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Introduction to Non-Deep Neural Network Techniques

Srideep Musuvathy

MLDL Tutorials, July 2023

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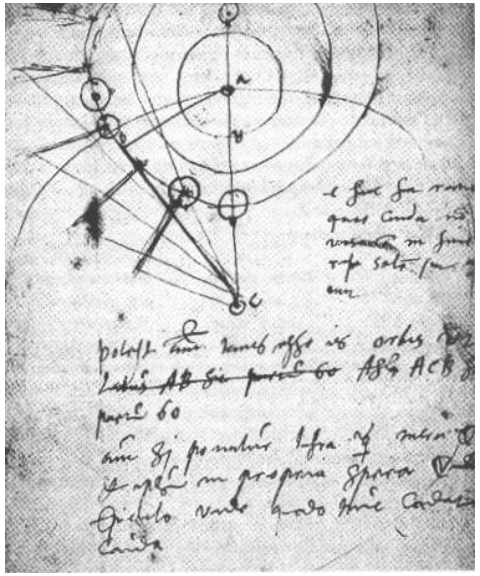
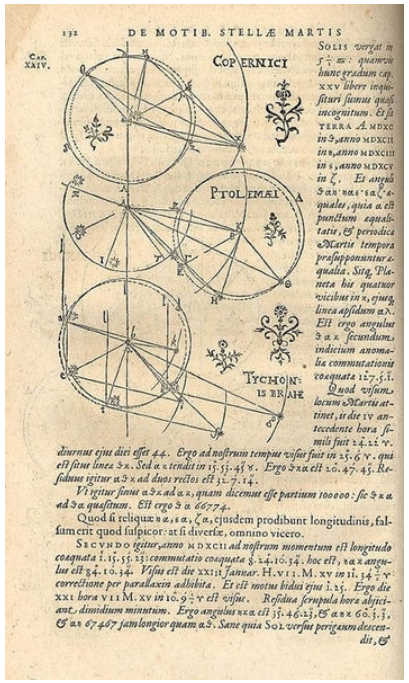
Tycho Brahe (1546-1601)



The Great Comet (1577)

Johannes Kepler (1571-1630)



Astronomia Nova (1609)

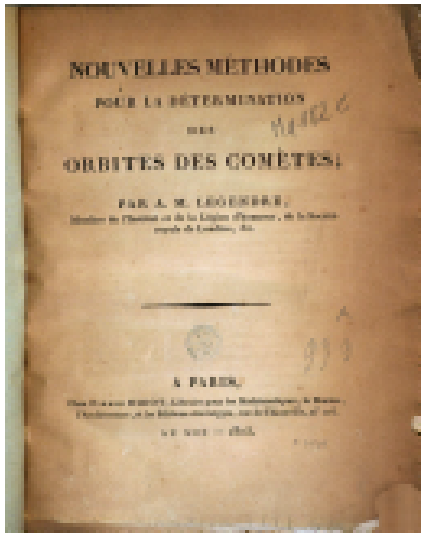
“The time has come,” the walrus said, “to talk of many things”

- Comets
- Regression
- Chile peppers
- Classification
- Neural Networks
- Other types of machine learning
- Function Approximation
- Wrap-up

Comets to Regression

Orbits Of Comets Are Ellipses

Legendre 1805



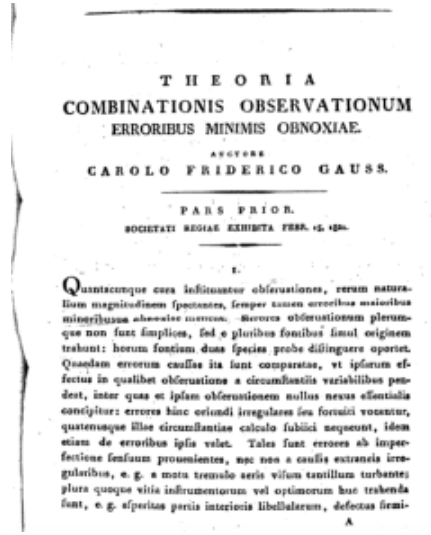
NOUVELLES MÉTHODES
POUR LA DÉTERMINATION
DES
ORBITES DES COMÈTES;
PAR A. M. LEGENDRE,
A PARIS,

Ellipses can be described by just 2 numbers

Both Legendre and Gauss showed how to calculate these two numbers from observed data

'Fitting a curve' with the 'principle of least squares'

Gauss 1809

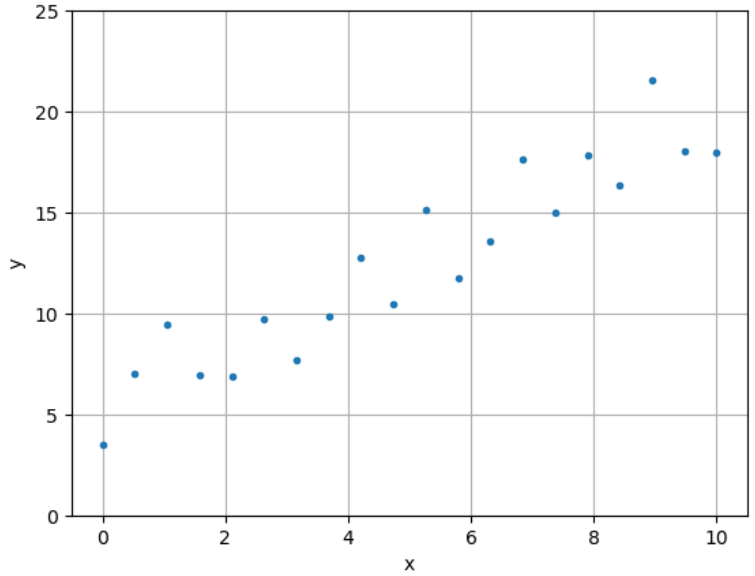


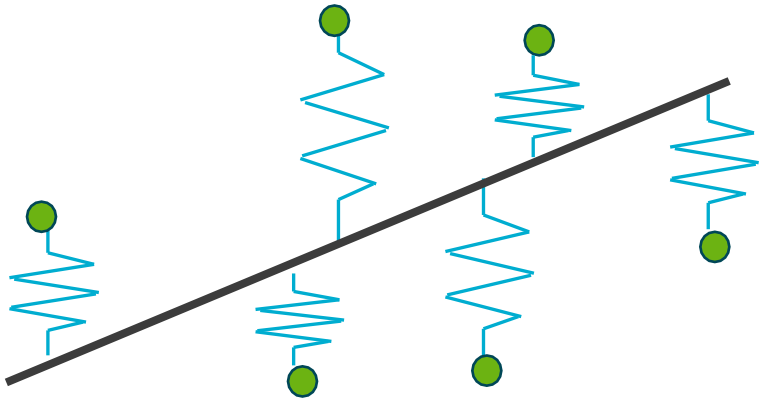
THEORIA
COMBINATIONIS OBSERVATIONUM
ERRORIBUS MINIMIS OBNOXIAE.
AUCTORE
CAROLO FRIDERICO GAUSS.
PARS PRIOR.
SOCIETATI REGIAE EXHIBITA FEBR. 15, 1821.

Quantacunque cura instituantur observationes, rerum naturalium magnitudinem spectantes, semper tamen erroribus molestis minoribus obnoxiae manent. Errores observationum plerumque non sunt simplices, sed e pluribus fontibus simul originem trahunt: horum fontium duos species probe distinguere oportet. Quaedam errorum causae ita sunt comparatae, vt ipsorum effectus in qualibet observatione a circumstantiis variabilibus pendeat, inter quas et ipsam observationem nullus nexus essentialis concipitur: errores hinc oriundi irregulares seu fortuiti vocantur, quatenusque illos circumstantias calculo subiici nequeunt, idem etiam de erroribus ipsis valet. Tales sunt errores ab imperfectione sensuum promanientes, nec non a causis extraneis irregularibus, e. g. a motu tremulo aeris visum tantillum turbante; plura quoque vitia instrumentorum vel optimorum huc trahenda sunt, e. g. asperitas partis interioris libellularum, defectus firmi-

A

Least Squares Approach To Fitting A Curve

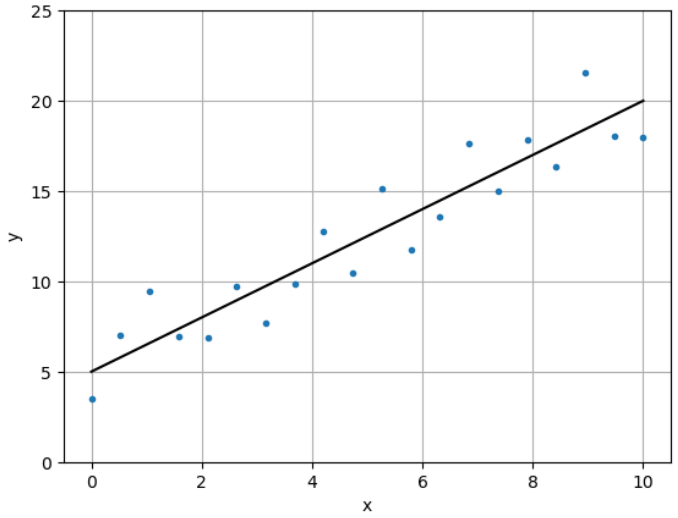


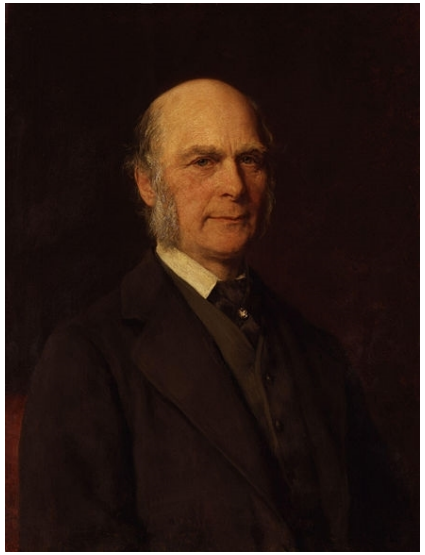


Springs settle in a minimum energy state

Minimize the square of the distance from the point to the line

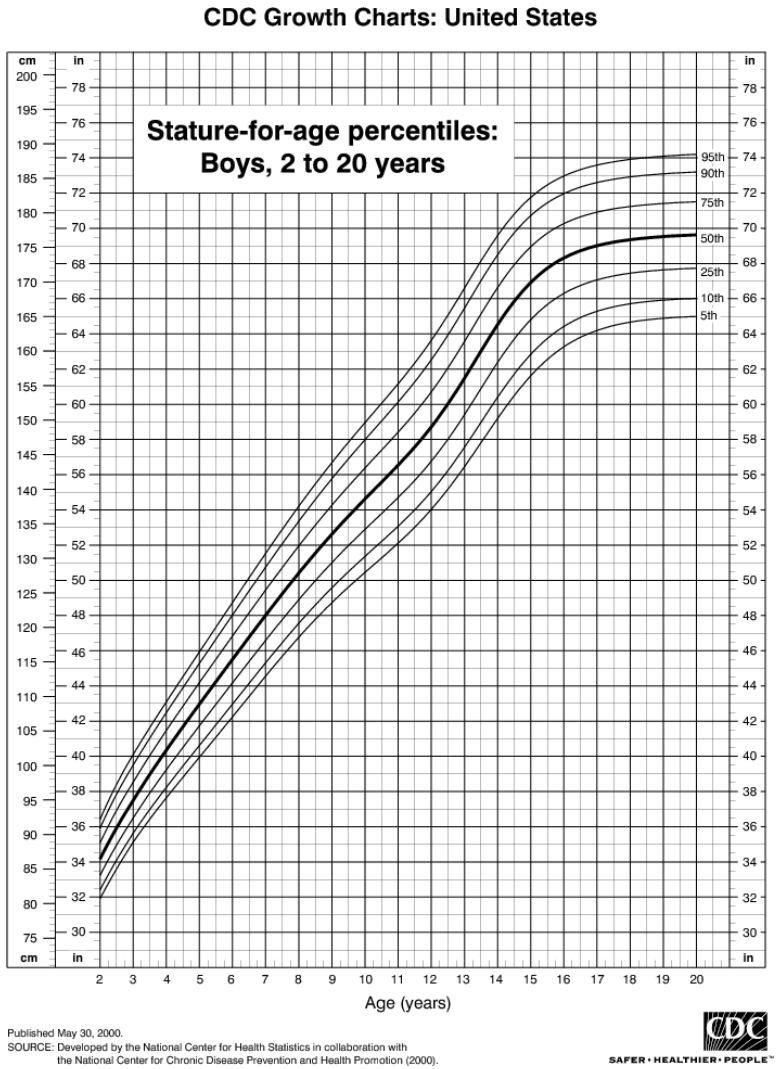
"Force" everything towards the mean!





Sir Francis Galton (1889)

Is The Data Well-Organized?



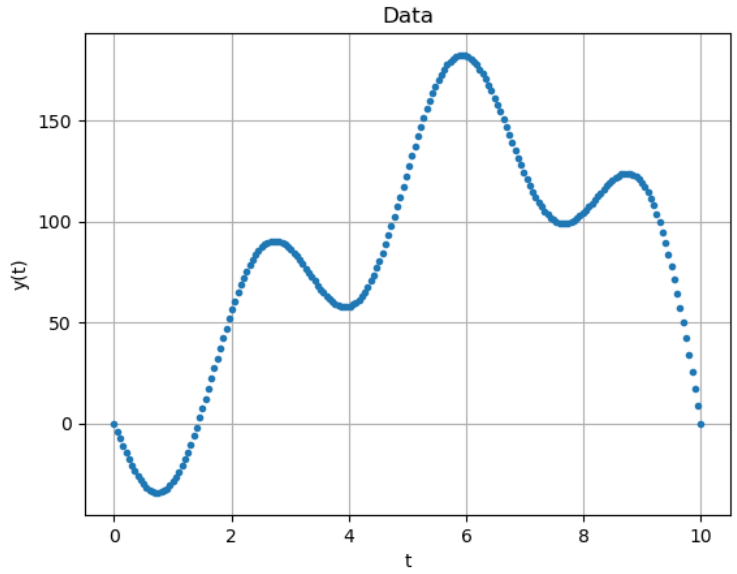
Was the data well sampled?

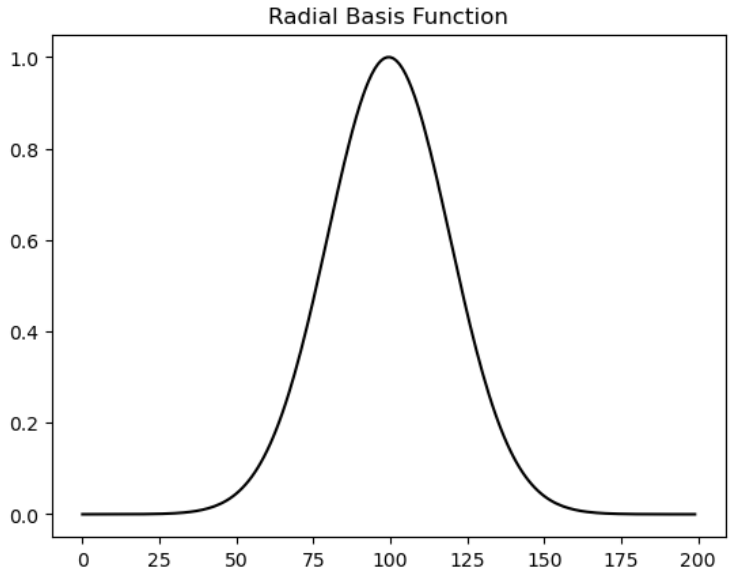
What else affects the data?

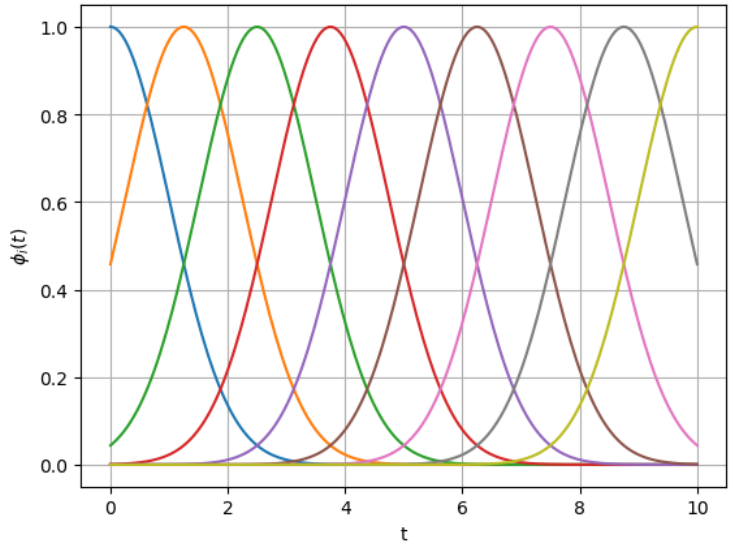
Interpolation vs extrapolation

Multiple lines?

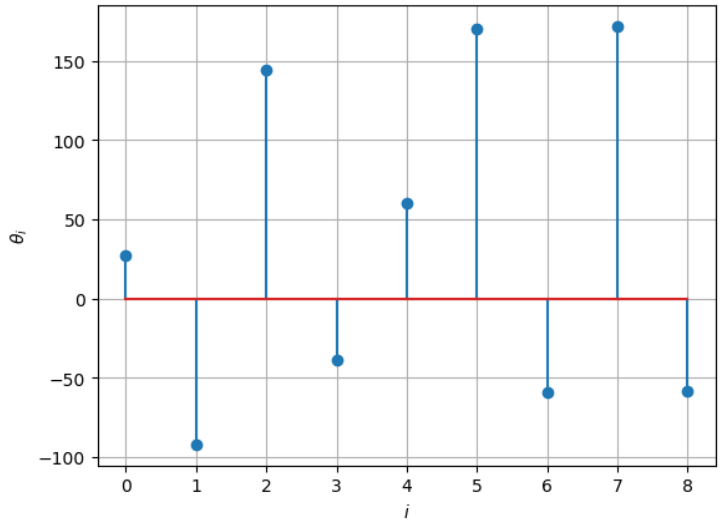
If The Curve Is Unknown, We Can Approximate!

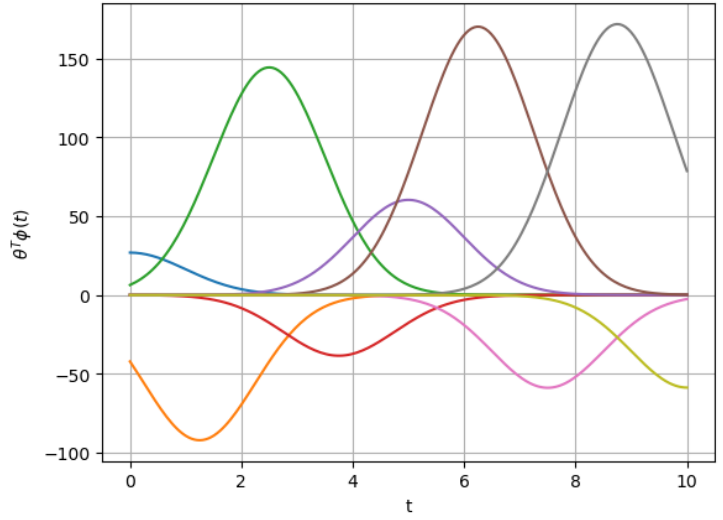


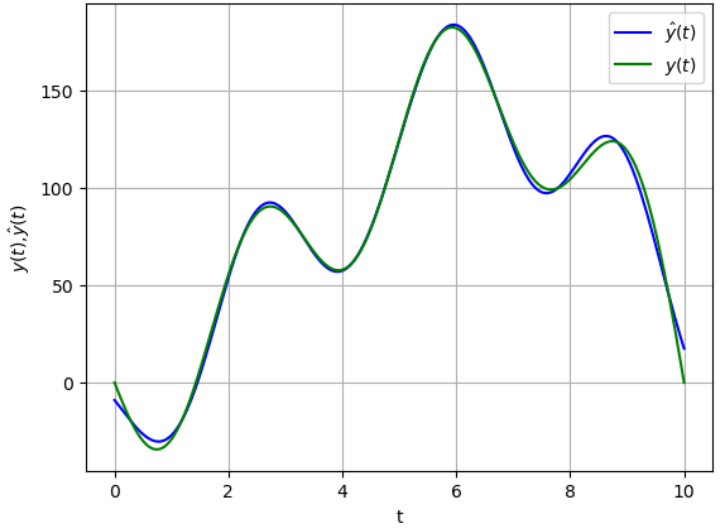




The Scaled Basis Set Approximates The Curve







Chiles to Classification

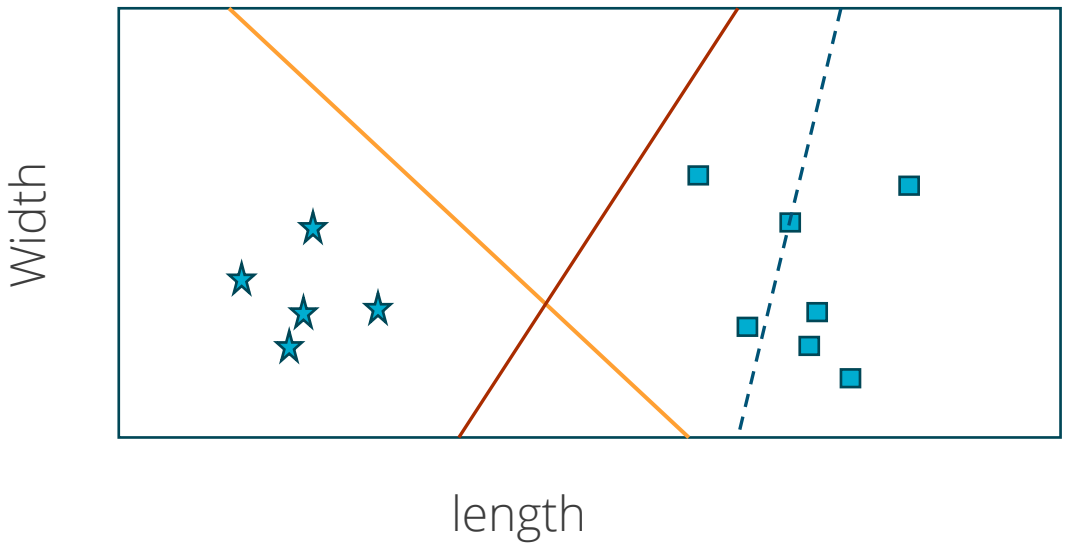
Chile Peppers! What Kind Are They?

Chimayo
~4.5 in

Big Jim
~7-17 in

Bell peppers
~3-5 in

Linear Separability

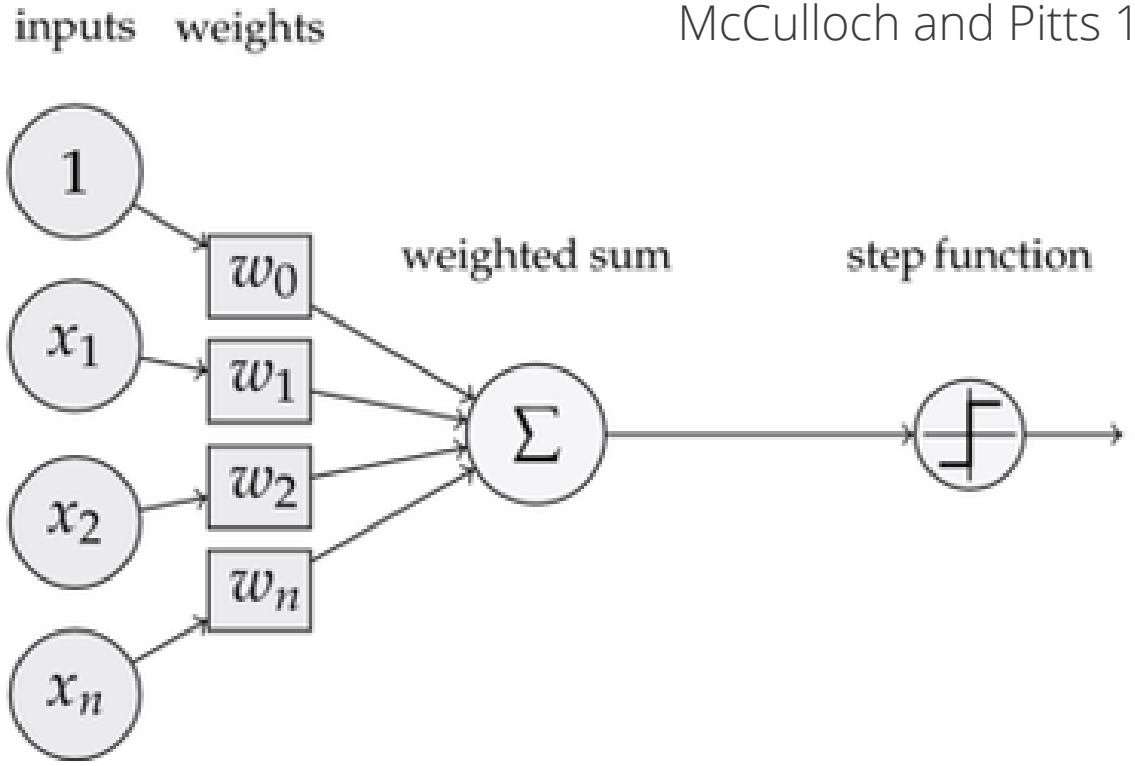


Red and Orange are good boundaries!
The dashed line is terrible!

Perceptron

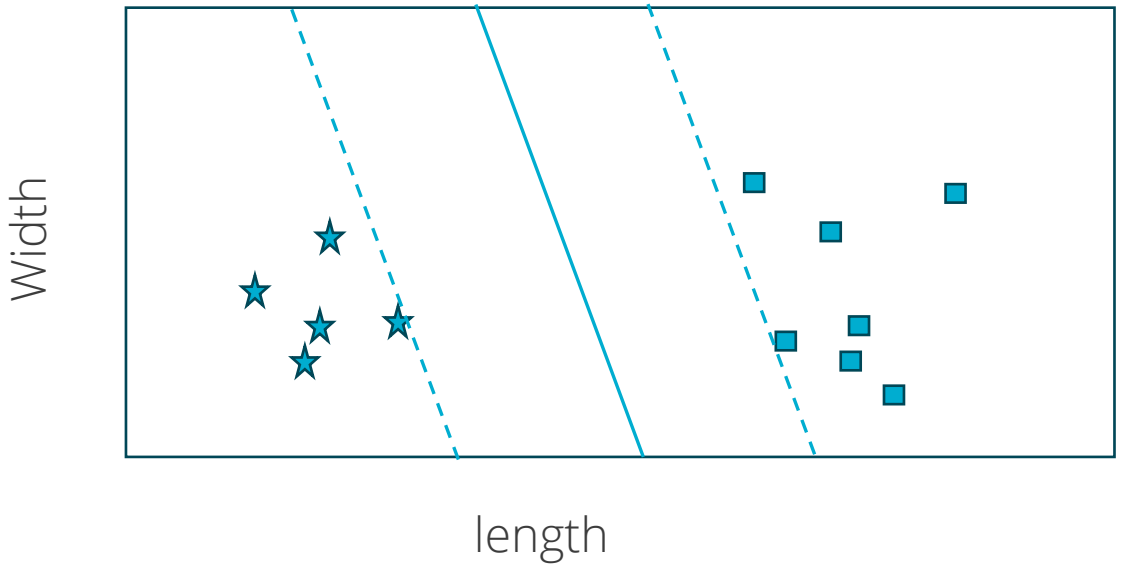
McCulloch and Pitts 1943

Rosenblatt 1956



This represents a line in 2-D and a 'hyperplane in n-D

Wide Margin Classifier



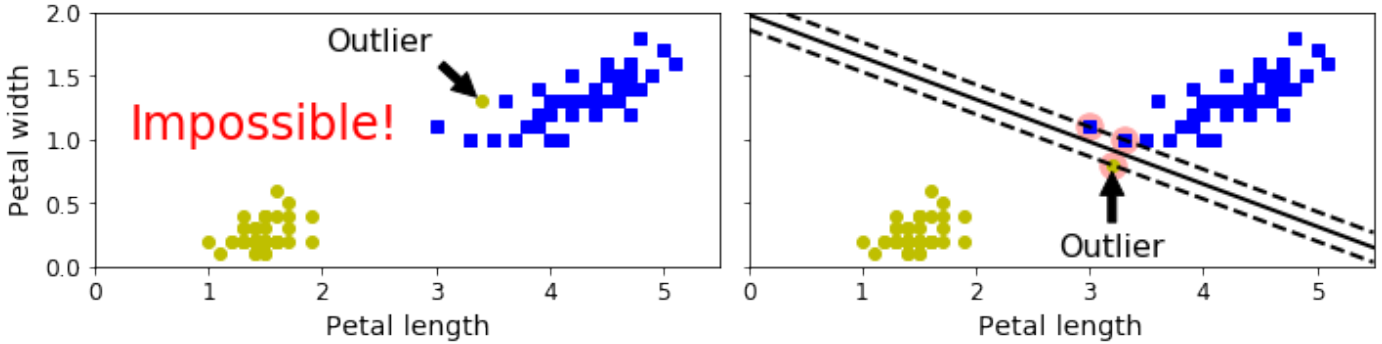
Also called a support vector machine

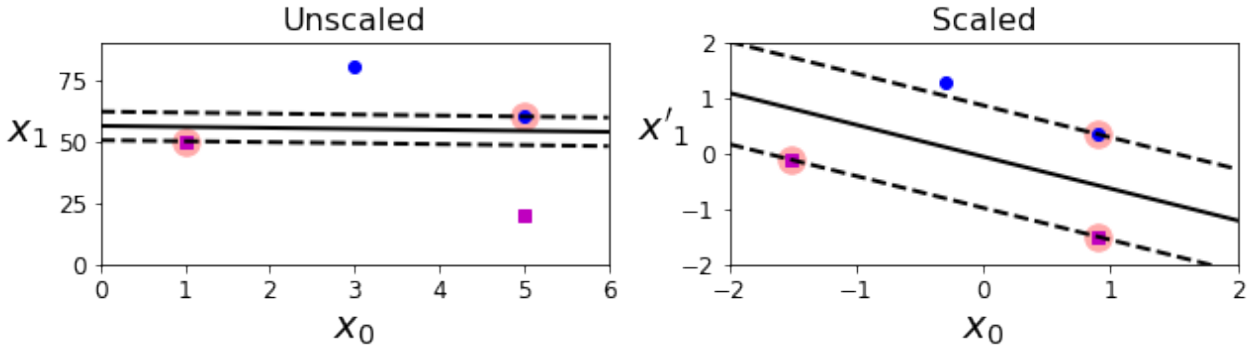
Some Challenges

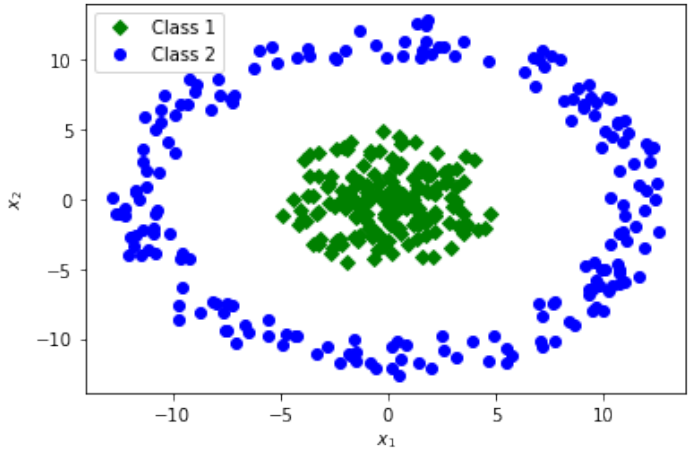
Feature Scales

Outliers

Not linearly separable!

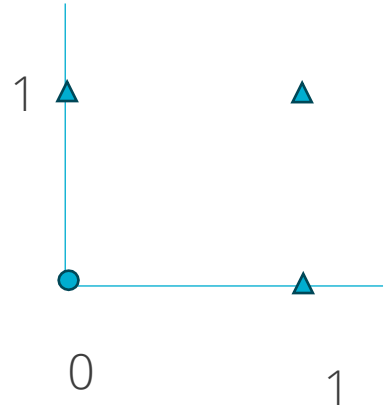




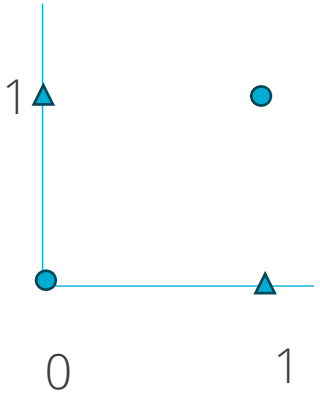


Logical Relationships

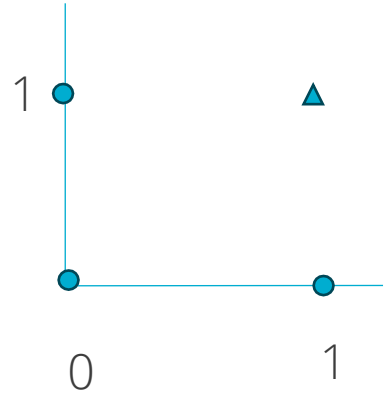
OR:
If you have a degree in Computer Science *or* Mathematics, then you are eligible to apply



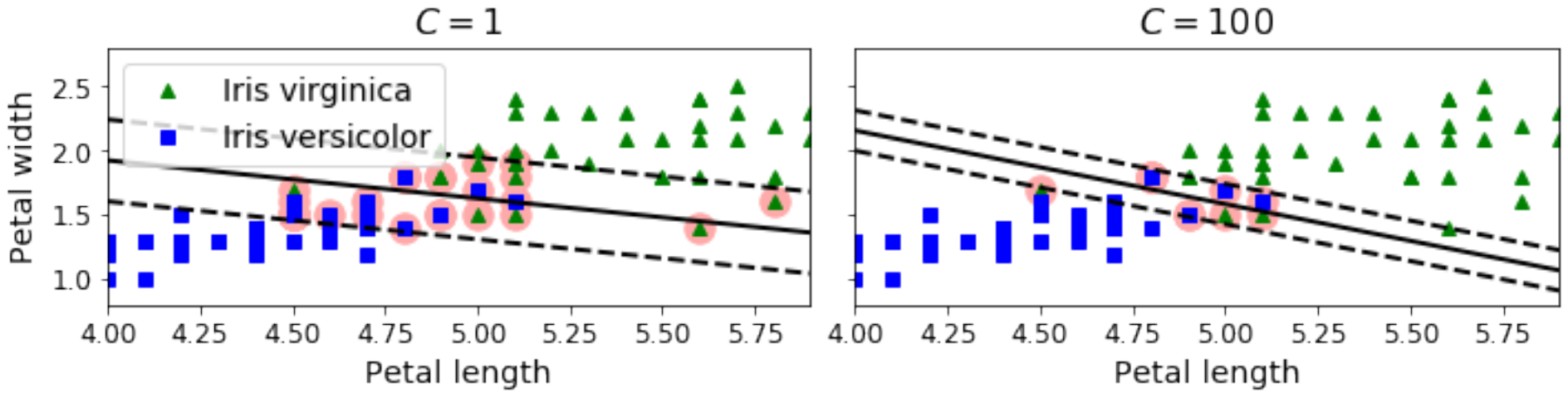
XOR:
To get to the destination you can *either* take the train *or* take the bus



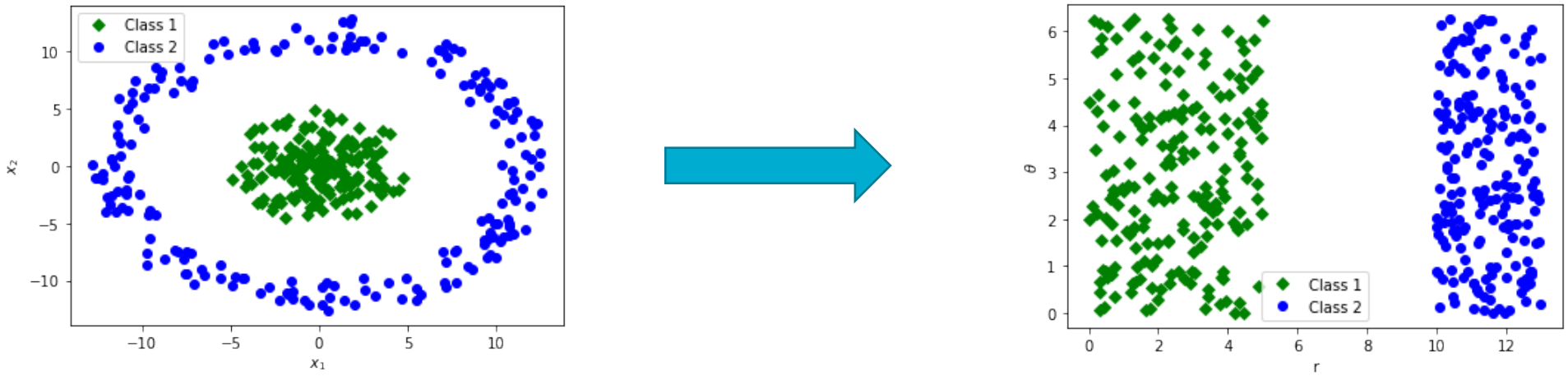
AND:
If you are a citizen *and* over 18, then you are eligible to vote



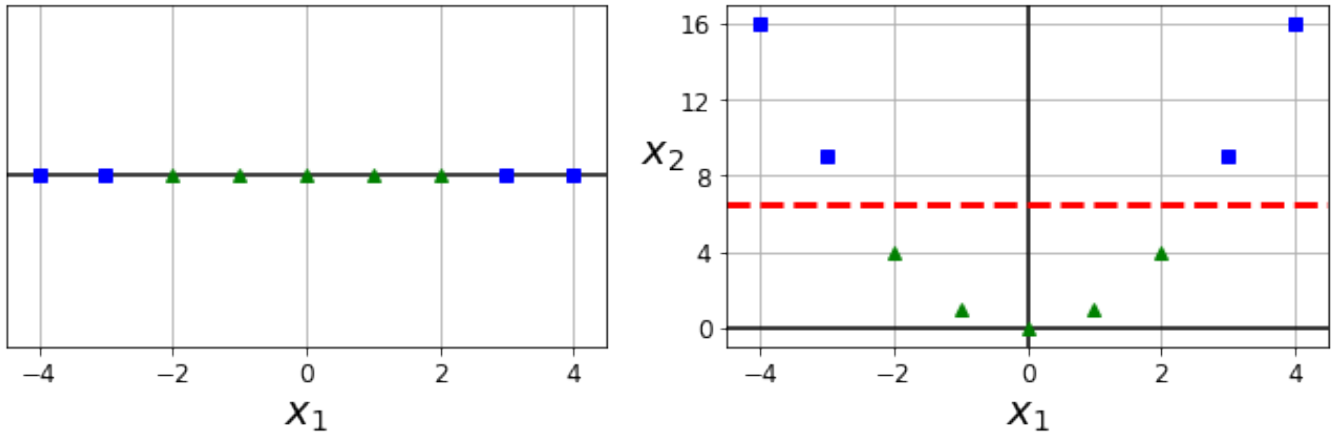
Hard vs Soft Margins



Transform The Data To Over Come Non-Linearly Separable Spaces

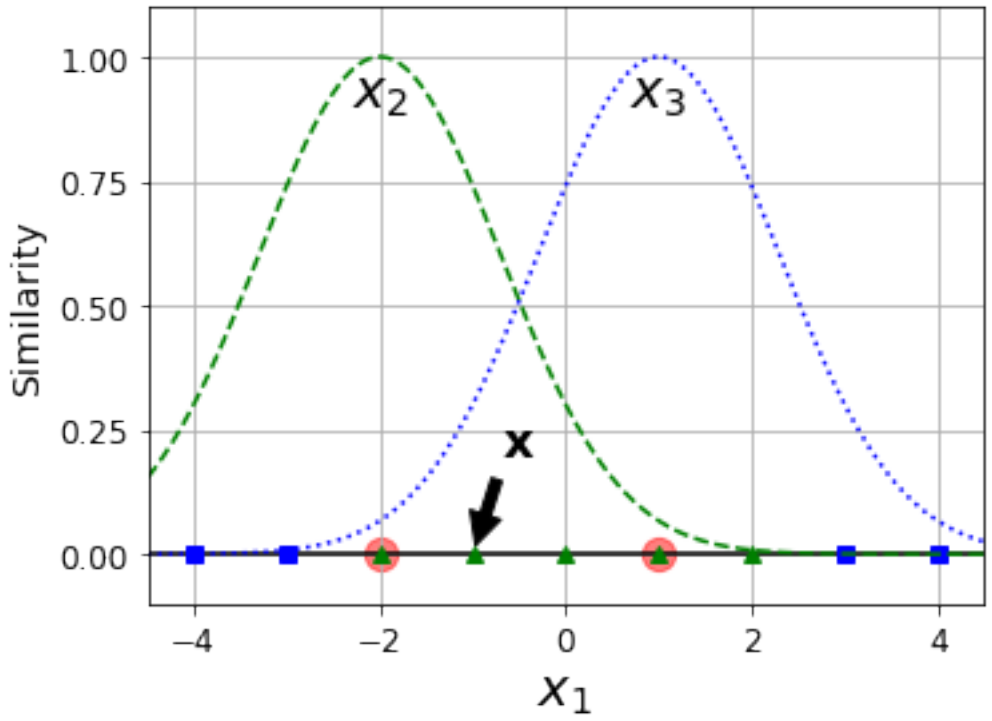


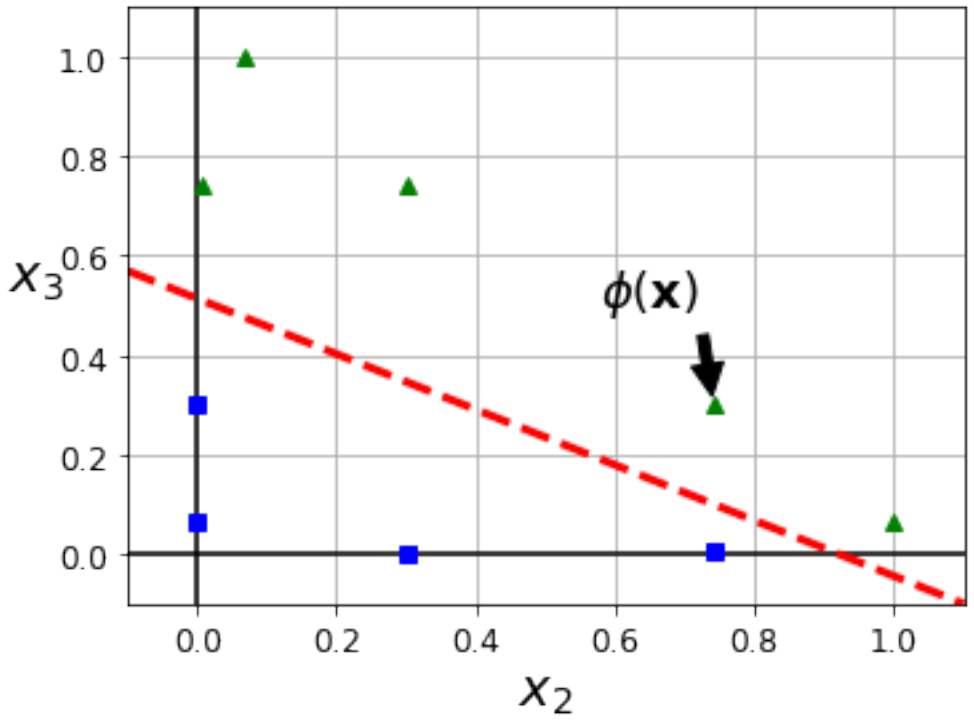
Or We Can Go To Higher Dimensions!



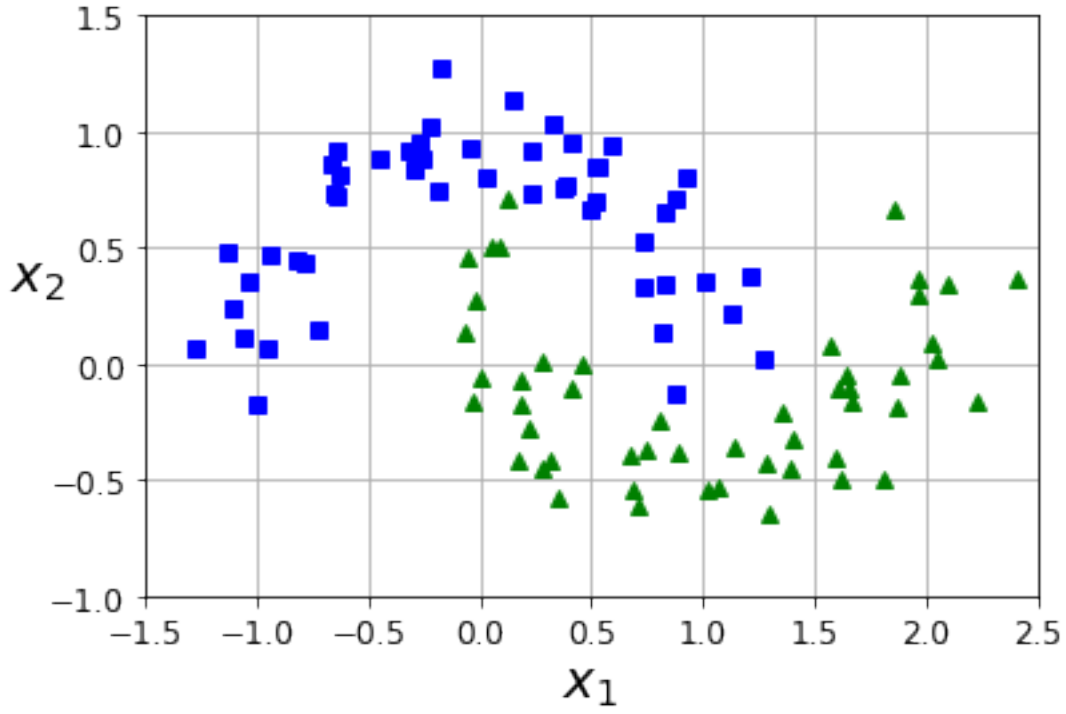
Similarity Features

$$\phi^{\gamma}(x, l) = \exp(-\gamma||x - l||^2)$$

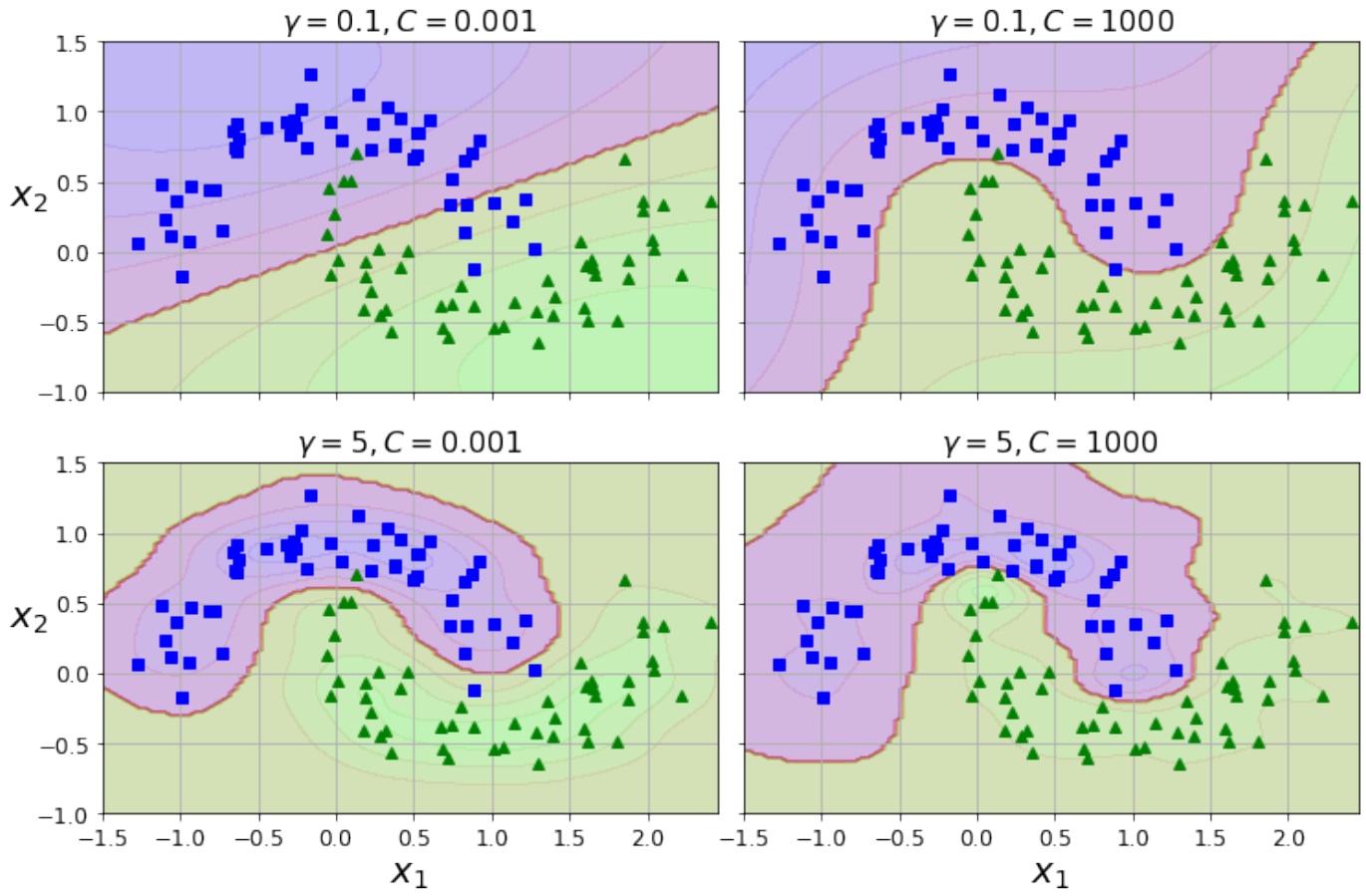




Moons Dataset



Similarity Features Applied To Moons Dataset



Support Vector Machines and Fully Connected Neural Networks

- SVMs can be probed to understand how the decision boundaries are built
  - At least in low dimensions, it can be visualized
- For non-linearly separable boundaries, you usually need a feature transform
  - Features engineering is hard!
  - Especially images: what makes a cat image recognizable as a cat?
- The same process as the SVM can be implemented in a neural network
  - But it gets harder to probe
- SVMs almost supplanted a fully connected neural networks in the 90s
- Deep Neural networks is a phoenix that rose out of the ashes of the fully connected neural networks
  - Convolutional neural networks automatically learn features
  - Graphics Processing Units (GPUs) transformed how neural networks are trained!

Other Types

What Else Can Machine Learning Do?

- Reinforcement Learning:
  - How do I learn to act in the world?
  - Especially if I don't know how the world works
- Recommender systems:
  - If I have watched a lot of funny cartoons and loved them, what else would I like?
- Forecasting:
  - Text prediction
  - Weather forecasting
- Language models

- What do they all have in common?

Function Approximation

Machine Learning Is Function Approximation

- A set is a collection of objects/things (called elements)
- A relation is an association between elements of two sets
- Relations can be represented as pairs:
  - (apple, fruit), (tomato, fruit), (carrot, root), etc.
- A function is a special kind of relation in which the second element is unique!
- Sometimes functions can be succinctly described, by an expression or an equation
  - (1, 2), (2, 4), (4, 8), (6, 12), (10, ?)
- Can this description be learnt?
- What is the function in:
  - Regression
  - Classification
  - Reinforcement Learning

Wrap-Up

Wrap-Up

- History of fitting observed data to a description
- Regression
- Machine Learning for Regression
- Classification
- From Neural Networks to Deep Learning
- Other kinds of Machine Learning
- Machine Learning is Function Approximation
- Several common themes and similar challenges!