Machine Learning

What is learning?

- Learning (for humans) is experience from past.
- A machine can be programmed to gather experience in the form of facts, instances, rules etc.
- A machine with learning capability can predict about the new situation (seen or unseen) using its past experience.
- Examples:
  - As we humans can tell a person's name seeing him/her second or fifth time, a machine can also do that.
  - As we humans can recognize a person's voice even if not seeing person's face, a machine can also be made to learn to do the same.

Class Experiment: Training

- Let
  - AA denote 5
  - BB denote 6
  - AAA denote 50
  - BBB denote 60
  - AAAA denote 500
  - BBBB denote 600
- Can you find out the equivalent numerical value of AAAAA? 5000: yes/no?
- Or of AABB? Not yet trained……

Learning pronunciation (by a young kid)

- Training
  - Cat (ae sound)
  - Pot(aw sound)
  - Pat (ae sound)
  - Tap (ae sound)
  - Cot (aw sound)
- Testing
  - How do you pronounce ‘not’? My students know the answer.
  - How do you pronounce ‘check’ ? The kid is not trained yet, hence learning is not to this level.

Learning example : Relate human learning with that of machine learning

- Training

  A coin is tossed 10 times and it is observed that it fell 7 times with head on top and 3 times tail on top. [observe that you are learning as you read the above]

- Testing

  Will you get head next? (Hypothesis: get the head on top)

  yes, most probably.

  What is the chance that the next coin when tossed will be head? (Hypothesis: next toss is head)

  P(next toss is head | Previous 10 tosses had 7 heads)

Learning

- Human

  Gain experience from day to day activities and gain ablility to predict.

- Machine

  Get trained with the numerical data (data can be text, image, sound, rules etc) and be able to predict.

Why Machine Learning?

- Humans have limitations in terms of accessibility and computational efficiency.
- Machine learning is required in
  - Navigation in Mars
  - Avalanche areas to detect buried
  - Speech recognition etc.
- Machine learning is not required in
  - General computations such as payroll
  - Computation of sum of numbers
  - Counting etc.

Machine Learning and Artificial Intelligence

- Machine Learning is a branch of Artificial Intelligence (AI) in which the intelligent system learns from its environment.
- AI systems include intelligence of different types such as reasoning, planning, search and game playing, learning etc. of which learning is specific to the Machine Learning systems.

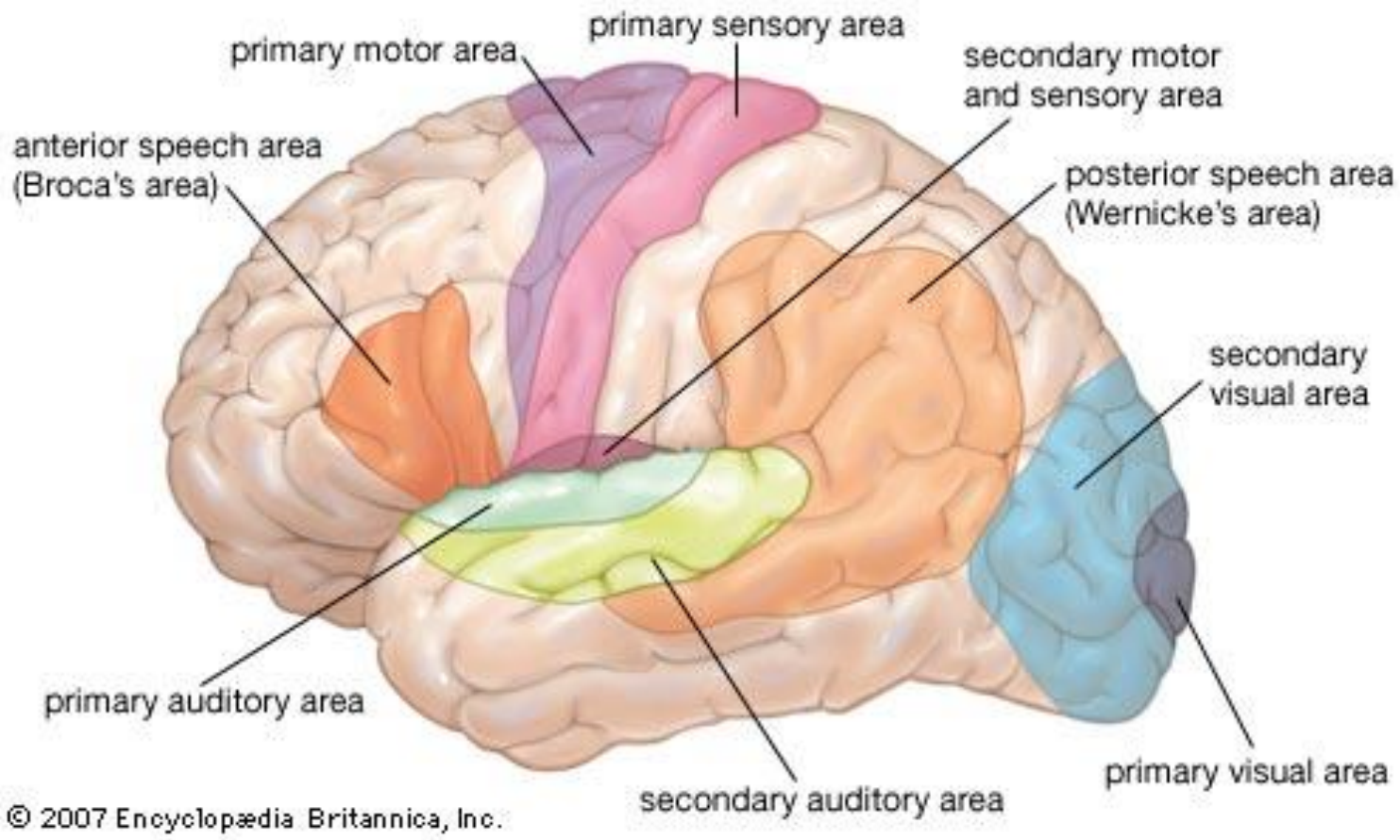
What is Artificial Intelligence?

- It is the computational intelligence of computers that enables them to behave and act human like.
- An artificial intelligent system possesses one or more of the human capabilities of reasoning, thinking, planning, learning, understanding, listening and responding.

Common attributes of Human mind

- Perception/Vision/Recognition,
- Reason,
- Imagination,
- Memory,
- Emotion,
- Attention, and
- A capacity for communication

Human brain


primary motor area
primary sensory area
secondary motor and sensory area
anterior speech area (Broca's area)
posterior speech area (Wernicke's area)
secondary visual area
primary auditory area
secondary auditory area
primary visual area
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Understanding Human brain

- Thought is a mental activity which allows human beings to make sense of things in the world, and to represent and interpret them in ways that are significant.
- Thinking involves the symbolic or semantic mediation of ideas or data, as when we form concepts, engage in problem solving, reasoning and making decisions.

Understanding Human Brain

- Memory is the ability to preserve, retain, and subsequently recall, knowledge, information or experience.
- Imagination is the activity of generating or evoking novel situations, images, ideas etc. in the mind.

Artificial Intelligence: An intelligent car navigation system [An Example]

- A system to navigate a car to the airport works on its vision enabled using camera mounted at the front of the car.
- The system "sees" the lane limits, the vehicles on the way and controls the car from colliding. **[Vision]**
- It follows the road directions.
- It also follows the road rules.
- The system learns to handle unforeseen situations. For example if the traffic flow is restricted on a portion of the road temporarily, the system takes the alternative path.**[learning]**

More intelligence can be expected

- The system “listens” to the person sitting in the car to stop at a nearby hotel for a tea and “sees” around to find a hotel, keeps travelling till it finds one and stops the car. **[speech Recognition, Vision]**
- Understands the mood of the person and starts music to suit the mood of the person. **[Facial Expression]**
- Can answer the queries, such as “how far is Pilani?”, “What is the time”, “can I sleep for an hour?”, “Please wake me up when it is 11:00 in the morning?” **[Natural Language Processing]**

Some of the Existing intelligent systems

- Watson : Question Answering Machine
- Deep Blue: A chess program that defeated the world chess champion Gary Kasparov

Deep Blue : Chess Program

Source : Google Images

Other intelligent systems

- Smart home
  - Lights switch off if there is no one in the room
  - Curtain pull off at the sun rise
  - Dust bin is emptied before it is overflowing
  - Smart water taps, toilets etc.
- Smart office
  - Automatic meeting summary
  - Speaker recognition and summary generation
- Automatic answering machine

Other intelligent machines

- An airplane cockpit can have a intelligent system that takes automatic control when hijacked [context and speech understanding, NLP, vision]
- Medical diagnosis systems trained with expert guidance can diagnose the patients disease based on the xray, MRI images and other symptoms
- Automated theorem proving
- General problem solver

AI Techniques

- The general problem of simulating (or creating) intelligence has been broken down into a number of specific sub-problems
  - Reasoning and deduction
  - Knowledge Representation
  - Planning
  - Learning
  - Natural Language Processing
  - Motion
  - Perception

Intelligent Agent

- An intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success.
- Artificial Intelligence aims to build intelligent agents or entities.

Intelligent agent

- An agent is anything that can be viewed as **perceiving** its **environment** through **sensors** and acting upon that environment through **actuators**
- Human Agent Vs. Machine Agent
  - Differ in sensor technology
    - Ear, nose, eye, touch, smell (HUMAN)
    - Speaker, camera, infrared sensors, smoke sensors, etc
  - Differ in their capacity to perceive the environment
  - Differ in acting upon the environment through actuators

Environment

- The parameters that are required for reasoning, thinking, perception and so on
- Example (for humans)
  - A one year old child's environment: Home, family members, toys
  - A 10 year old child's environment : Home, family members, school, teachers, books, play mates
- Example (for machines)
  - Washing machine intelligent agent's environment: dirt, clothes, detergent etc
  - Intelligent Automobile Robot: parts of automobile and their exact description

How does an intelligent agent work in given environment?

- It perceives the environment.
- Acts based on the experience and query.
- Responds in terms of adding to the knowledge base
- Thus must Learn from the history of percepts

Machine Learning Applications

- Speech recognition
- Automatic news summary
- Spam email detection
- Credit card fraud detection
- Face recognition
- Function approximation
- Stock market prediction and analysis
- Etc.

Machine Learning

- 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. (Tom Mitchell)

Learning From Observations

- Learning Element:
  - responsible for making improvements
- Performance Element:
  - responsible for selecting external actions
- The learning element uses feedback from the critic on how the agent is doing and determines how the performance element should be modified to do better in the future

Design of a learning Element

- Affected by three major issues:
  - Which components of the performance element are to be learned
  - What feedback is available to learn these components
  - What representation is used for the components.

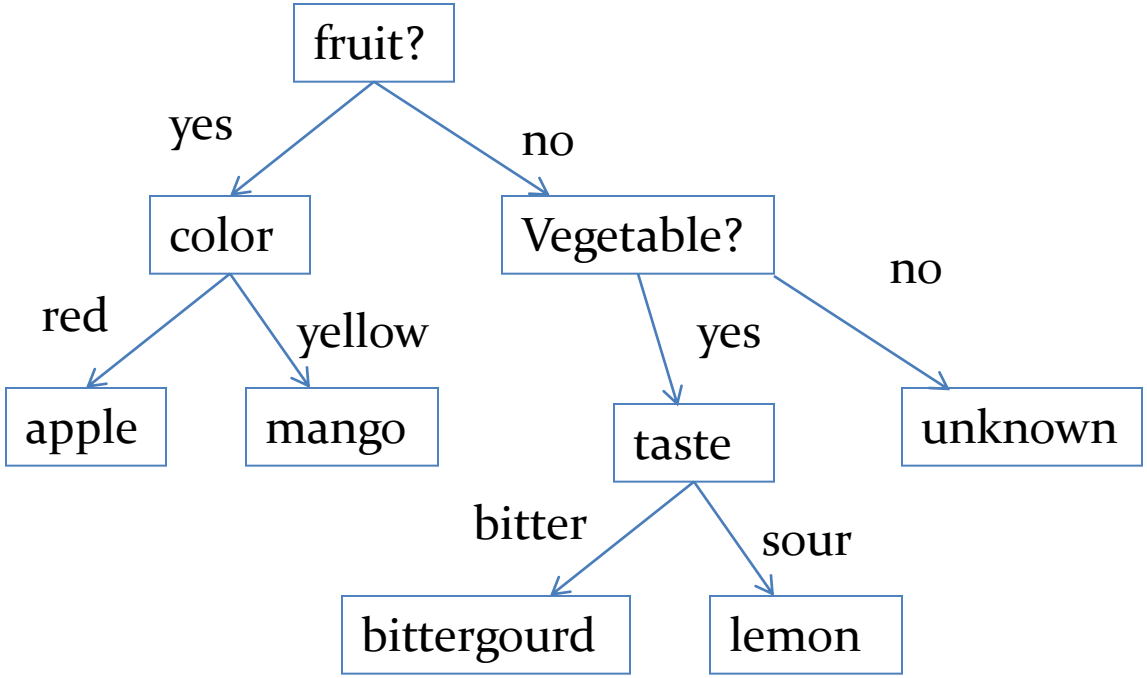
Types of feedback for learning

- Supervised
  - Inputs and outputs
- Unsupervised
  - Inputs available, but no specific output
- Reinforced
  - Reward or penalty

Learning Algorithms

- Decision Trees
- Neural Networks based learning algorithms
- Ensemble Learning
- Bayes' classifier
- EM (expectation Maximization) algorithm
- Support Vector Machines etc.

Inductive Learning using Decision Trees: An example to learn to identify an object



Decision Tree

- A decision tree takes as input an object or situation described by a set of attributes and returns a decision.
- This decision is the predicted output value for the input.
- The input attributes can be discrete or continuous.
- Classification Learning:
  - Learning a discrete valued function is called classification learning
- Regression :
  - Learning a continuous function is called Regression.

Decision Tree

- A decision tree reaches its decision by performing a sequence of tests.
- All non leaf nodes lead to partial decisions and assist in moving towards the leaf node.
- Leaf nodes are the decisions based on properties satisfied at non leaf nodes on the path from the root node.

Decision tree

- Leaf nodes depict the decision about a character having attributes falling on the path from the root node
- Each example that participate in the construction of the decision tree is called a training data and the complete set of the training data is called as training set.

Limitations of Decision Tree Learning

- The tree memorizes the observations but does not extract any pattern from the examples.
- This limits the capability of the learning algorithm in that the observations do not extrapolate to examples it has not seen.

Attribute Creation/Selection in various problem domains (recognition)

google images

Obtain the most suitable Features/ attributes
- Color
- shape
- No of wheels
- Capacity
- Rear mirrors
- No of headlights

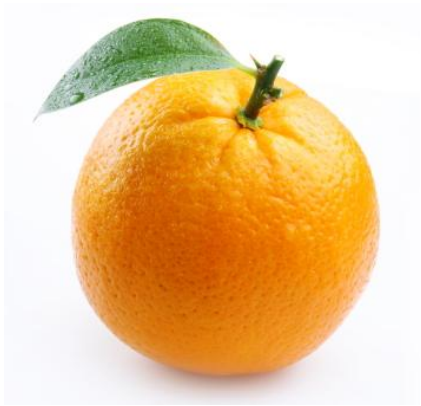
Availability of information
- Images
- Actual data

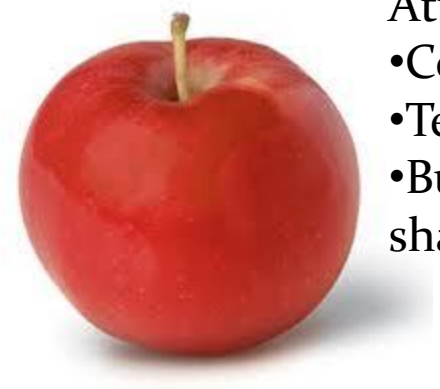
- Attributes will differ

Fruits recognition

T: fruit recognition
P: recognition accuracy
E: experience by training

First specify the problem clearly
Do you want to discriminate amongst the ones shown below or want to put them in one category.





Attributes
- Color
- Texture
- But not shape

Face Recognition

Training examples of a person

Test images

AT&T Laboratories, Cambridge UK
http://www.uk.research.att.com/facedatabase.html

Human face recognition

T: Face recognition
P: recognition accuracy / rejection accuracy
E: experience by training

Humans are very quick in recognizing face of a person.
Analyze your brain's capacity of remembering number of features of a person's face

Selection of attributes
- No of eyes X
- Hair?
- Spects
- Nose line
- Chin shape
- Number of ears
- Wrinkles
- Male?
- Ratio of lip length and eye length
- What else?

Attributes

Mathematical features
- DCT coefficients
- Pixel values
- Average pixel intensity

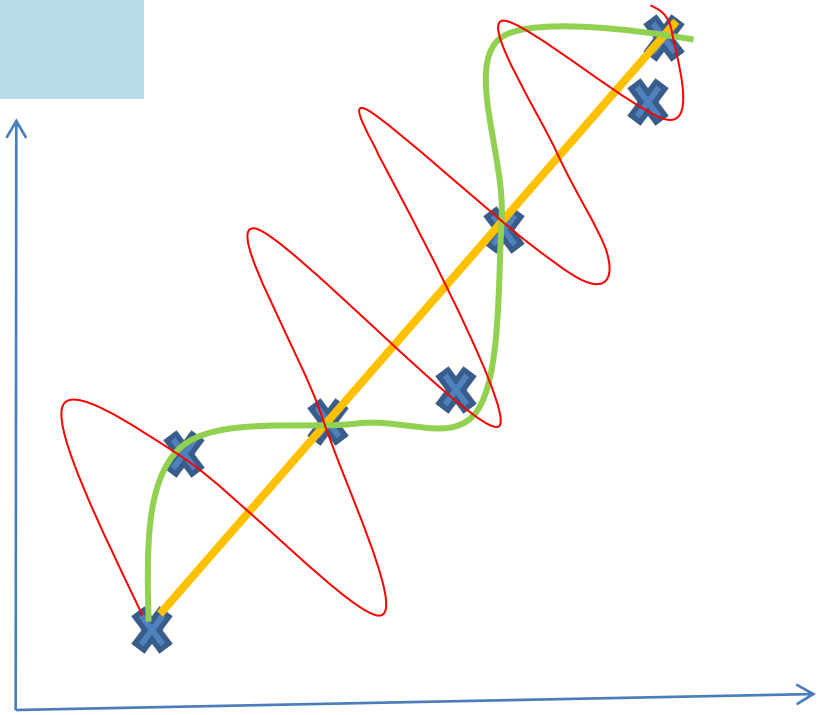
Training set can be a set of face images with varying expressions, illumination, pose etc

An intelligent system will be said to be with capability of learning (human like) if it recognizes unseen data

Learning of a function from given sample data

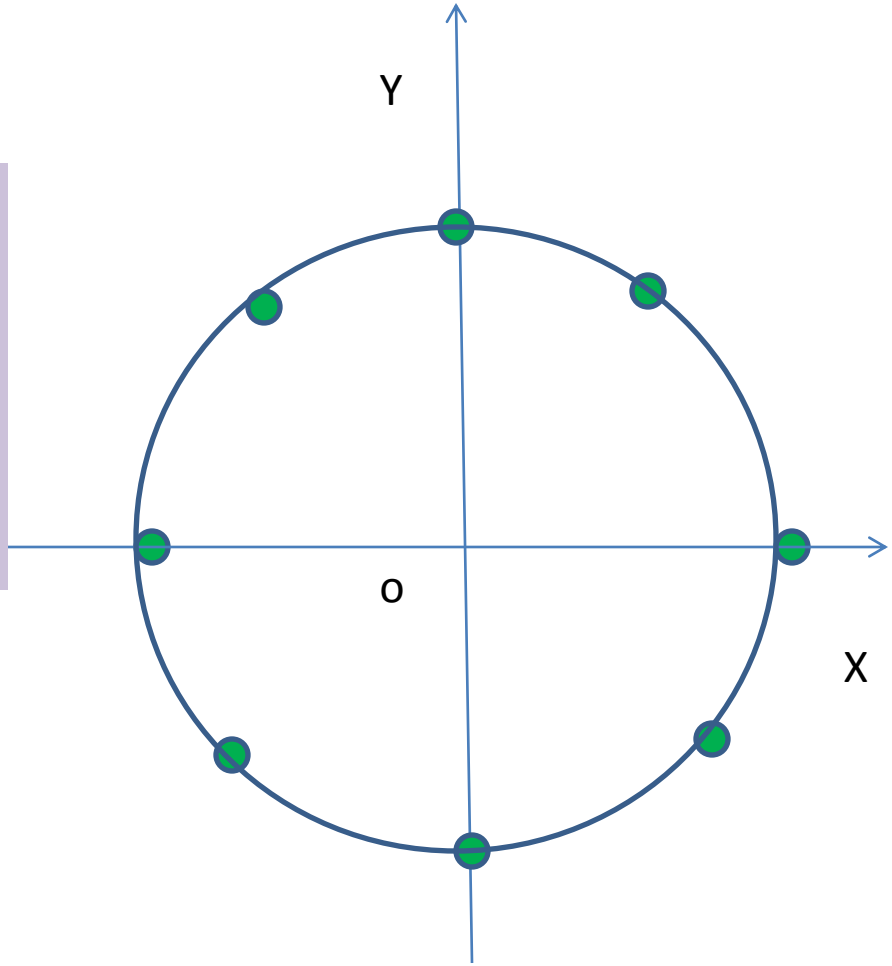
T: prediction of y-value for given x-value
P: least error
E: experience by training

1. Straight Line
2. Sinusoidal Curve
3. Other higher order polynomial



Generalization in Function Approximation

Generalization
If the NN answers -
-
What is f(-0.25)?
Or
f(0.001)
correctly

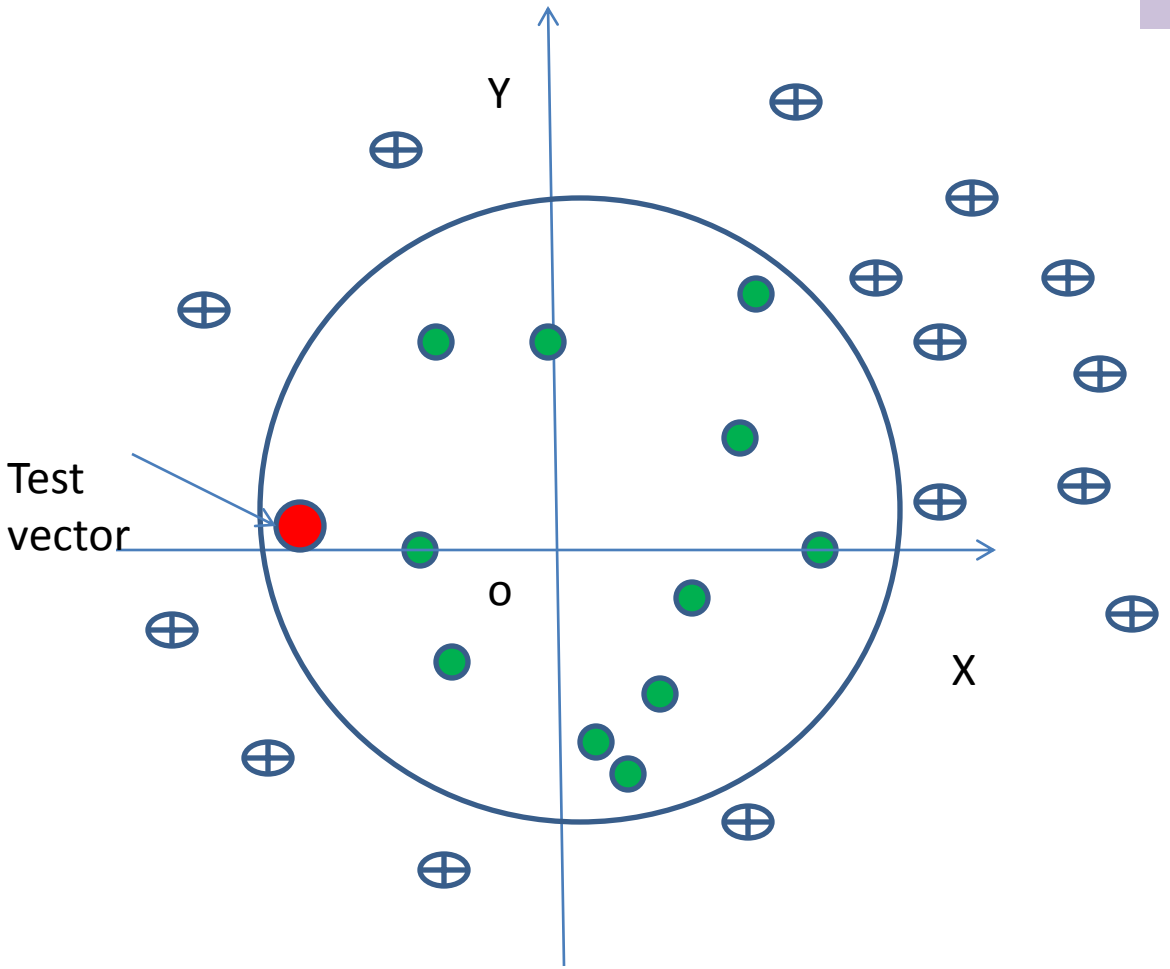


X	Y
1	0
0	1
0	-1
0.6	0.8
0.6	-0.8
-0.6	0.8
-0.6	-0.8
-1	0

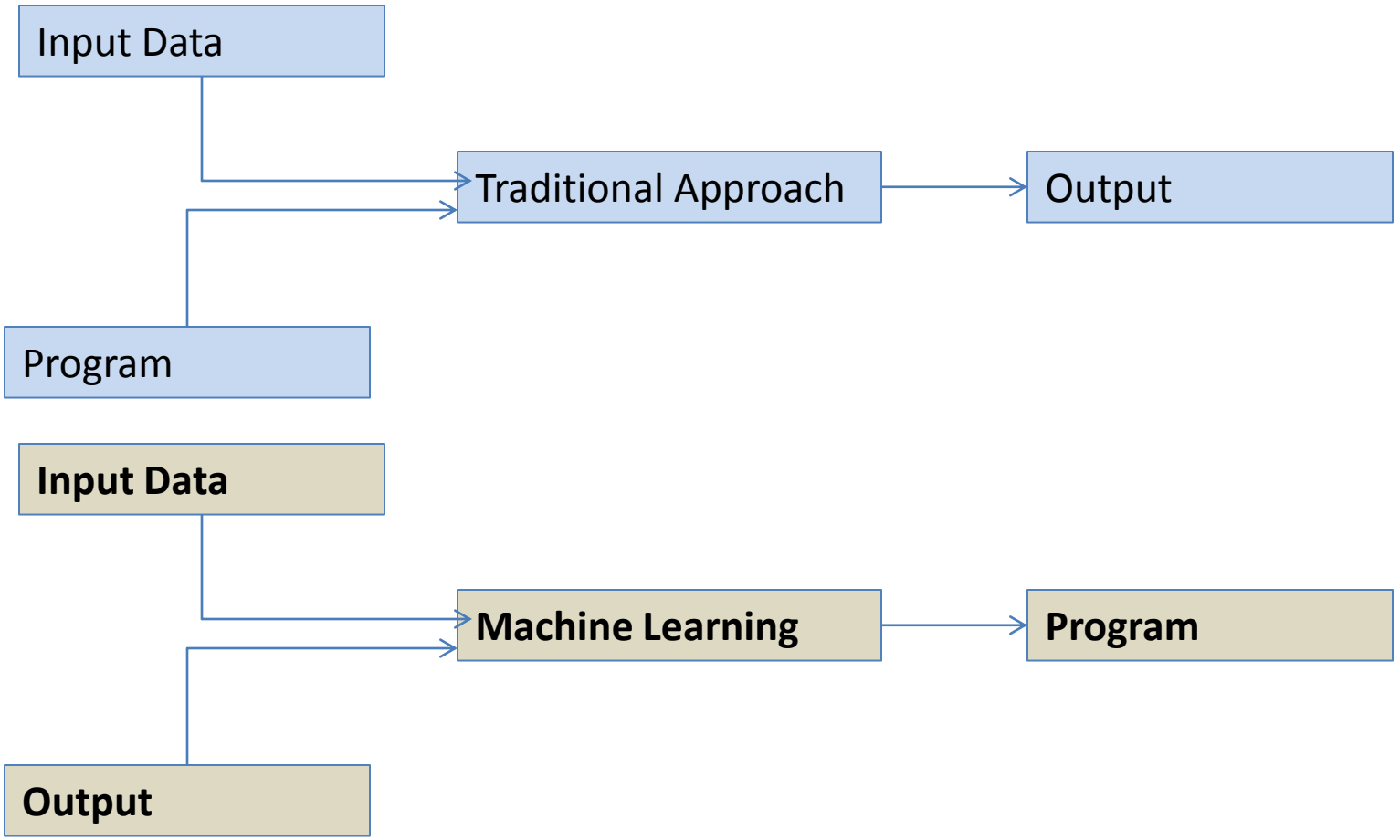
$Y = \pm \sqrt{(1-X^2)}$

Generalization in Classification Problem

Generalization
If the test feature vector can be correctly classified



Traditional Vs. Machine Learning



How does a program as an output realized?

- Program is characterized by its parameters.
- For example:
  - A neural network classifier is represented by its weights
  - Weights are obtained by analyzing input and output data
  - A decision tree is characterized by its attributes obtained by training input and output classes

Neural Networks

- Mathematical Models representing the massively parallel machines
- Model inspired by the working of human nervous system
- Has a number of neurons performing the task similar to human neuron
- Each neuron triggers the received input according to the weight.
- A neural network captures the environment it has to learn in terms of the weights.

A Neuron

- A mathematical neuron is a processing unit capable of receiving inputs from single or multiple neurons and triggers a desired response.
- Each neuron has an associated activation function which takes as input the weighted sum of the inputs coming to the neuron and triggers a response depending on the associated threshold