Deep Neural Networks

Lecture 1

Robert Bogucki

Format

- Lecture + Labs (hands-on)
- Instructors: Robert Bogucki, Marek Cygan, Maciek Klimek, Marcin Mucha
- Slack: dl1617.slack.com
- Slides will be available (slack)

Grading

- 65% hands-on assignments
- 35% oral exam
- You need to **pass both**

Two options for hands-on assignments:

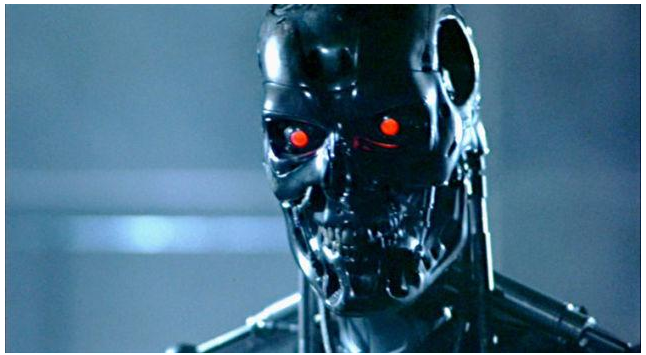
- 3 small projects,
- 1 big project (teaming up is allowed, max 3 people per team)

Books, tutorials, ...

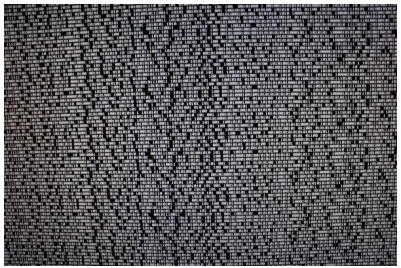
- http://www.deeplearningbook.org/
- Convolutional Neural Networks for Visual Recognition
  http://cs231n.stanford.edu/
- Kaggle.com
- Machine Learning: A Probabilistic Perspective (Kevin Murphy)

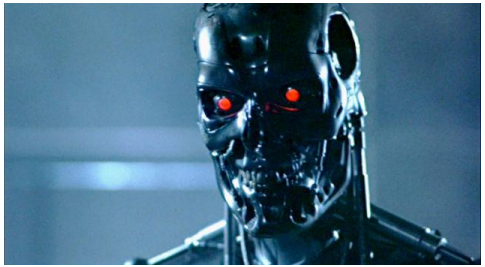
Plan for the next two weeks

- A refresher on Machine Learning

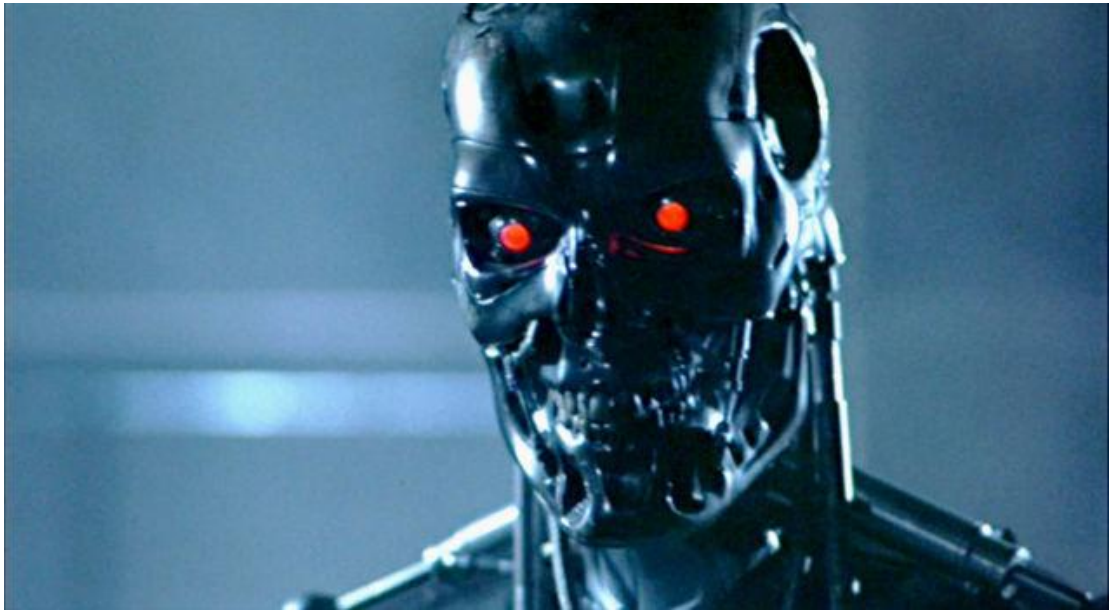


How computers learn to do things?





AI demystified



$$= [w_1, w_2, ..., w_n]$$

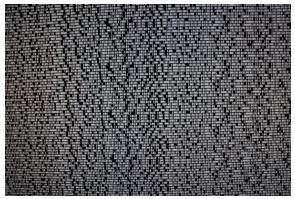
A simple example

$$apartment's\ price \approx w_1 \cdot area + w_2 \cdot district + ...$$

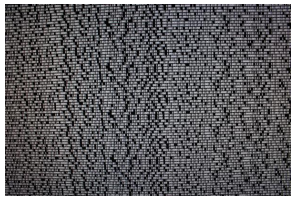
A simple example

$$apartment's\ price \approx w_1 \cdot area + w_2 \cdot district + \ldots$$

If you know those, you can predict the price!

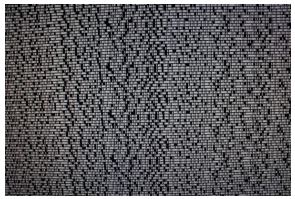


$= \quad [area,\ district,\ ...]$



$=$ $[area,\ district,\ ...]$

$=$ $[w_1, w_2, ..., w_n]$

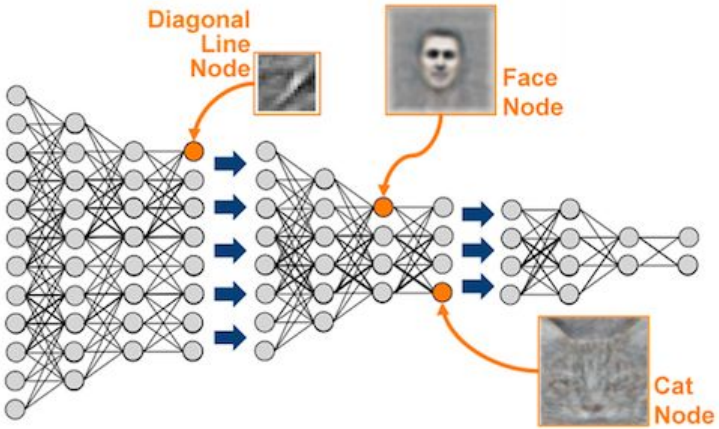


$=$ $[area,\ district,\ ...]$

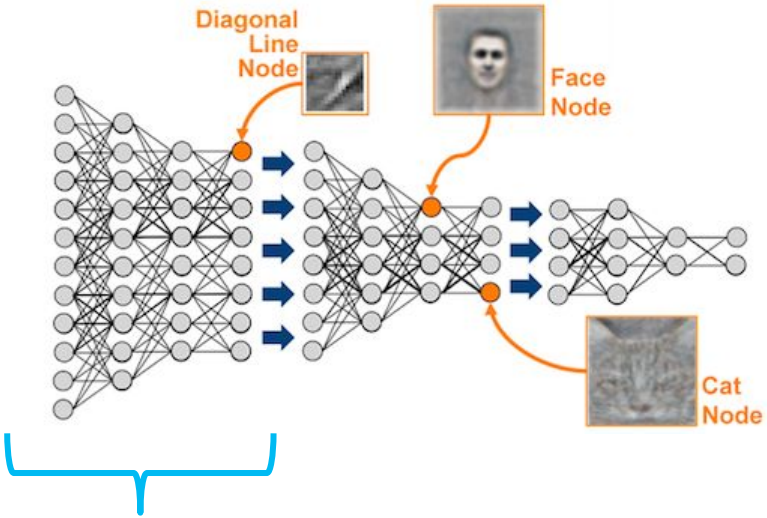
$=$ $[w_1, w_2, ..., w_n]$

$=$ $apartment's\ price \approx w_1 \cdot area + w_2 \cdot district + ...$

Why should we care about Deep Learning?



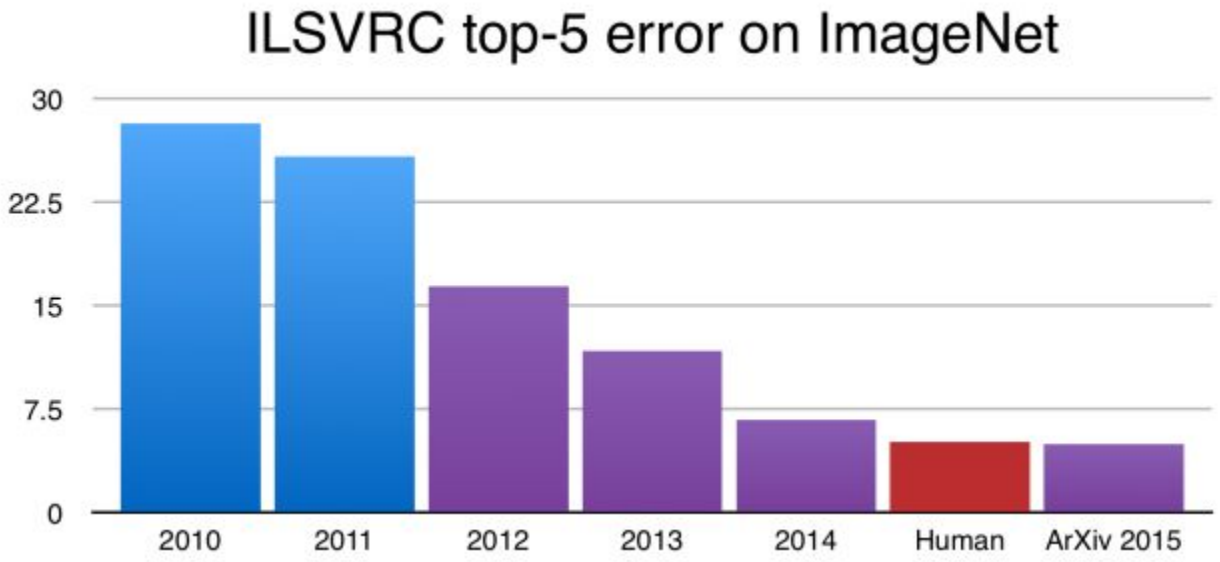
Why should we care about Deep Learning?



humans did this part manually just a few years ago (2011)...

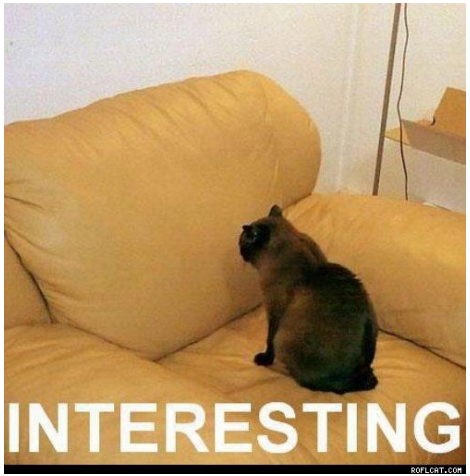
Why should we care about Deep Learning?

...and we're not that good at it.



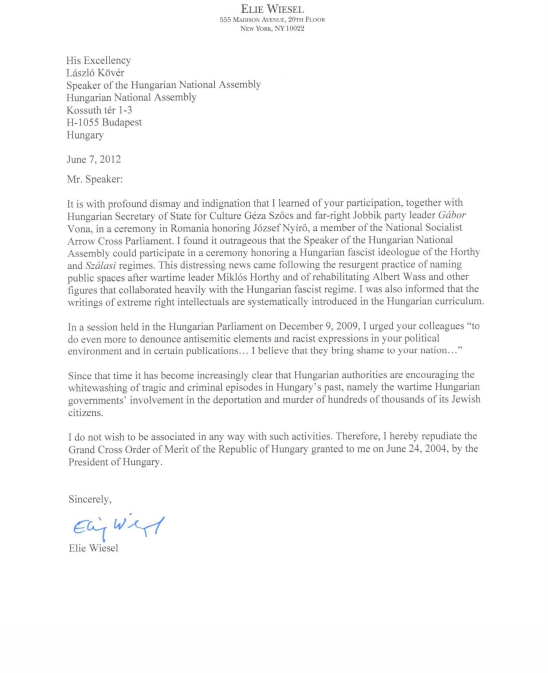
Classification

vs



Classification

vs



ELIE WIESEL
555 MADISON AVENUE, 20TH FLOOR
NEW YORK, NY 10022

His Excellency
László Kövér
Speaker of the Hungarian National Assembly
Hungarian National Assembly
Kossuth tér 1-3
H-1055 Budapest
Hungary

June 7, 2012

Mr. Speaker:

It is with profound dismay and indignation that I learned of your participation, together with Hungarian Secretary of State for Culture Géza Szőcs and far-right Jobbik party leader *Gábor* Vona, in a ceremony in Romania honoring József Nyirő, a member of the National Socialist Arrow Cross Parliament. I found it outrageous that the Speaker of the Hungarian National Assembly could participate in a ceremony honoring a Hungarian fascist ideologue of the Horthy and *Szálasi* regimes. This distressing news came following the resurgent practice of naming public spaces after wartime leader Miklós Horthy and of rehabilitating Albert Wass and other figures that collaborated heavily with the Hungarian fascist regime. I was also informed that the writings of extreme right intellectuals are systematically introduced in the Hungarian curriculum.

In a session held in the Hungarian Parliament on December 9, 2009, I urged your colleagues "to do even more to denounce antisemitic elements and racist expressions in your political environment and in certain publications… I believe that they bring shame to your nation…"

Since that time it has become increasingly clear that Hungarian authorities are encouraging the whitewashing of tragic and criminal episodes in Hungary's past, namely the wartime Hungarian governments' involvement in the deportation and murder of hundreds of thousands of its Jewish citizens.

I do not wish to be associated in any way with such activities. Therefore, I hereby repudiate the Grand Cross Order of Merit of the Republic of Hungary granted to me on June 24, 2004, by the President of Hungary.

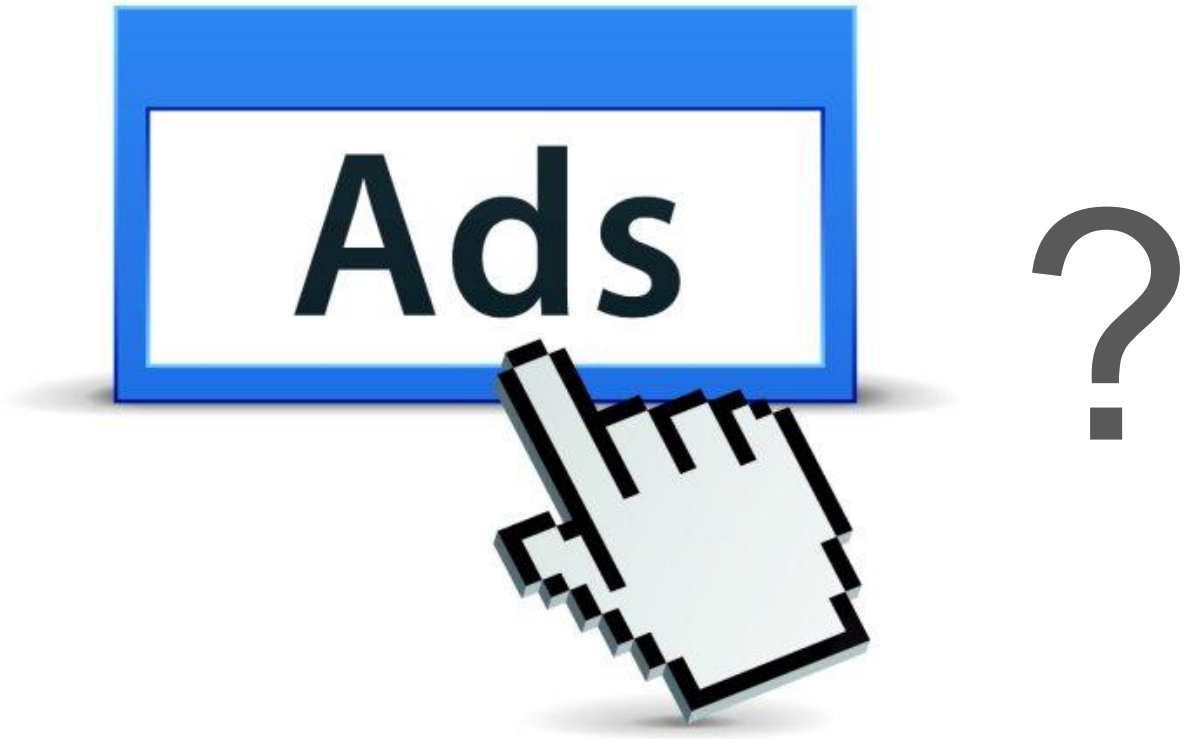
Sincerely,

Elie Wiesel

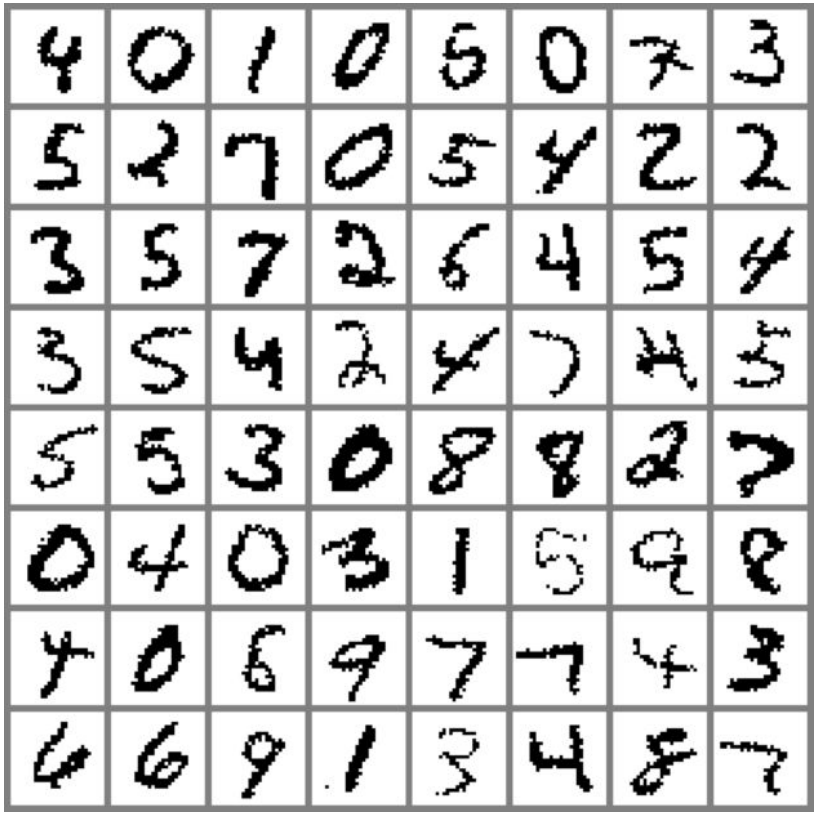
Classification

?

Classification



Classification

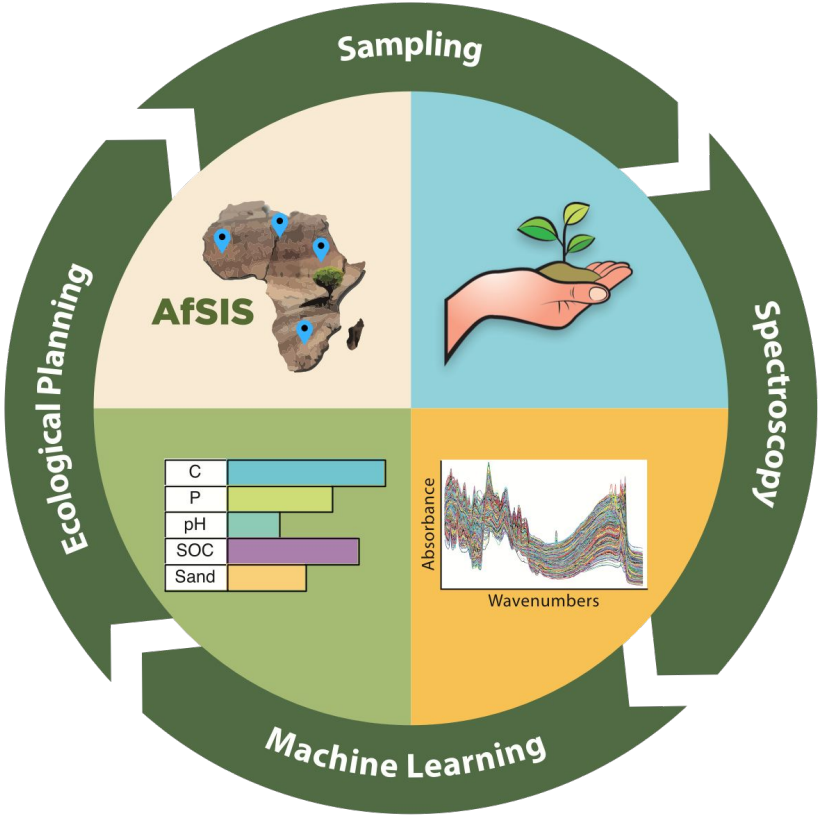


Classification

Regression

Regression

Regression


Sampling
Spectroscopy
Machine Learning
Ecological Planning
AfSIS
C
P
pH
SOC
Sand
Absorbance
Wavenumbers

Which one is it?

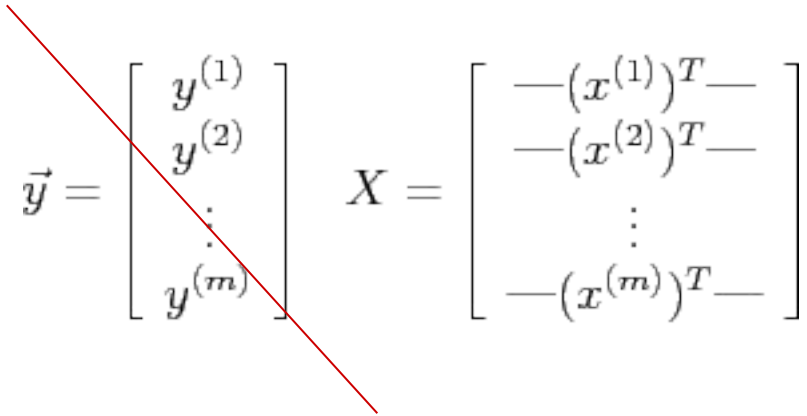
Supervised learning

Classification, regression

$$\vec{y} = \begin{bmatrix} y^{(1)} \\ y^{(2)} \\ \vdots \\ y^{(m)} \end{bmatrix} \quad X = \begin{bmatrix} —(x^{(1)})^T— \\ —(x^{(2)})^T— \\ \vdots \\ —(x^{(m)})^T— \end{bmatrix}$$

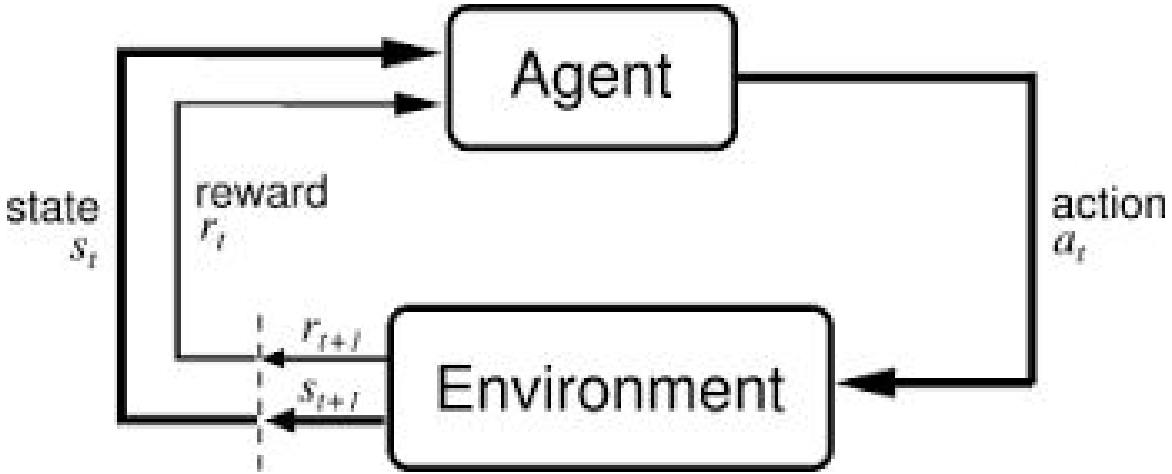
Unsupervised learning

Clustering, dimensionality reduction



Reinforcement learning

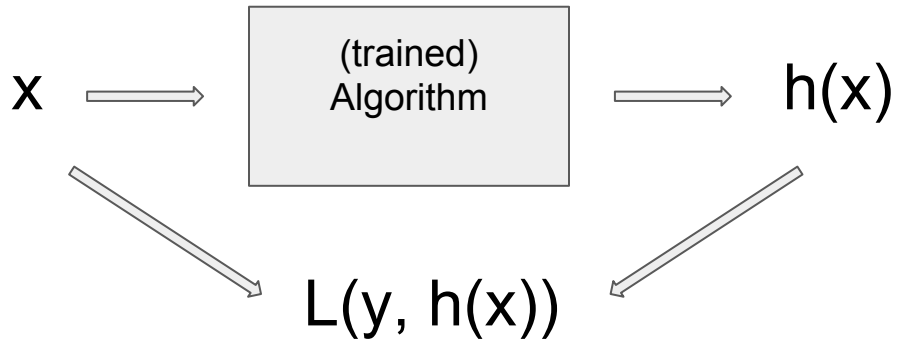
Game-like environment



How to judge our algorithm?

L - Loss function

(x, y) - a single instance (desired mapping)



(we usually look at the mean: $1/m \Sigma L(y_i, h(x_i))$

Examples of loss functions

Regression

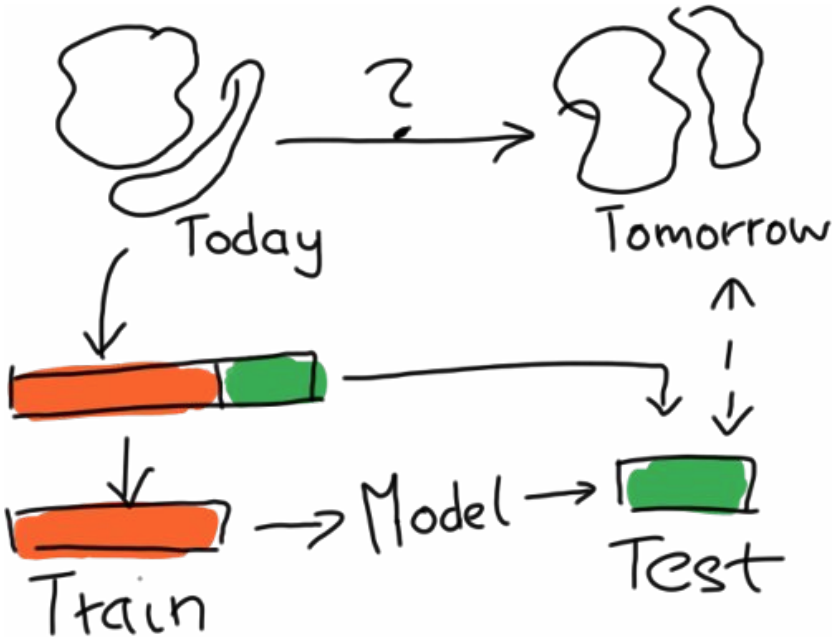
- $(y - h(x))^2$
- $|y - h(x)|$
- $(|y - h(x)| - \varepsilon)\, I(|y - h(x)| > \varepsilon)$

Classification

- $I(y \neq h(x))$
- $-y \log h(x) - (1 - y) \log(1 - h(x))$
- top5 error

Loss function is the protagonist here

We would like to minimize it “in the future”



Machine Learning demystified

Why should we care about the loss function?

Let h(x) = const, what constant should we choose?

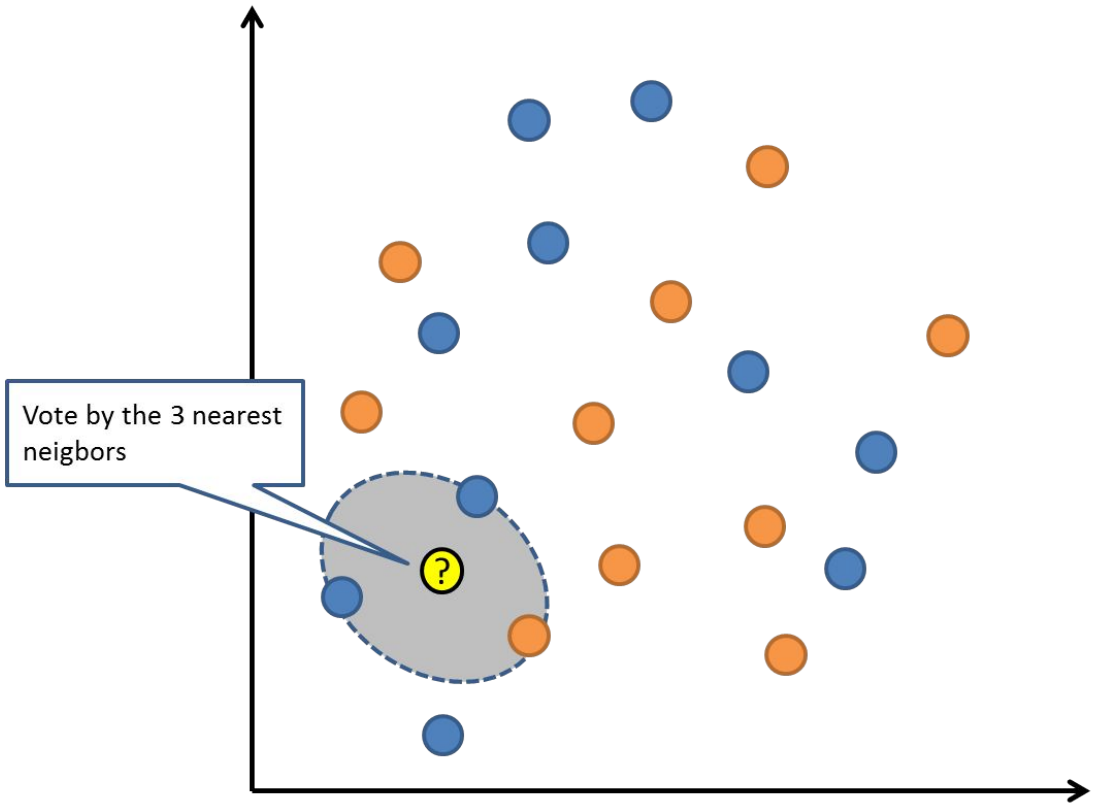
Regression

- $(y - h(x))^2$
- $|y - h(x)|$
- $(|y - h(x)| - \varepsilon)\, I(|y - h(x)| > \varepsilon)$

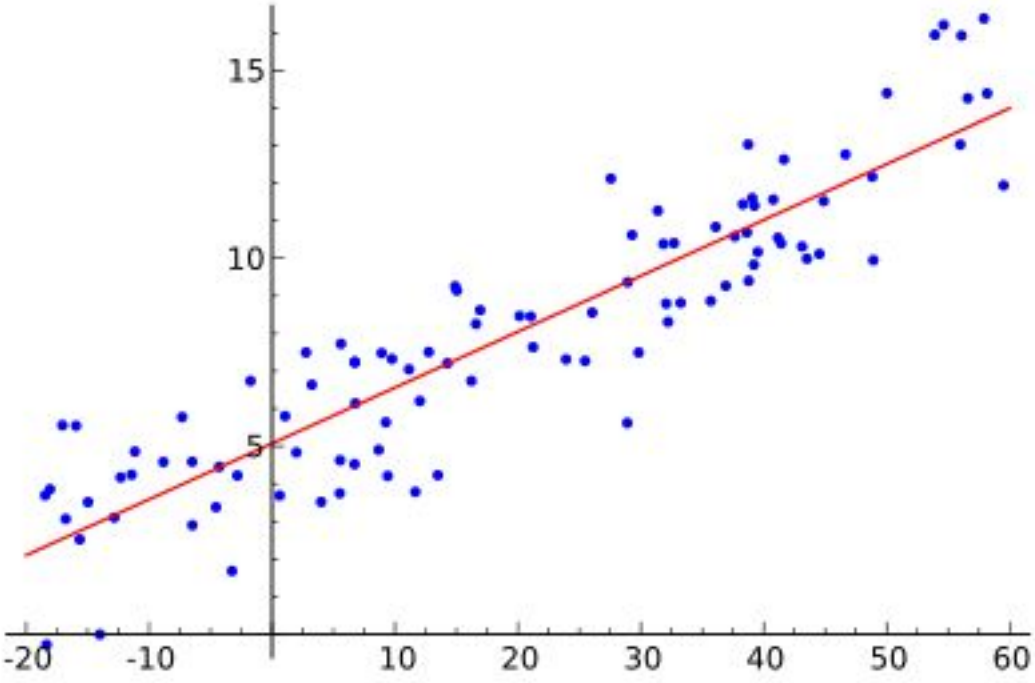
Classification

- $I(y \neq h(x))$
- $-y \log h(x) - (1 - y) \log(1 - h(x))$
- top5 error

kNN



Linear regression



Linear regression

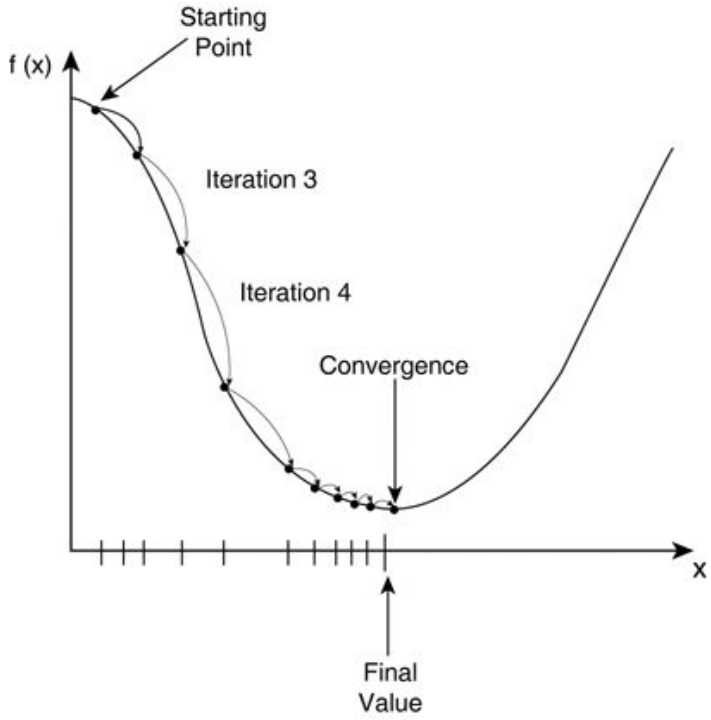
- $h(x) = w^T x$ (assuming $x_0 = 1$)
- We minimize RMSE (root mean square error):

$$\sqrt{\frac{1}{n}\sum_{k=1}^{n}(y_i - h(x_i))^2}$$

Linear regression

How do we find w?

Gradient descent



Gradient descent

$$J(w) = \frac{1}{n} \sum_{k=1}^{n} (y_i - w^T x_i))^2$$

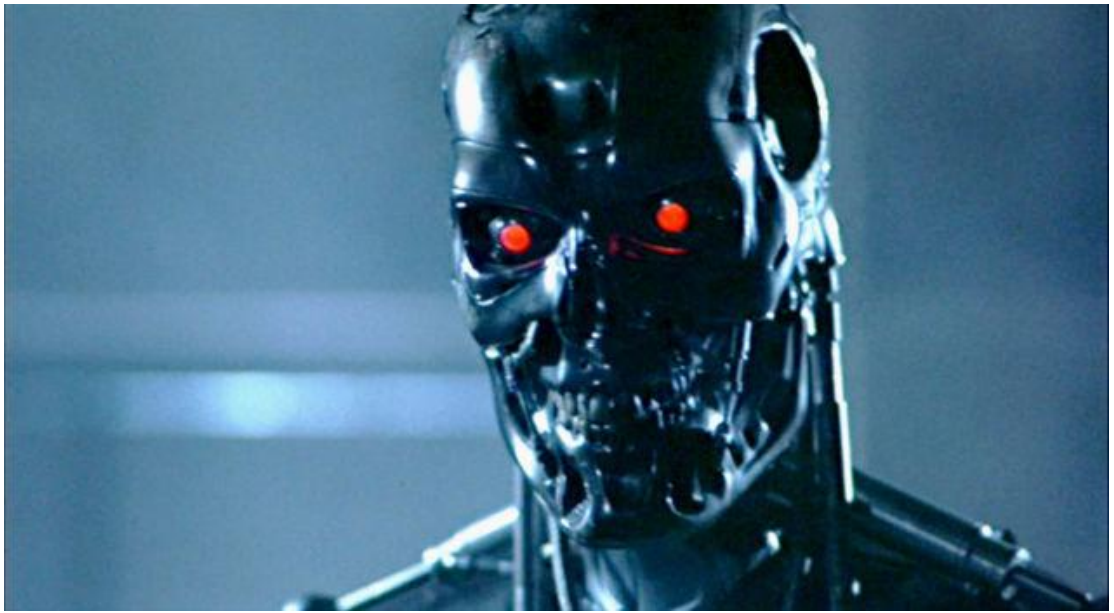
$$\nabla J(w) = ?$$

Finding the right weights

Gradient descent: $$w_j^{(t+1)} := w_j^{(t)} - \alpha \frac{\partial J(w)}{\partial w_j}$$

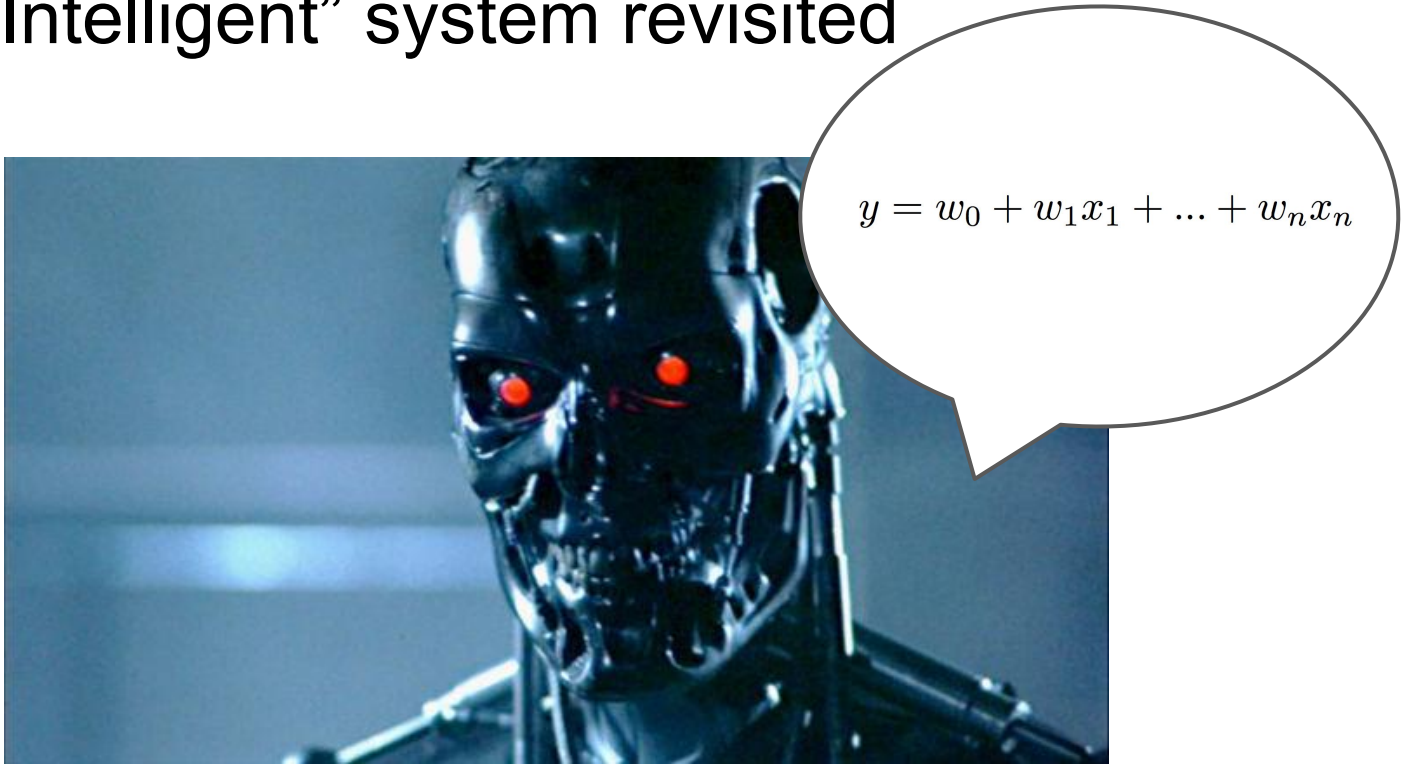
Exact formula: $$w = (X^T X)^{-1} X^T y$$

“Intelligent” system revisited



$$= [w_0, w_1, ..., w_n]$$

“Intelligent” system revisited

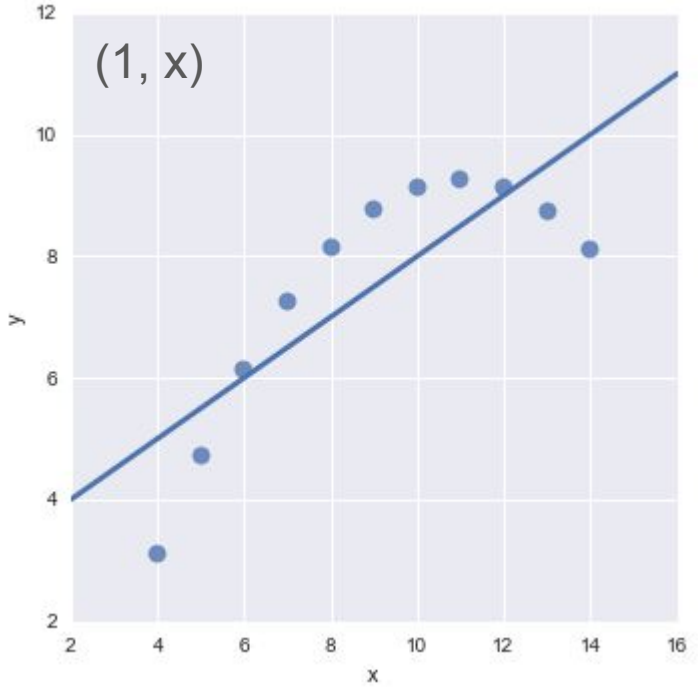


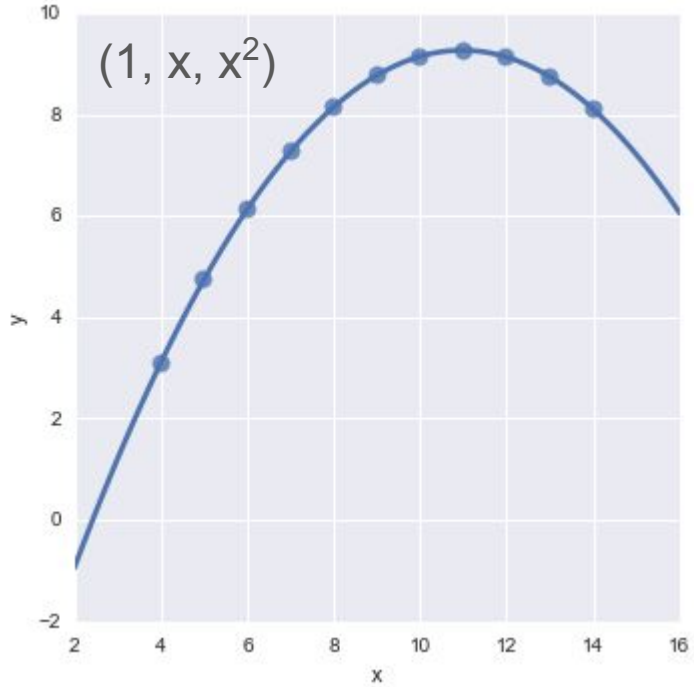
Beyond linearity - feature engineering!

$$x \longrightarrow \phi(x)$$

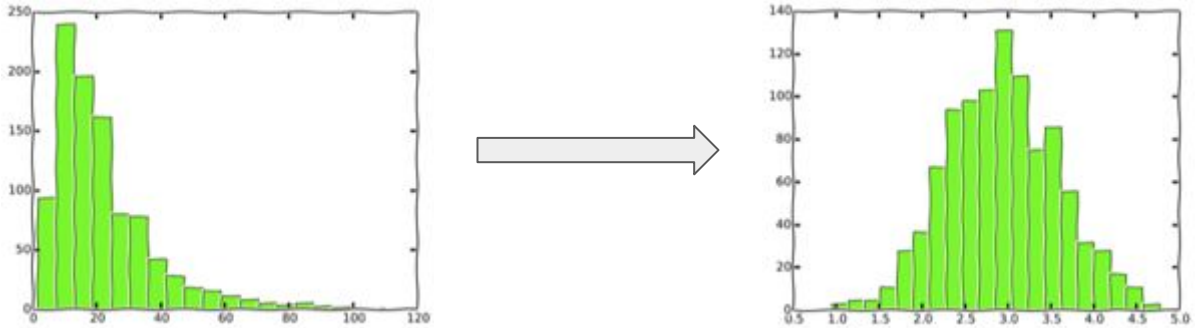
$$w^T x \longrightarrow w^T \phi(x)$$

The devil is in the features





The devil is in the features



The devil is in the features

id	...	ulubione zwierzę	...
1	...	wombat	...
2	...	jenot	...
3	...	pies	...
4	...	kot	...
...	...	...	...

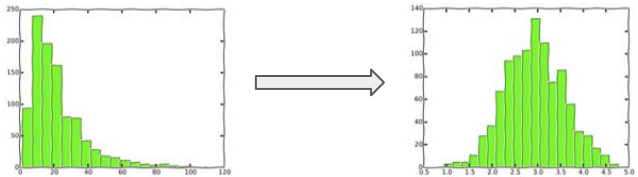
Feature engineering

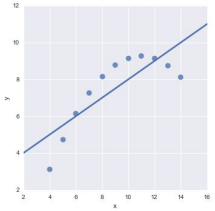
This is often the most tedious but the most rewarding (score-wise) part!

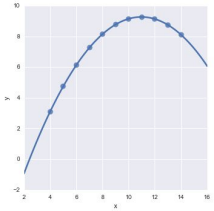
$$x \longrightarrow \phi(x)$$

$$w^T x \longrightarrow w^T \phi(x)$$

id	⋯	ulubione zwierzę	⋯
1	⋯	wombat	⋯
2	⋯	jenot	⋯
3	⋯	pies	⋯
4	⋯	kot	⋯
⋯	⋯	⋯	⋯







Recap

$$x_1, x_2, ..., x_n \in R^D \text{ (features)}$$
$$y_1, y_2, ..., y_n \in R \text{ (targets)}$$

Goal: find $w_0, w_1, ..., w_D \in R$ so that our prediction

$$h(x) = w^T x$$

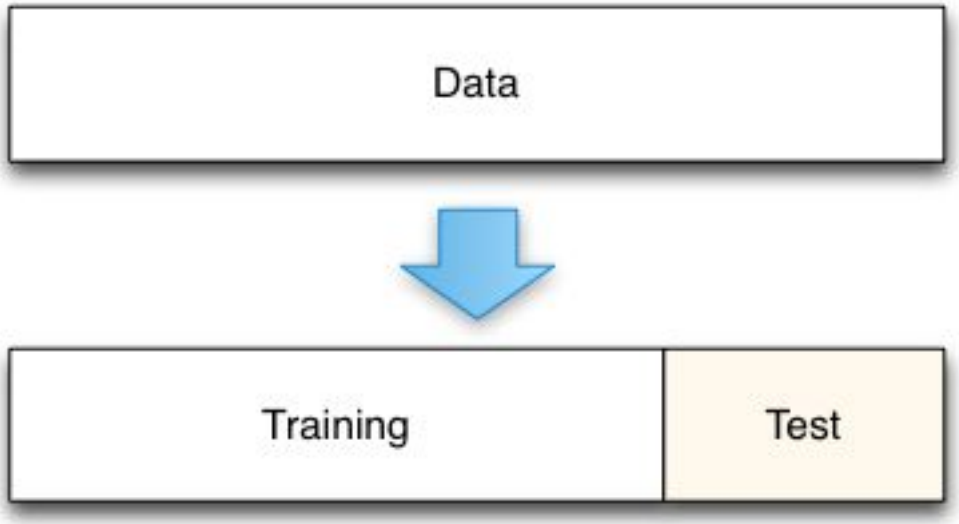
is good. For now, our proxy for goodness is the MSE loss function:

$$J(w) = \frac{1}{n} \sum_{i=1}^{n} (y_i - w^T x_i))^2.$$

Some questions...

- How do we choose the right algorithm?
- How do we choose the right hyperparameters?
- How do we anticipate the future performance?

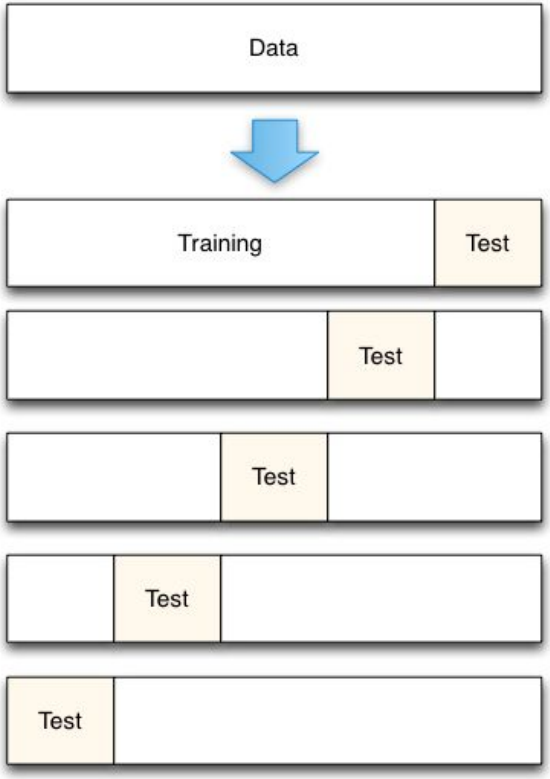
Train/Test split



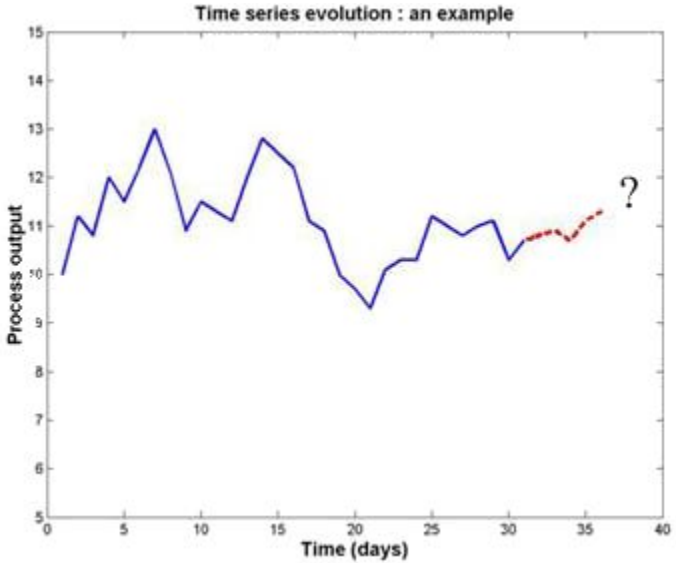
Train/Validation/Test split

Useful if you need to anticipate the score on top of optimizing the hyperparameters

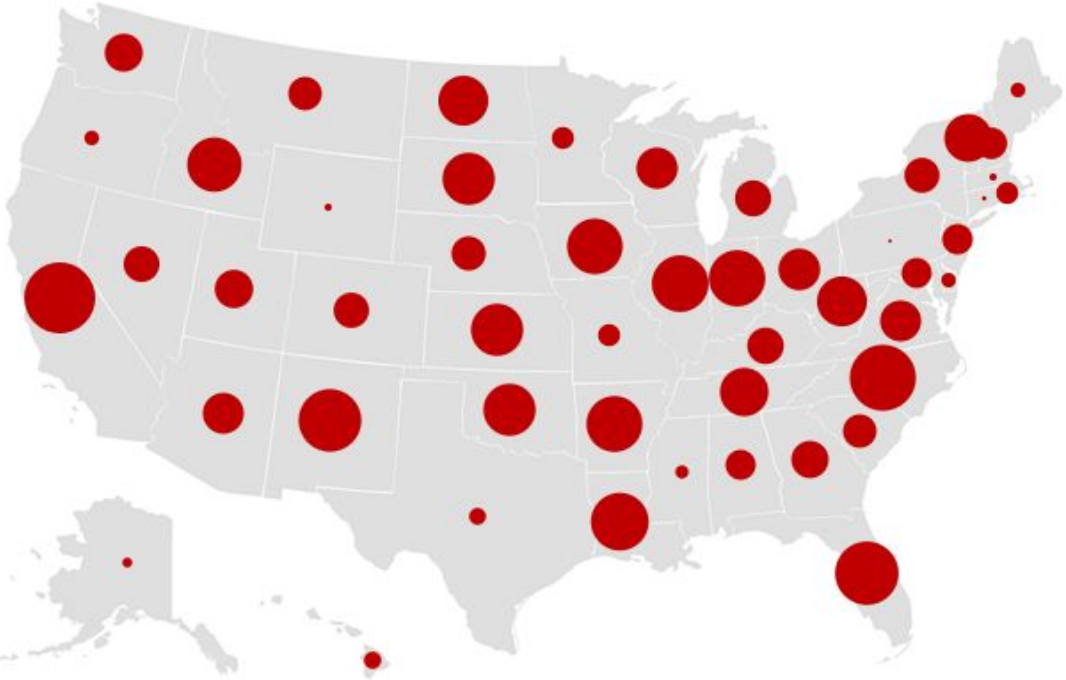
Cross validation



It’s a Trap! #1


Time series evolution : an example
Process output
Time (days)
?
15
14
13
12
11
10
9
8
7
6
5
0
5
10
15
20
25
30
35
40

It’s a Trap! #2



It’s a Trap! #3

<feature selection.ipynb>

Where to read more about it?

- Machine Learning A Probabilistic Perspective (1. Introduction) (recommended)
  http://www.cs.ubc.ca/~murphyk/MLbook/pml-intro-22may12.pdf
- An Introduction to Statistical Learning (2. Statistical Learning)
  http://www-bcf.usc.edu/~gareth/ISL/ISLR%20Fourth%20Printing.pdf
- Elements of Statistical Learning (2. Overview of Supervised Learning)
  http://statweb.stanford.edu/~tibs/ElemStatLearn/printings/ESLII_print10.pdf

Where to read more about it?

- Machine Learning A Probabilistic Perspective (7. Linear Regression) (math heavy + we'll cover regularization next week anyway)
- An Introduction to Statistical Learning (3. Linear Regression) http://www-bcf.usc.edu/~gareth/ISL/ISLR%20Fourth%20Printing.pdf
- 10 things I wish I knew… …about Machine Learning Competitions - http://people.inf.ethz.ch/jaggim/meetup/slides/ML-meetup-9-vonRohr-kaggle.pdf and http://blog.kaggle.com/2014/08/01/learning-from-the-best/ (I don't agree with everything, but might be a good start if you plan to compete on Kaggle)