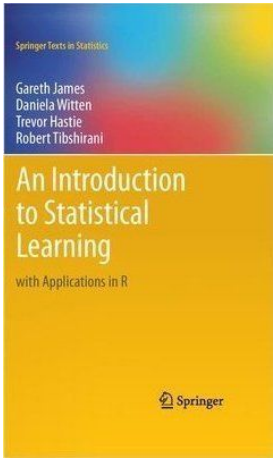
CSCU9YE - Artificial Intelligence

Lecture 7: Introduction to Machine Learning

Prof. Gabriela Ochoa, University of Stirling

Main sources

- Chapter 18 Learning from Examples from Artificial Intelligence: A Modern Approach,
- A Course in Machine Learning by Hal Daumé III (http://ciml.info/)
- The Hundred-Page Machine Learning Book by Andriy Burkov (http://themlbook.com/wiki/doku.php)
- An Introduction to Statistical Learning by by Gareth James, Daniela Witten, Trevor Hastie and Rob Tibshirani (http://faculty.marshall.usc.edu/gareth-james/ISL/)
- Online courses: Udacity (https://www.udacity.com/)



What is machine learning?

Machine learning is the science of getting computers to act without being explicitly programmed.

A system is learning if it improves its performance on future tasks after making observations about the world

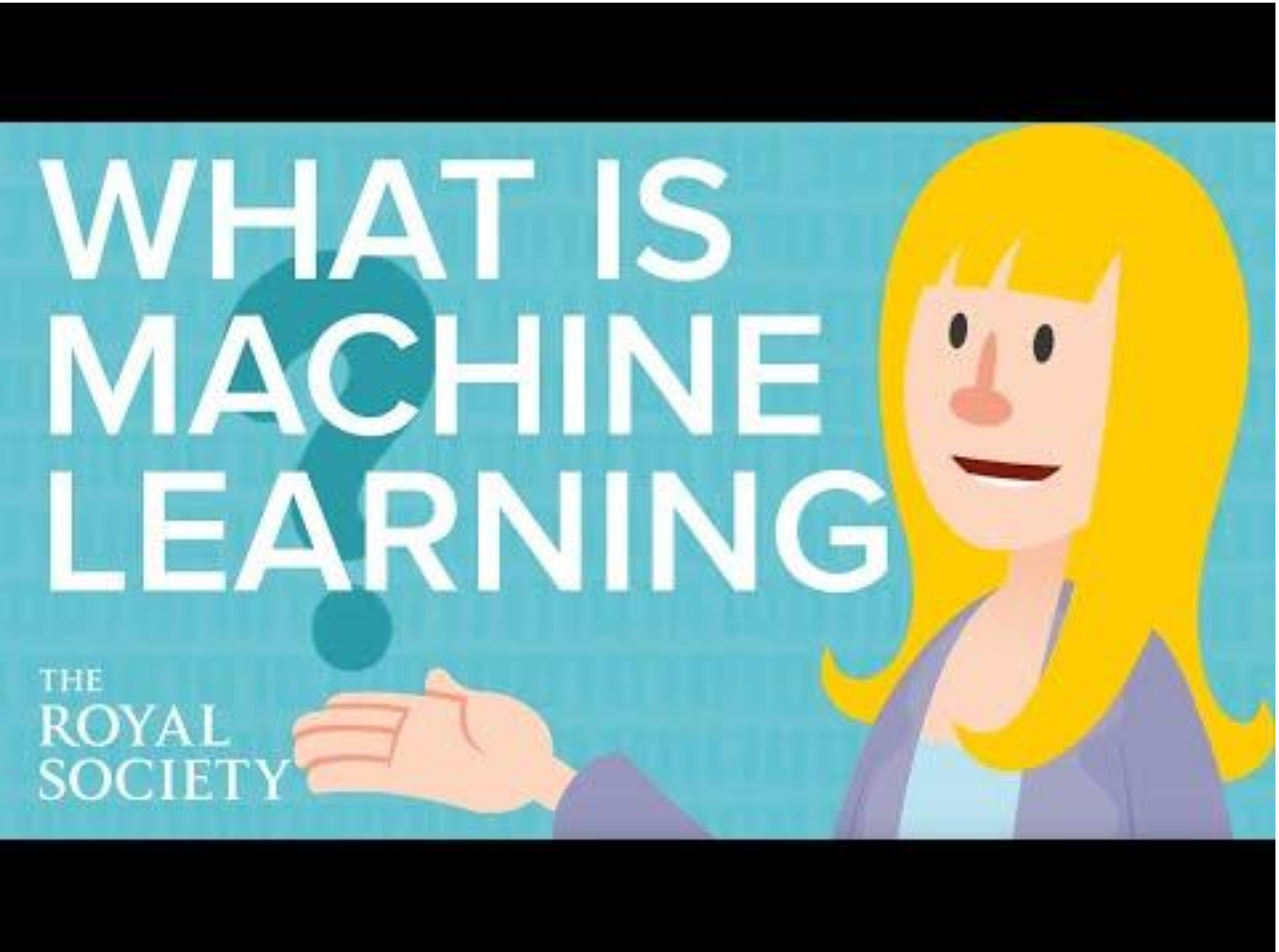
Machine learning is the process of solving a practical problem by:

1. Gathering a dataset
2. Algorithmically building a statistical model based on that dataset

Why do we need learning algorithms?

3 main reasons:

1. The designers cannot anticipate all possible situations that software will encounter (e.g. different texts for translation, different faces)
2. The designers cannot anticipate all changes over time. Conditions may change. (e.g. a program for predicting stock market prices)
3. Sometimes, human programmers have no idea how to program a solution themselves (e.g. language translations, face recognition)



What is Machine Learning? The Royal Society

Types of machine learning algorithms

According to the *feedback* available to learn from:

Supervised

Given example input-output pairs, learn a function that maps from input to outputs

Tasks: classification, regression

Unsupervised

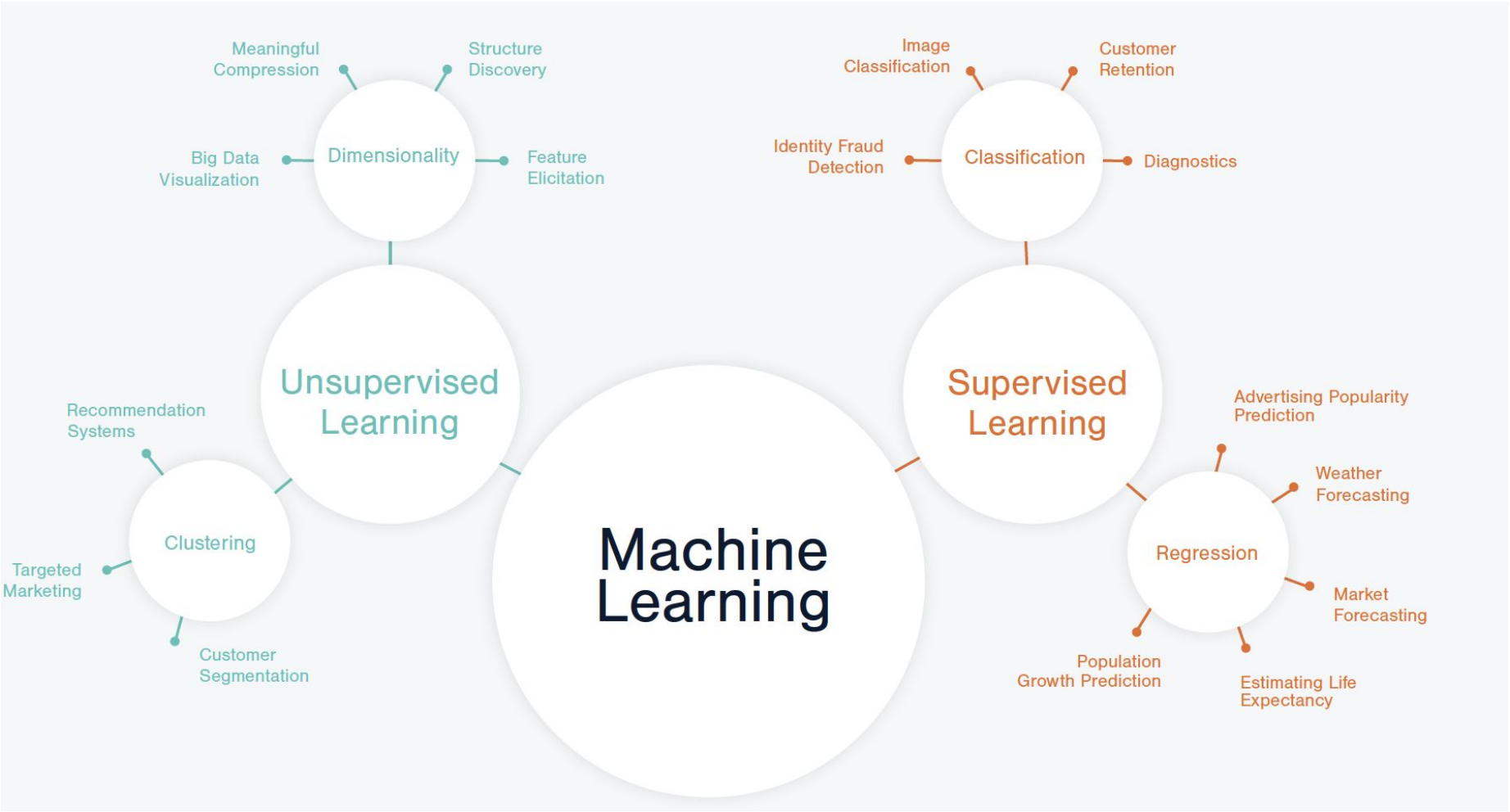
Given inputs, learn patterns even though no explicit feedback is supplied.

Tasks: clustering, dimensionality reduction

Reinforcement

Given feedback from the environment (rewards, punishments), determine the ideal behaviour

Tasks: game playing, online control



Supervised vs. Unsupervised Learning https://content.alegion.com/supervised-vs-unsupervised

Typical machine learning tasks (supervised)

Binary Classification

Predict a simple yes/no response, only two classes.

Applications: diagnostics, spam detection,

Multiclass classification

Identify an object into one of a number of classes.

Applications: a story is about politics, science, entertainment, etc

Regression

Predicting a continuous-valued attribute associated with an object

Applications: drug response, stock prices, etc.

Ranking

Put a set of objects in order of relevance

Applications: ranking preferences of user for movies or books

Typical machine learning tasks (unsupervised)

Clustering

- Organise similar items into groups.
- Applications: customer segmentation, grouping experiment outcomes

Dimensionality reduction

- Taking high dimensional data and embedding it in a lower dimension space
- Low-dimensional data representations that remove noise but retain the signal of interest can be instrumental in understanding hidden structures and patterns
- Applications: feature extraction, data compression, exploration, and visualisation.

Terminology

Input variables

Target variable

Date	Temperature	Humidity	Wind Speed	Weather
01/10/17	22	48	2.7	Sunny
02/10/17	15	80	3.8	Rainy
03/10/17	12	45	17.9	Windy
04/10/17	14	77	4.2	Cloudy

Samples

Other names for variable

- Column
- Feature
- Attribute
- Field
- Dimension

Other names for sample

- Row
- Record
- Observation
- Example
- Instance

Variable types

Most common

- Numeric: discrete, continuous
- Categorical: binary, nominal, ordinal

Others

- String
- Date …

Numeric Variables

Values are numbers

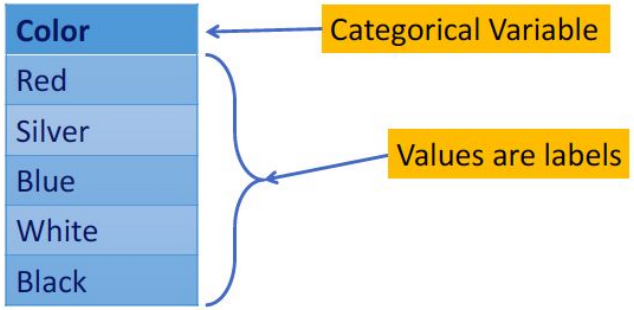
Also called ‘quantitative’

1, 4.450, -0.8767, $7x10^5$

Categorical Variables

Values are labels, names, or categories

Also called ‘qualitative’ or ‘nominal’



Classification: weather forecast

Given input variables, predict a a category or class

Data:

Input variables

Target variable

Date	Temperature	Humidity	Wind Speed	Weather
01/10/17	22	48	2.7	Sunny
02/10/17	15	80	3.8	Rainy
03/10/17	12	45	17.9	Windy
04/10/17	14	77	4.2	Cloudy

What would be the wheatear in the future?
Weather in 05/10/17?

Binary classification: spam filter

Input: an email

Output: spam/no spam

Setup:

- Get a large collection of example emails, each labeled “spam” or “not spam”
- **Note**: someone has to hand label all this data!
- Want to learn to predict labels of new, future emails

Features: Attributes used to decision

- Words: FREE!
- Text Patterns: $dd, CAPS
- Non-text: SenderInContacts

...

Dear Sir.

First, I must solicit your confidence in this transaction, this is by virtue of its nature as being utterly confidential and top secret. …

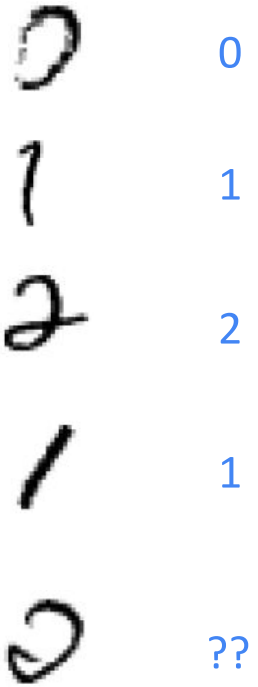
TO BE REMOVED FROM FUTURE MAILINGS, SIMPLY REPLY TO THIS MESSAGE AND PUT "REMOVE" IN THE SUBJECT.

99 MILLION EMAIL ADDRESSES FOR ONLY $99

Ok I'm beginning to go insane. Had an old Dell Dimension XPS sitting in the corner and decided to put it to use, I ….

Classification: digit recognition

- Input: images / pixel grids
- Output: a digit 0-9
- Setup
  - Get a large collection of example images, each labeled with a digit
  - **Note**: someone has to hand label all this data!
  - Want to learn to predict labels of new, future digit images
- Features: The attributes used to make the digit decision
  - Pixels: (6,8)=ON
  - Shape Patterns: NumComponents, AspectRatio, NumLoops
  - …



Demo

Microsoft Research ML

- Facial detection and recognition
- Gender prediction
- Age prediction

https://how-old.net/

Regression: stock price forecast

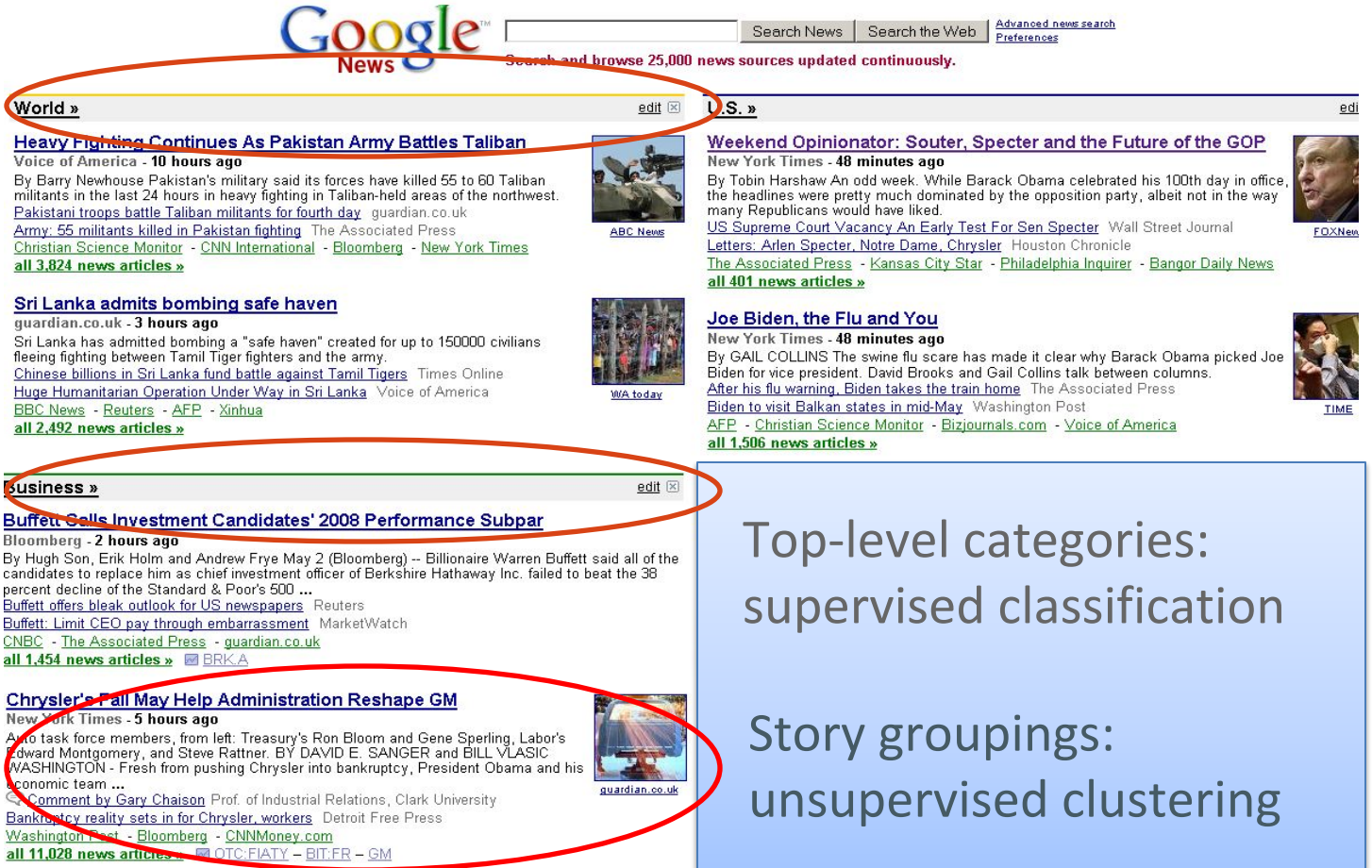
Predicting the value of a target continuous numerical value from input variables

Microsoft's stock price (blue line) and forecast (purple line) made in 22-Oct-2001.

The yellow points show stock prices since the forecast was made.

http://www.growth-dynamics.com/news/sep22_03.htm

Clustering: grouping google news



Top-level categories: supervised classification

Story groupings: unsupervised clustering

Supervised learning

Data a list of observations <X,y>

Learn a function from examples

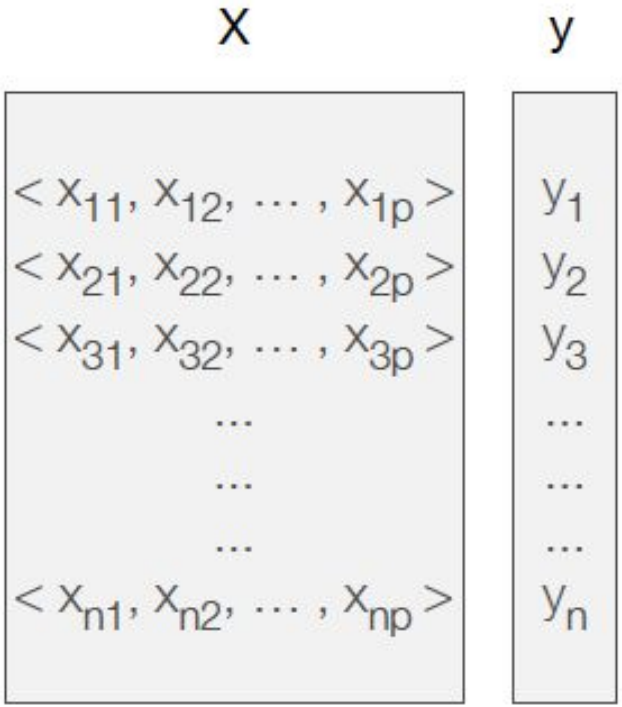
f is the target function - unknown!

An example is a pair (*x*, *y*) *y=f(x)*

Problem: find a hypothesis or estimate of *f*, let us call it *h*

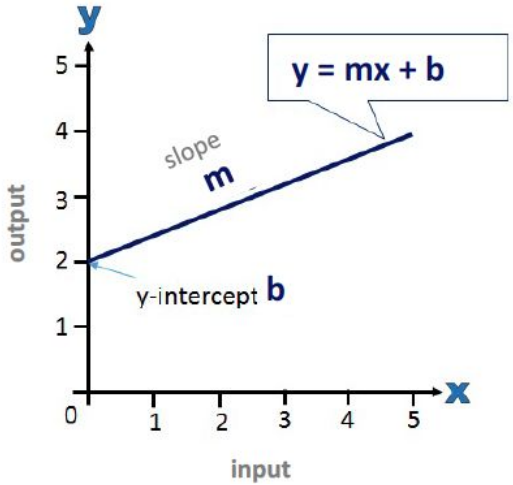
such that $h \simeq f$

given a training set of examples



What is a machine learning model?

Input variables (X) → Model Y = *f*(X) → Output (Y)



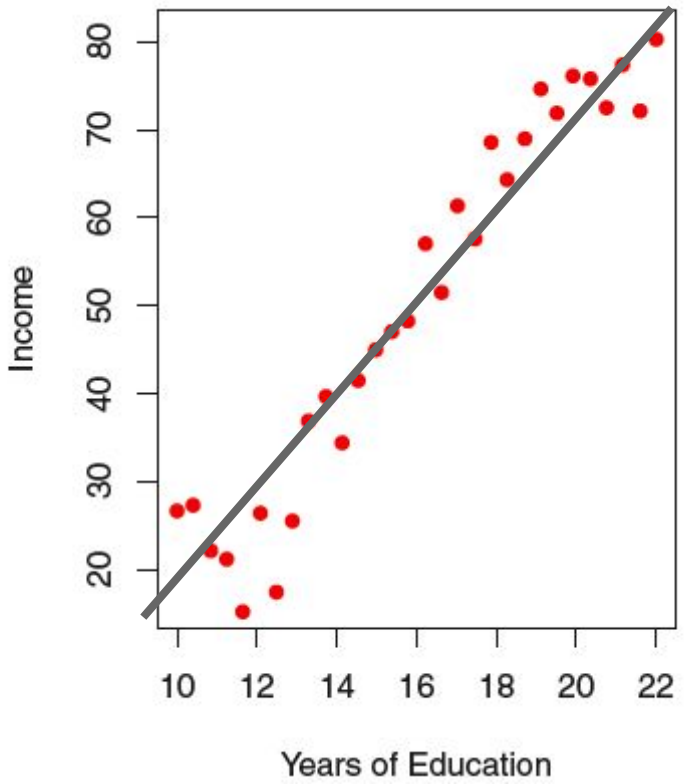
A *mathematical* expression or algorithmic representation that maps input to output

Example of the simplest possible model, a line

y = mx + b, m and *b* are the parameters

Model parameters are adjusted during model training to change input-output mapping.

Example linear model income dataset



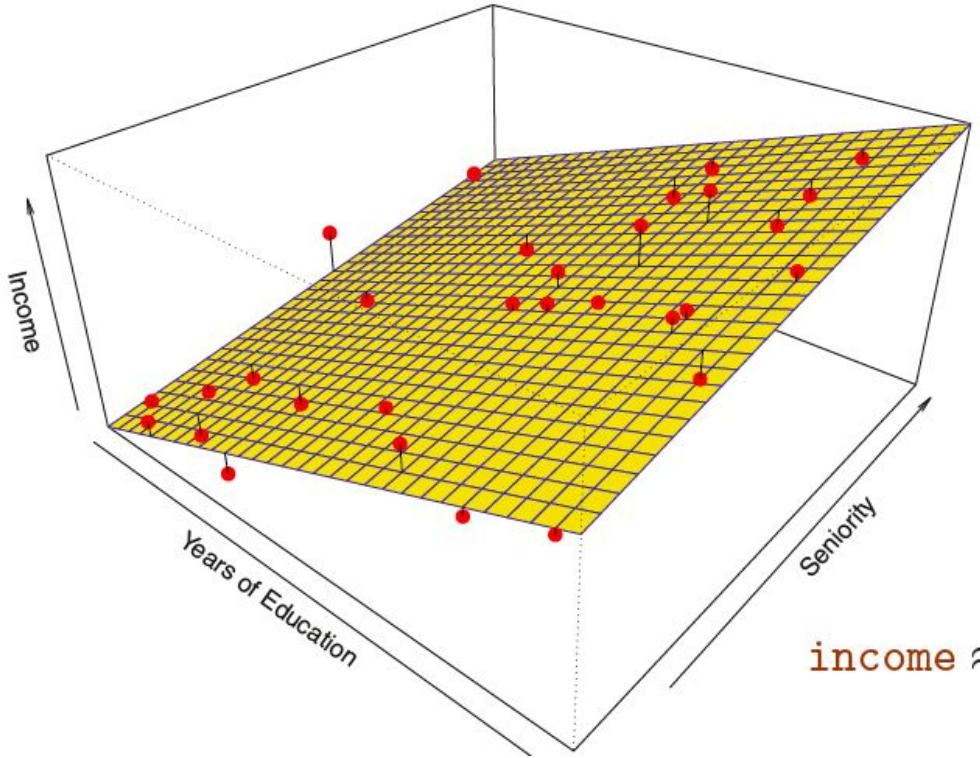
Y = income (in thousands of £)

X = single variable years of education

It seems that we can estimate income with a linear function.

Of course there is always some error in the estimation

Example linear model income dataset



Y = income (in thousands of £)

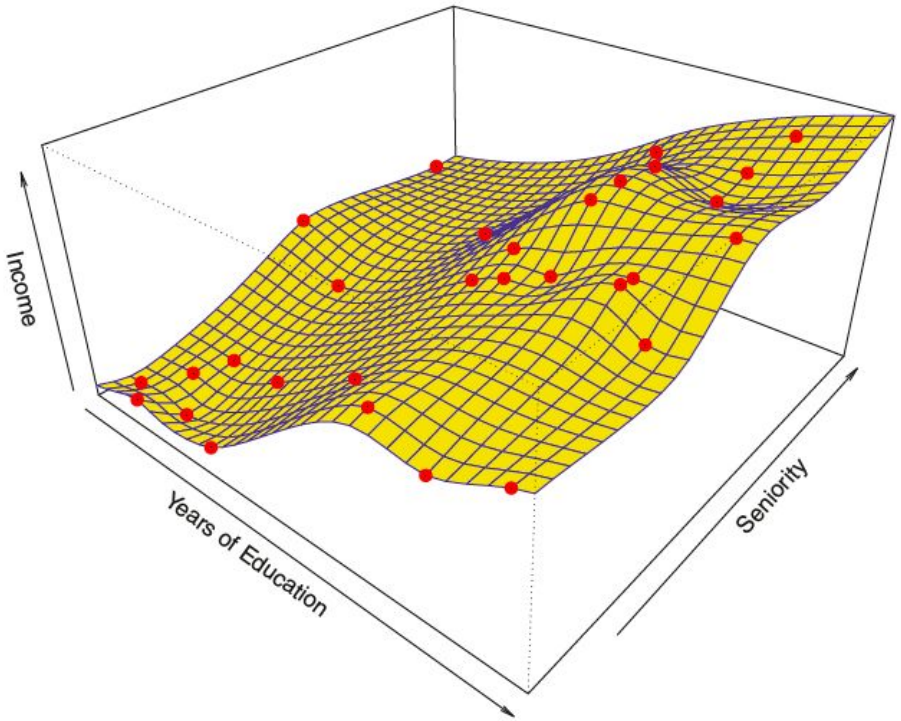
X: 2 variables: Years of Education and Seniority

The observations are shown in red

The yellow plane indicates a linear model (parametric model) fitted with a method known as *least squares*.

$$\texttt{income} \approx \beta_0 + \beta_1 \times \texttt{education} + \beta_2 \times \texttt{seniority}.$$

Example non-linear model income dataset



Non-parametric approach, *thin-plate spline*, is used to estimate *f*.

Does not impose any pre-specified model on *f*.

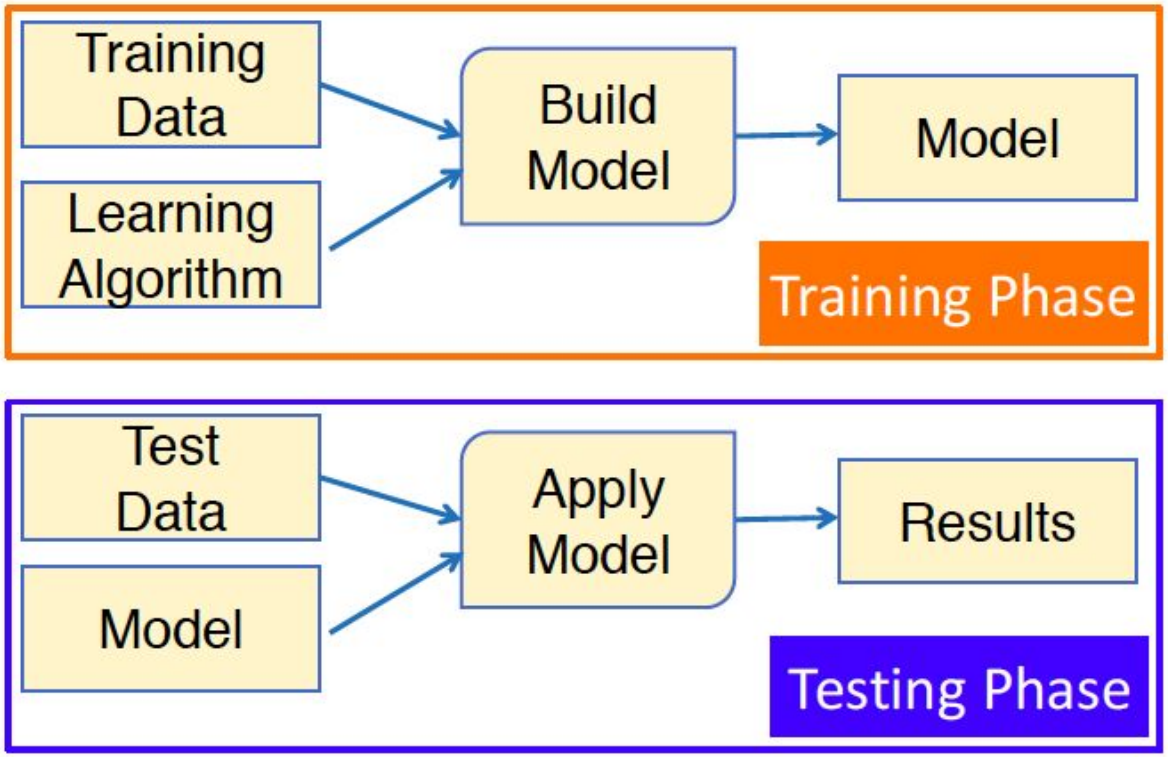
Attempts an estimate for *f* that is as close as possible to the observed data (smooth function in yellow)

This model fits the data better, but may suffer from *overfitting*.

What is overfitting?

- Occurs when a statistical model or machine learning algorithm captures the *noise* of the data (as opposed to the *signal*).
- Intuitively occurs when the model or the algorithm fits the data too well.
- Is often a result of an excessively complicated model
- Can be prevented by fitting multiple models and using validation or cross-validation to compare their predictive accuracies on test data.

Training set and testing set



ML is about learning some properties of a data set and then testing those properties against another data set

ML algorithms are evaluated by splitting a data set into two sets.

1. **Training set:** learning the model;
2. **Testing set:** test the quality (accuracy) of he model.

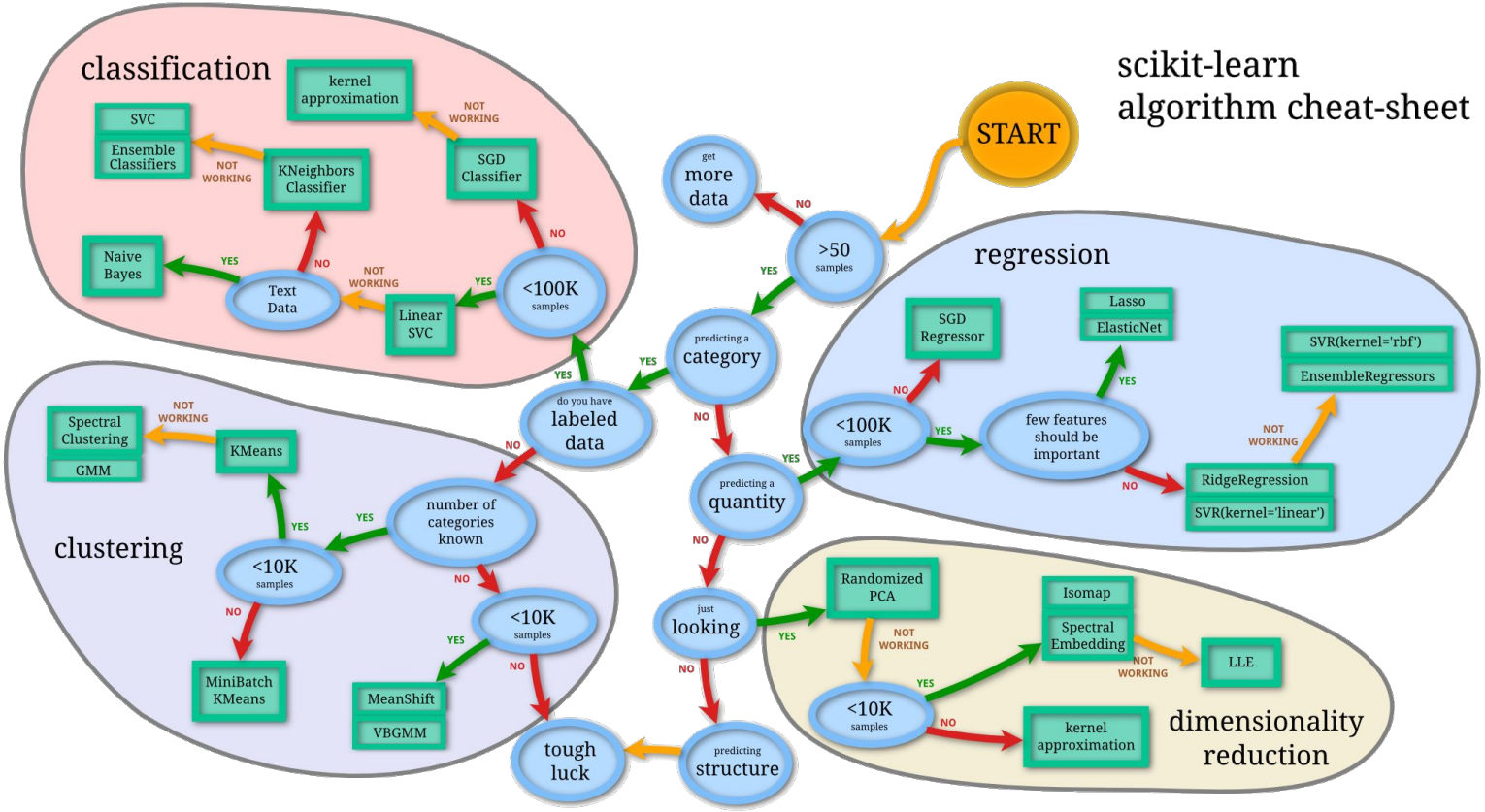
Python library: scikit-learn

- Open source library for Machine Learning in Python
- Built on top of NumPy, SciPy, Matplotlib
- Improved continuously, activite community
- Provides easy to use API for training, and making predictions
- Collection of the best, most popular, algorithms in one place.
- Great documentation!

http://scikit-learn.org/stable/documentation.html

Machine Learning Algorithms: where to start?

map by A. Mueller, scikit-learn



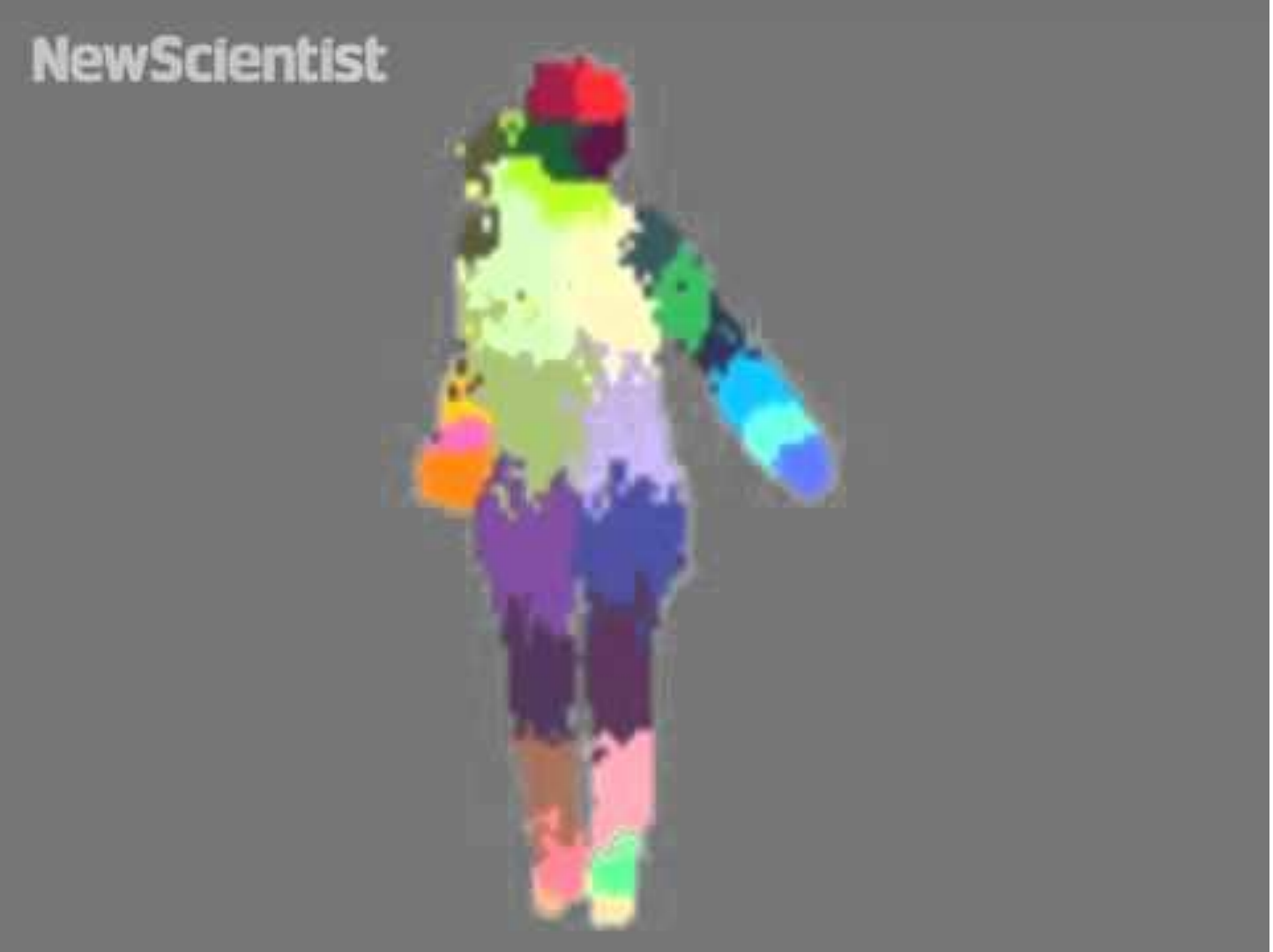
Some Acronyms

SGD: Stochastic Gradient Descent (linear classifiers)

SVC: Support Vector Classifier

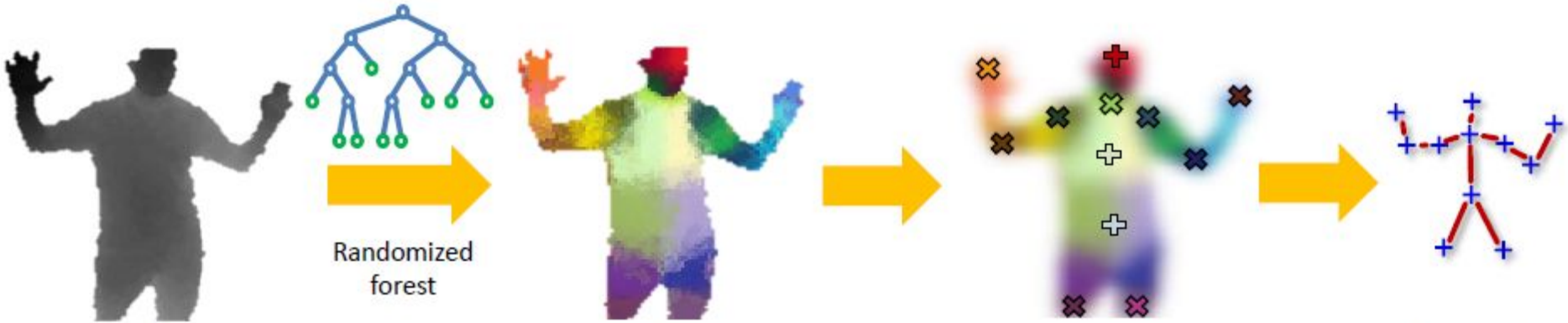
SVR: Support Vector Regression

PCA: Principal Component Analysis



Supervised learning and the Kinect

Supervised learning and the Kinect



Random forest: use many decision trees and pick the class which is the general consensus among the trees.

https://www.microsoft.com/en-us/research/publication/real-time-human-pose-recognition-in-parts-from-a-single-depth-image/

Supervised learning and the Kinect

Figure 2. **Synthetic and real data**. Pairs of depth image and ground truth body parts. Note wide variety in pose, shape, clothing, and crop.

Random forest: use many decision trees and pick the class which is the general consensus among the trees.

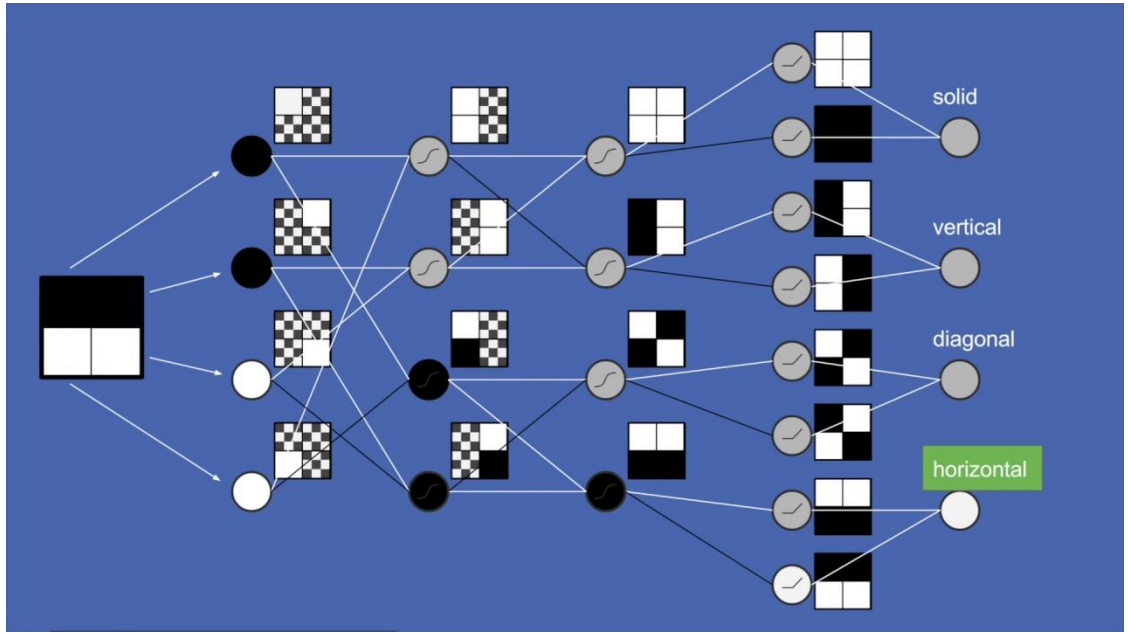
https://www.microsoft.com/en-us/research/publication/real-time-human-pose-recognition-in-parts-from-a-single-depth-image/

Supervised Learning with Neural Networks

Multiple layers of neurons which encode different levels of information in order to predict some class.

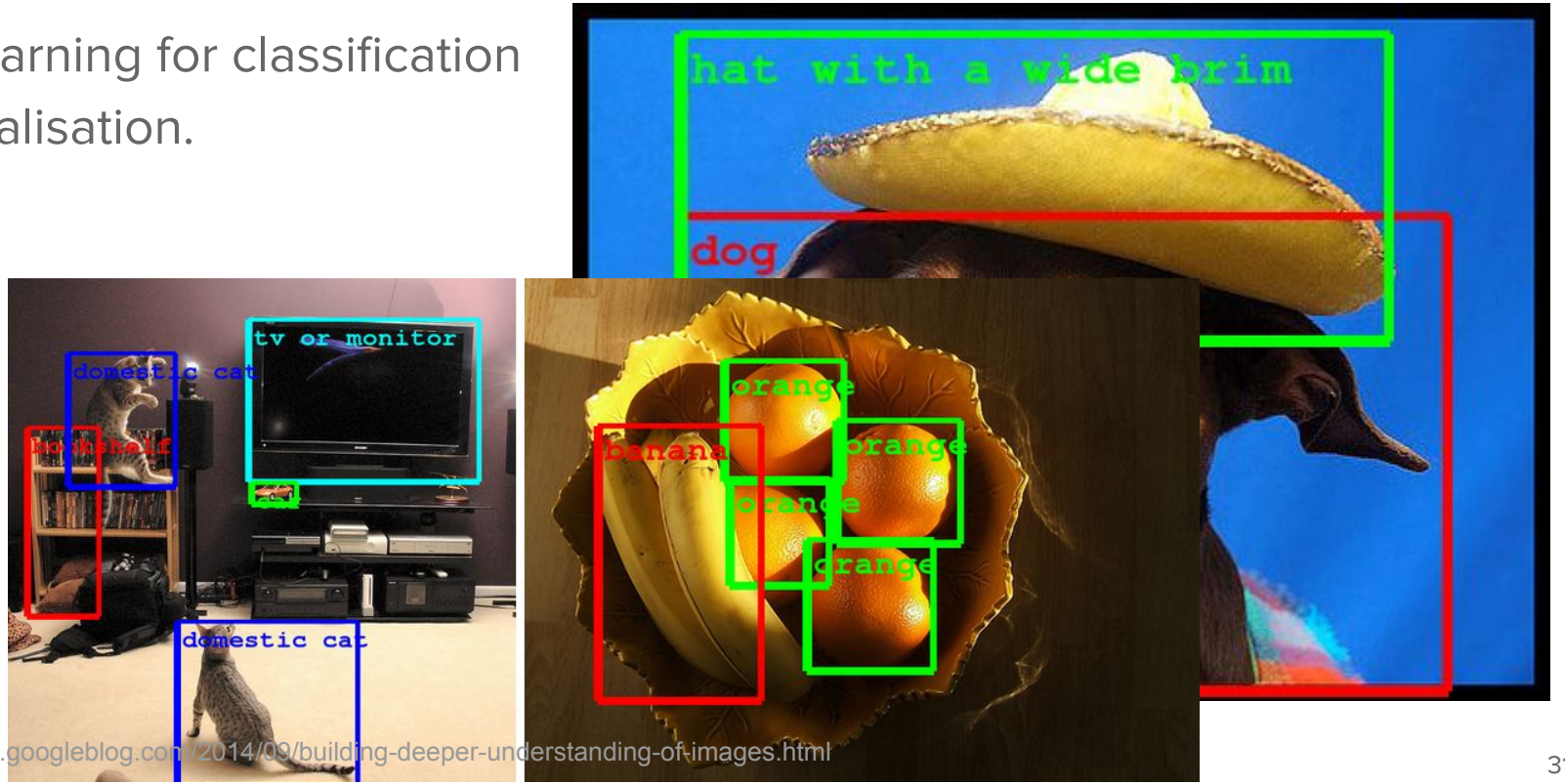
Deep network: many hidden layers.

Finding the right structure for a neural network is not trivial.

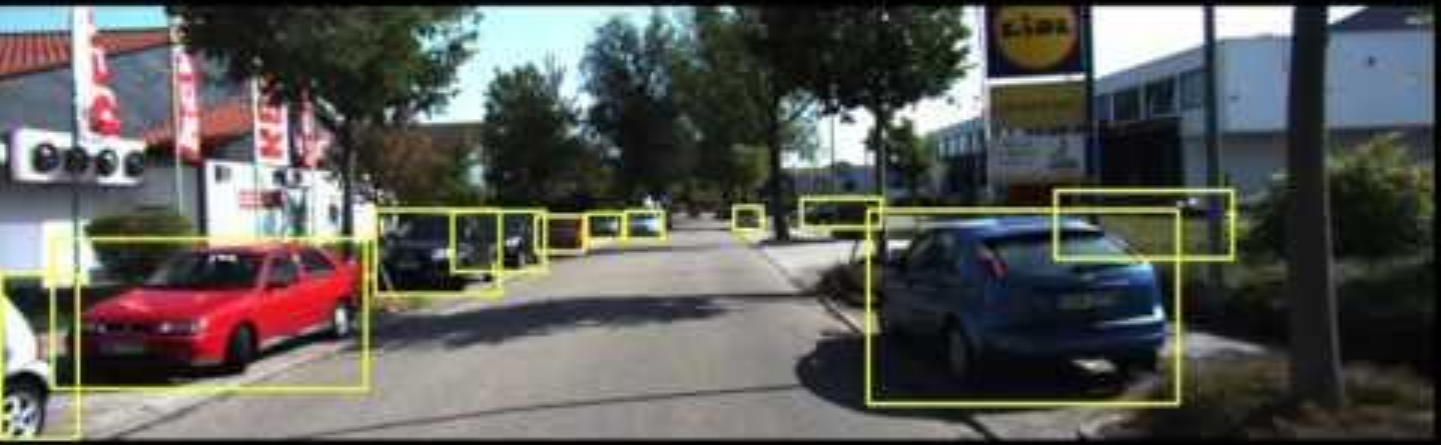


Supervised Learning with Neural Networks

Deep learning for classification with localisation.



https://research.googleblog.com/2014/09/building-deeper-understanding-of-images.html



Supervised Learning and Self-driving cars

Deep network to recognise different objects (classes).

https://www.youtube.com/watch?v=HJ58dbd5g8g

Summary

- Machine learning is the science of getting computers to act without being explicitly programmed.
- ML builds a model that can be used for predicting the future or making decisions
- ML Types: Supervised, Unsupervised, Reinforcement
- ML Tasks: Classification, Regression, Clustering
- No single algorithm is the best suited to all tasks and problems!