: Dr. A.R.Kiruthiga

Mail Id: [kiruthiga@wilp.bits-pilani.ac.in](mailto:kiruthiga@wilp.bits-pilani.ac.in)

Learning Facilitator:

## Disclaimer and Acknowledgement



- The content for these slides has been obtained from books and various other source on the Internet
- I hereby acknowledge all the contributors for their material and inputs.
- I have provided source information wherever necessary
- I have added and modified the content flow to suit the requirements of the course and for ease of class presentation
- Students are requested to refer to the textbook and detailed content of this presentation deck over canvas

# Course Introduction

## ➤ Objective of course

- Introduction to the basic concepts and techniques of Machine Learning
- Gain experience in basics of doing independent study and research in the field of Machine Learning
- Develop skills of using recent machine learning software tools to evaluate learning algorithms and model selection for solving practical problems

Python,

## ➤ Focus of this course

- Strong Mathematical Foundations of ML algorithms
- Structured Data Analytics
- IDD (Independent & Identically Distributed Data)

## ➤ Topics not expected of this course

- Unstructured Data Analytics
- Time Series/Sequence Data Analytics
- Deep Learning



# Course Plan

M1      Introduction

M2      Machine learning Workflow

M3      Linear Models for Regression

M4      Linear Models for Classification

M5      Decision Tree

M6      Instance Based Learning

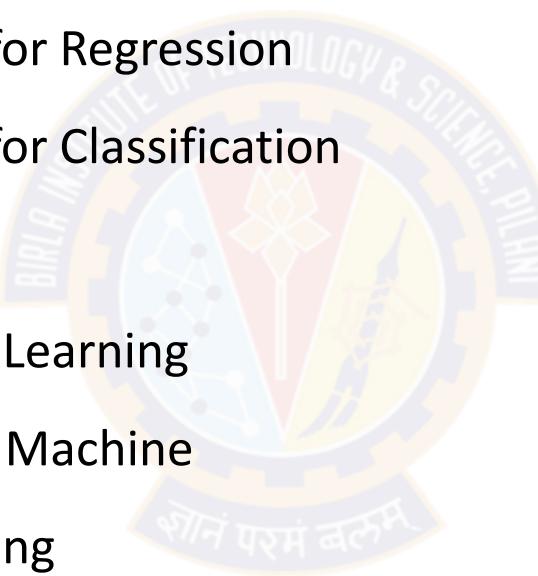
M7      Support Vector Machine

M8      Bayesian Learning

M9      Ensemble Learning

M10     Unsupervised Learning

M11     Machine Learning Model Evaluation/Comparison



## Text books and Reference book(s)

T1 Tom M. Mitchell: Machine Learning, The McGraw-Hill Companies

R1 Christopher M. Bishop: Pattern Recognition & Machine Learning, Springer

P. Tan, et al. Introduction to Data Mining, Pearson

R2 C.J.C. BURGES: A Tutorial on Support Vector Machines for Pattern Recognition, Kluwer Academic

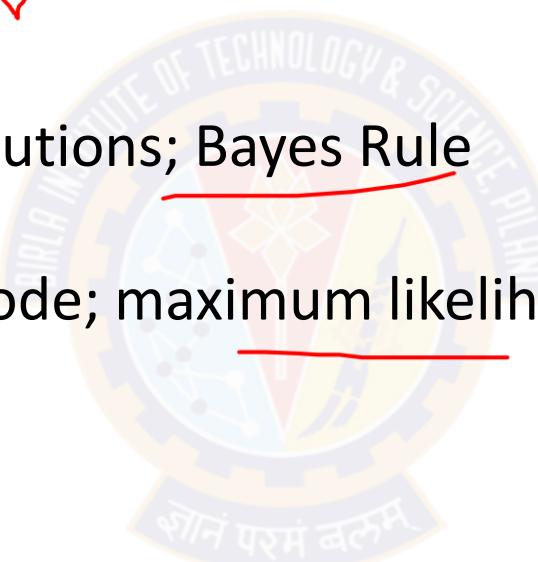
R3 Publishers, Boston.

### Evaluation scheme

- Quiz (10% - Best 2 of 3 quizzes)**
- Assignment (20% - 1 Progressive Assignment)**
- Mid-semester exam (30%)**
- Comprehensive exam (40%)**

# Pre-requisites

- Linear algebra: vector/matrix manipulations, properties
- Calculus: partial derivatives ✓
- Probability: common distributions; Bayes Rule
- Statistics: mean/median/mode; maximum likelihood



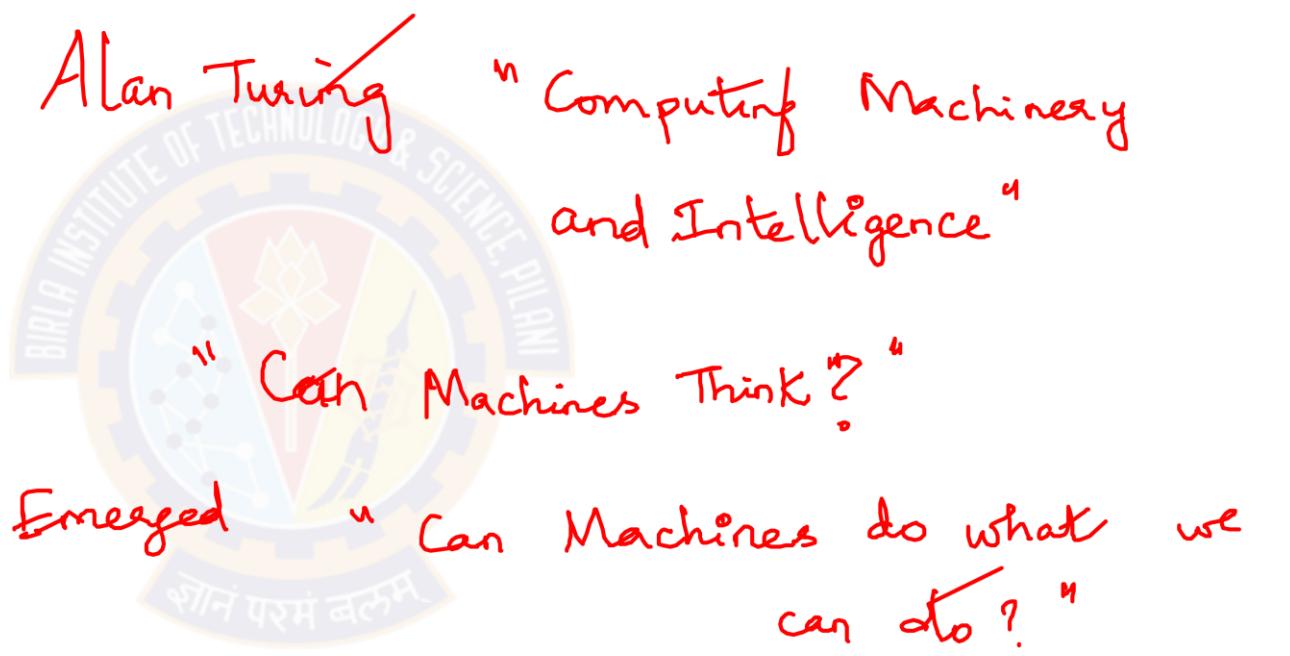
# Lab Plan

<b>Lab No.</b>	<b>Lab Objective</b>
1	End to End Machine Learning
2	Linear Regression and Gradient Descent Algorithm
3	Logistic Regression Classifier
4	Decision Tree
5	Naïve Bayes Classifier
6	Random Forest

# Agenda

- What is Machine Learning?
- Why Machine Learning is important?
- Types of Machine Learning
- Application Areas
- Issues in Machine Learning
- Demo Case study





Alan Turing "Computing Machinery  
and Intelligence"

"Can Machines Think?"

Emerged "Can Machines do what we  
can do?"

Modern ML algorithms

Classification

Prediction

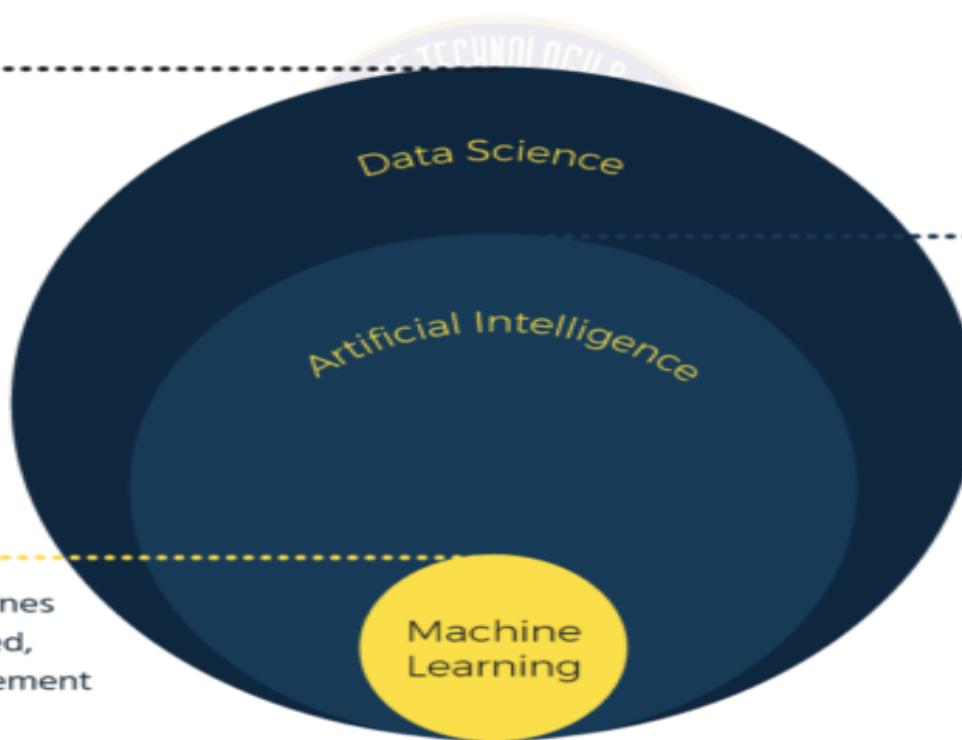
# AI vs. Data Science vs. Machine Learning

## Data Science

- Collection, preparation, and analysis of data
- Leverages AI/ML, research, industry expertise, and statistics to make business decisions

## Machine Learning

- Algorithms that help machines improve through supervised, unsupervised, and reinforcement learning
- Subset of AI and Data Science tool



## Artificial Intelligence

- Technology for machines to understand/interpret, learn, and make 'intelligent' decisions
- Includes Machine Learning among many other fields

# Introduction to Machine Learning

## Common Use cases - Security & Transaction Domain

- Self Driving Cars      *path, inputs from human drivers,*
- Fraud Detection in Banking
- Email Filtering
- Dynamic Pricing in Travel

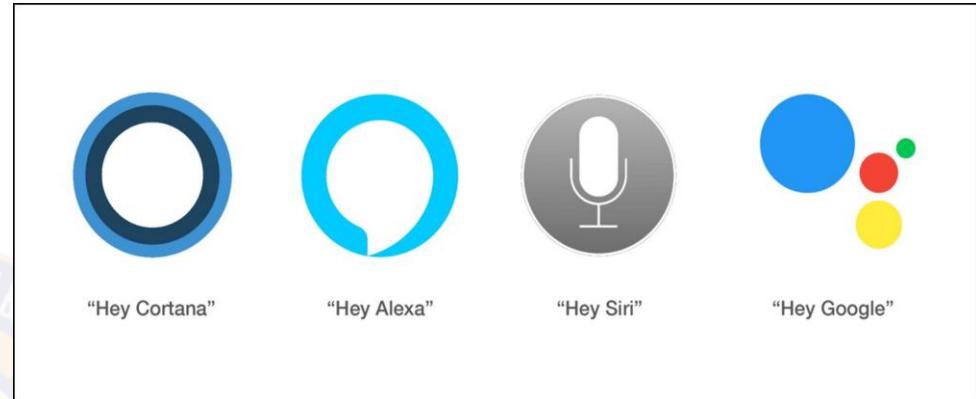
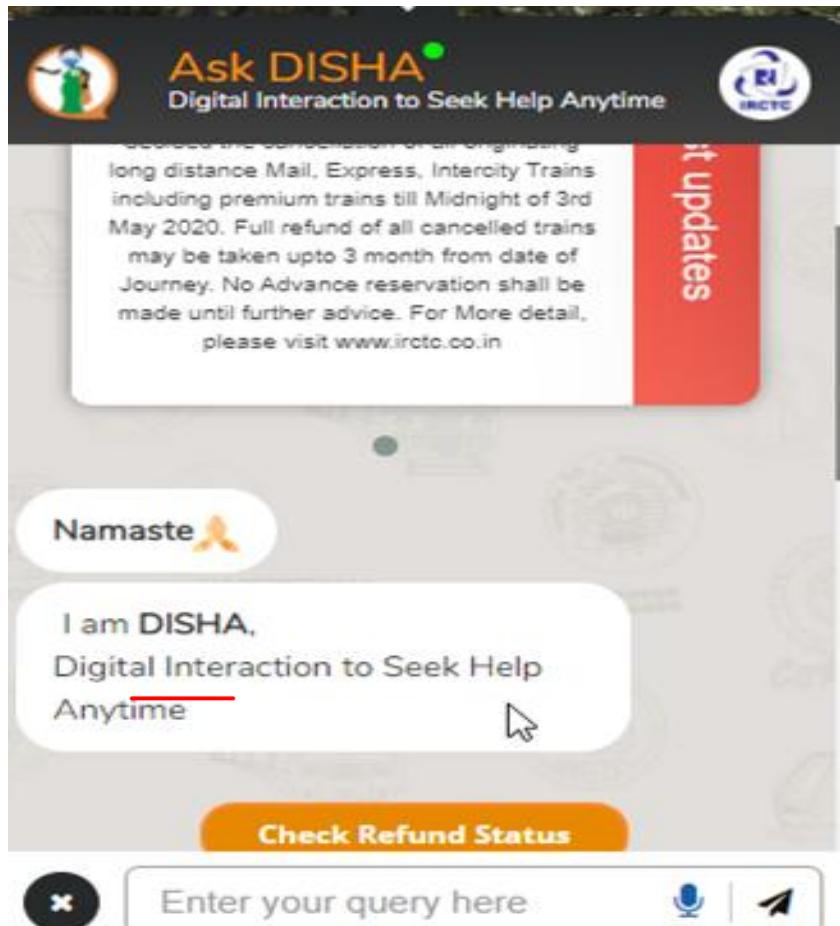
### Derived Applications:

- Cyber Security
- Video Surveillance
- Object Detection



# Introduction to Machine Learning

## Common Use cases - Customer Support Systems



- Apple's Siri
- Google Assistant
- Amazon's Alexa
- Google Duplex
- Microsoft's Cortana
- Samsung's Bixby

### Derived Applications:

- > Customer Support Query (Voice vs Text)
- > Chatbots

# Introduction to Machine Learning

## Common Use cases - Recommendation Engines

The screenshots illustrate the 'Recommended for You' feature on Amazon.com and Amazon.ca. The top section shows recommendations based on purchased items, including books like 'BIG' by Tom Peters and movies like 'Sherlock Holmes [Blu-ray]' and 'Alice in Wonderland [Blu-ray]'. The bottom section shows recommendations for sandals, specifically Birkenstock Women's Gizeh Cork Footbed Thong Sandals.

- E-commerce sites like Amazon and Flipkart
- Book sites like Goodreads
- Movie services like IMDb and Netflix
- Hospitality sites like MakeMyTrip, Booking.com, etc.
- Retail services like StitchFix
- Food aggregators like Zomato and Uber Eats

### Derived Applications:

- > Personalized Marketing
- > Personalized Banking

# **ML – What, When, Where ?**



# What is Machine Learning (ML)?

- The science (and art) of programming computers so they can *learn from data*
- More general definition

Field of study that gives computers the ability to learn without being explicitly programmed

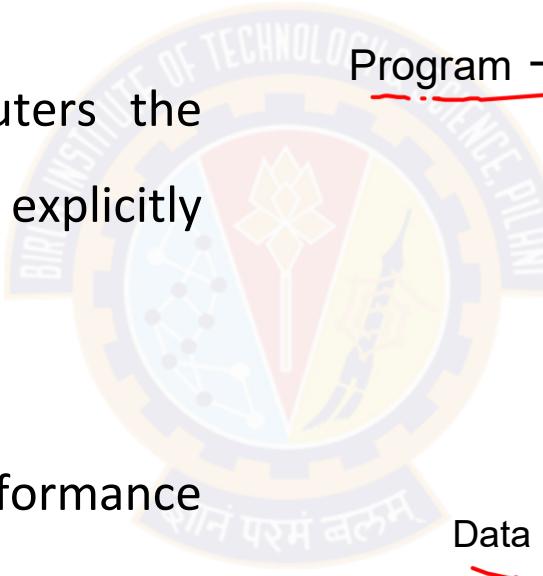
- Engineering-oriented definition

Algorithms that improve their performance

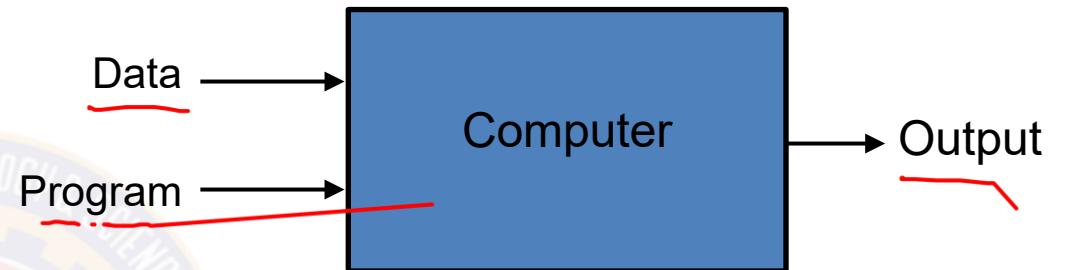
P at some task T with experience E

- A well-defined learning task is given by

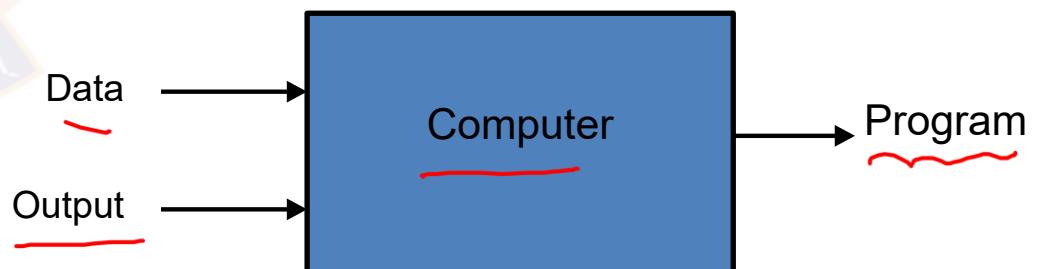
$\langle P, T, f \rangle$



## Traditional programming



## Machine Learning



# Introduction to Machine Learning

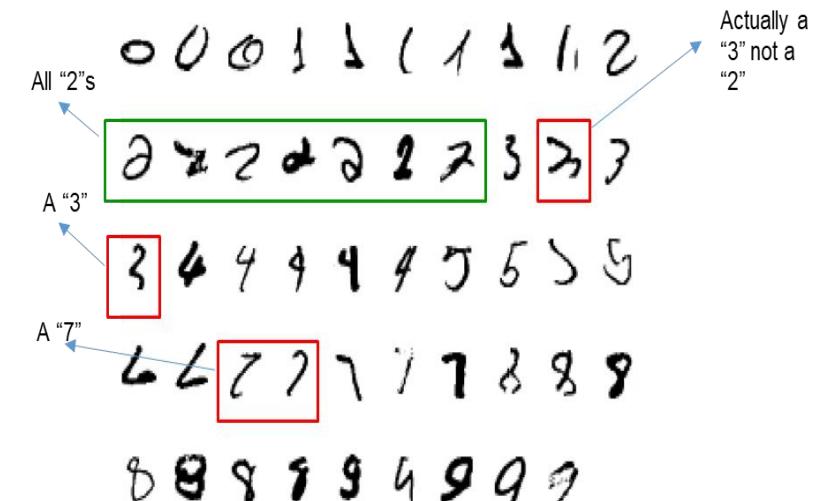
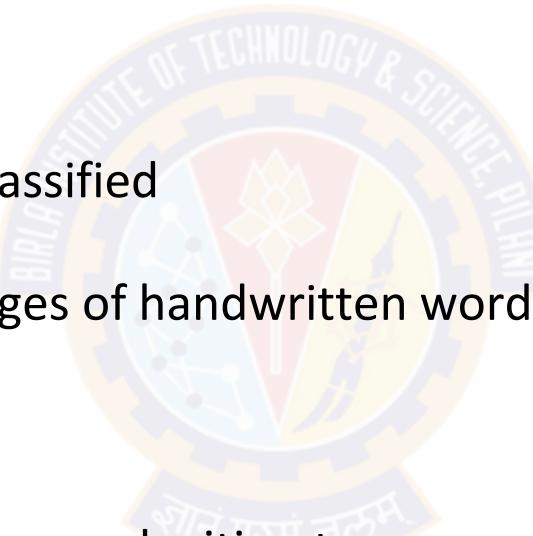
## Defining the Learning Tasks

### ➤ Example 1

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

### ➤ Example 2

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



# Introduction to Machine Learning

## Defining the Learning Tasks

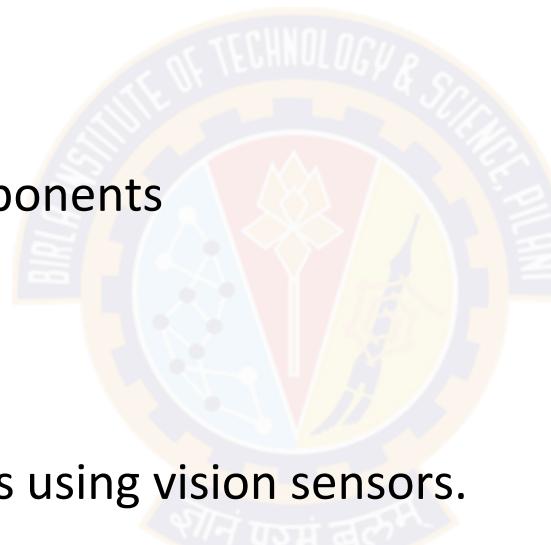
Improve on task T, with respect to performance metric P, based on experience E

### Example 3

T: Playing Checkers

P: Percent of games won against opponents

E: Games Played against itself



### Example 4

T: Drive on public four-lane highways using vision sensors.

P: Average distance travelled before an error (as judged by human).

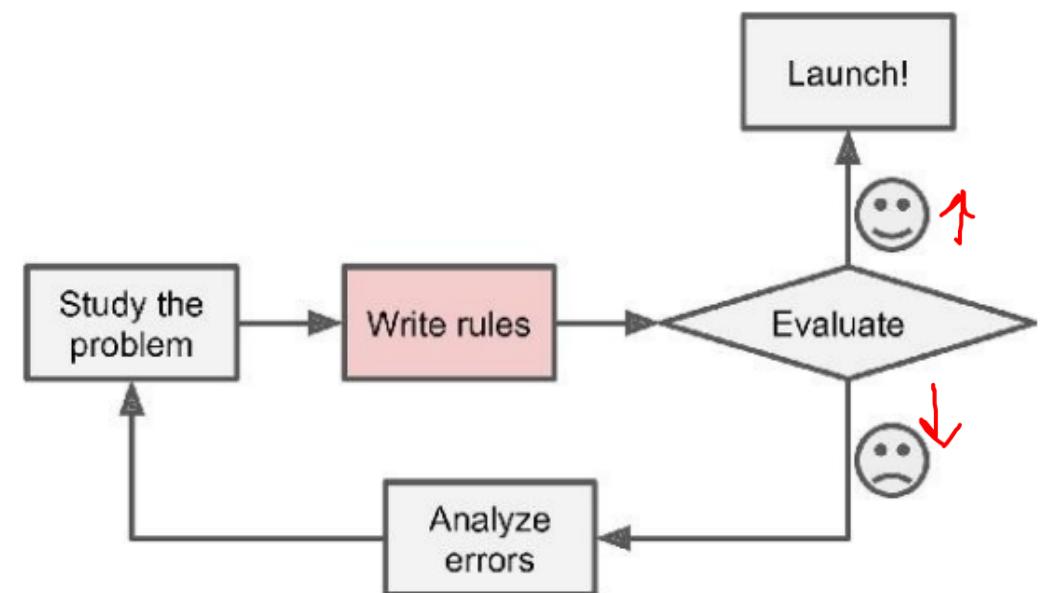
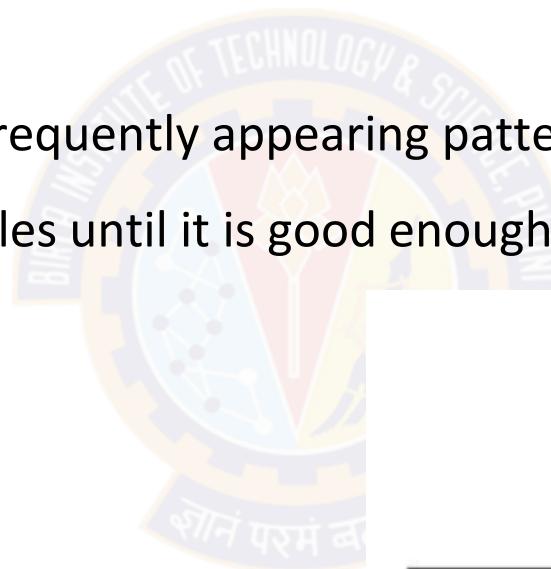
E: A sequence of images and steering commands recorded while observing a human driver



# Introduction to Machine Learning

## Traditional Approach - Spam Filtering

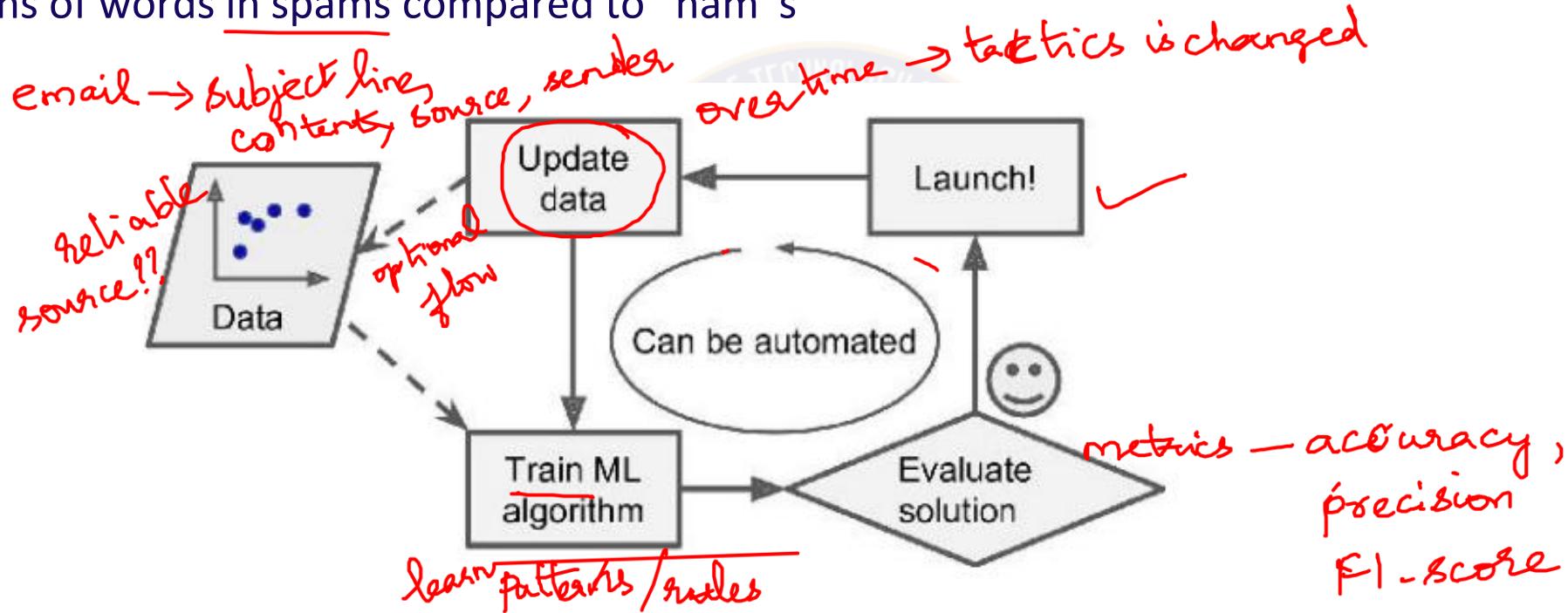
- Spam typically uses words or phrases such as “4U,” “credit card,” “free,” and “amazing”
- Solution
  - Write a detection algorithm for frequently appearing patterns in spams
  - Test and update the detection rules until it is good enough.
- Challenge
  - Detection algorithm likely
  - to be a long list of complex rules
  - hard to maintain.



# Introduction to Machine Learning

## ML Approach - Spam Filtering

Automatically learns phrases that are good predictors of spam by detecting unusually frequent patterns of words in spams compared to "ham"s



The program is much shorter, easier to maintain, and most likely more accurate.

# Introduction to Machine Learning

## Applications - Perspectives

### Object Categorization



- Medical Diagnosis ✓
- Transaction Analysis
- Recommendation System
- Speech – Text Processing

Voice msg

### Sequence Prediction

- Pattern Recognition
- Optimization
- Decision System



# Introduction to Machine Learning

## Applications - Perspectives

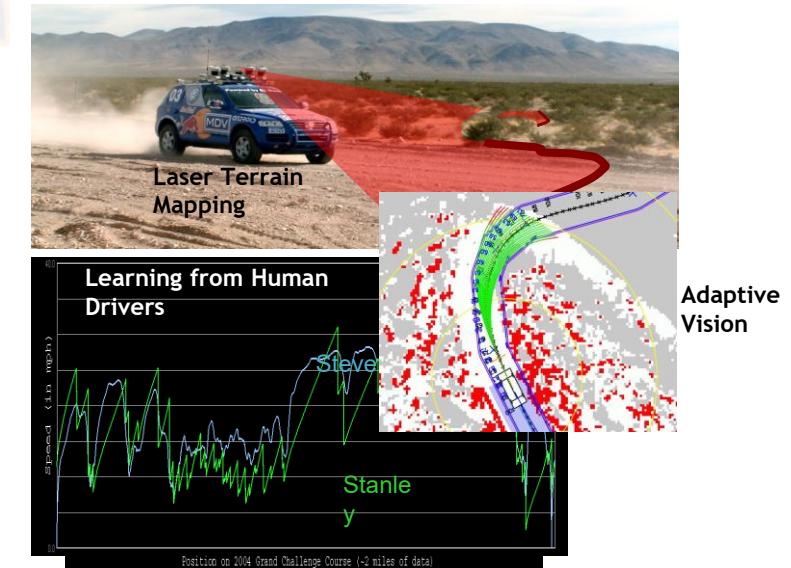
### Planning



- Navigation
- Path Finding
- Gaming
- Controlling

### Sequence Prediction

- Pattern Recognition
- Optimization
- Decision System



# Why ML



# When Do We Use Machine Learning?

ML is used when:

- Human expertise does not exist (navigating on Mars)
- Humans can't explain their expertise (Biometrics)
- Models must be customized (personalized medicine)
- Learning isn't always useful:
  - There is no need to "learn" to calculate payroll

x y



S.I. is Bank P, R, N  
PNR  
→ 100

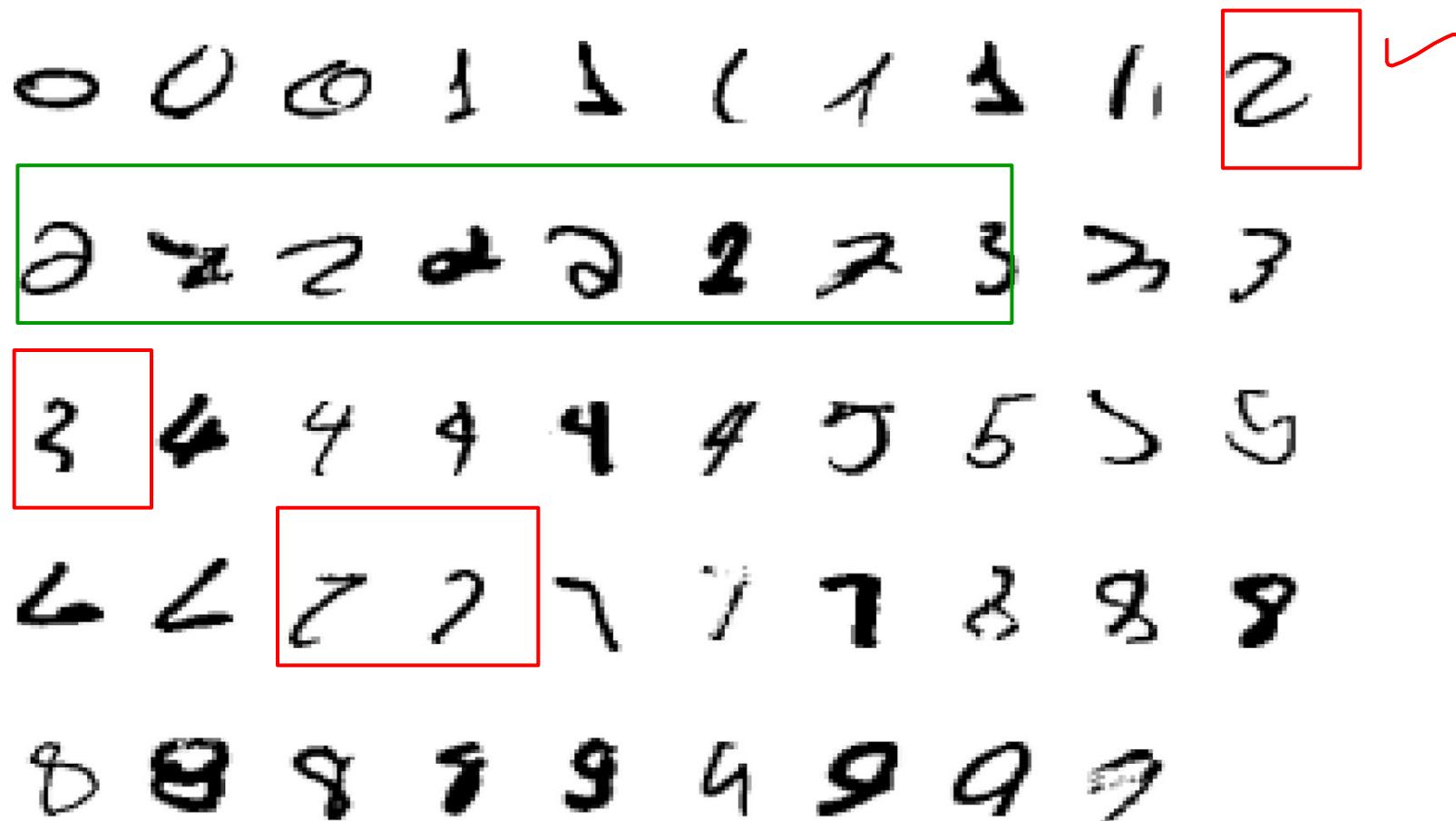


# Why only ML?

- Some tasks cannot be defined well, except by examples.
  - It is very hard to write programs that solve problems like recognizing a handwritten digit
  - What distinguishes a 2 from a 7?
  - How does our brain do it
- Hidden relationships and correlations in data
- large data makes it difficult for explicit encoding by humans (e.g., medical diagnostic)
- Continuous availability of new knowledge

# Pattern recognition

It is very hard to say what makes a 2

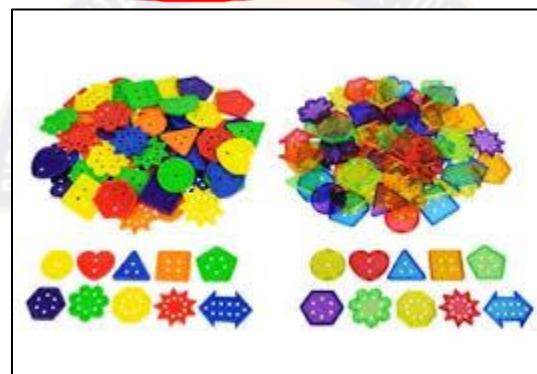
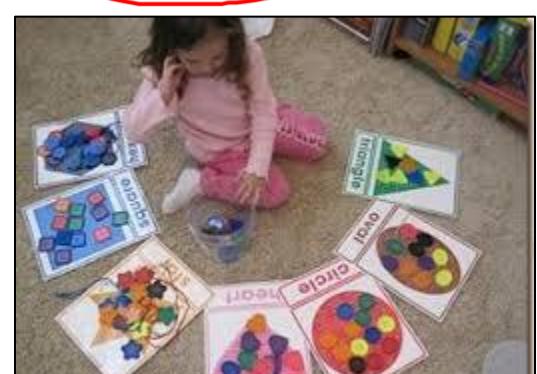


# Types of ML



# Introduction to Machine Learning

## Types : Inputs: Based on level of supervision

Feedback	No Feedback	Delayed Feedback (rewards/penalty)
Supervised	Unsupervised	Reinforcement
		

Colours



# Machine Learning - Examples

## **Objective: Employability Prediction**

### **Features / Attributes / Predictors ✓**

- ✓ CGPA
- ✓ Communication Skills
- ✓ Aptitude
- ✓ Programming Skills

S.No.	CGPA	Communication Skills	Aptitude	Programming Skills	Job Offered?
1	9.1	Average	Good	Excellent	Yes
2	8.4	Good	Good	Good	Yes
3	8.3	Poor	Average	Average	No
4	7.1	Average	Good	Average	No
5	8.2	Good	Excellent	Excellent	No

# Machine Learning - Examples

**Objective : Predicting price of a used car**

**Features / Attributes / Predictors**

- ✓ Brand
- ✓ Year (Mfg) ✓
- ✓ Engine Capacity ✓
- ✓ Mileage ✓
- ✓ Distance travelled -
- ✓ Cab?



S.No	Brand	Year (Mfg)	Engine Capacity	Mileage	Distance travelled	Cab?	Price (in Rs.)
1.	Honda City ZX	2008	1100	10.5	45000	N	3,50,000
2							
3							
4							

# Machine Learning - Examples

## Objective: Market Segmentation Study

### Features / Attributes / Predictors

- ✓ Family income ✓
- ✓ # of visits in a month
- ✓ Average money spent in a month
- ✓ Zip code

Customers for a retailer may fall into

- ✓ two groups say big spenders and low spenders
- ✓ three groups say big spenders, medium spenders and low spenders
- ✓ Four groups, ....

S.No.	Zip Code	Family Income	# of visits in a month	Average Money Spent in a month
1	500078	11,50,000	4	8,000

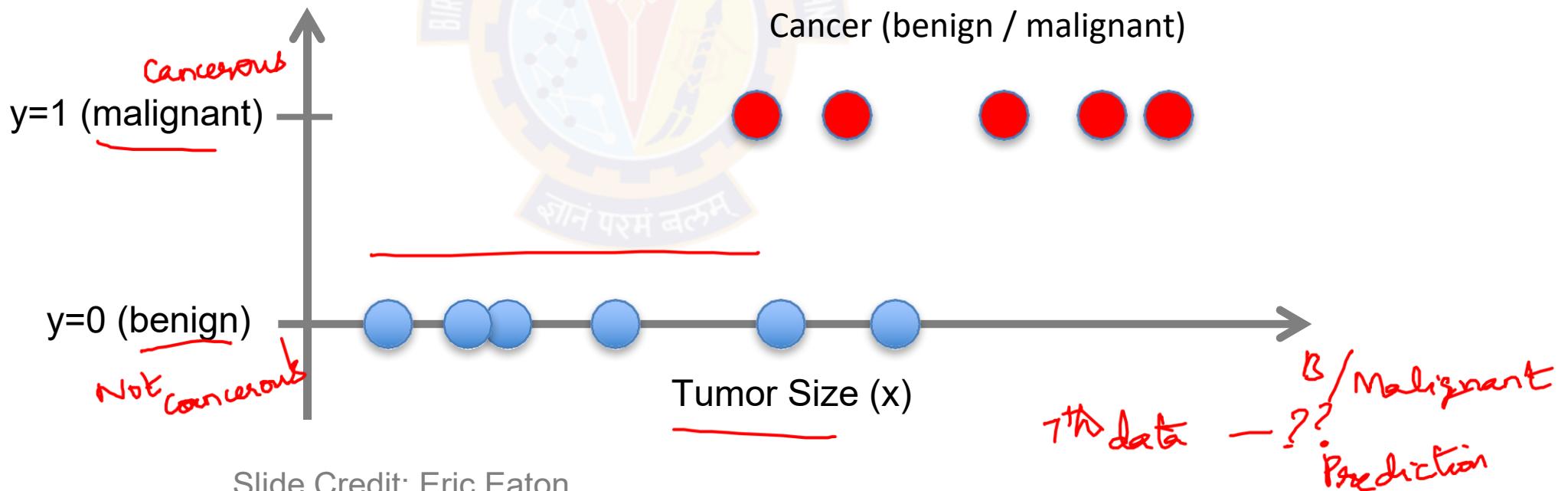
# Introduction to Machine Learning

## Supervised Learning: Classification

GOAL : Previously unseen records should be assigned a class as accurately as possible.

- Given  $(\checkmark^A x_1, \checkmark^A y_1), (\checkmark^A x_2, y_2), \dots, (\checkmark^B x_n, y_n)$
- Learn a function  $f(x)$  to predict  $y$  given  $x$ 
  - $y$  is categorical

$$\begin{aligned}x_1 &= (1, 2) \\x_2 &= (1, 3)\end{aligned}$$



# Introduction to Machine Learning

## Classification Applications

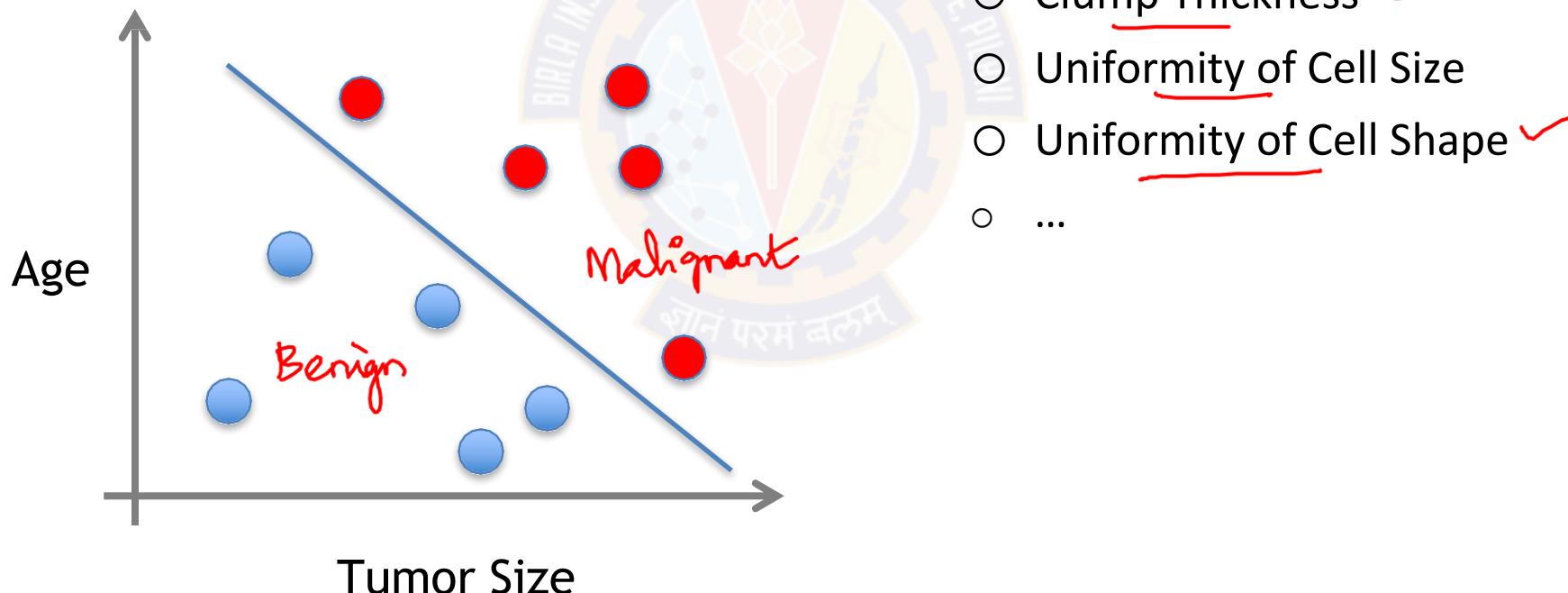
- Google Image Classification ✓ 
- Face recognition system ✓
- Spam filters – Specific Controls
- Document tagging
- Fraud detection

✓  
parking  
road

# Introduction to Machine Learning

## Supervised Learning: Classification

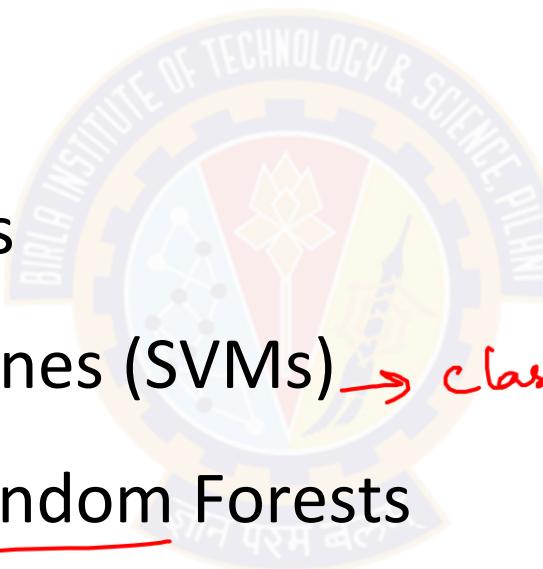
- $x$  can be multi-dimensional
  - Each dimension corresponds to an attribute



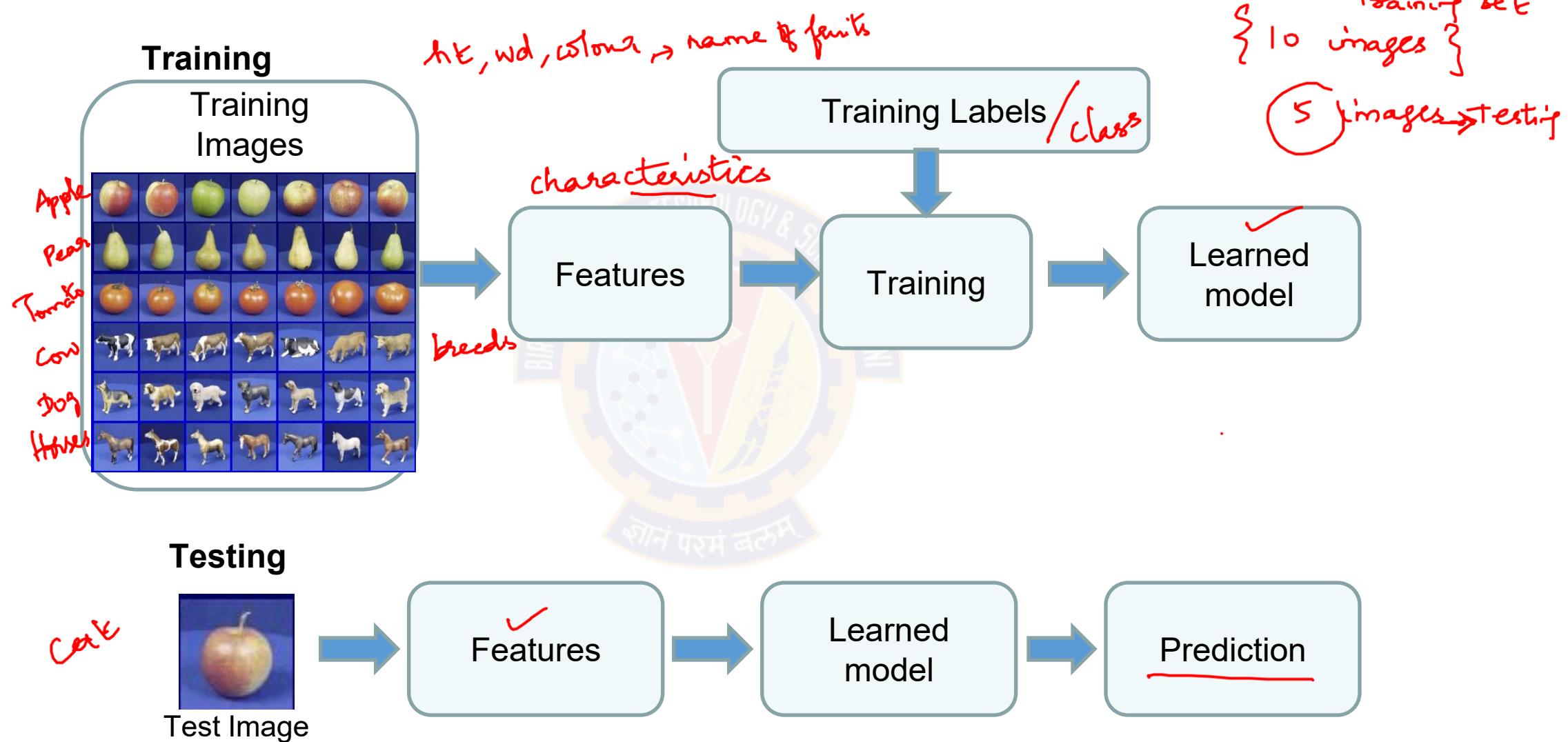
# Introduction to Machine Learning

## Supervised Learning Techniques / Algorithms

- Linear Regression ✓
- Logistic Regression ✓
- Naïve Bayes Classifiers
- Support Vector Machines (SVMs) → classification
- Decision Trees and Random Forests
- Neural networks



# A Typical Supervised Learning Workflow (for Classification)

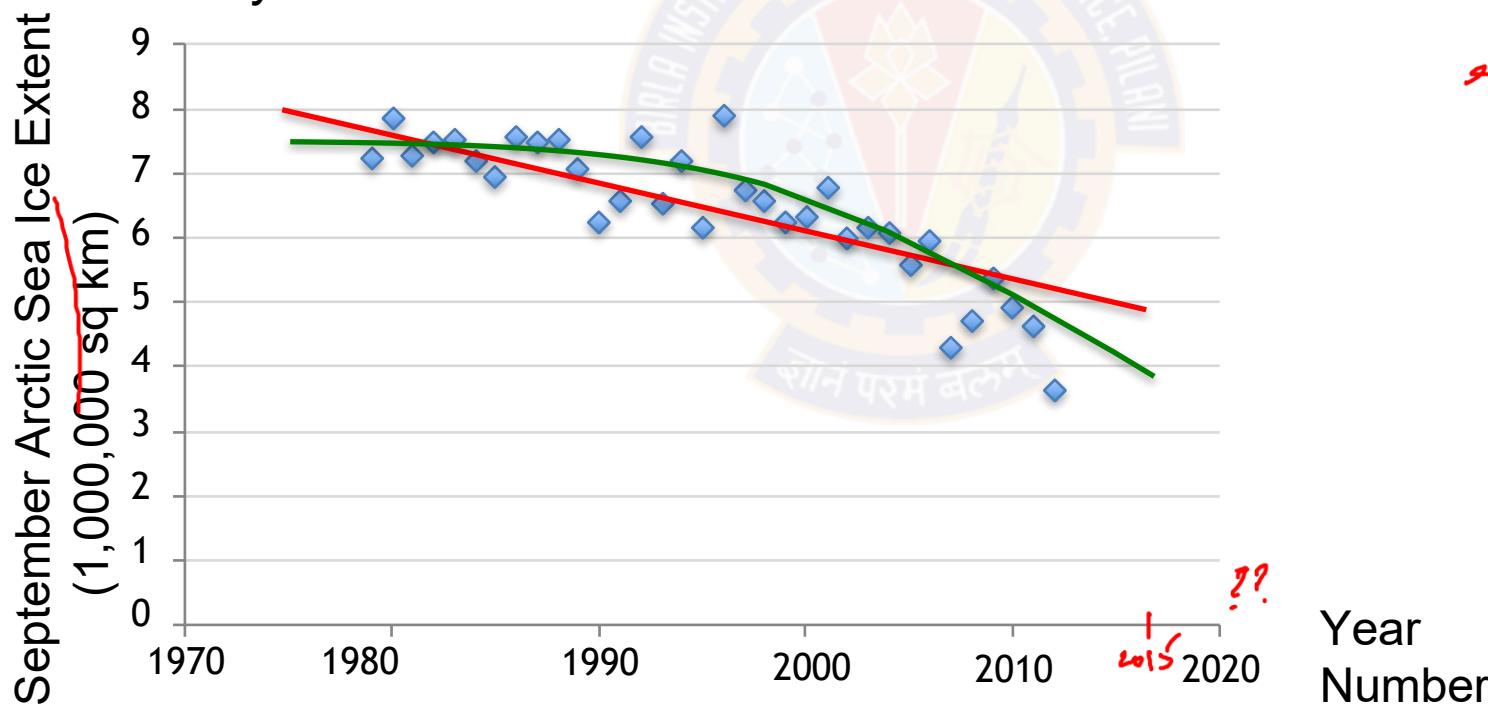


# Introduction to Machine Learning

## Supervised Learning: Regression

GOAL : Previously unseen records should be assigned a value as accurately as possible.

- Given  $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$
- Learn a function  $f(x)$  to predict  $y$  given  $x$ 
  - $y$  is real-valued



$x \rightarrow$  hours of study  
 $y \rightarrow$  grades in Exam  
relationship b/w  $x \& y$

$$y = 4x + 3$$

$$y = x^2$$

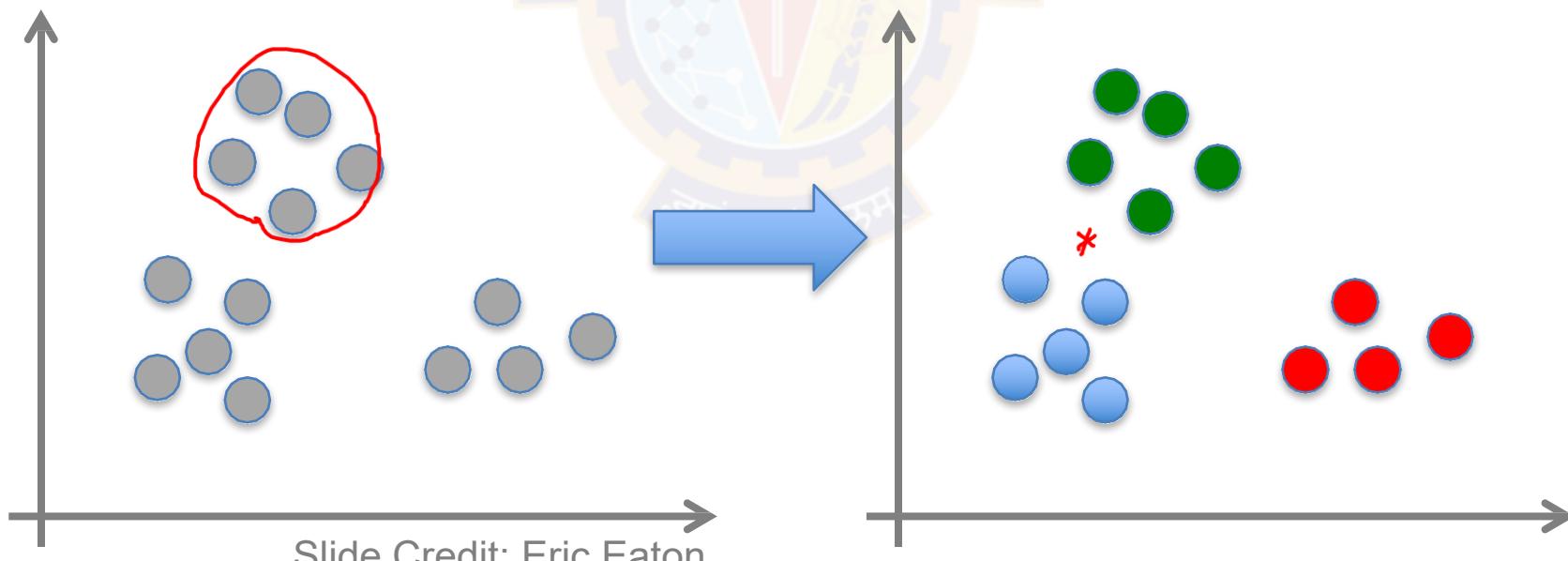
# Introduction to Machine Learning

## Unsupervised Learning<sub>single</sub>

GOAL : Intra cluster distances are minimized and inter cluster distances are maximized

- Given  $x_1, x_2, \dots, x_n$  (without labels)
- Output hidden structure behind the x's
  - e.g., clustering → *grouping data together*

Mean, Median, centroid

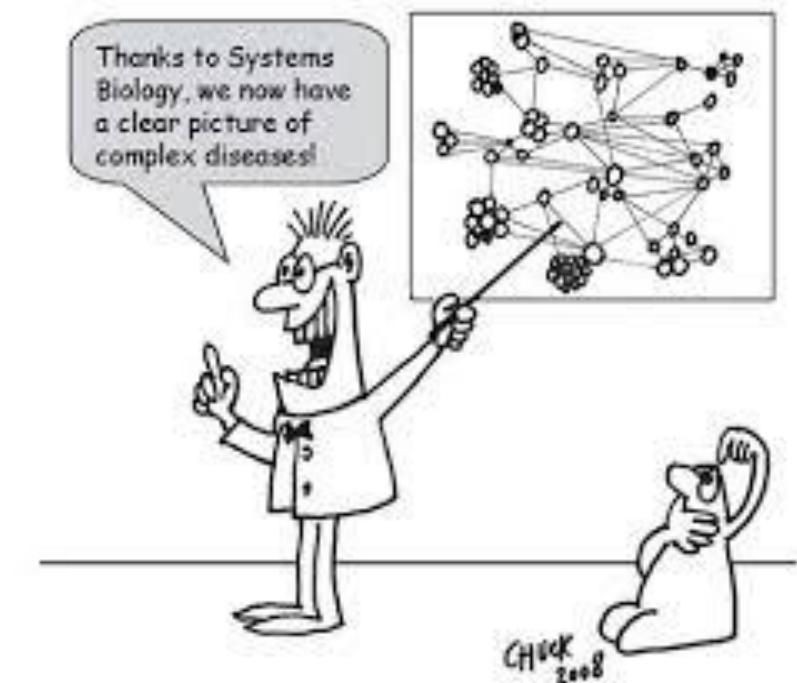


Slide Credit: Eric Eaton

# Introduction to Machine Learning

## Unsupervised Learning Applications

- Personalized recommendation system → Online websites
- Targeted marketing ✓ credit card offers, loan
- Spam Filters classifying the emails
- Content Management – News hosted in Web
- Campaigning Political campaign  
Social awareness

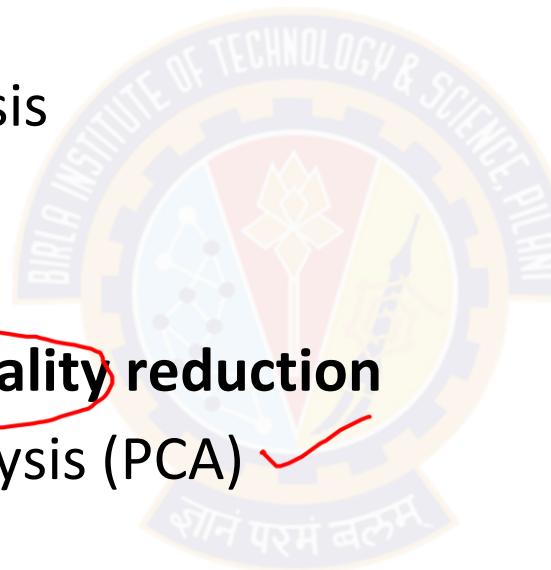


# Introduction to Machine Learning

## Unsupervised Learning Techniques

### Clustering

- k-Means ✓
- Hierarchical Cluster Analysis
- Expectation Maximization



### Visualization and dimensionality reduction

- Principal Component Analysis (PCA) ✓
- Kernel PCA
- Locally-Linear Embedding (LLE)
- t-distributed Stochastic Neighbor Embedding (t-SNE)

	Before Test From Marks	After training
x	$y_1$	$y_2$
1	5	7
2	7	8
3	3	9
4	6	10
5	4	7.5

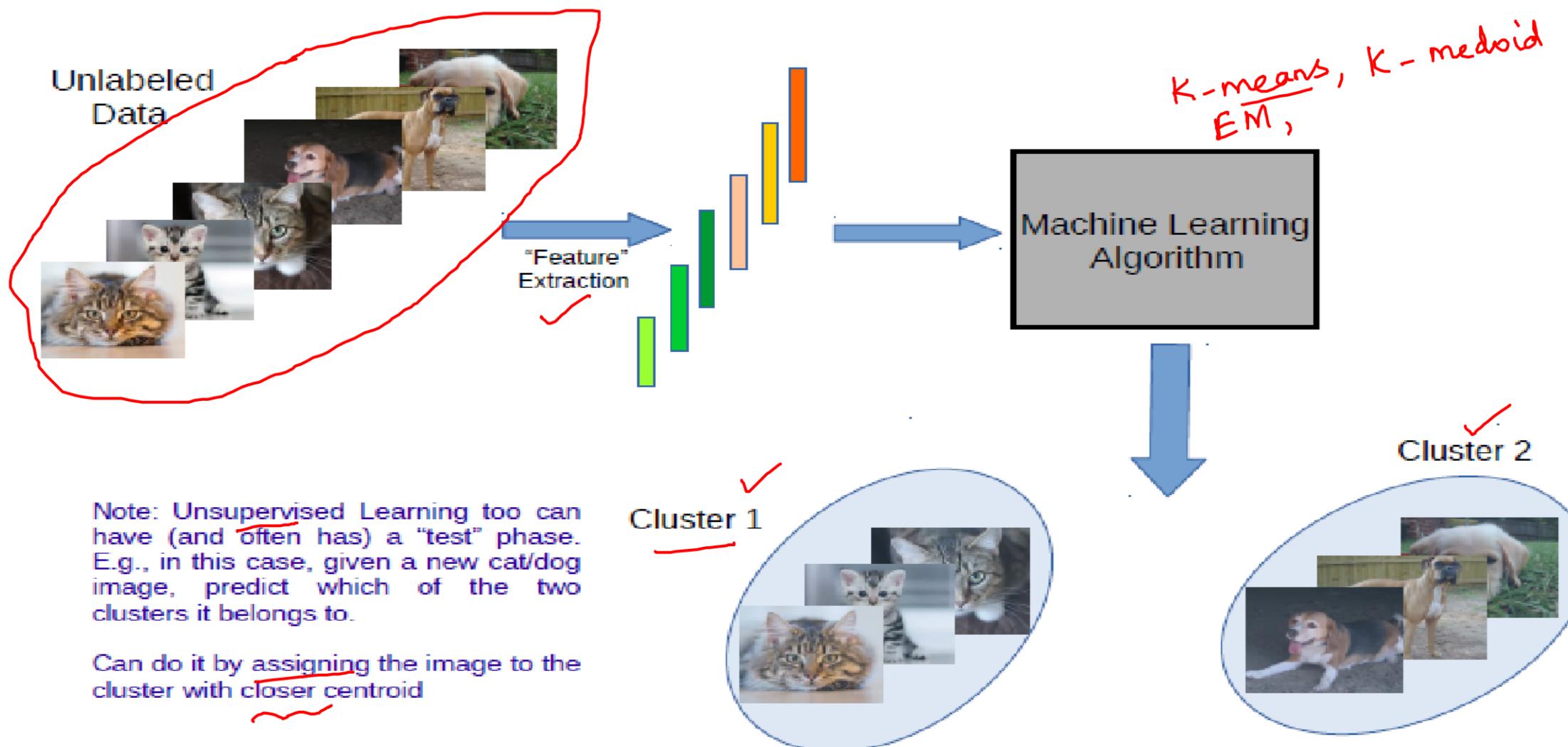
Obj: The effectiveness of the training

Correlation

$$\gamma = \begin{cases} +1 & \text{for positive correlation} \\ -1 & \text{for negative correlation} \end{cases}$$

$$-1 \leq \gamma \leq +1$$

# A Typical Unsupervised Learning Workflow (for Clustering)



# Introduction to Machine Learning

## Reinforcement Learning

- feedback-based Machine learning technique
- agent learns automatically using feedbacks without any labeled data, unlike supervised learning
- an agent learns to behave in an environment by performing the actions and seeing the results of actions
- For each good action, the agent gets positive feedback, and for each bad action, the agent gets negative feedback or penalty

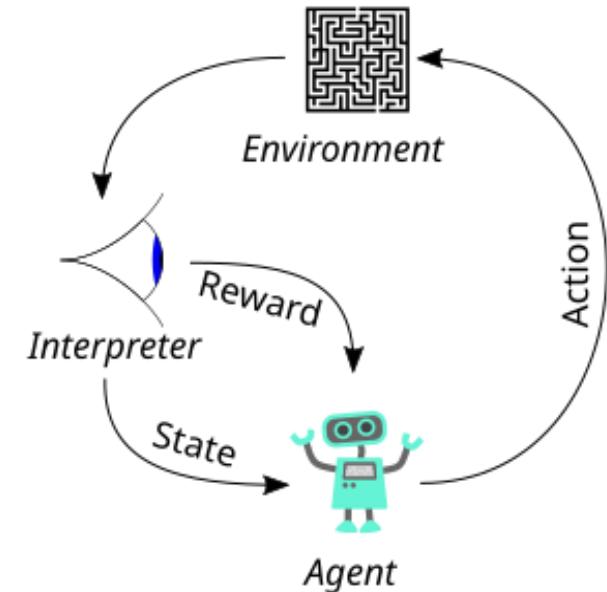
**Example** - How a Robotic dog learns movement of his arms

- solves specific type of problem where decision making is sequential, and the goal is long-term, such as game-playing, robotics, etc.

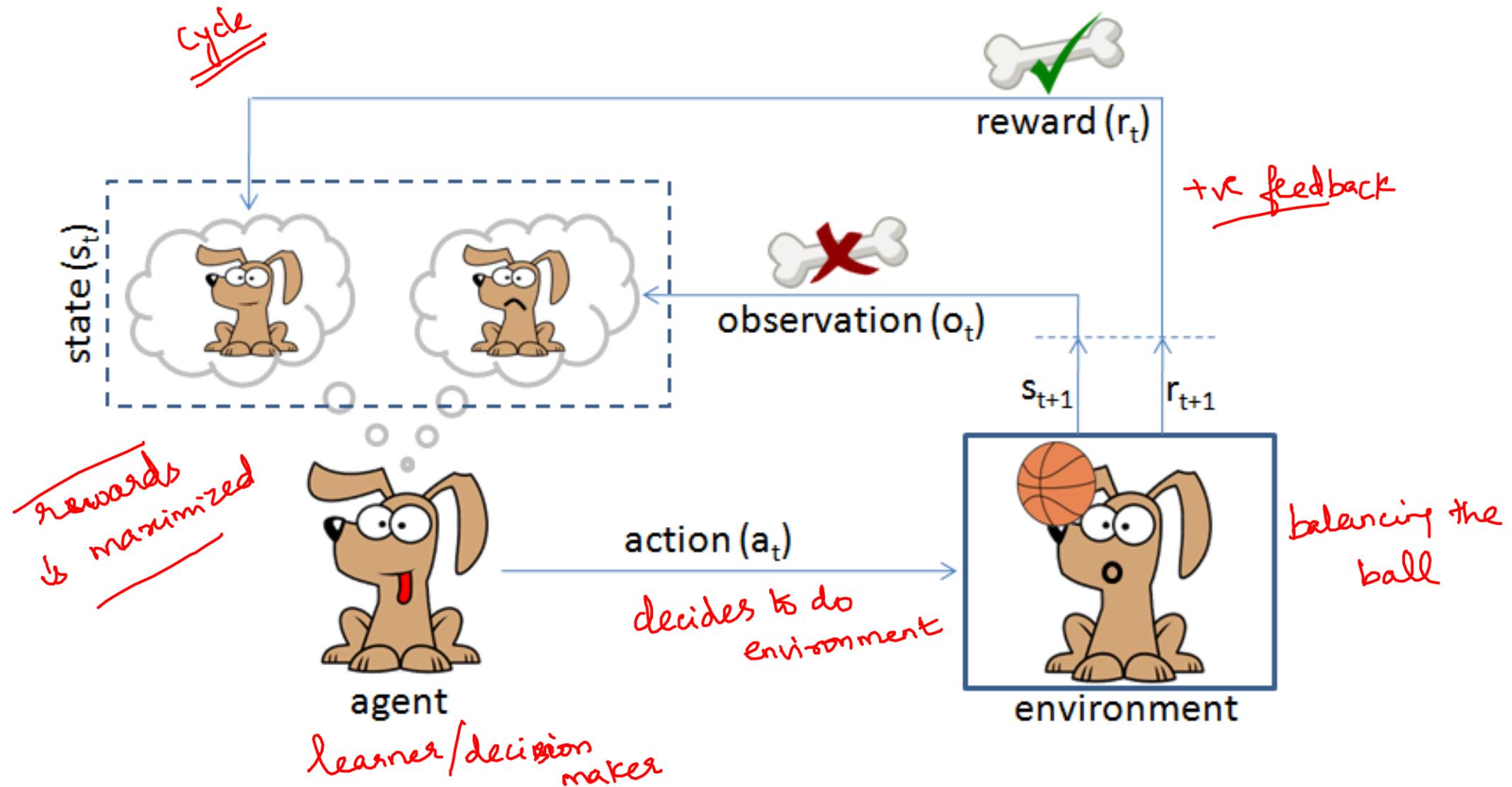
# Introduction to Machine Learning

## Reinforcement Learning

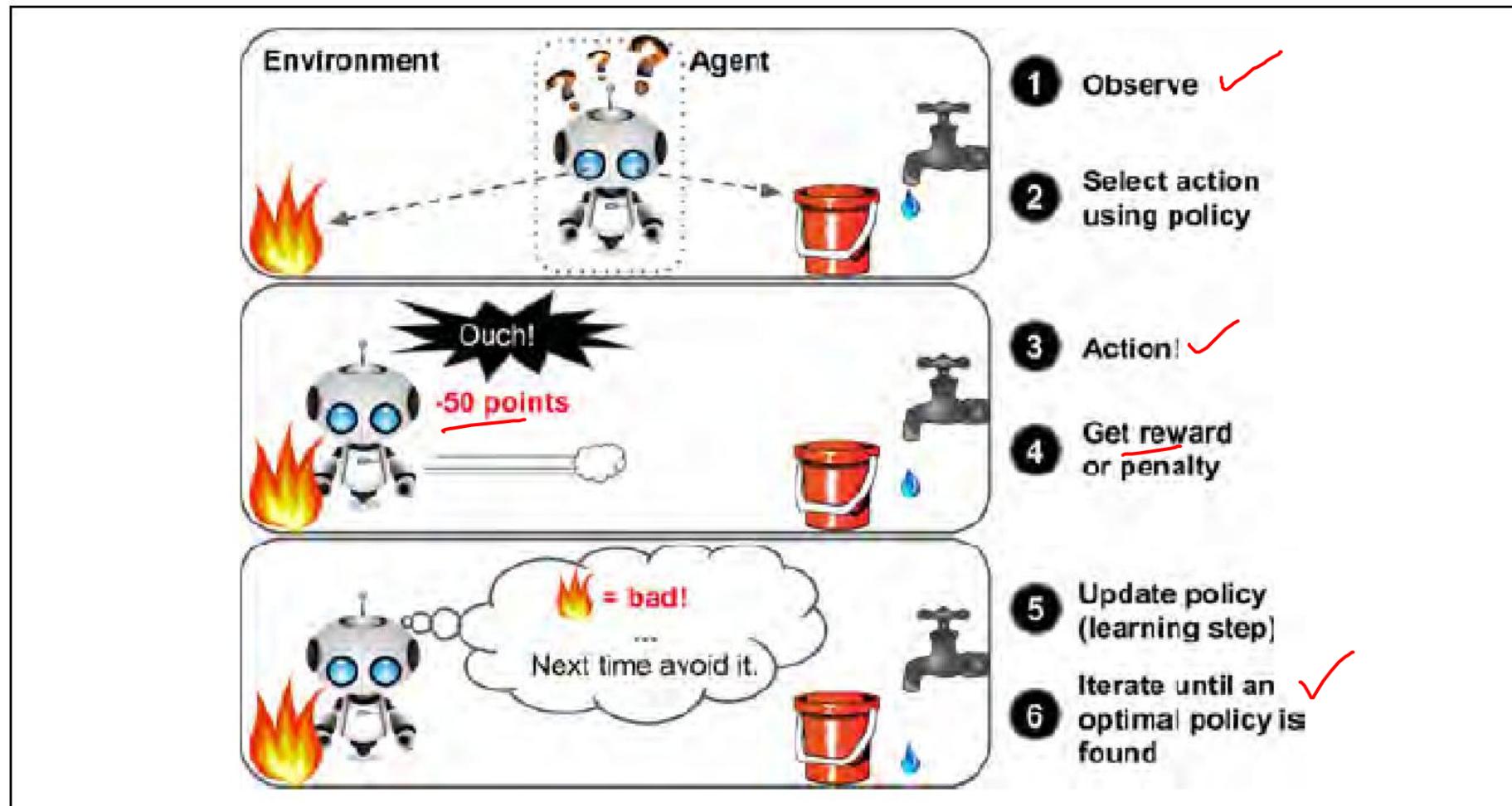
- RL centered around a digital agent who is put in a specific environment to learn
- Similar to way that we learn new things, agent faces a game-like situation
- must make a series of decisions to try to achieve correct outcome
- Through trial and error, agent will learn what to do (and what not to do) and is rewarded and punished accordingly
- Every time it receives a reward, it reinforces the behaviour and signals the agent to employ the same tactics again next time.



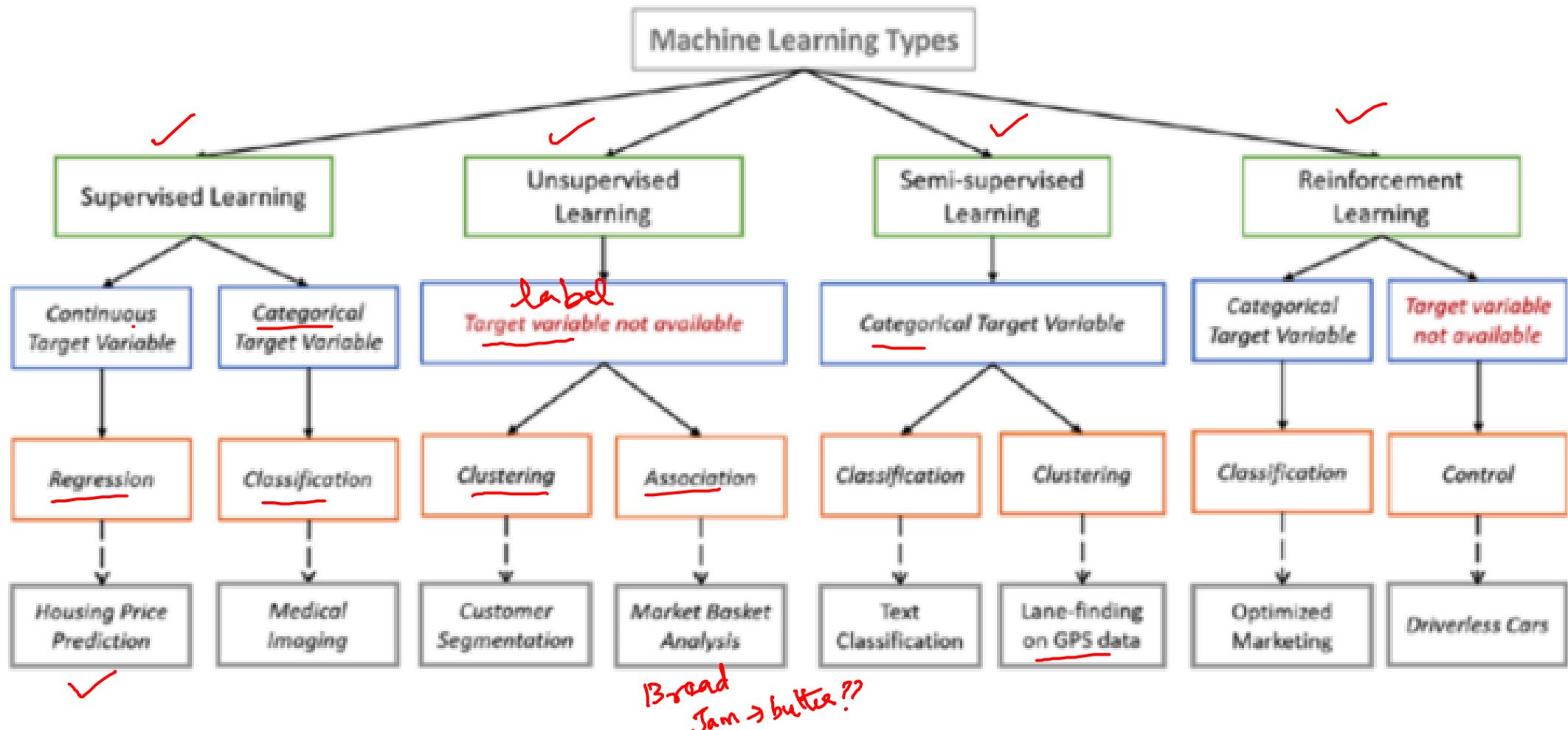
# Reinforcement Learning



# Reinforcement Learning



# Summary : Types of Learning



# Comparison : Supervised, Unsupervised and Reinforcement Learning

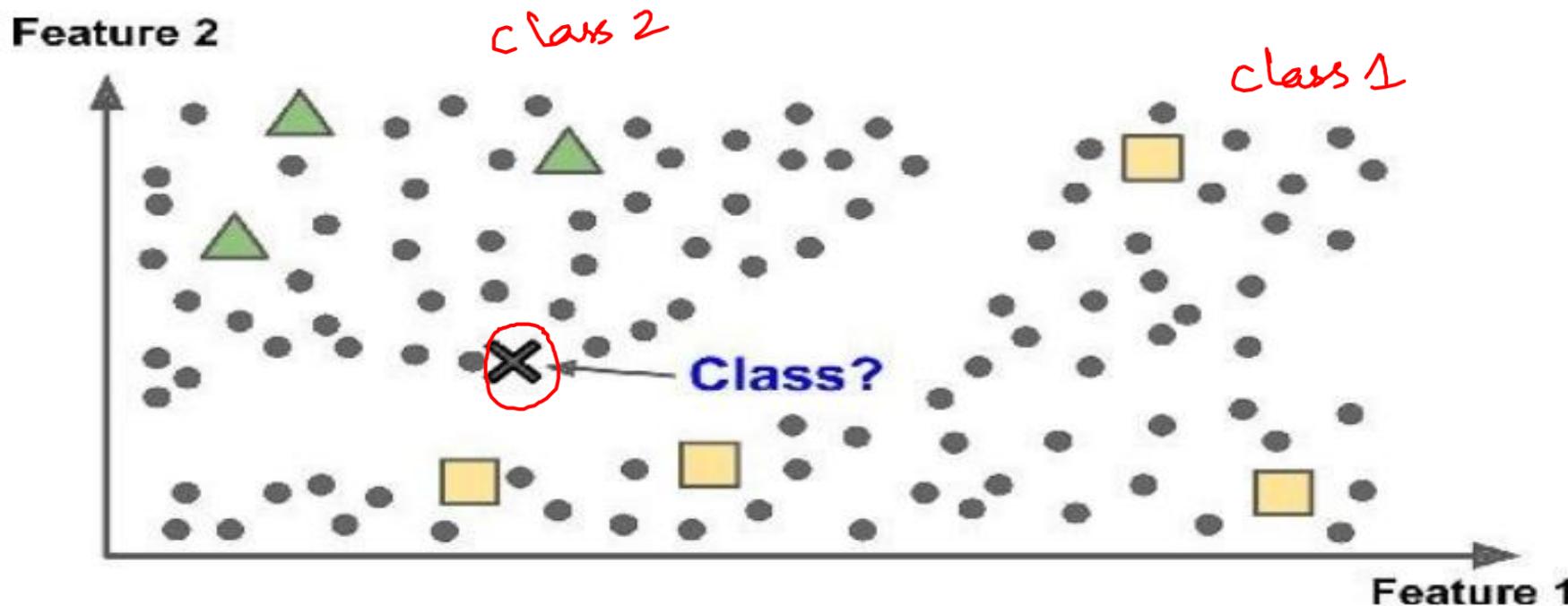
Criteria	Supervised Learning ✓	Unsupervised Learning ✓	Reinforcement Learning ✓
Definition	The machine learns by using labeled data	The machine is trained on unlabeled data without any guidance	An agent interacts with its environment by performing actions & learning from errors or rewards
Type of problems	Regression & classification ✓	Association & clustering ✓	Reward-based ✓
Type of data	Labeled data	Unlabeled data	No predefined data
Training	External supervision ✓	No supervision	No supervision
Approach	Maps the labeled inputs to the known outputs	Understands patterns & discovers the output	Follows the trial-and-error method

# Introduction to Machine Learning

## Semi supervised Learning

Partially labelled data – some labelled data and a lot of unlabelled data

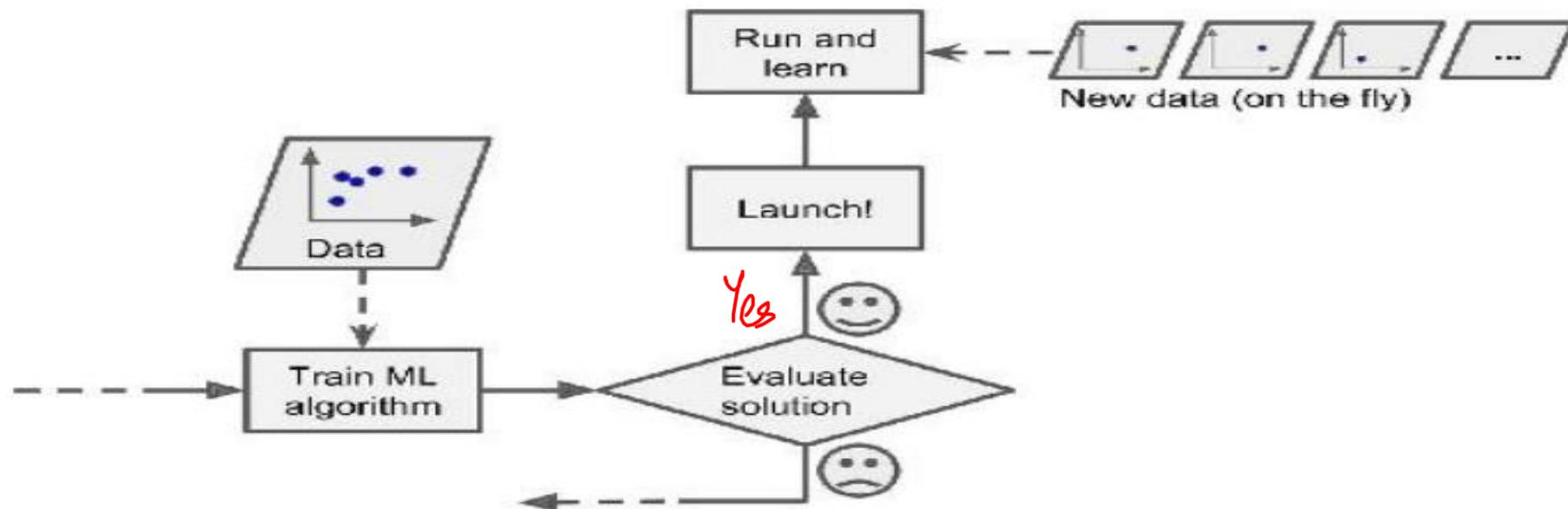
- Combines unsupervised and supervised learning algorithms
- Photo hosting service, e.g., google photos



# Introduction to Machine Learning

## Types: Based on how training data is used

- Batch learning: Uses all available data at a time during training
- Mini Batch learning: Uses a subset of available at a time during training
- Online (incremental) learning: Uses single training data instance at a time during training



# Introduction to Machine Learning

## Types: Based on how training data is used

- Instance Based Learning: Compare new data points to known data points
- Model Based learning : Detect patterns in the training data and build a predictive model

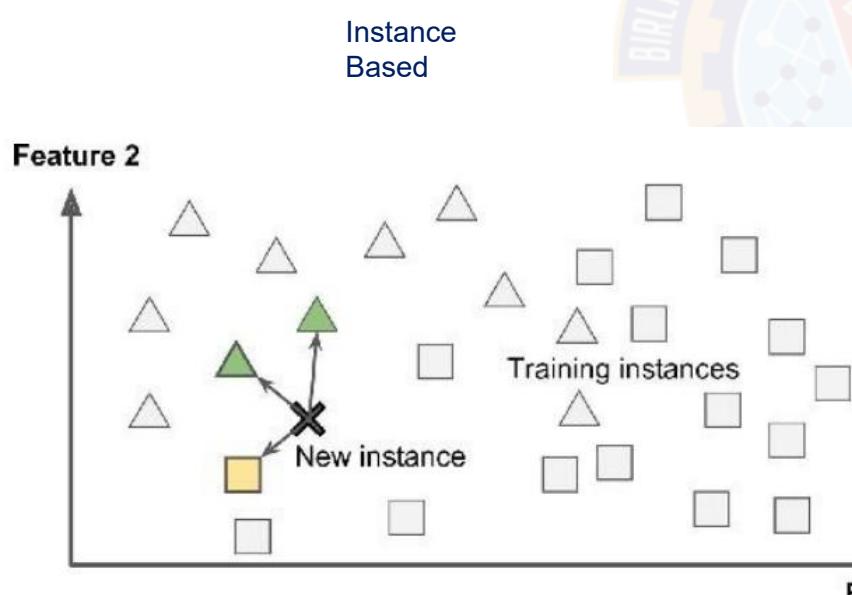


Fig:1

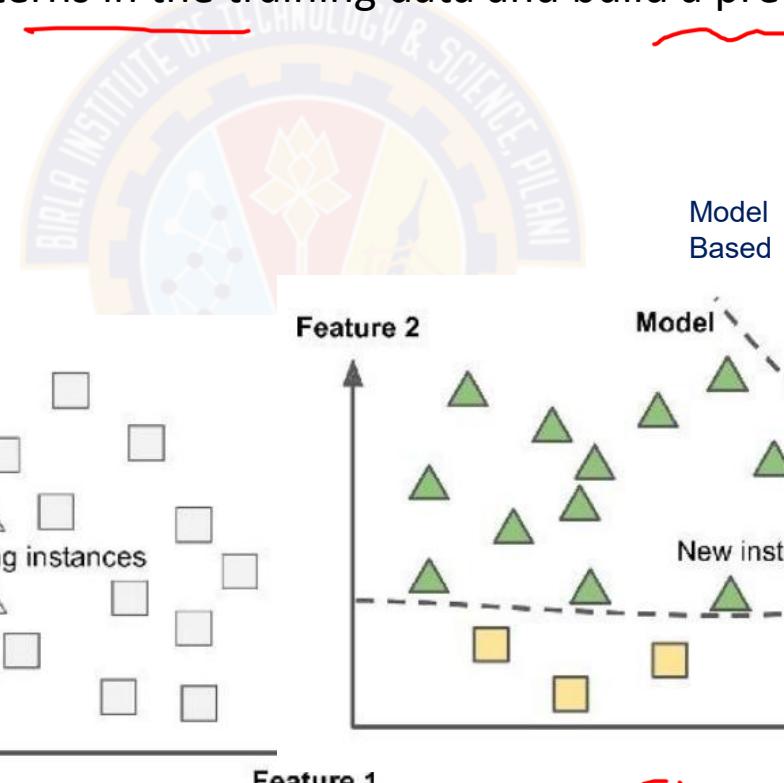
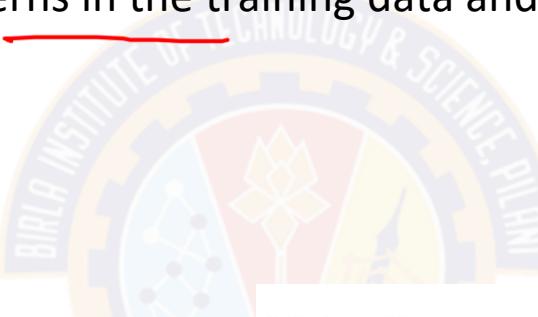


Fig: 2



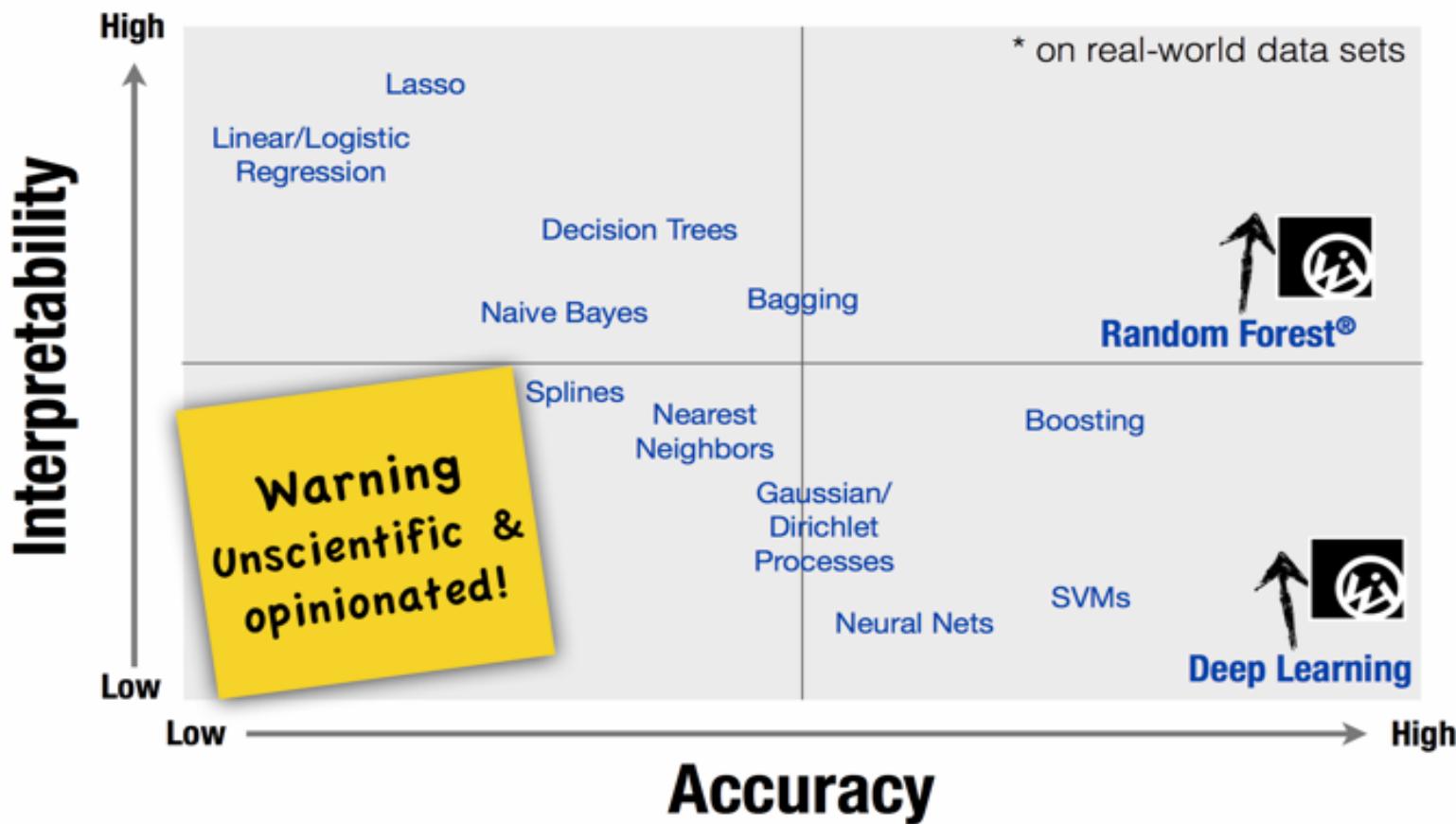
# Open source ML programming tools

	<b>Platform</b>		<b>Algorithms or Features</b>
Scikit Learn	Linux, Mac OS, Windows	Python, C, C++	Classification, Regression, Clustering Preprocessing, Model Selection Dimensionality reduction.
PyTorch	Linux, Mac OS, Windows	Python, C++ <u>  </u>	Autograd Module, Optimization Module NN Module
TensorFlow	Linux, Mac OS, Windows	Python, C++	Provides a library for dataflow programming.
Weka	Linux, Mac OS, Windows	Java	Data preparation, Classification Regression, Clustering, Visualization Association rules mining

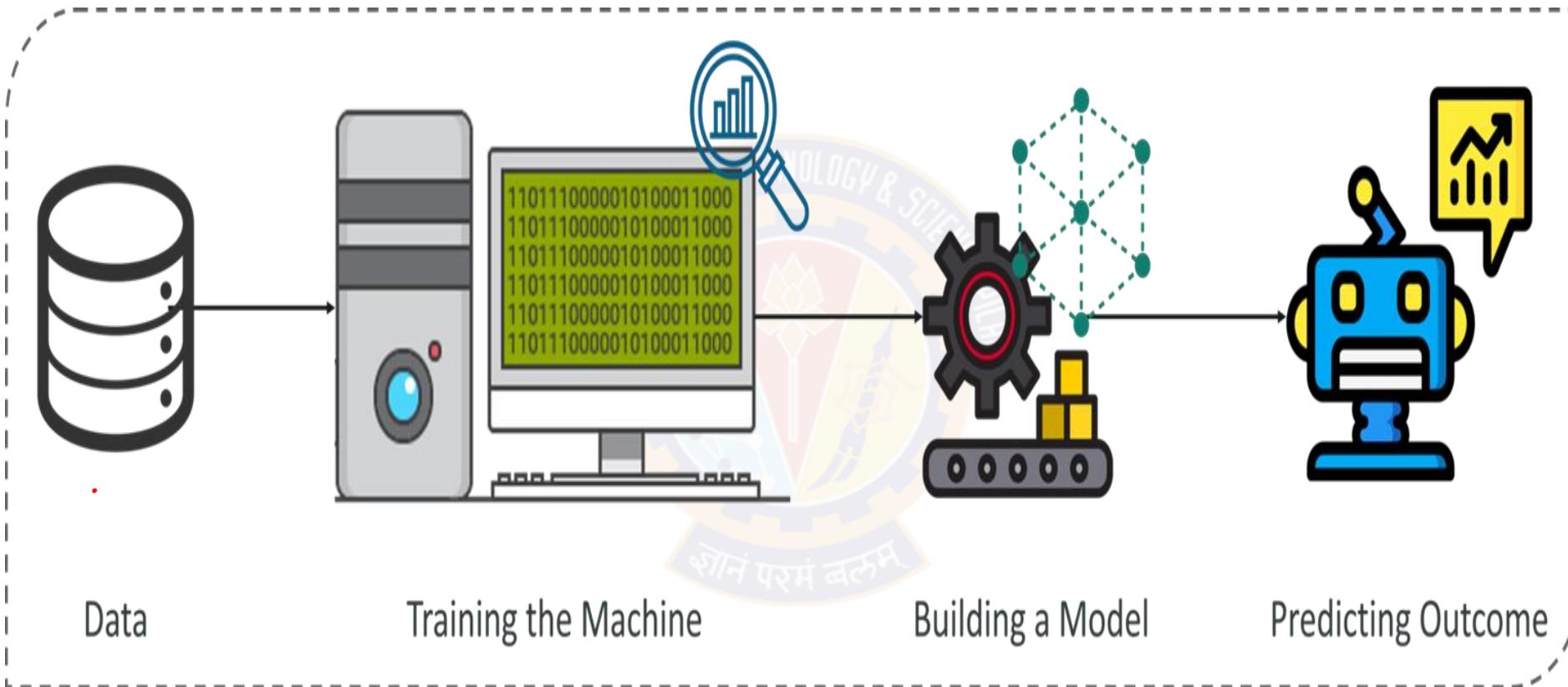
# Open source ML programming tools

✓Colab	Cloud Service	-	Supports libraries of PyTorch, Keras, TensorFlow, and OpenCV
Apache Mahout	Cross-platform	Java Scala	Preprocessors, Regression Clustering, Recommenders Distributed Linear Algebra.
Accors.Net	Cross-platform	C#	Classification, Regression, Distribution Clustering, Hypothesis Tests & Kernel Methods, Image, Audio & Signal & Vision
Shogun	Windows Linux, UNIX Mac OS	C++	Regression, Classification, Clustering Support vector machines. Dimensionality reduction, Online learning etc.
Keras.io	Cross-platform	Python	API for neural networks

# ML Algorithmic Trade-Off



# ML workflow



# ML workflow

1. Should I use ML on this problem?
  - Is there a pattern to detect?
  - Can I solve it analytically?
  - Do I have data?
2. Gather and organize data.
3. Preprocessing, cleaning, visualizing.
4. Choosing a model, loss, regularization, ...
5. Optimization
6. Hyper parameter search.
7. Analyze performance and mistakes, and iterate back to step 5 (or 3)

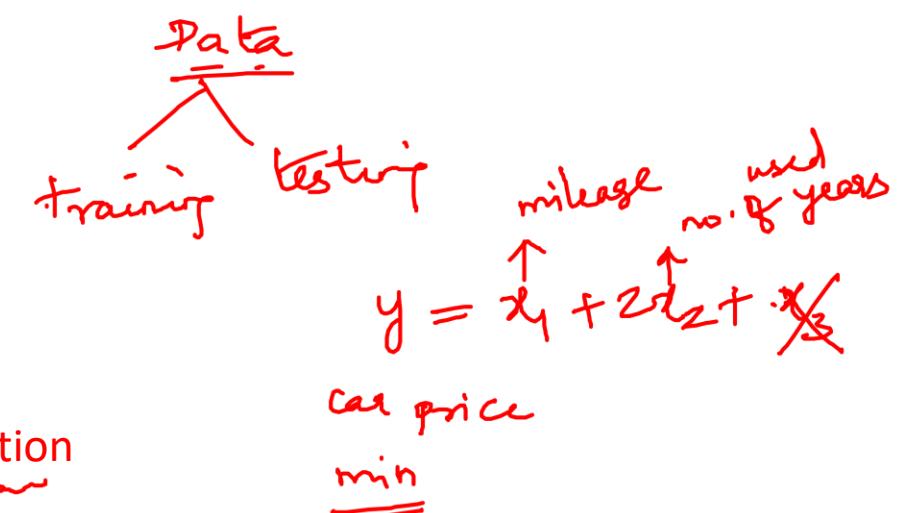


# Example: Car Price prediction based on Mileage

- Define the Objective
- Data Gathering: survey, Past Purchase data
- Data Preprocessing
  - training set; test set
  - representation of input features; output
- Exploratory Data Analysis
  - identifying the pattern
  - Structuring
  - visualizing
  - Handling missing data
- Choose form of model: linear regression ✓
- System's performance evaluation: objective function
- Optimize performance by setting appropriate parameters: Optimization
- Evaluate on test set: generalization

X Mileage	Y Car Price	H0	Error L1
9.8	10.48	9	2
9.12	1.75	8	7
9.5	6.95	9	3
10	2.51	9	7

Car Model  
Maruti ✓  
Skoda ✓



# References

Chapter 1 – Machine Learning, Tom Mitchell

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<http://www.cs.princeton.edu/courses/archive/spr08/cos511/> [Web]

<https://www.softwaretestinghelp.com/machine-learning-tools/>



**Thank you**