Classical Data Analysis
Day 1

Master in Big Data & A.I. Solutions

BARCELONA TECHNOLOGY SCHOOL

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Happy 2022!!

Class schedule, organization & grades

- Class starts at 9:00
- After 10 minutes of the class beginning the student will have to wait until the break to access the class and it will be counted as half abscence.
- Two 15 minutes breaks from 10:30 to 10:45 and from 11:45 to 12:00 (approx.)
- Absence will be measured. 85% attendance is required to pass the course.

Class schedule, organization & grades

- Class will be divided in 2 parts (usually). One more theoretical where we will discuss a particular subject, review alternatives, see design patterns, etc. And another with a hands on approach where we will work in the subject.

- Expect the same number of hours of work on your own per hour spent in class.

- Assignments will be graded. Corrections will be done in class.

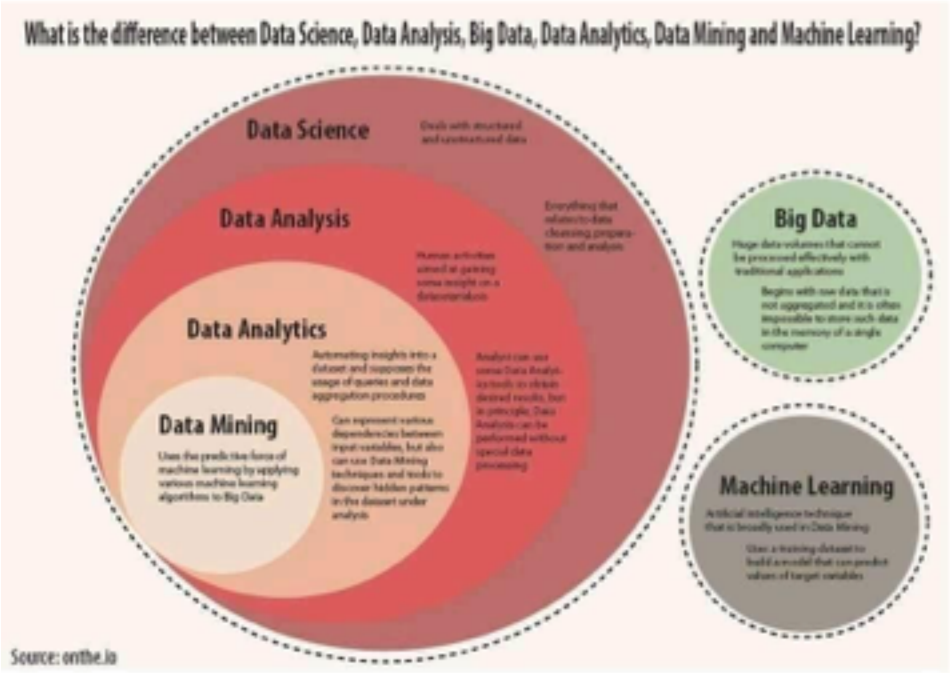
- Some assignments will include presentations in the class

Class schedule, organization & grades

- 20% Participation & presentations
- 60% Assignments & Tests
- 20% Final project

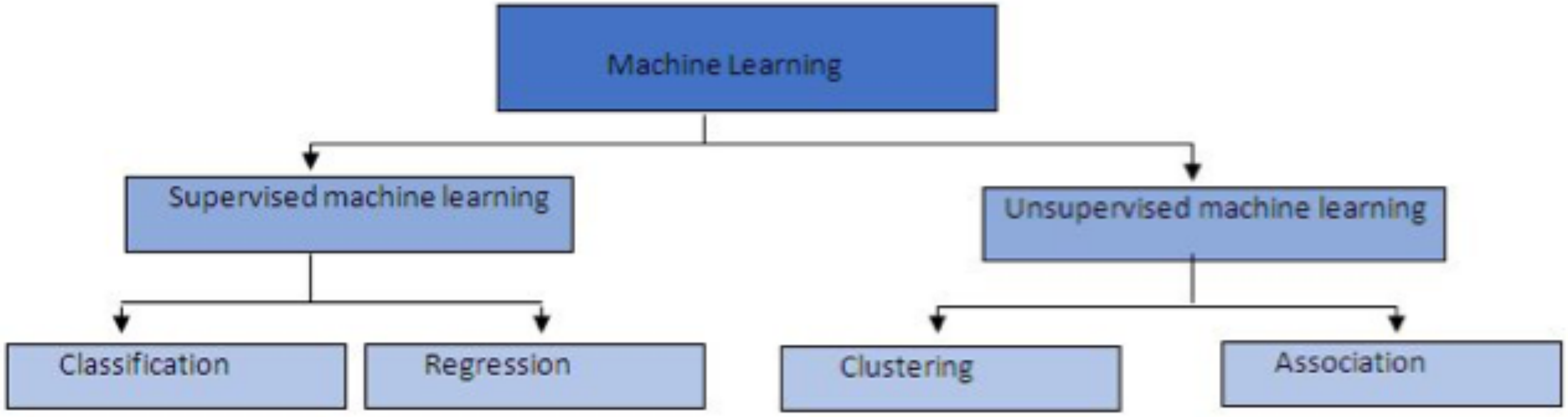
A definition for Data Analysis

”Extracting, cleaning, transforming, modeling and visualization of data with an intention to uncover meaningful and useful information that can help in deriving conclusion and take decisions.”



Data Analysis is characterized by a wide use of Data Mining algorithms

What we will learn in CDA



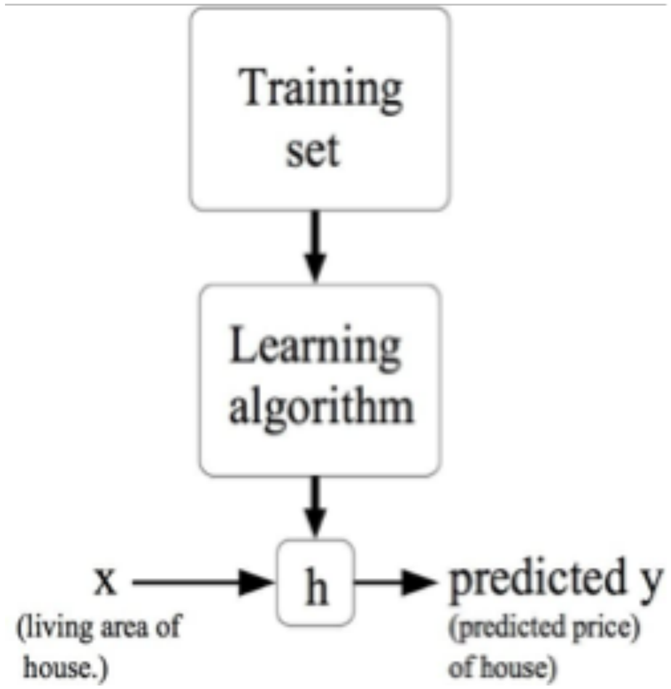
What we will learn in CDA

- Introduction to data analysis
- Linear Regression
- Logistic Regression
- Regression analysis (Polynomial, Ridge, Lasso, etc.)
- Neural Networks (MLPs in depth)
- Support Vector Machines (SVM)
- Decision Trees
- Ensemble Methods (Random Forests, Bagging, etc.)
- Other Classifier (KNN, Naïve Bayes)
- K-Means
- PCA
- Hierarchical Clustering

Supervised learning algorithms

Formal Definition: given a training set, to learn a function h : X → Y (h is also called hypothesis function) so that h(x) is a “good” predictor for the corresponding value of y, where:

- X denote the space of input values
- Y the space of output values.



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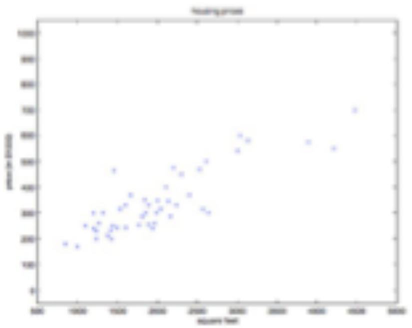
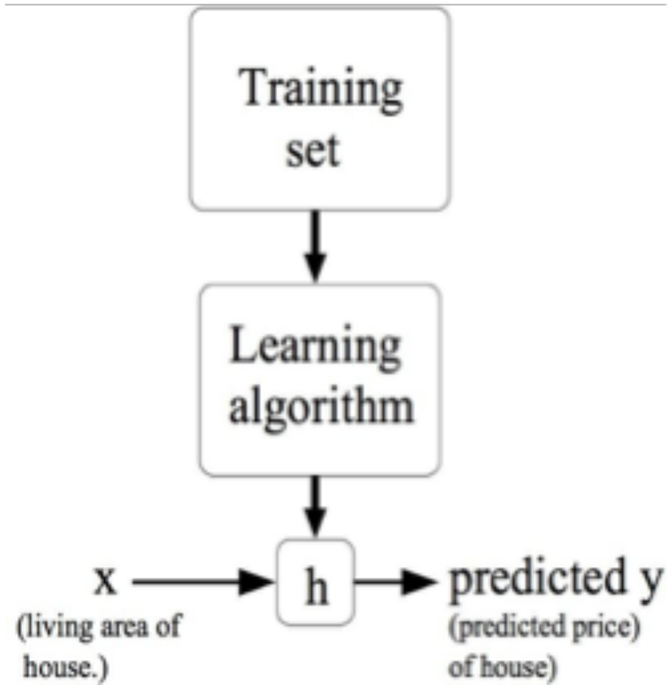
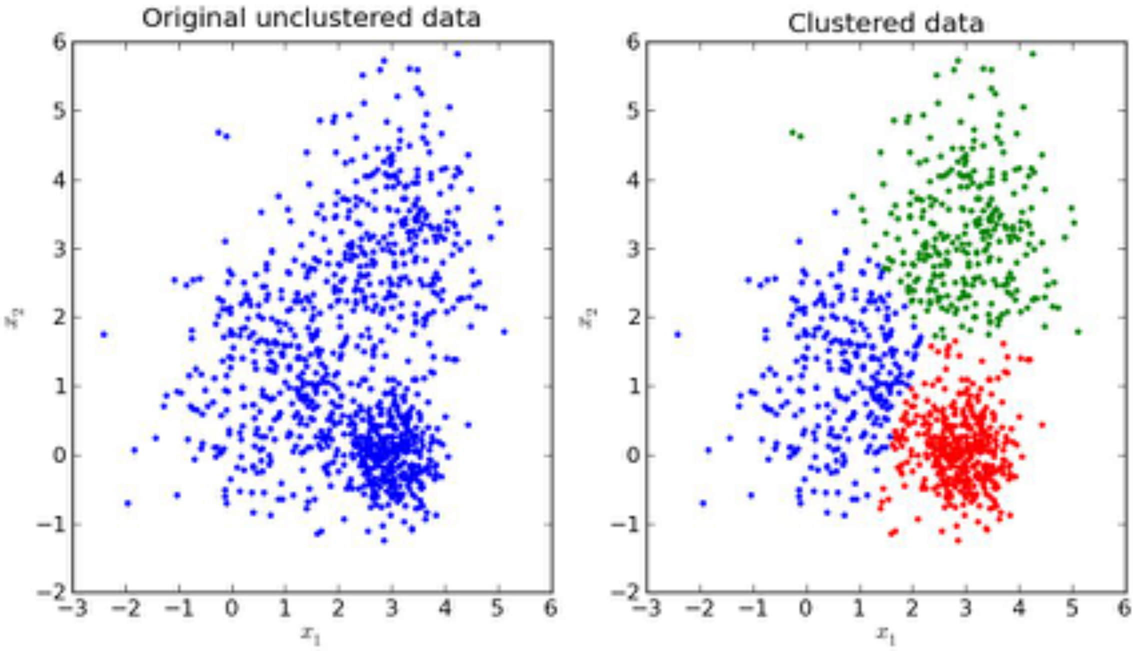
Living area (feet^2)	Price (1000\$s)
2104	400
1600	330
2400	369
1416	232
3000	540
⋮	⋮



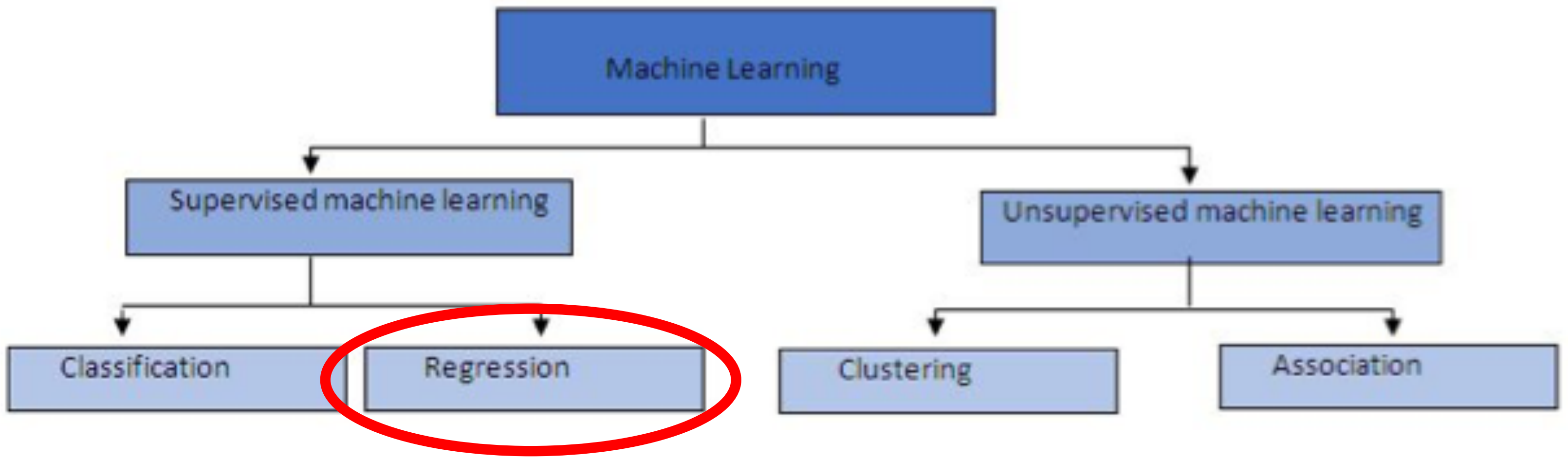


Unsupervised learning algorithms

Example (Clustering): Take a collection of 1 Milion different travelers and find a way to automatically group these travelers in clusters that are somehow similar based on different aspects, such as trip distances, durations, purpose, etc.



Supervised learning: Regression



Supervised learning: Regression

Regression: Predict continuous valued output

Examples:

- Predict stock market index based on other indicator
- Predict the total amount of sales of a company based on the total budget spent for advertising
- Predict the price of a house based based on its characteristic

- Other examples?

Supervised learning: Regression

Given a dataset

x_1	x_2	y
Living area (feet^2)	#bedrooms	Price (1000$s)
2104	3	400
1600	3	330
2400	3	369
1416	2	232
3000	4	540
⋮	⋮	⋮

- x1 and x2 are the explanatory variables (aka independent variables). They can be either discrete or continuous.
- y is the target (aka dependent variable). It must be continuous.

Linear Regression performs the task to predict a dependent variable value (y) based on a given independent variable (x).So it finds out a linear relationship between x(input) and y(output).

- The goal is to find the function that best fits the data minimizing the error.
- The error in a regression task is the difference between the prediction of the regression model h(X) and the actual target value y. It can be expressed as:

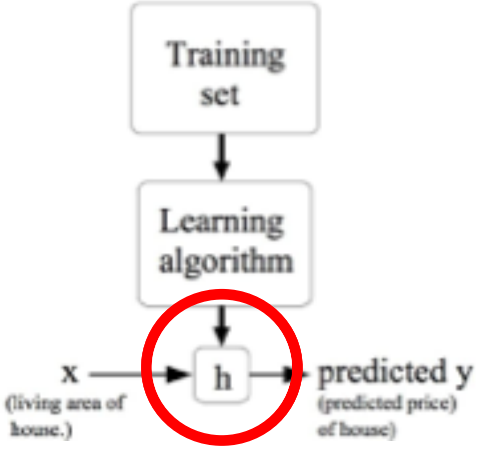
Absolute error: $\sum_i |y_i - h_\theta(x_i)|$

Squared error: $\sum_i (y_i - h_\theta(x_i))^2$

Supervised learning: Regression

Training Set

Size in feet² (x)	Price ($) in 1000's (y)
2104	460
1416	232
1534	315
852	178
...	...



We assume a linear model $h_\vartheta(x) = \vartheta_0 + \vartheta_1 x$

Given some estimates of the coefficients θ0 and θ1 we predict future observations using:

$$h_\vartheta(x) = \hat{y} = \hat{\vartheta}_0 + \hat{\vartheta}_1 x$$

we want to come up with values for the parameters ϑ0 and ϑ1 so that hϑ(x) (the prediction) is close to y (the actual value) for our training set (X,Y).

Supervised learning: Regression

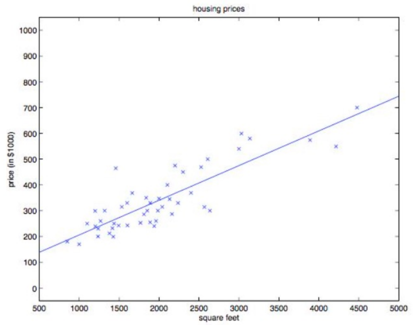
Univariate VS Multivariate Linear regression

Univariate (Simple LR)

Size in feet² (x)	Price ($) in 1000's (y)
2104	460
1416	232
1534	315
852	178
…	…

Hypothesis:

$$h_\theta(x) = \theta_0 + \theta_1 x$$

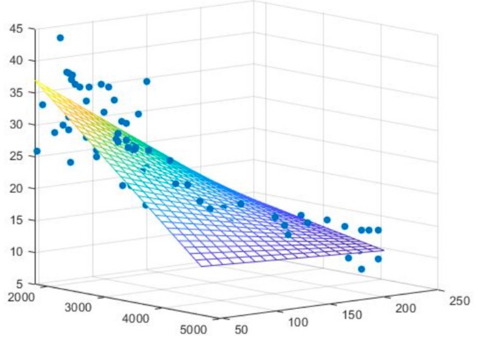


Multivariate

Living area (feet^2)	#bedrooms	Price (1000$s)
2104	3	400
1600	3	330
2400	3	369
1416	2	232
3000	4	540
⋮	⋮	⋮

Hypothesis:

$$h_\theta(x) = \theta_0 + \theta_1 x_1 + \theta_2 x_2$$



Supervised learning: Regression

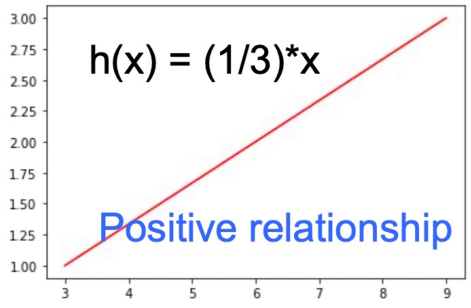
Univariate (simple) Linear regression

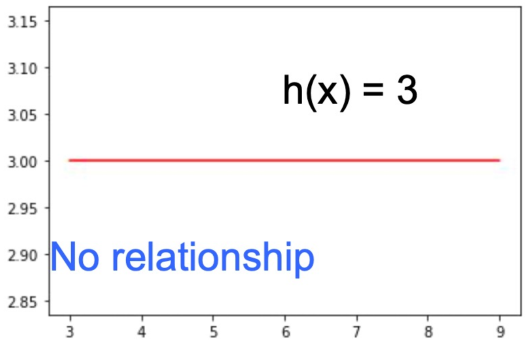
Hypothesis:

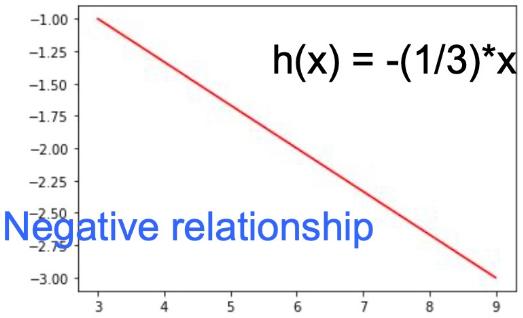
$$h_\theta(x) = \theta_0 + \theta_1 x$$

- θ_0: is the intercept of the line. It is the expected value of y when x=0
- θ_1: is the slope of the line. A value very close to 0 indicates little to no relationship; large positive or negative values indicate large positive or negative relationships, respectively.

Examples







Supervised learning: Regression

Linear regression Interpretation

The coefficient value signifies how much the mean of the dependent variable changes given a one-unit shift in the independent variable while holding other variables in the model constant.

Examples

$h(x) = -3 + 2x$

$h(4) = 5$

If we change x of 1 unit, which will be the value of y? $h(5) = ?$

$h(5) = -3 + 2*5 = 7$

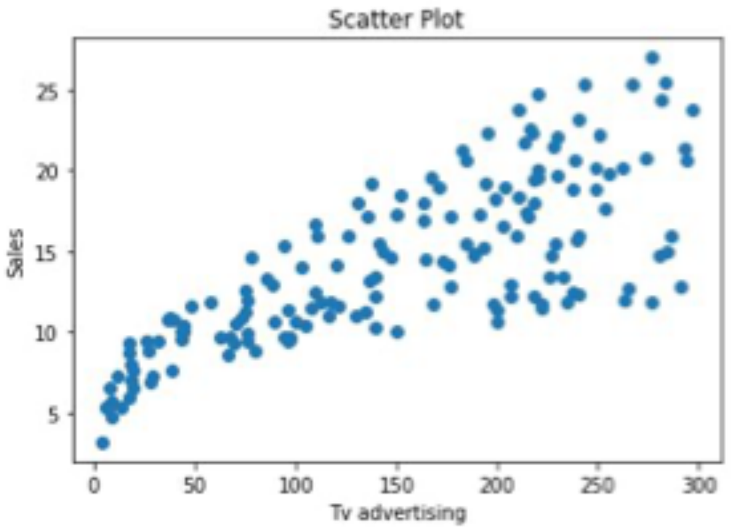
Changing 1 unit in x we obtained a change of 2 (the slope) units in the dependent variable

Supervised learning: Regression

Assumptions Of Linear Regression Algorithm

Hypothesis:

1. Linear Relationship between the features (x) and target (y)



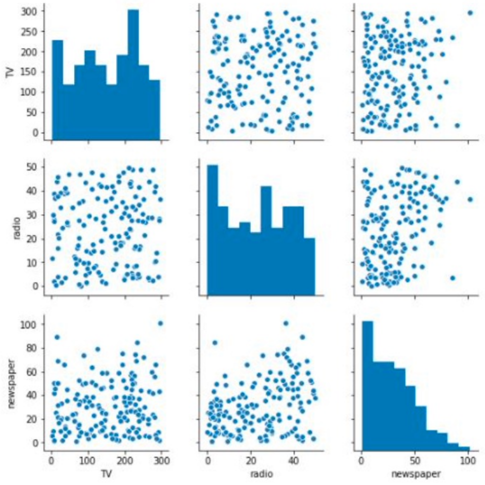
It can be validated by plotting a scatter plot between the features and the target.

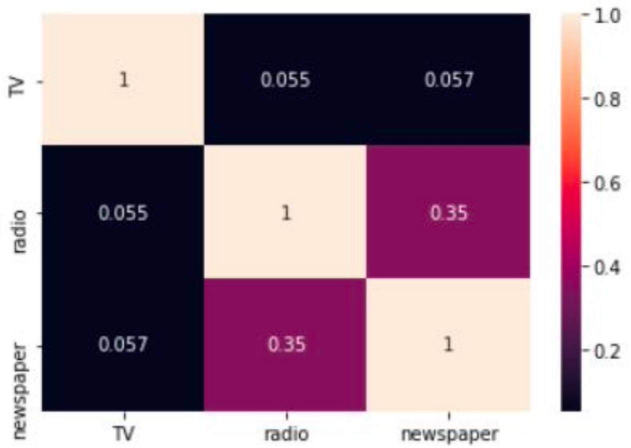
Supervised learning: Regression

Assumptions Of Linear Regression Algorithm

Hypothesis:

2. Little or no Multicollinearity between the features, i.e., very high inter-correlations or inter-associations among the independent variables





Pair plots and heatmaps(correlation matrix) can be used for identifying highly correlated features.

Supervised learning: Regression

Evaluation Metrics

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \hat{y}_j)^2}$$

RMSE (Root Mean Square Error) – Particularly used because it is differentiable

$$\text{MAE} = \frac{1}{n}\sum_{j=1}^{n}|y_j - \hat{y}_j|$$

MAE (Mean Absolute Error) - is a linear score

$$\hat{R}^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} = 1 - \frac{\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

R Squared - The maximum is 1 but minimum can be negative infinity (even if it is unlikely scenario, usually the minimum is 0)

$$R^2_{adj} = 1 - \left[\frac{(1 - R^2)(n - 1)}{n - k - 1}\right]$$

Adjusted R Squared

https://medium.com/usf-msds/choosing-the-right-metric-for-machine-learning-models-part-1-a99d7d7414e4

Supervised learning: Regression

Learning the parameters of the model

Training Set

Size in feet² (x)	Price ($) in 1000's (y)
2104	460
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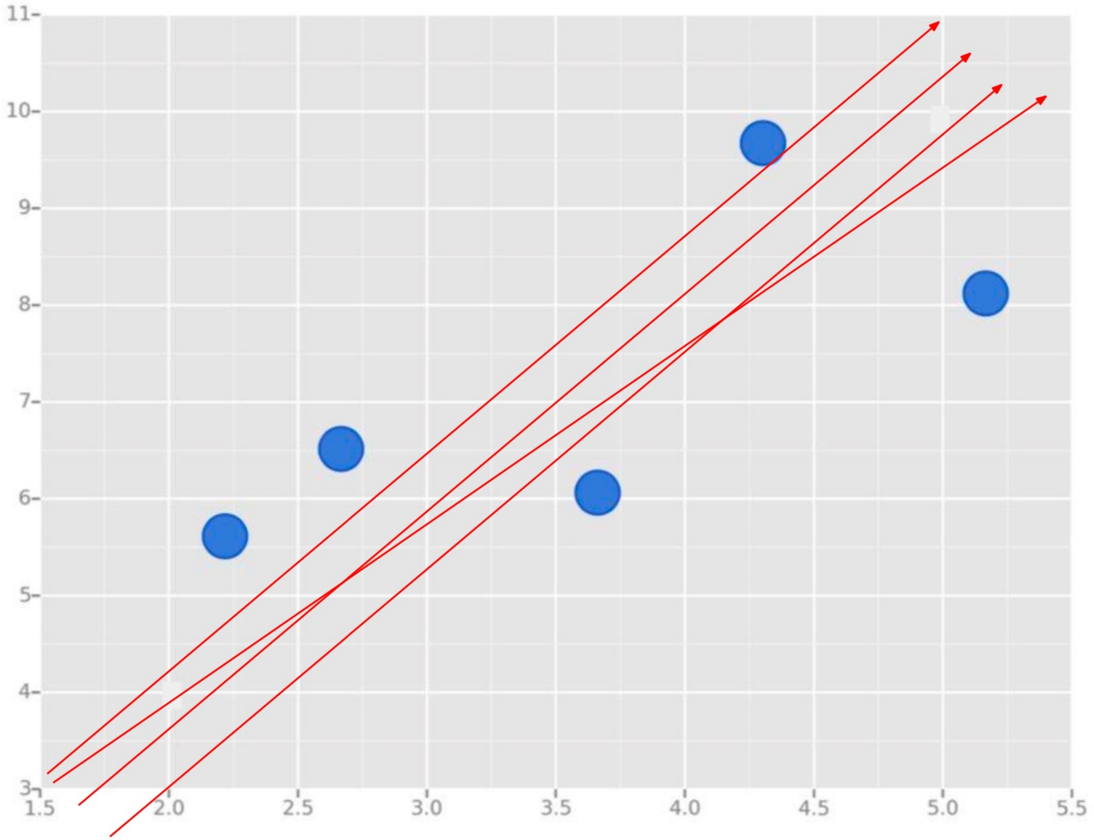
...	...

How to choose $\theta 0$ and $\theta 1$ to minimize the distance between actual values (Y) and predictions(h(x))?

- **Ordinary least squares**
- **Gradient Descent**

Supervised learning: Regression

Ordinary least squares

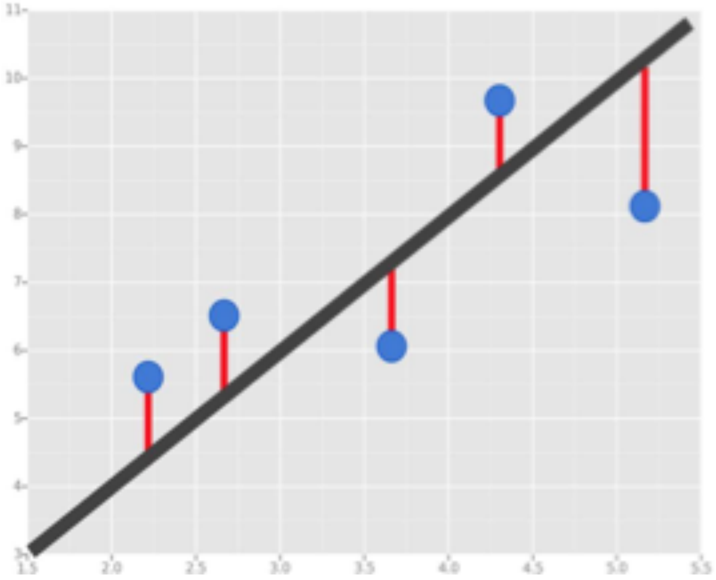


Supervised learning: Regression

Ordinary least squares

we want to come up with values for the parameters θ_0 and θ_1 so that $h_\theta(x)$ (the predicion) is close to y (the actual value) for our training set (X,Y).

Linear Model: $h(x) = \theta_0 + \theta_1 x$



The least squares approach chooses θ0 and θ1 to minimize the RSS (residual sum of squares).

$$\theta_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$\theta_0 = \bar{y} - \hat{\beta}_1 \bar{x},$$

Supervised learning: Regression

Gradient Descent

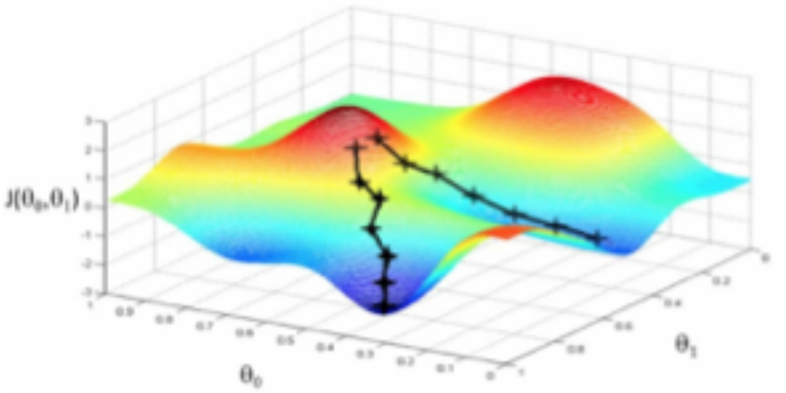
The gradient descent algorithm is: $\theta_j := \theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\theta_0, \theta_1)$

j=0,1 represents the feature index number.

At each iteration, one should simultaneously update the parameters θ1,θ2,....

Model: $h_\theta(x) = \theta_0 + \theta_1 x_1 + \theta_2 x_2$

Cost function: $J(\theta) = \frac{1}{2} \sum_{i=1}^{m} (h_\theta(x^{(i)}) - y^{(i)})^2.$



Thank you!

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