Introduction to Machine Learning Using Python

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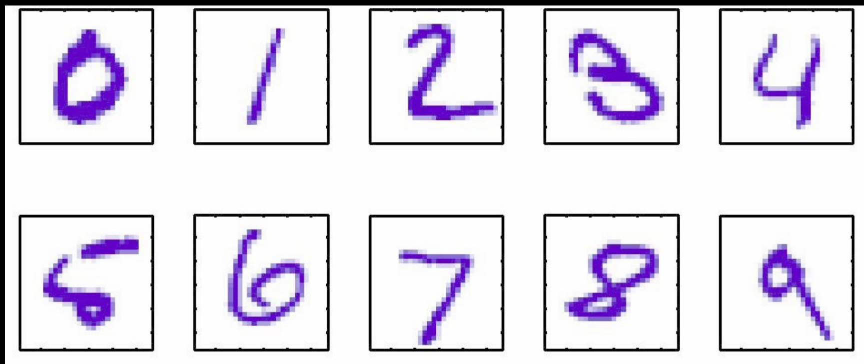
Contents:

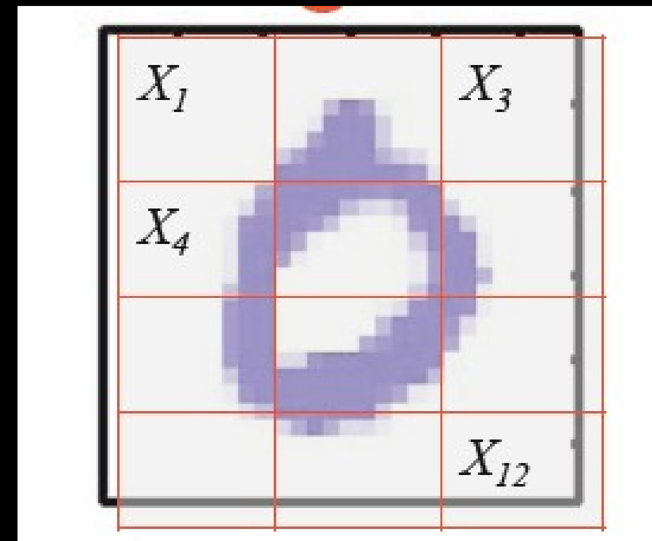
Definition:

A computer program is said to '<u>learn</u>' 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

Example:

Classification: Digit Recognition





Input (X_i) : Image Features

Output (Y): Class Labels { $y^0, y^1, .. y^9$ }

Features(X_i):

Proportion of pixels in Each of the 12 cells

$X_i \, where \, i = 1,2,\ldots,12$

$x_i^0 = 0\text{-}10\%$
$x_i^1 = 10\text{-}20\%$
....

$Val(Xi) = 10$

No of parameters $= 10^{12} - 1$

Handcrafted Rules will result in a large number of rules and exceptions

- We need ML in cases where we cannot directly write a program to handle every case

So it's better to have a machine that *learns* from a large training set

So, according to the definition earlier:

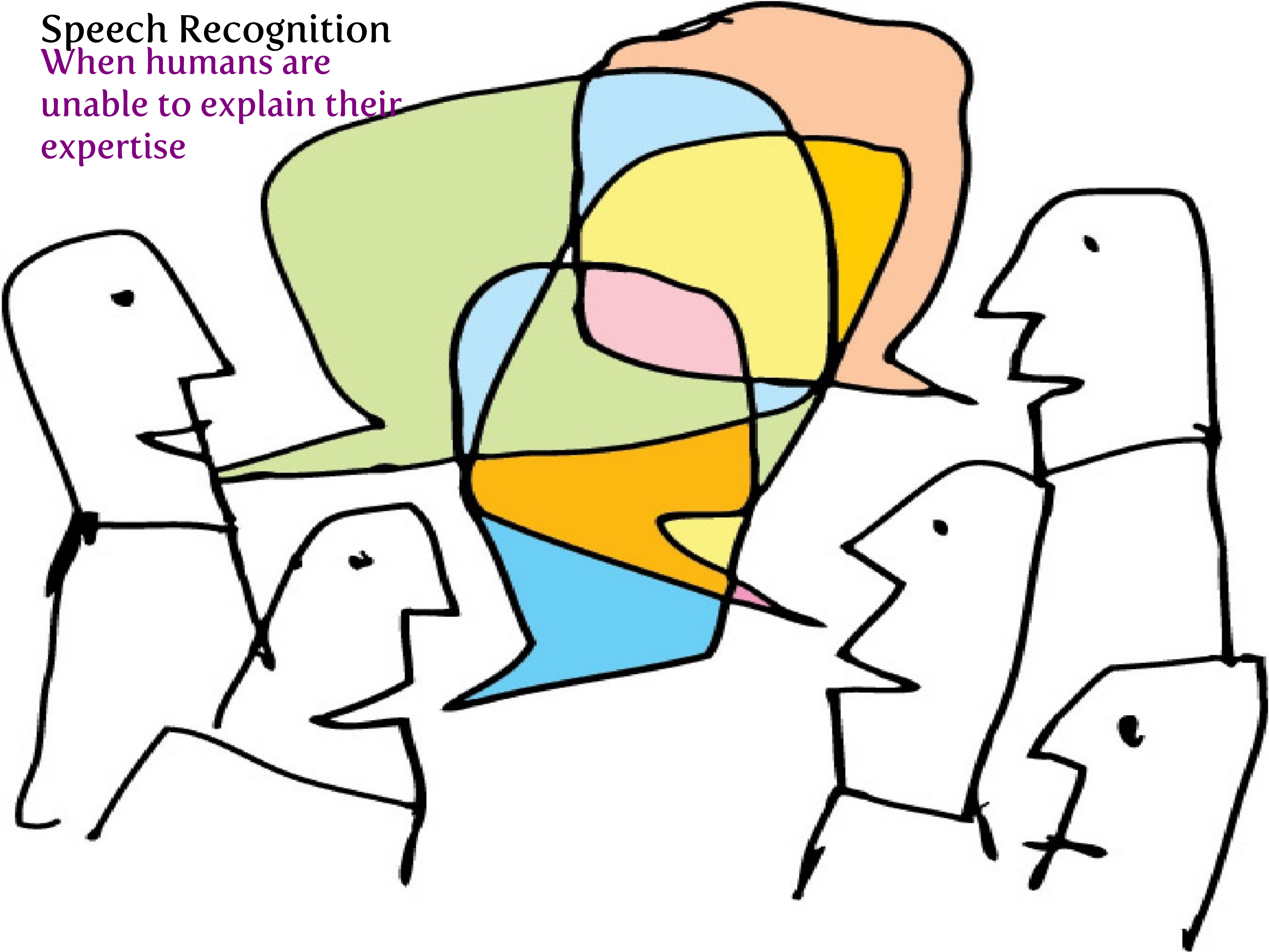
Task (T): recognizing and classifying handwritten words within images

Performance measure (*P*): percent of words correctly classified

Training experience (E): a database of handwritten words with given classifications

Speech Recognition

When humans are unable to explain their expertise



Where ML is used…


Inbox
Outbox
Spam (3015)
Trash

Google news [Search News]

Advanced news search

U.S. edition ▾ Add a section »

Top Stories
- National Collegiate Athletic Association
- Boston Celtics
- Abby Sunderland
- BP
- Big Ten Conference
- New York Mets
- South Africa
- Chicago Blackhawks
- Philadelphia Phillies
- Iran

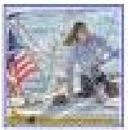
- Starred ☆
- Richland, WA
- Google
- Social Networking
- World
- U.S.
- Business
- Sci/Tech
- Entertainment
- Sports
- Health
- Spotlight
- Most Popular

All news
- Headlines
- Images

Top Stories


Kansas City...

BP »
Scientists offer varied estimates, all high, on size of BP oil leak
Washington Post - Joel Achenbach, Juliet Eilperin - 17 minutes ago
Cleanup and containment efforts continue at the Gulf of Mexico site of the oil spill following the Deepwater Horizon explosion. By Joel Achenbach and Juliet Eilperin Pick a number: 12600 barrels .
Anger rises along with spill size estimate Houston Chronicle
New Estimates Double Rate of Oil That Flowed Into Gulf New York Times
The Associated Press - San Jose Mercury News - Citizens for Legitimate Government - ABC News - Wikipedia: Deepwater Horizon oil spill
all 576 news articles »


Telegraph.c...

Abby Sunderland »
Rescue teams head to stricken teen sailor
ABC Online - 2 hours ago
Jessica Watson's family say their thoughts and prayers are with a solo teenage sailor missing in mountainous seas in the middle of the Indian Ocean.
⊞ Video: Teen May Be Lost at Sea During Solo Sail The Associated Press
Teenage sailor in ocean distress BBC News
CNN - New York Times - Xinhua - The Press Association - Wikipedia: Abby Sunderland
all 1,370 news articles »


Telegraph.c...

Mobile Industry »
FBI Opens Probe Into IPad E-Mail Security Breach
BusinessWeek - Karen Gullo, Greg Bensinger - 1 hour ago
June 10 (Bloomberg) -- The Federal Bureau of Investigation started an investigation of a security breach in AT&T Inc.'s wireless network that exposed the e-mail addresses of users of Apple Inc.'s iPad 3G.
⊞ Video: iPad AT&T Hacker Revealed Weev Escher Auernheimer Goatse Security White Hat FBI Investigates Santa Barbara Arts TV
Hacker defends going public with AT&T's iPad data breach (Q&A) CNET
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all 1,543 news articles »

News for you
View as: **List** - Sections

This page will adapt to show news about your interests. Choose how often you like to read news from each section and add topics you follow. ✕

How often do you read:	Rarely	Sometimes	Always
World	○	◉	○
U.S.	○	◉	○
Business	○	◉	○
Sci/Tech	○	◉	○
Entertainment	○	◉	○
Sports	○	◉	○
Health	○	◉	○
Google - Remove		○	◉
Social Networking - Remove		○	◉

Add any news topic [Add] [Save and close]

Recent
Beached whale found on island near New York
CNN - 23 minutes ago

Chaos at Arlington Cemetery: Mismarked graves, dumping of urns
Washington Post - Michael E. Ruane - 37 minutes ago

Mexico's Coach Feeds Passion Of a Nation
New York Times - Jeré Longman - 15 minutes ago

Richland, WA - Edit
70°F 69°F | 50°F
Fri 77°F | 50°F
Sat 85°F | 57°F

Richland man sidelined from swim due to fog
Mid Columbia Tri City Herald - 10 hours ago

Vit plant project director to speak Tuesday in Richland
Mid Columbia Tri City Herald - 4 hours ago

Delvin pushes for waste to go to Yucca Mountain
Mid Columbia Tri City Herald - 10 hours ago

Spotlight
Feds eye Apple-Google ad war
Fortune - Philip Elmer-DeWitt - 14 hours ago

Dressed to Distract
New York Times - Maureen Dowd - Jun 5, 2010

Karl Rove: Obama and the Trouble With Voting 'Present'
Wall Street Journal - Karl Rove - 12 hours ago

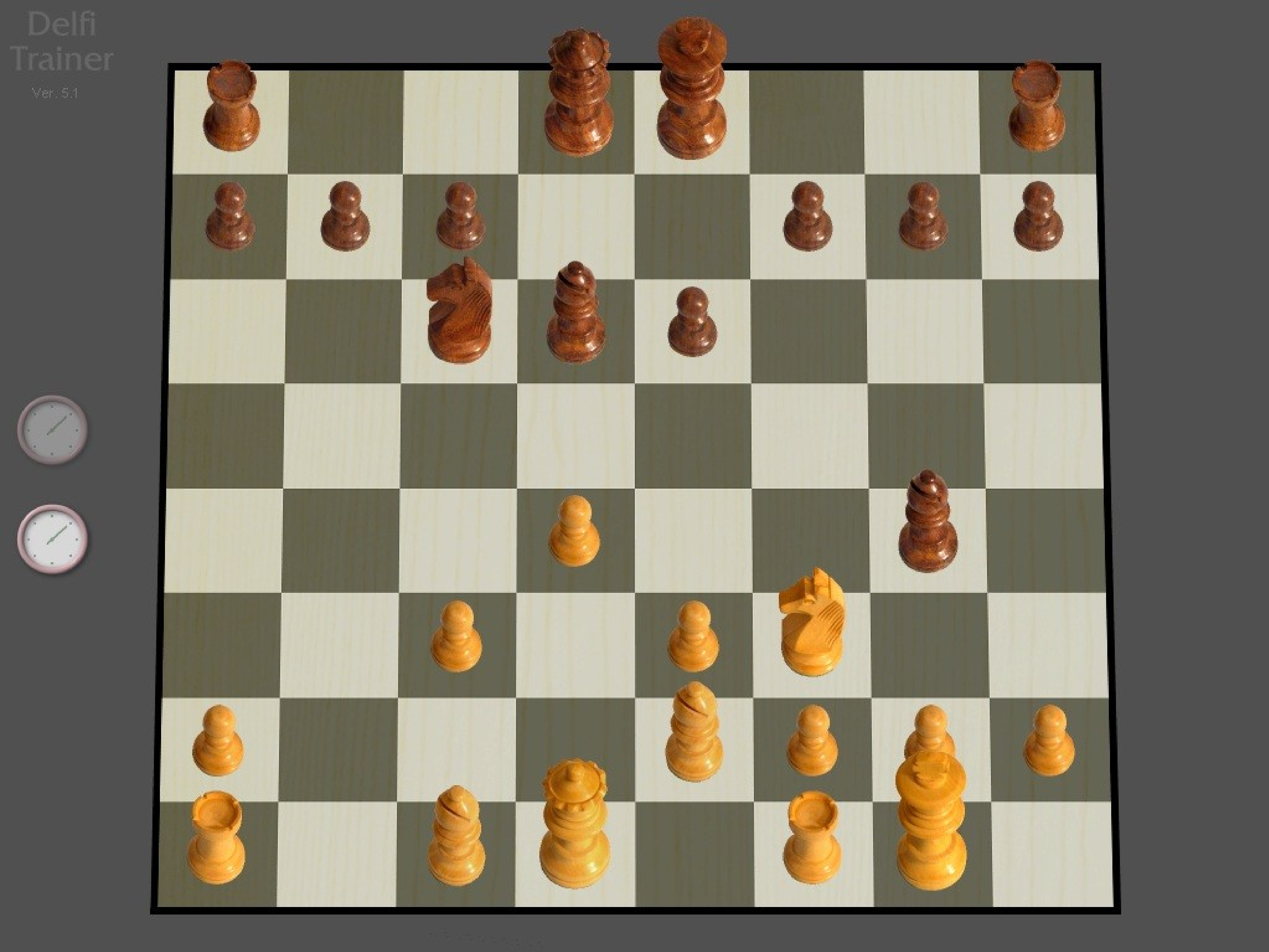
Many studies great news for mice, not so much for humans
CNN - Elizabeth Landau - Jun 8, 2010

Studies Show Jews' Genetic Similarity
New York Times - Nicholas Wade - Jun 9, 2010

In Medium Raw, Bourdain Is the Last Honest Man
TIME - Josh Ozersky - Jun 8, 2010


GRAND
DARPA
CHALLENGE
Autonomous Ground Vehicles
03
Electronics Research Laboratory
Red Bull
SunFuel
ANDROID
MDV
MOHR DAVIDOW VENTURES
Drivers not required.


POWER7
POWER7
POWER7
WATSON
POWER7
POWER7


Delfi
Trainer
Ver. 5.1

Major Classes of Learning Algorithms:

Learning Algorithms

- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning

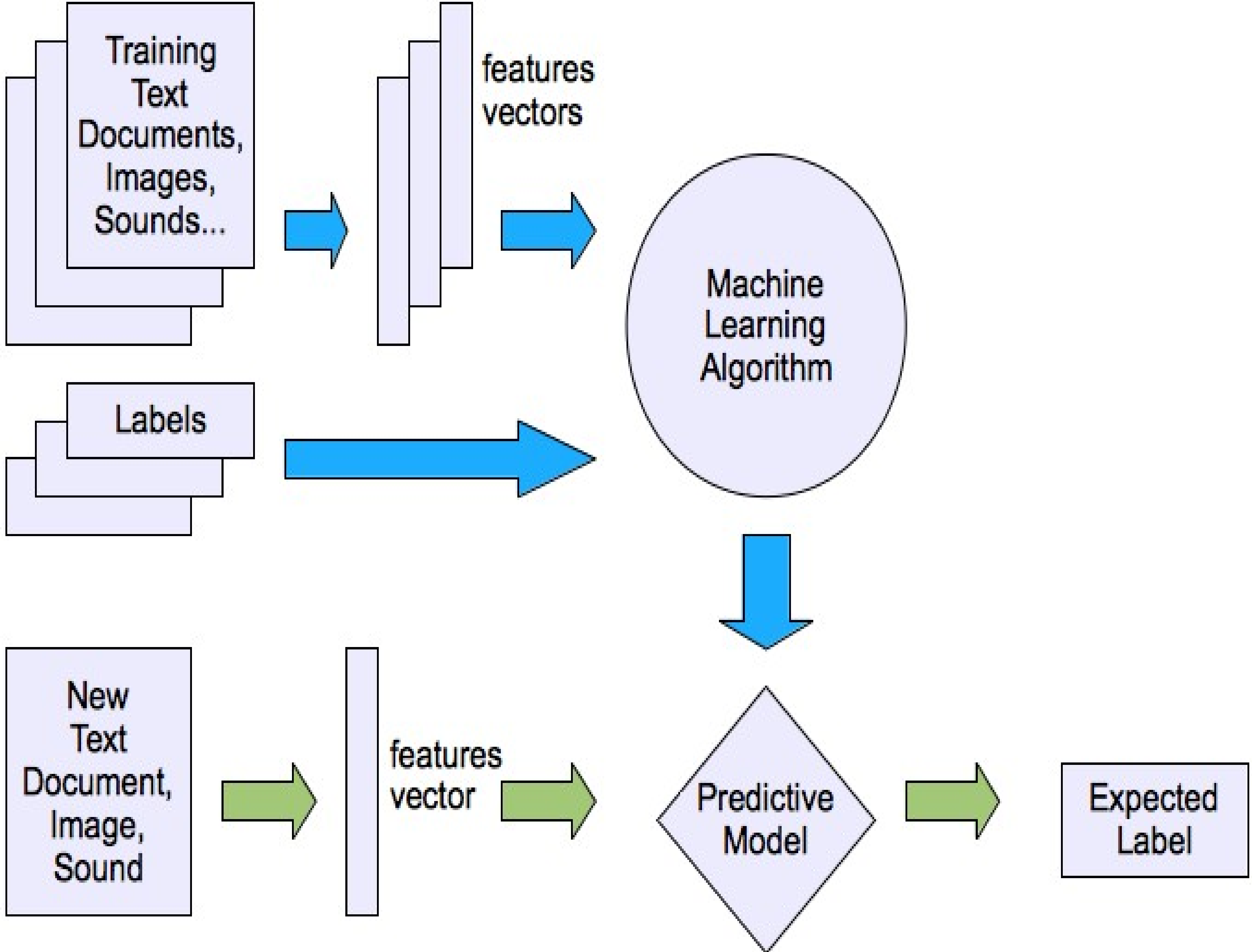
Supervised Learning:

- The set of data (training data) consists of a set of input data and correct responses corresponding to every piece of data.

- Based on this training data, the algorithm has to generalize such that it is able to correctly (or with a low margin of error) respond to all possible inputs..

- In essence: The algorithm should produce sensible outputs for inputs that weren't encountered during training.

- Also called learning from exemplars


Training
Text
Documents,
Images,
Sounds...
features
vectors
Machine
Learning
Algorithm
Labels
New
Text
Document,
Image,
Sound
features
vector
Predictive
Model
Expected
Label

Supervised Learning

Regression Problems

Classification Problems

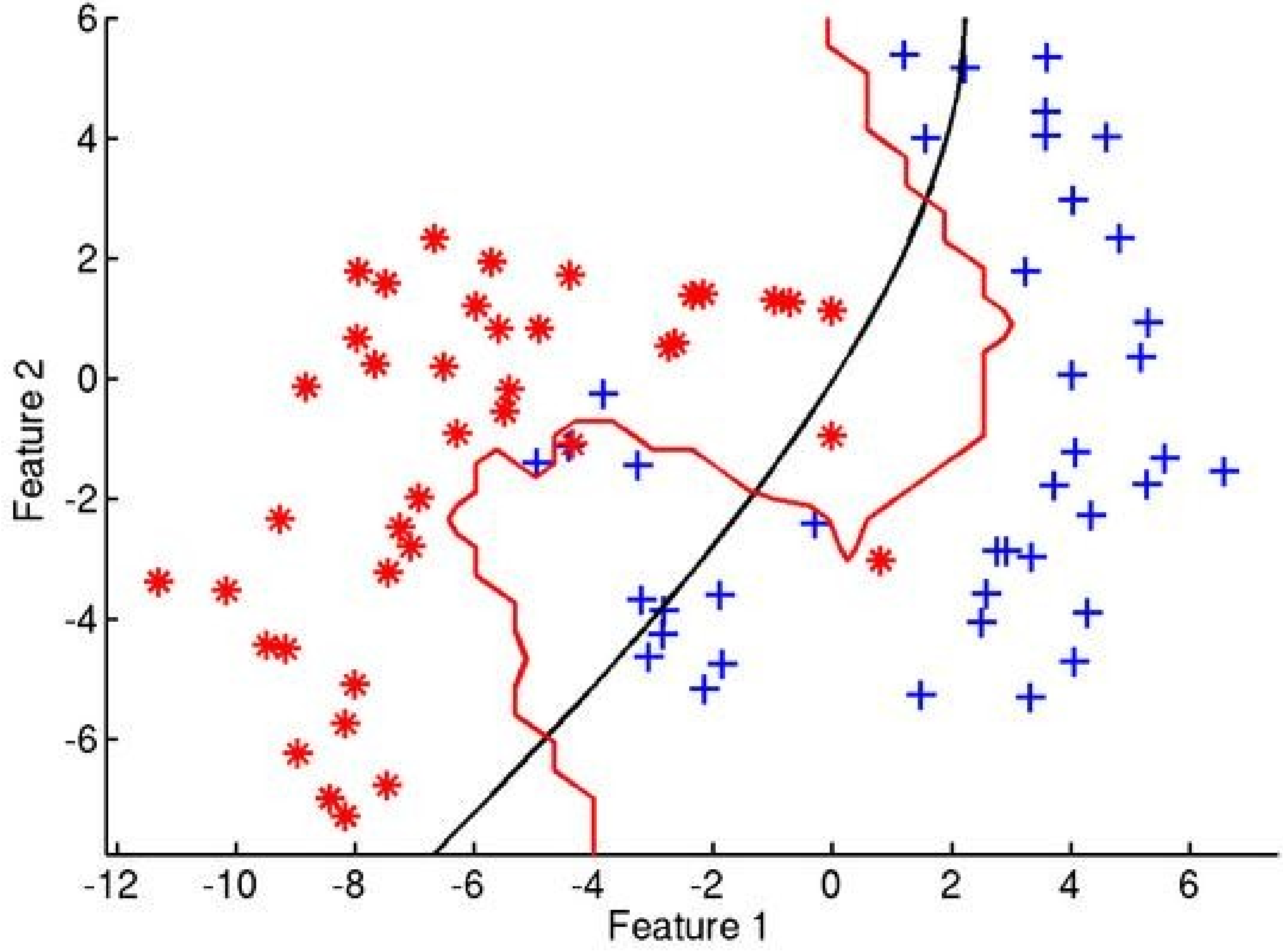
Supervised Learning: Classification Problems

“ Consists of taking input vectors and deciding which of the N classes they belong to, based on training from exemplars of each class.“

- Is discrete (most of the time). i.e. an example belongs to precisely one class, and the set of classes covers the whole possible output space.

How it's done: Find 'decision boundaries' that can be used to separate out the different classes.

Given the features that are used as inputs to the classifier, we need to identify some values of those features that will enable us to decide which class the current input belongs to



6
4
2
0
-2
-4
-6
Feature 2
-12
-10
-8
-6
-4
-2
0
2
4
6
Feature 1

Supervised Learning: Regression Problems

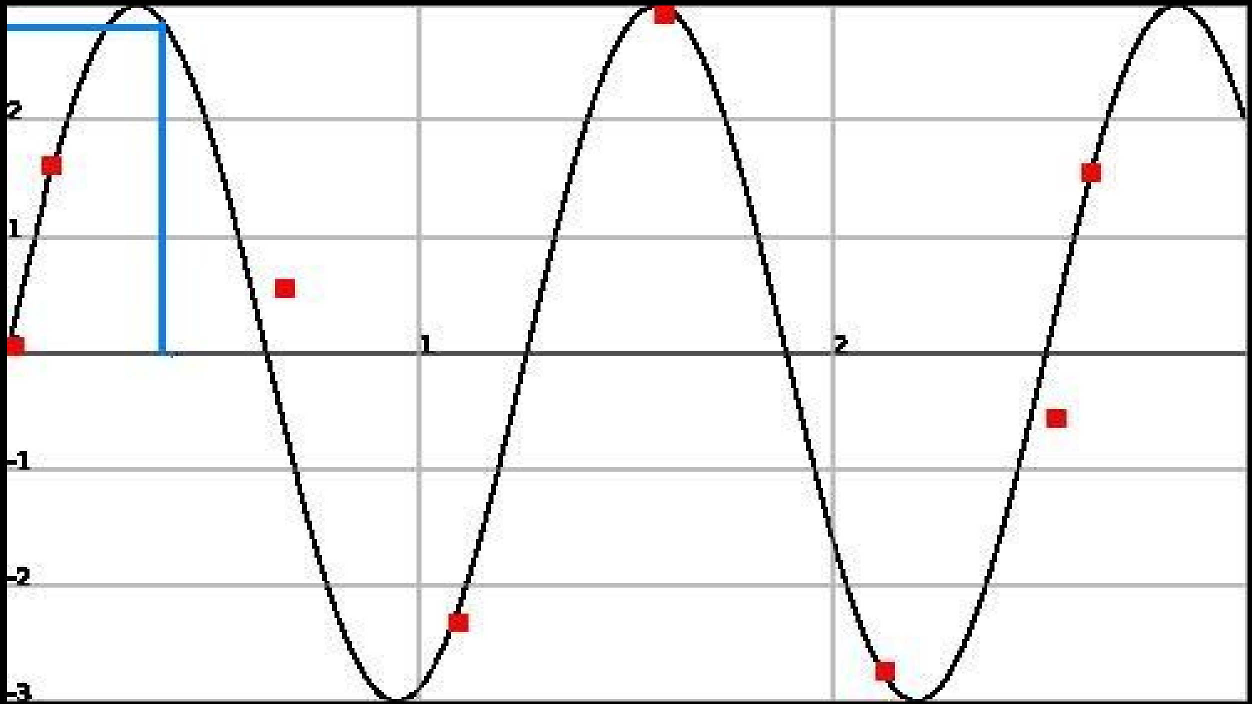
Given some data, you assume that those values come from some sort of function and try to find out what the function is.

In essence: You try to fit a mathematical function that describes a curve, such that the curve passes as close as possible to all the data points.

So, regression is essentially a problem of function approximation or interpolation

x	y
0	0
0.5236	1.5
1.5708	3.0
2.0944	-2.5981
2.6180	1.5
2.6180	1.5
3.1416	0

To Find: y at x =0.44



Unsupervised Learning:

- Conceptually Different Problem.

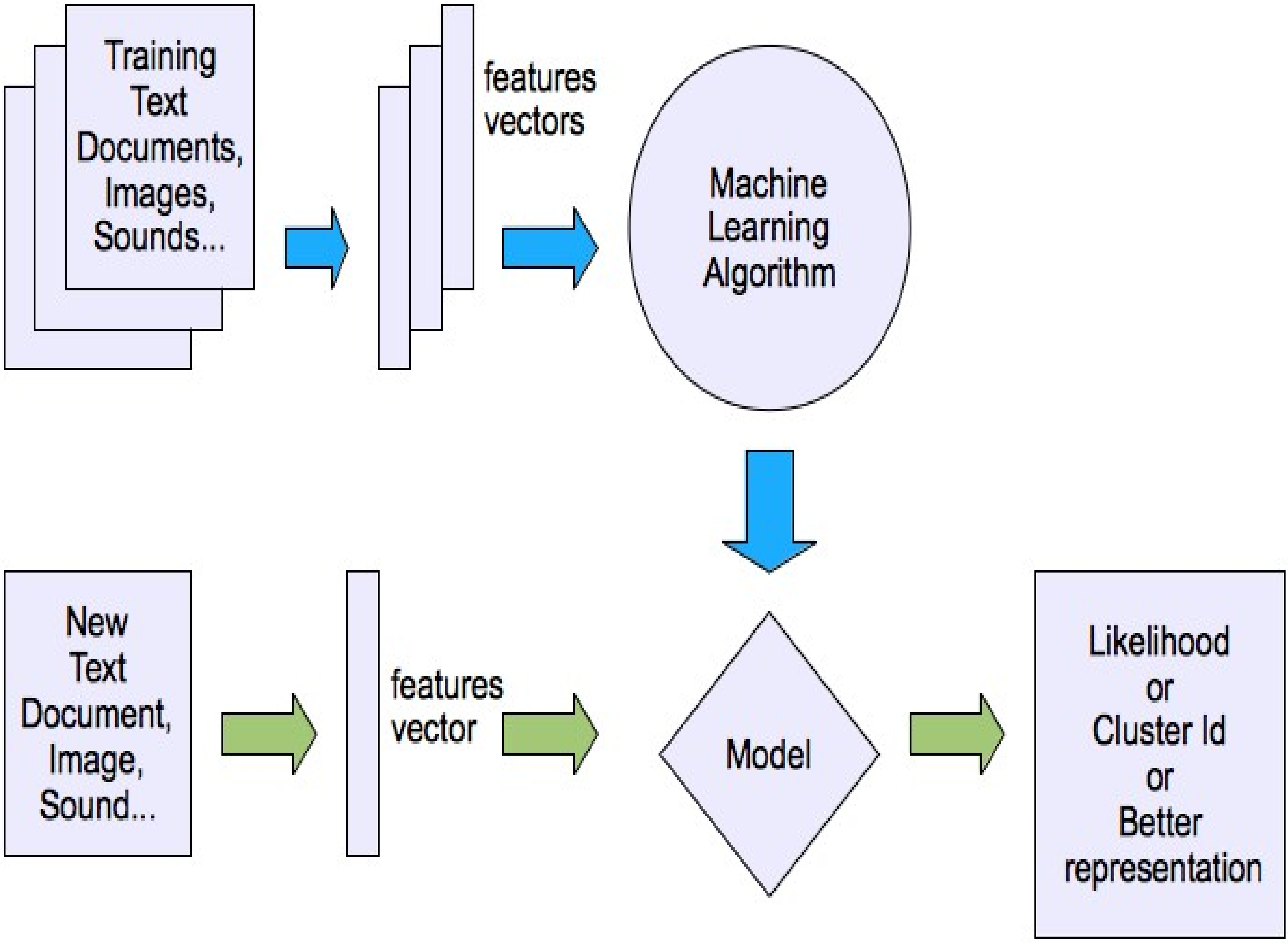
- No information about correct outputs are available.

- No Regression → No guesses about the function can be made

-**Classification?**

No information about the correct classes. But if we design our algorithm so that it exploits similarities between inputs so as to cluster inputs that are similar together, this might perform classification automatically

In essence: The aim of unsupervised learning is to find clusters of similar inputs in the data without being explicitly told that some datapoints belong to one class and the other in other classes. The algorithm has to discover this similarity by itself


Training Text Documents, Images, Sounds...
features vectors
Machine Learning Algorithm
New Text Document, Image, Sound...
features vector
Model
Likelihood or Cluster Id or Better representation

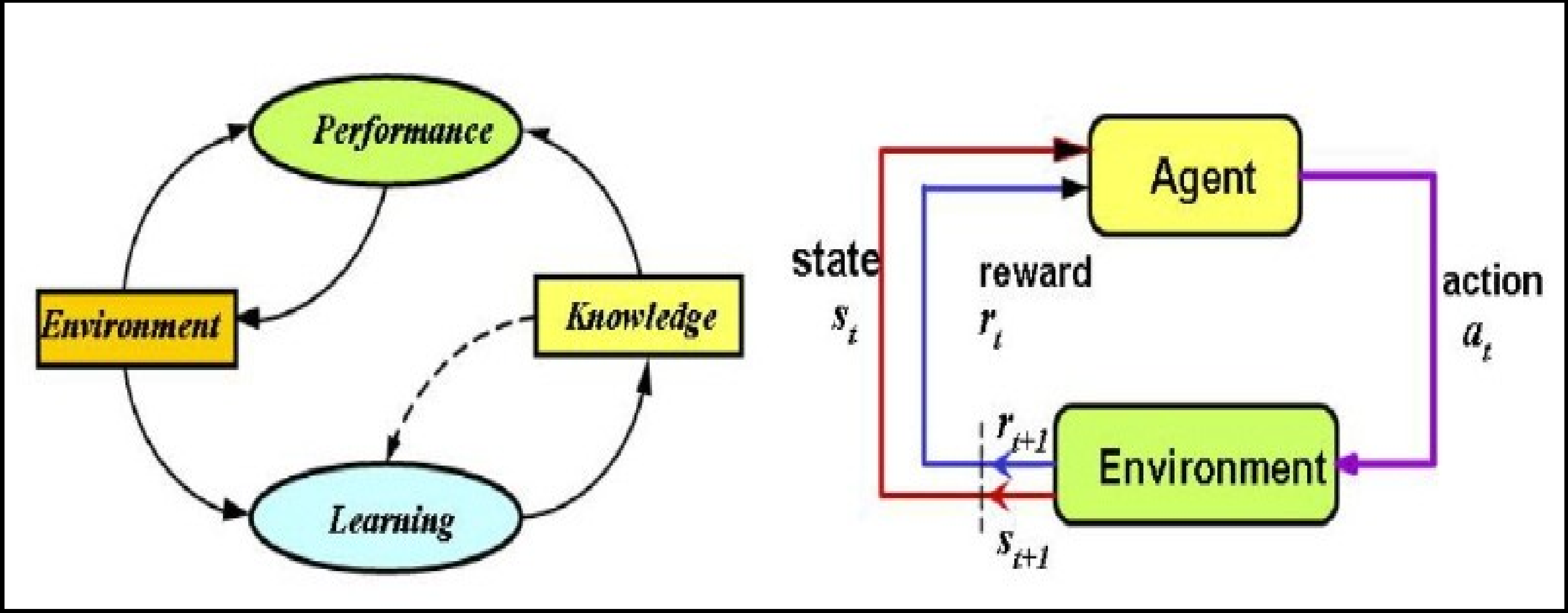
Reinforcement Learning:

Stands in the middle ground between supervised and unsupervised learning.

The algorithm is provided information about whether or not the answer is correct but not how to improve it

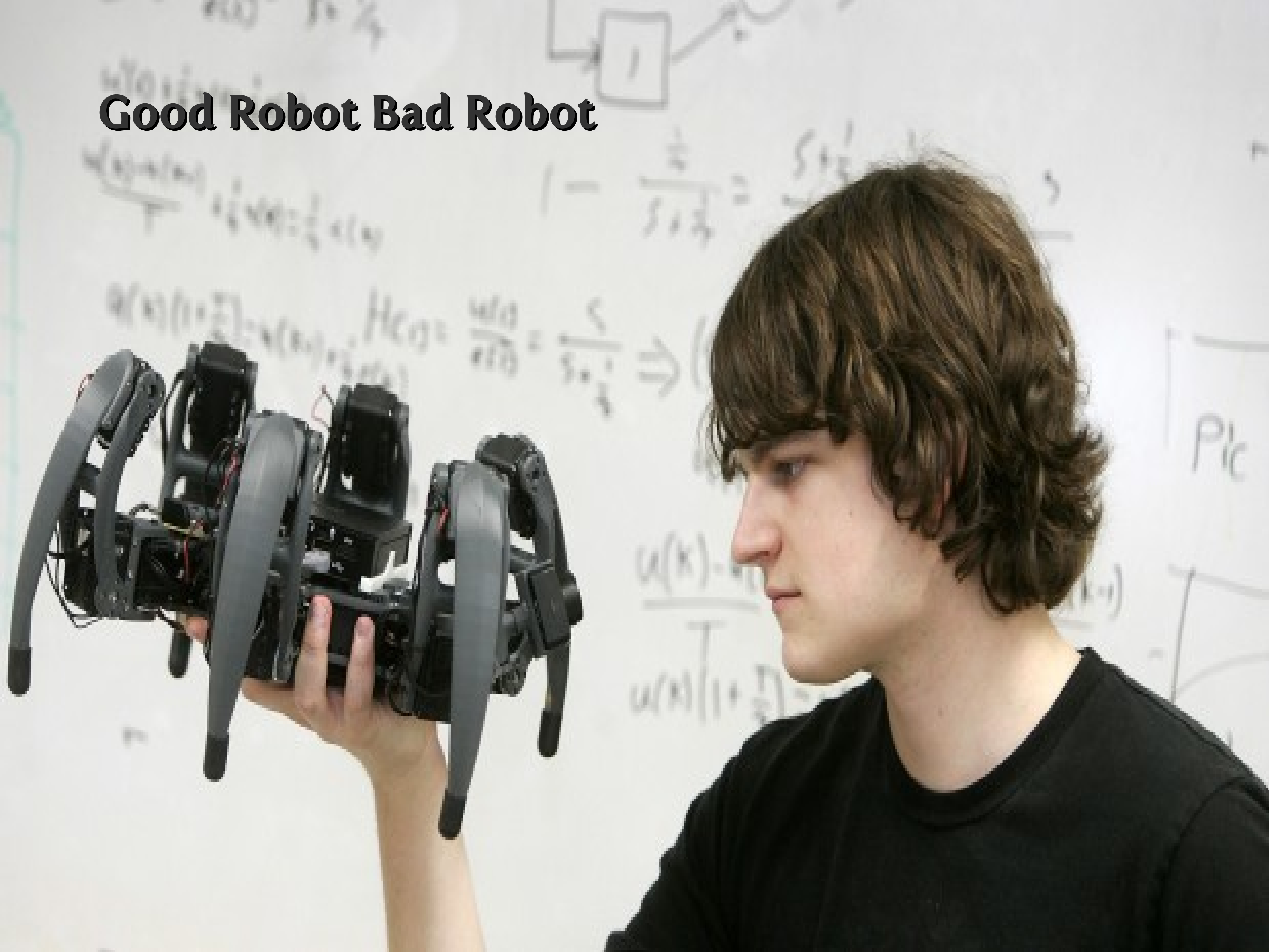
The reinforcement learner has to try out different strategies and see which works best

In essence: The algorithm searches over the state space of possible inputs and outputs in order to maximize a reward




GOOD DOG/BAD DOG

Good Robot Bad Robot



Supervised Learning: Linear Regression & Gradient Descent

Notation:

m : Number of training examples

x : Input variables (Features)

y: Output variables (Targets)

(x,y): Training Example (Represents 1 row on the table)

($x^{(i)}, y^{(i)}$) : ith training example (Represent's ith row on the table)

n : Number of features (Dimensionality of the input)

Representation of the Hypothesis (Function):

- In this case, we represent 't' as a linear combination of the inputs (x)

- Which leads to:

$$h(\Theta)=\Theta_0+\Theta_1 x_1+\Theta_2 x_2$$

where $(\Theta_i\text{'s})$ are the parameters (also called weights).

For convenience and ease of representation: $x_0=1$
So that, the above equation becomes:

$$h(x)=\sum_{i=0}^{n}(\Theta^T x)$$

The objective now, is to 'learn' the parameters Θ
So that h(x) becomes as close to 'y' at least for the training set.

Define a function that measures for each value of the theta's, how close the $h(x^{(i)})'s$

are to the corresponding $y^{(i)}'s$

We define the 'cost function' as:

$$J(\Theta)=\frac{1}{2}\sum_{i=1}^{m}(h_{(\Theta)}(x^{(i)})-y^{(i)})^2$$

We want to choose the parameters so as to minimize $J(\Theta)$

The LMS (Least Mean Squares) algorithm begins with some initial value of Θ and repeatedly changes Θ so as to make $J(\Theta)$ smaller

We now come to the Gradient Descent algorithm:

Gradient Descent starts off with some initial Θ, and continually performs the following update:

$$\Theta_j := \Theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\Theta)$$

(This update is simultaneously performed for all values of j=0,1,....,n)

α *is called the learning rate*

This, in effect assumes the following form:

$$\Theta_j := \Theta_j - \alpha \frac{\partial}{\partial \theta_j} \left(\frac{1}{2} \sum_{i=1}^{m} \left(h_{(\Theta)}(x^{(i)}) - y^{(i)} \right)^2 \right)$$

I'll leave this to you :)

A little mathematical 'hacking' of the above equation yields: (for a single training example)

$$\Theta_j := \Theta_j + \alpha \left(y^{(i)} - h_{\Theta}\left(x^{(i)} \right) \right) x_j^{(i)}$$

There are 2 ways of generalizing the above equation for more than one training example:

The first one is:

Repeat until convergence

{

$$\Theta_j := \Theta_j - \alpha \sum_{i=1}^{m} \left(y^{(i)} - h_{\Theta}\left(x^{(i)} \right) \right) x_j^{(i)} \qquad \text{For every j}$$

}

This above method is called batch gradient descent

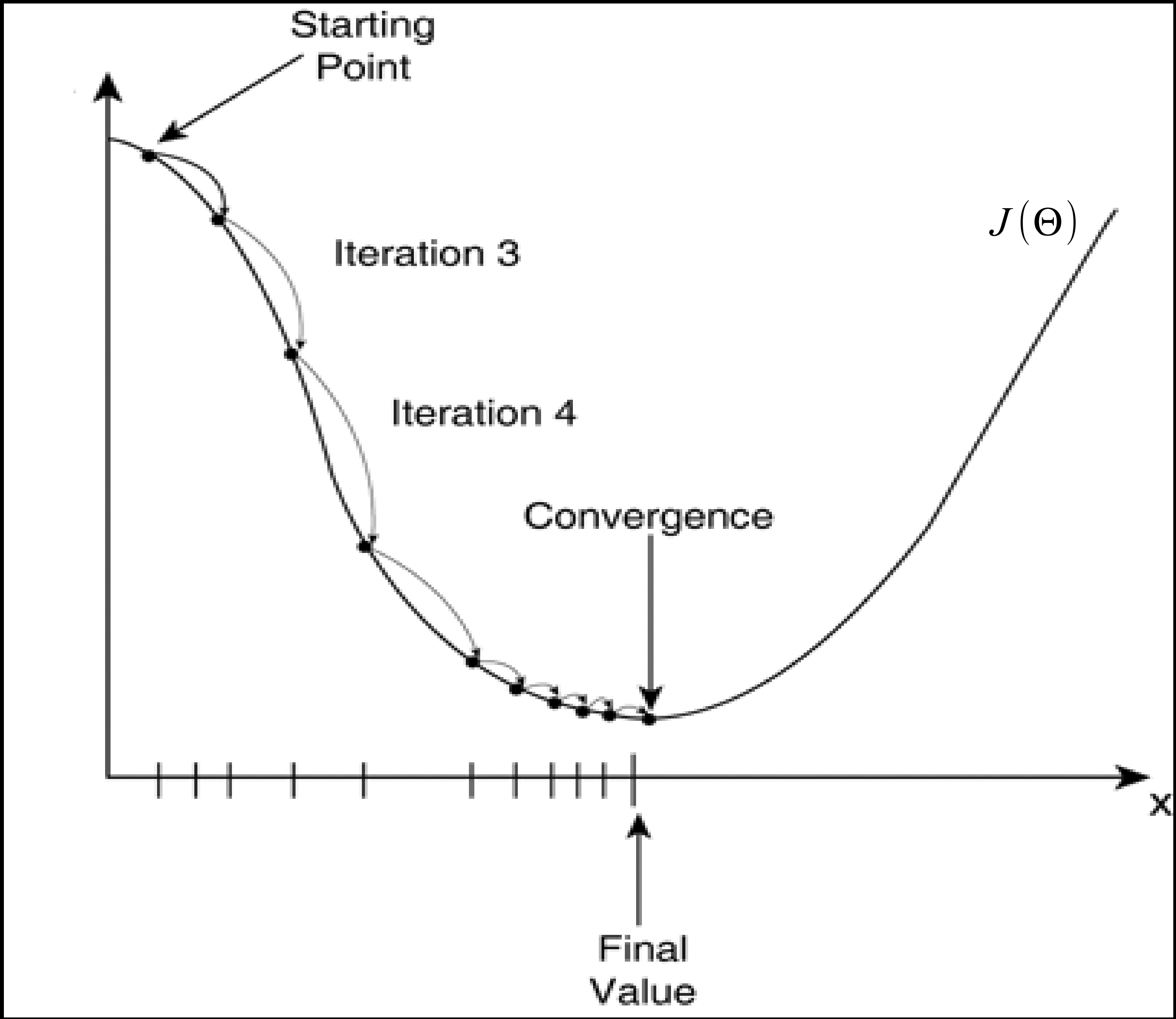
The second one is:

```
Loop
{
        for i=1 to m
        {
```

$$\Theta_j := \Theta_j + \alpha\left(y^{(i)} - h_{\Theta}\left(x^{(i)}\right)\right)x_j^{(i)} \qquad \text{(for every j)}$$

```
        }
}
```

This is called stochastic gradient descent or incremental gradient descent


Starting Point
$J(\Theta)$
Iteration 3
Iteration 4
Convergence
x
Final Value

Code Time

In this example, we generate random points and try use Stochastic Gradient Descent to fit a straight line.

Unsupervised Learning :
Clustering & K-Means

Clustering

Clustering is considered to be the most important unsupervised learning problem.

Deals with finding structure in unlabeled data

i.e. unlike supervised learning, target data isn't provided

In essence:
Clustering is “the process of organizing objects into groups whose members are similar in some way”.

A cluster is therefore a collection of objects which are “similar” between them and are “dissimilar” to the objects belonging to other clusters.

The Goals of Clustering

The goal of clustering is to determine the intrinsic grouping in a set of unlabeled data.

But how does one decide what constitutes a good clustering?

It can be shown that there is no absolute “best” criterion which would be independent of the final aim of the clustering. Consequently, it is the user which must supply this criterion, in such a way that the result of the clustering will suit their needs.

Most common applications:

Marketing: finding groups of customers with similar behavior given a large database of customer data containing their properties and past buying records

Biology: classification of plants and animals given their features

Insurance: Fraud Detection

City-planning: identifying groups of houses according to their house type, value and geographical location;

Earthquake studies: clustering observed earthquake epicenters to identify dangerous zones;

WWW: document classification; clustering clickstream data to discover groups of similar access patterns. Creating recommender systems

Unsupervised Learning : K-Means clustering

The algorithm is composed of the following steps:

1. Place K points into the space represented by the objects that are being clustered. These points represent initial group centroids.

2. Assign each object to the group that has the closest centroid

3. When all objects have been assigned, recalculate the positions of the K centroids

4. Repeat steps 2 and 3 until the centroids no longer move.

Code Time

Meet the data: The Iris Dataset

No. of training examples(instances):150

Number of features (x's) : 4

Number of classes : 3

Attribute Information:
Features :

1. sepal length in cm
2. sepal width in cm
3. petal length in cm
4. petal width in cm

Classes:
-- Iris Setosa
-- Iris Versicolour
-- Iris Virginica

Neural Networks

Motivation:

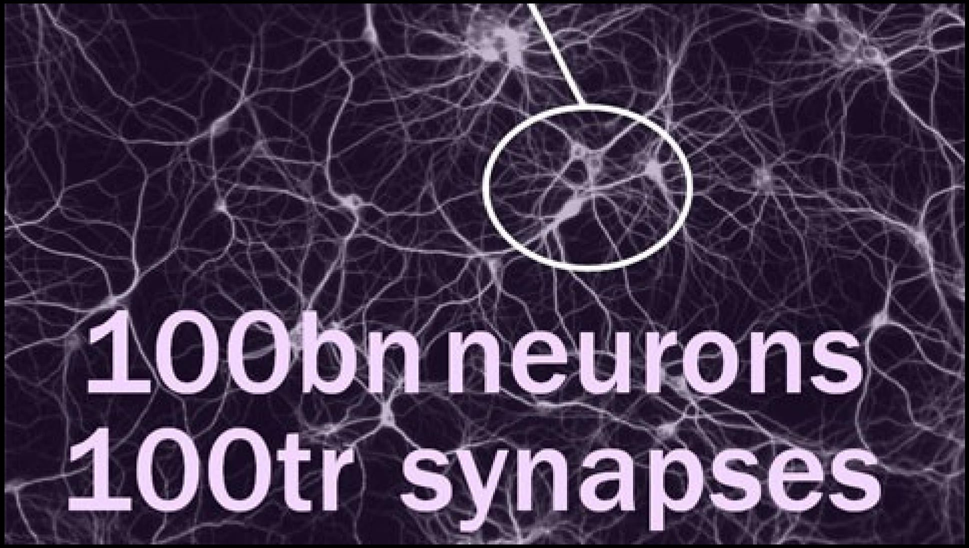
Animals learn and learning occurs within the brain

If we can understand how the brain works then there are probably things that we can copy and use for our machine learning system.

The brain is massively complex and impressively powerful,
But the basic atomic building blocks are simple and easy to understand.

The brain does exactly what we want it to. It deals with noisy and inconsistent data, and produces answers that are usually correct from very high dimensional data
(like images) very quickly

Basic Processing unit of the brain are neurons



Each neuron can be thought of as a processor. Each performing a very simple computation: deciding whether to fire or not.

The brain is hence a massively parallel computer made up of billions of 'processors'

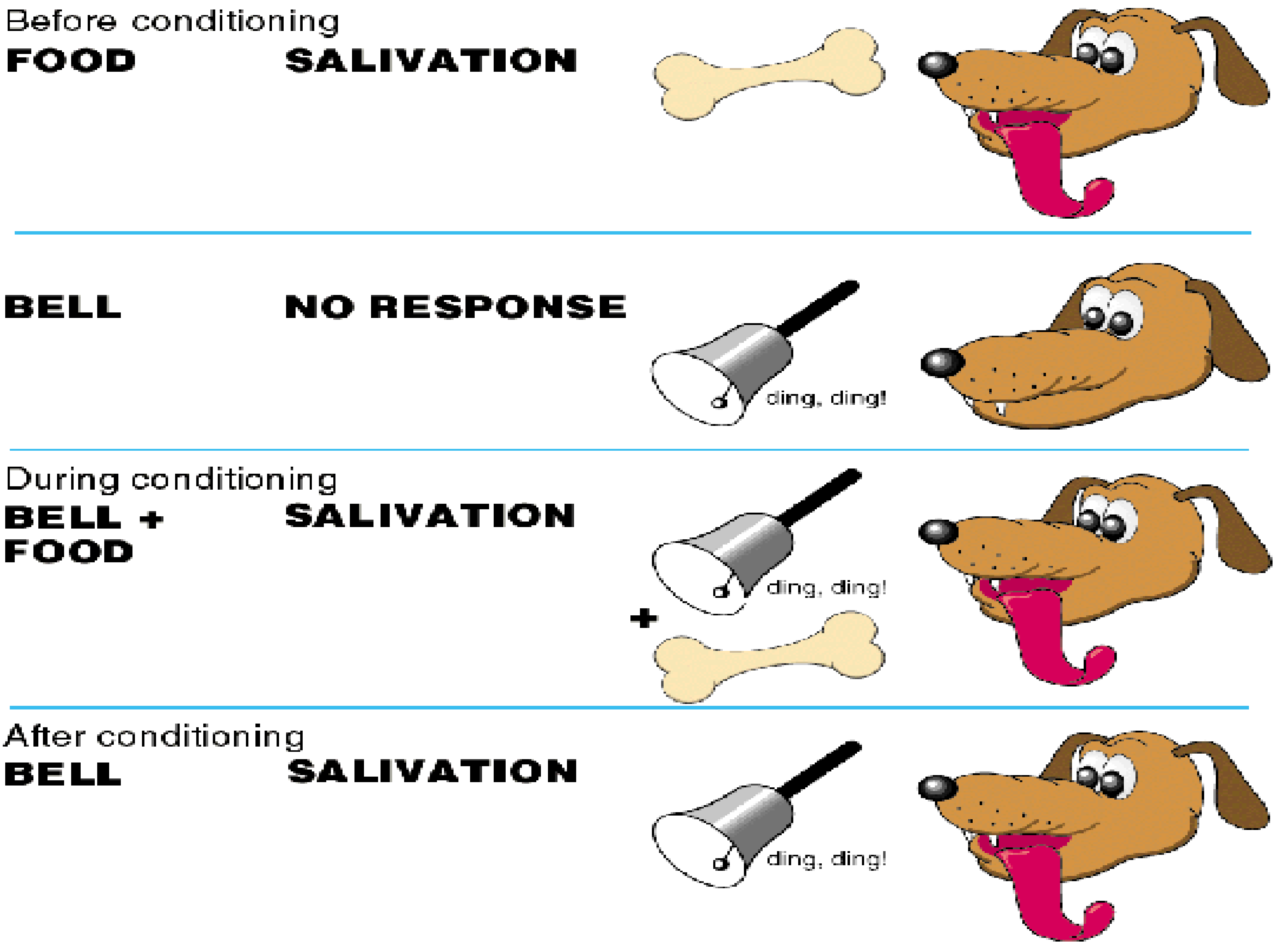
How does learning occur in the brain?

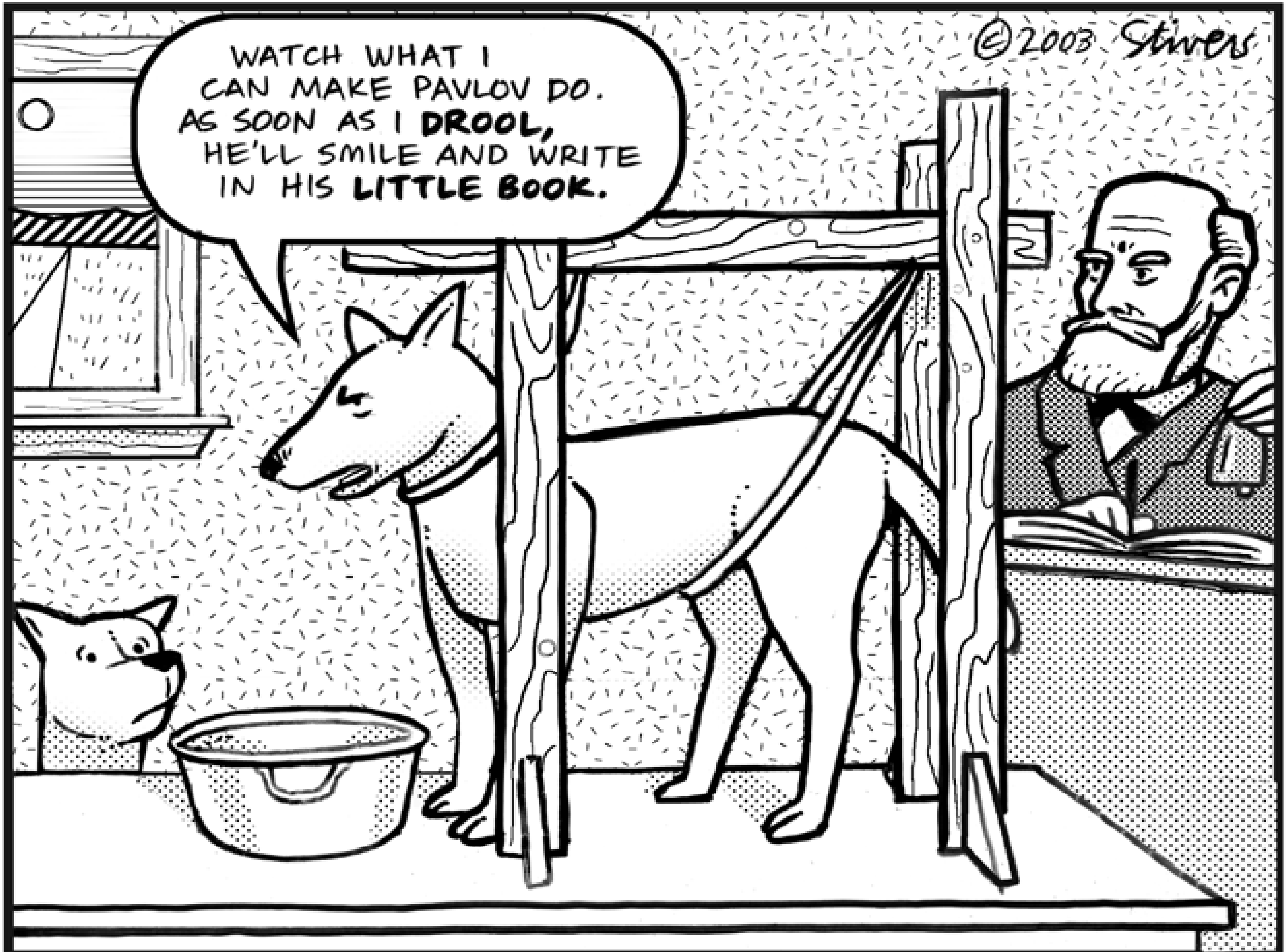
Plasticity: modifying the strength of connections between neurons and creating new connections

Hebbs Rule:

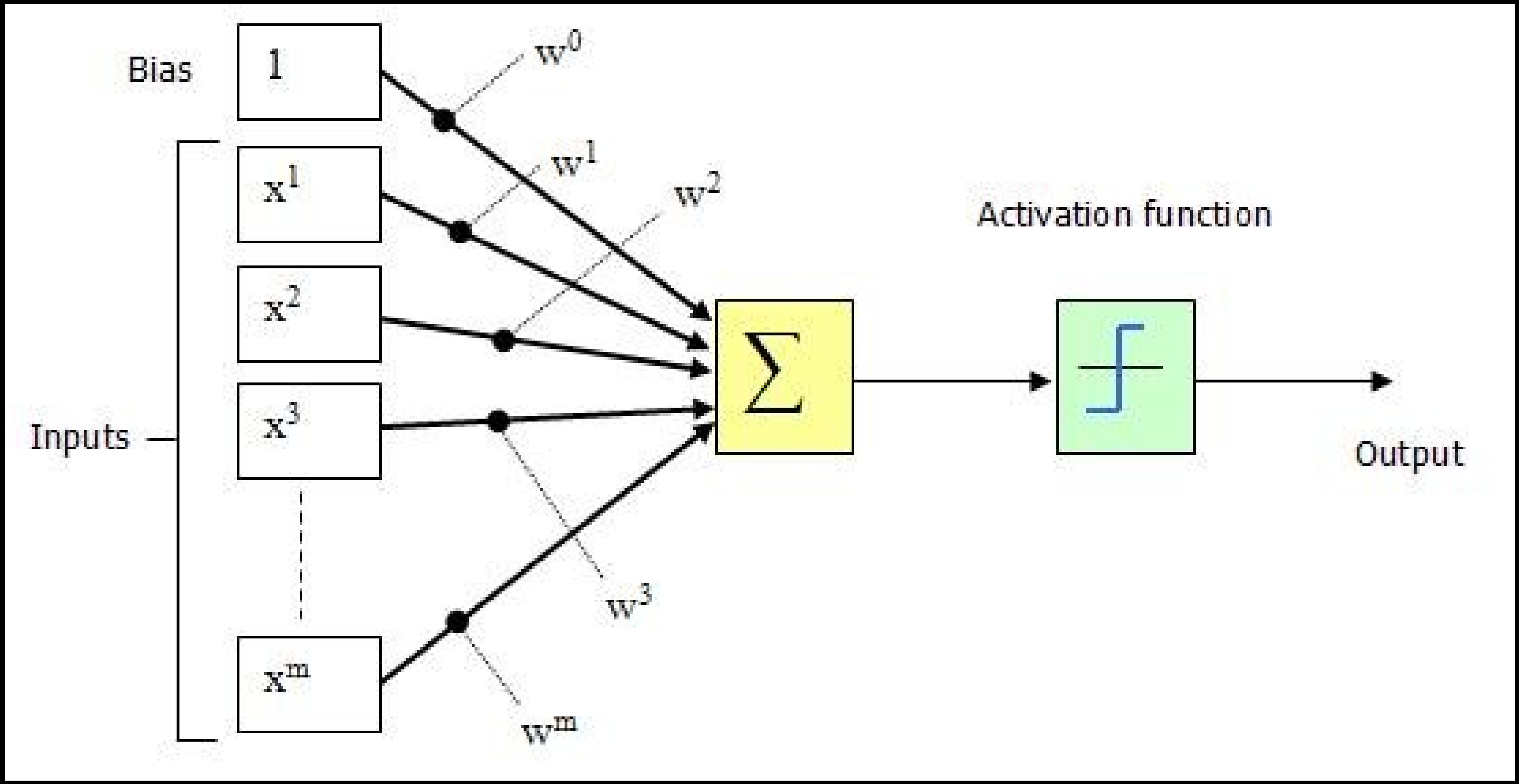
"Changes in the strength of interneuron (synaptic) connections are proportional to the correlation in the firing of the two connecting neurons."

Basically: "Neurons that fire together, wire together"


Before conditioning
FOOD
SALIVATION
BELL
NO RESPONSE
ding, ding!
During conditioning
BELL +
FOOD
SALIVATION
ding, ding!
+
After conditioning
BELL
SALIVATION
ding, ding!


©2003 Stivers
WATCH WHAT I CAN MAKE PAVLOV DO. AS SOON AS I DROOL, HE'LL SMILE AND WRITE IN HIS LITTLE BOOK.

The Perceptron:



Code Time

Resources:

Datasets:

UCI Repo: http://archive.ics.uci.edu/ml/

Discussions

Machine Learning subReddit: http://www.reddit.com/r/MachineLearning/

Books:

Pattern Classification (Duda, Hart)
Machine Learning (Tom Mitchell)
Introduction to Machine Learning (Ethem Alpaydin)
Neural Networks (Simon Haykin)
Machine Learning: an algorithmic approach (Marsland)

Thank You

Kosshans?