Data Science

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Classes and Meeting Hours

Schedule	
	Tuesdays and Thursdays
Classes	11:30 to 13:00
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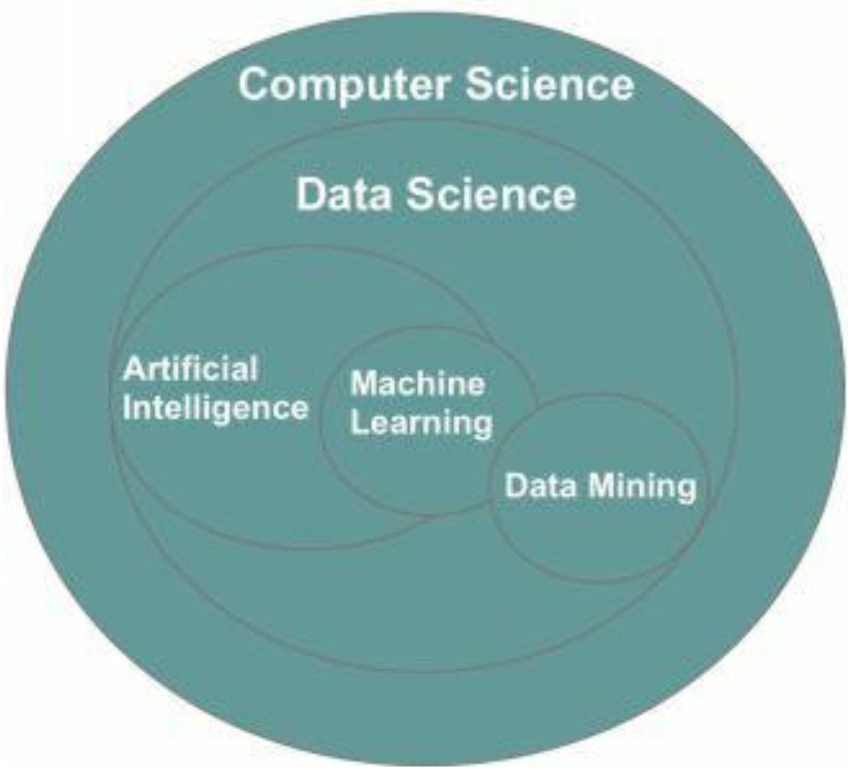
What is Data Science?

- Data science is a subdomain of computer science that expertise to uncover actionable insights hidden in (an organization’s) data. These insights can be used to guide decision making and strategic planning.

- Data science uses the tools of artificial intelligence, machine learning and data mining.



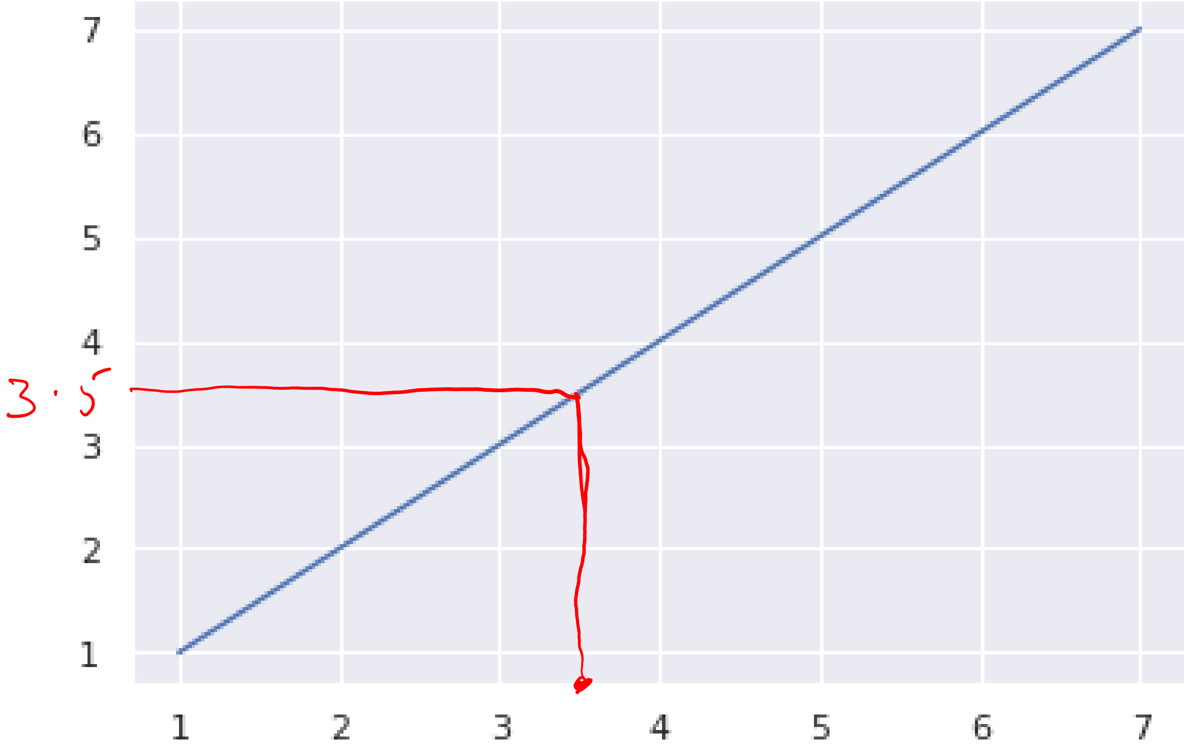
Exploratory Data Analysis

- `x = [1, 2, 3, 4, 5, 6, 7]`
- `y = [1, 2, 3, 4, 5, 6, 7]`

Exploratory Data Analysis

- **x** = [1, 2, 3, 4, 5, 6, 7]
- **y** = [1, 2, 3, 4, 5, 6, 7]

$x = 3.5$



Exploratory Data Analysis

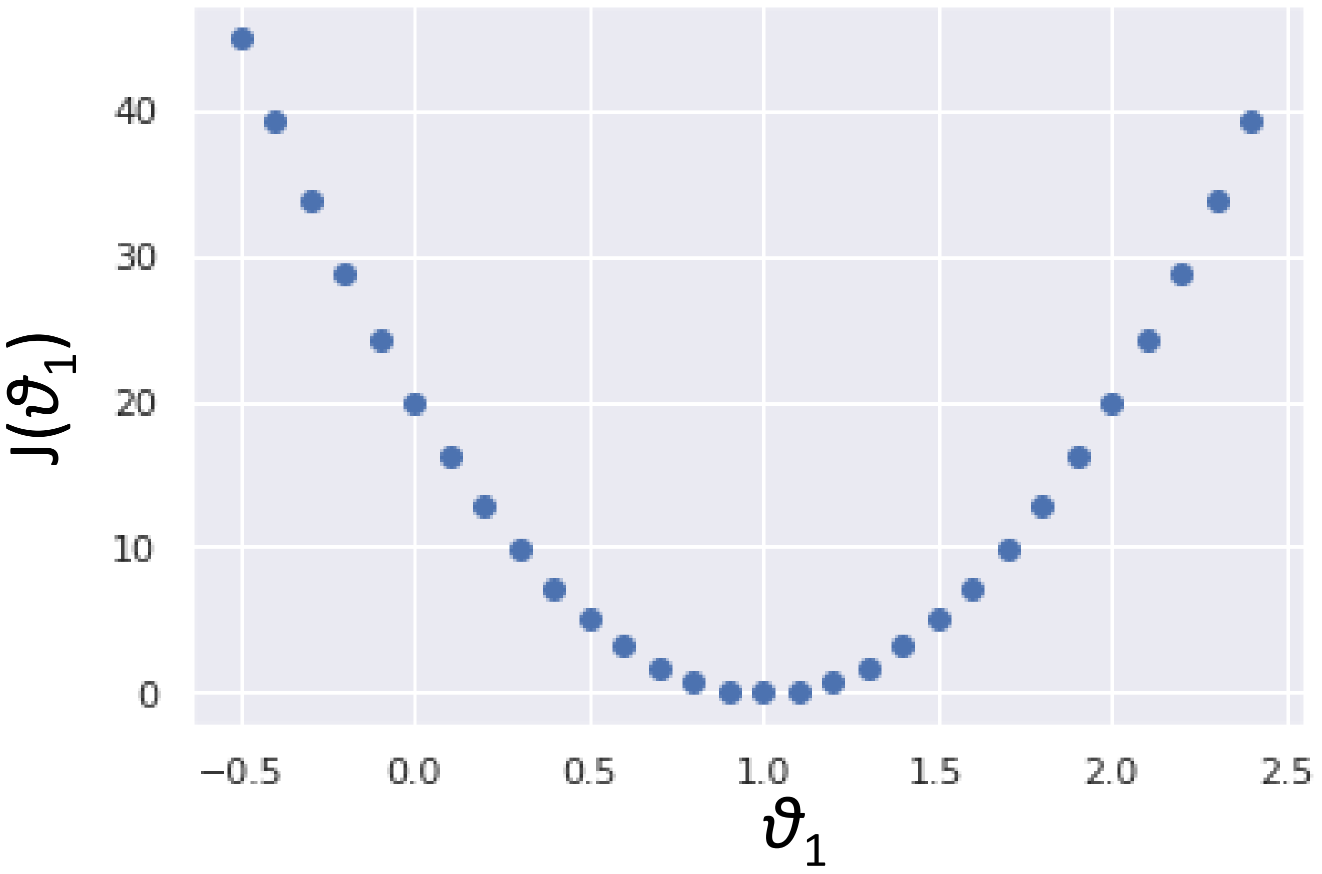
- **x** = [1, 2, 3, 4, 5, 6, 7]
- **y** = ~~[2, 4, 6, 8, 10, 12, 14]~~

y = [3, 5, 7, 9, 11, 13, 15]

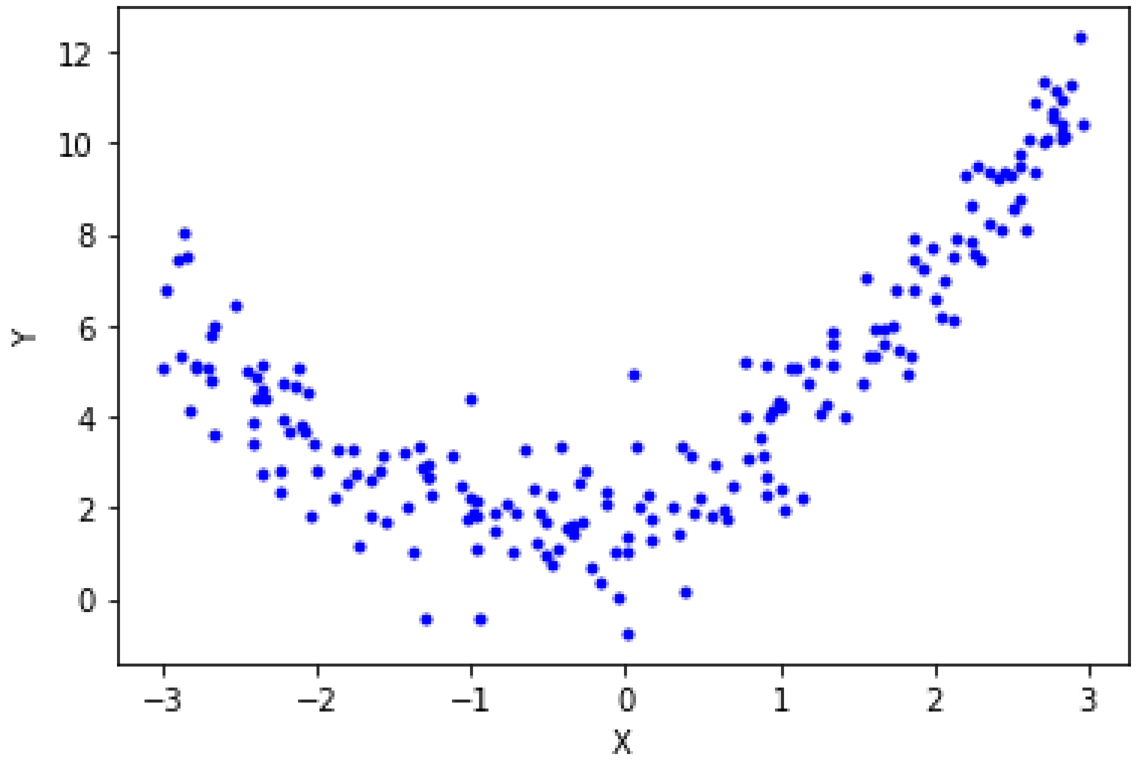
$$y = 2x + 1$$

Exploratory Data Analysis

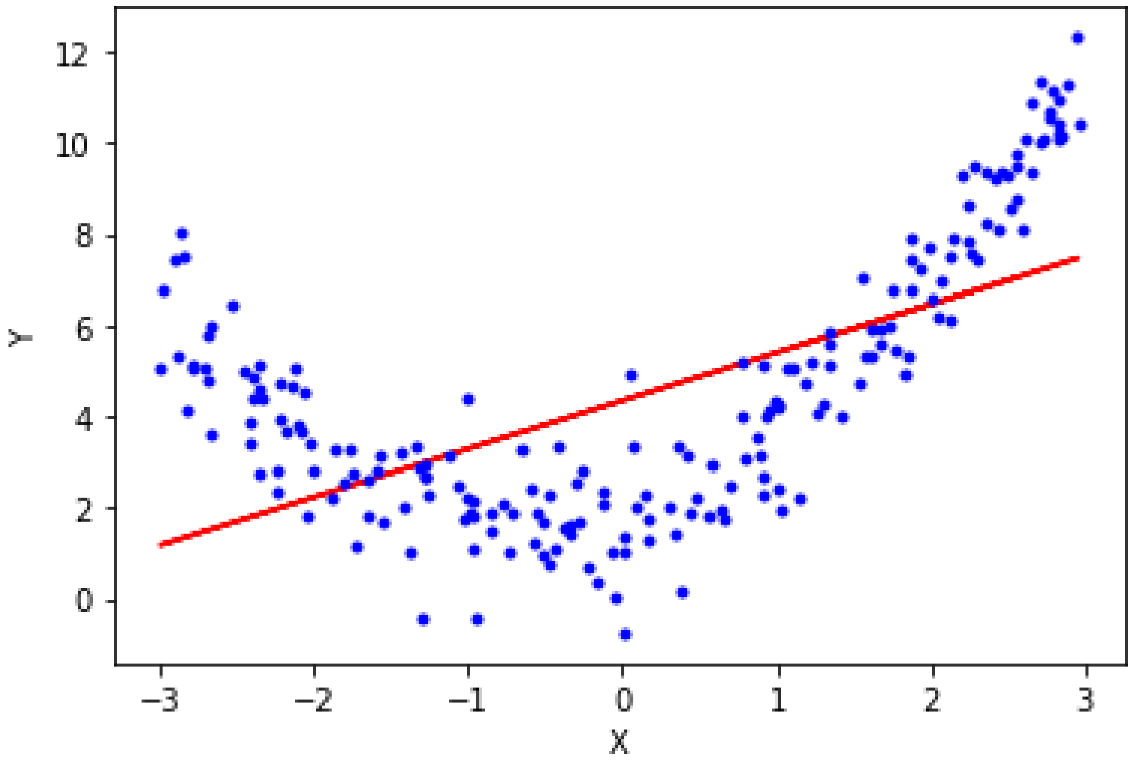
- θ_1 = [-0.5, -0.25, 0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25]
- $J(\theta_1)$ =[45.0, 31.25, 20.0, 11.25, 5.0, 1.25, 0.0, 1.25, 5.0, 11.25, 20.0, 31.25]



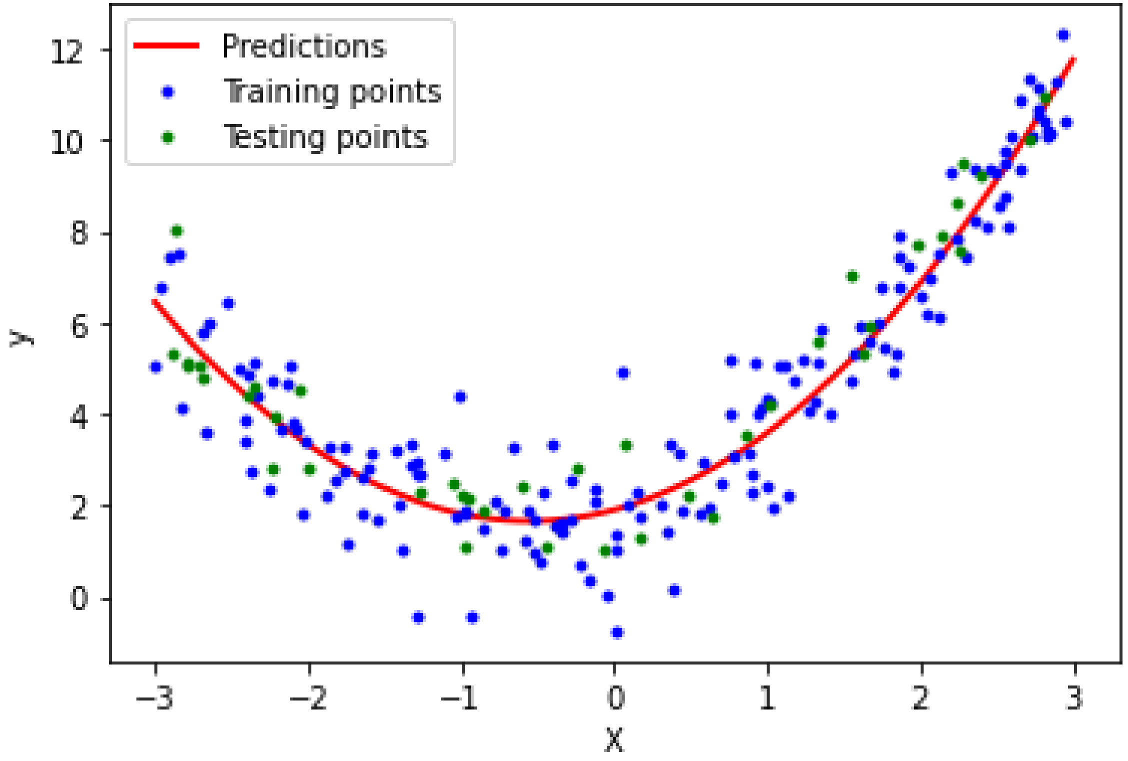
Exploratory Data Analysis



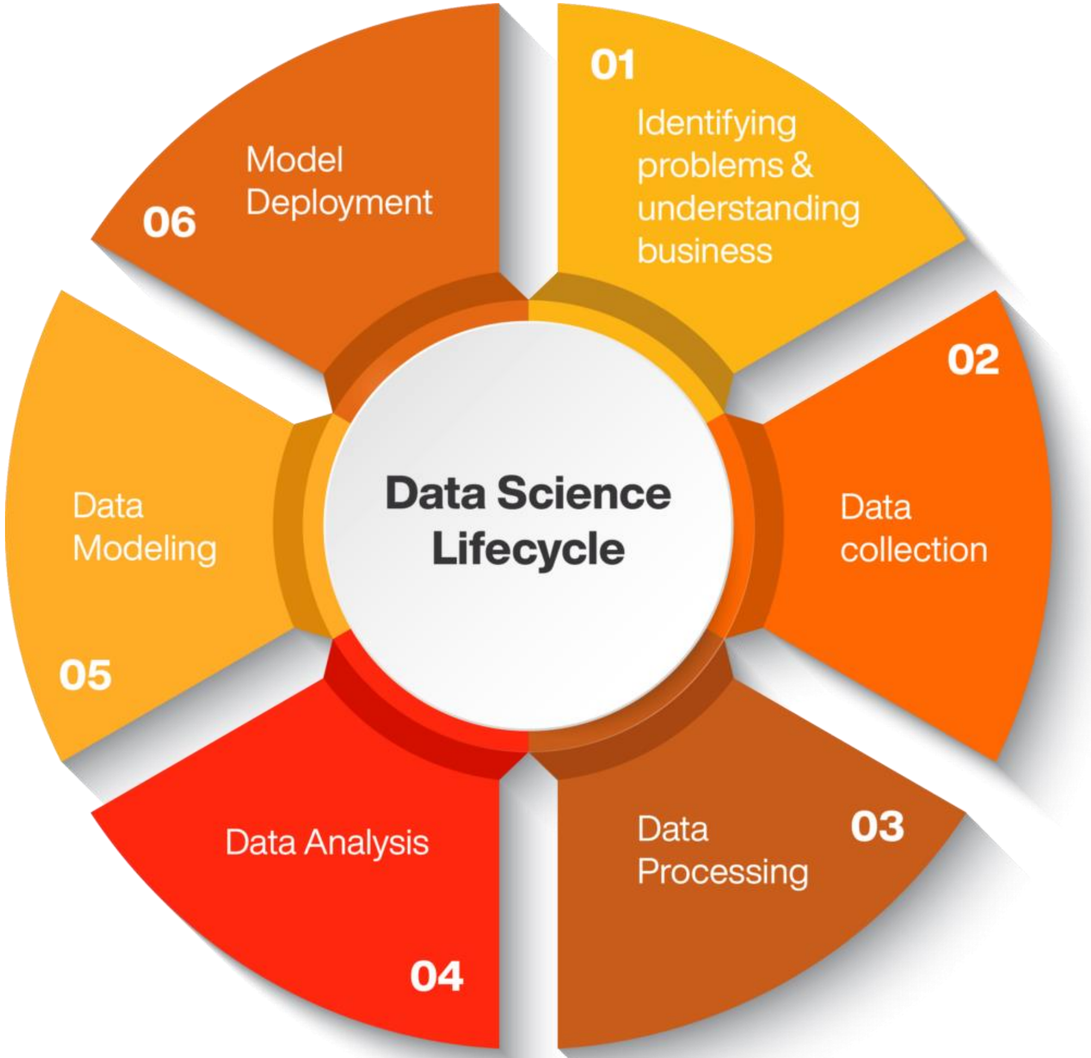
Exploratory Data Analysis



Exploratory Data Analysis



Data Science Life Cycle



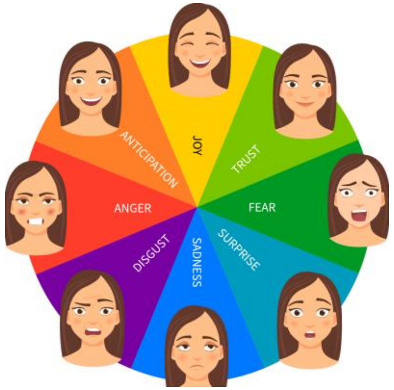
Data Science Life Cycle

- **Identifying problems and understanding business:** Discovering the answers for basic questions including requirements, priorities and budget of the project.
- **Data Collection:** Collecting data from relevant sources either in structured or unstructured form.
- **Data processing:** Processing and fine-tuning the raw data, critical for the goodness of the overall project.
- **Data analysis:** Capturing ideas about solutions and factors that influence the data life cycle.
- **Data modelling:** Preparing the appropriate model to achieve desired performance.
- **Model deployment:** Executing the analysed model in desired format and channel.

Applications/Use cases of Data Science

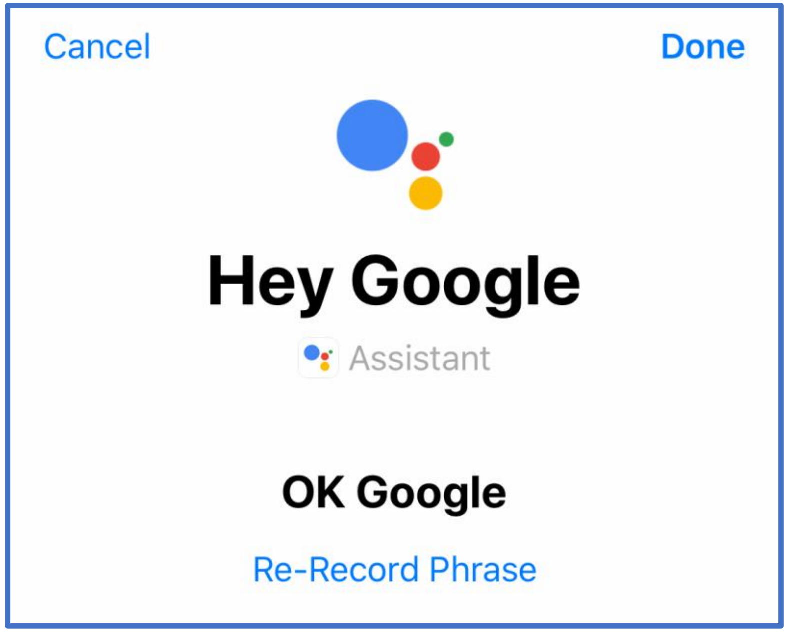
- Fraud and Risk Detection: An international bank delivers faster loan services with a mobile app using machine learning-powered credit risk models.
- Health Care: An activity recognition system may detect the level of independent living of an elderly person.
- Internet Search: All search engines (like Google, Yahoo, Bing, Ask, AOL, and so on) make use of data science algorithms to deliver the best result for our searched query in a fraction of seconds.
- Targeted Advertising, and many others…

Applications



Applications

- Virtual Personal Assistant



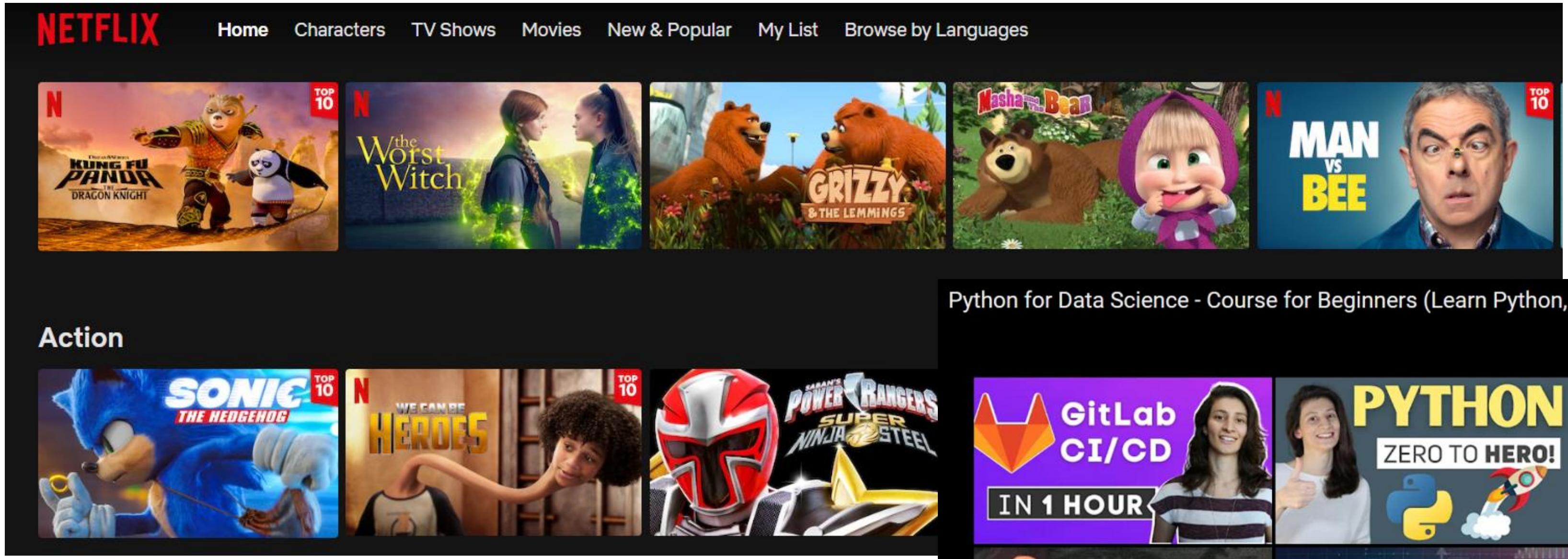
SILVIA
Intelligence On Command

amazon alexa

Bixby

Applications

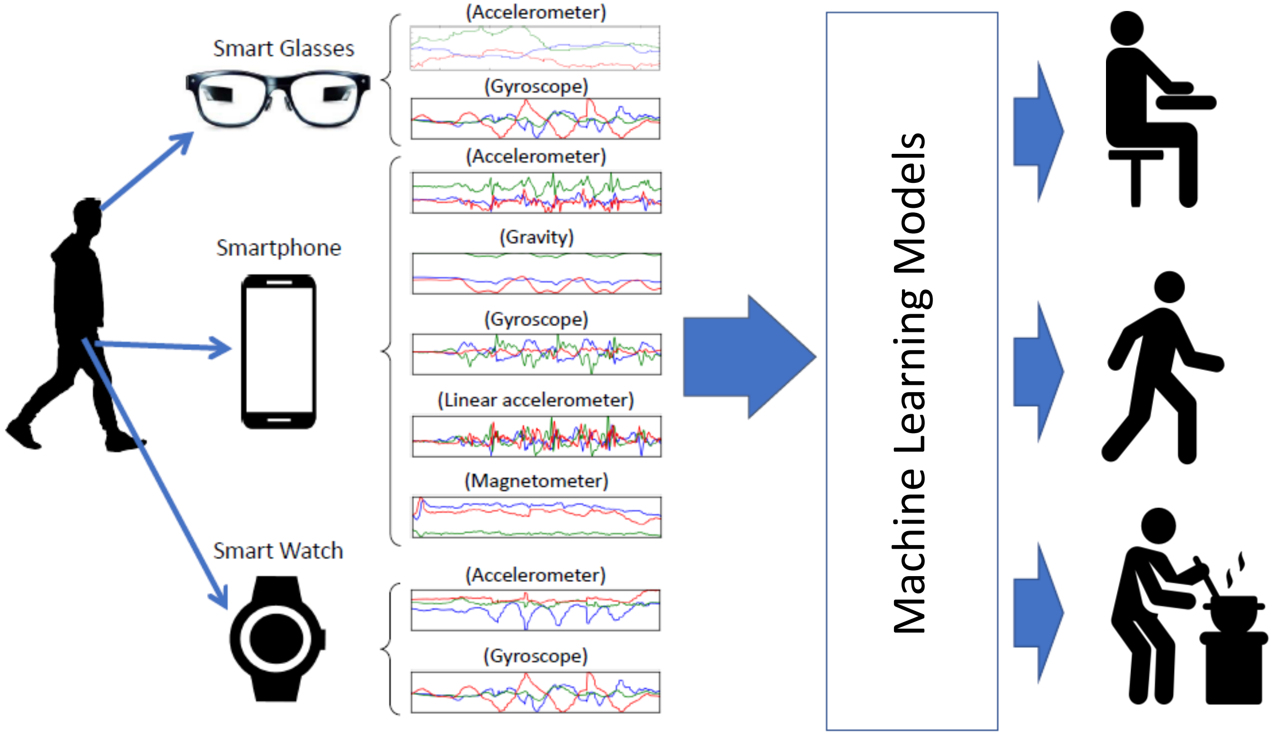
- Recommendation System



Applications

Activity Recognition / Sensors Data Understanding

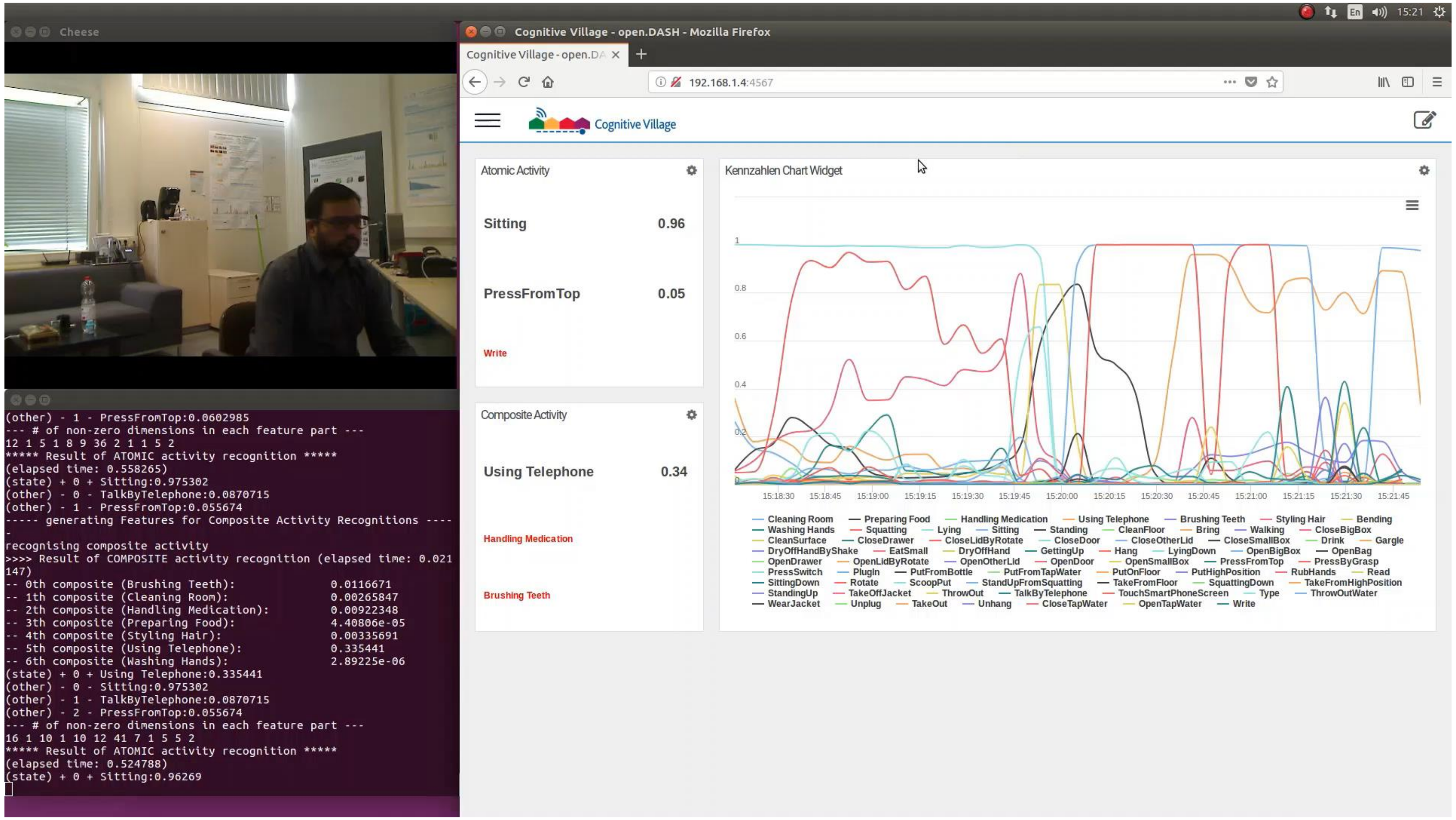
- Inertial Sensors



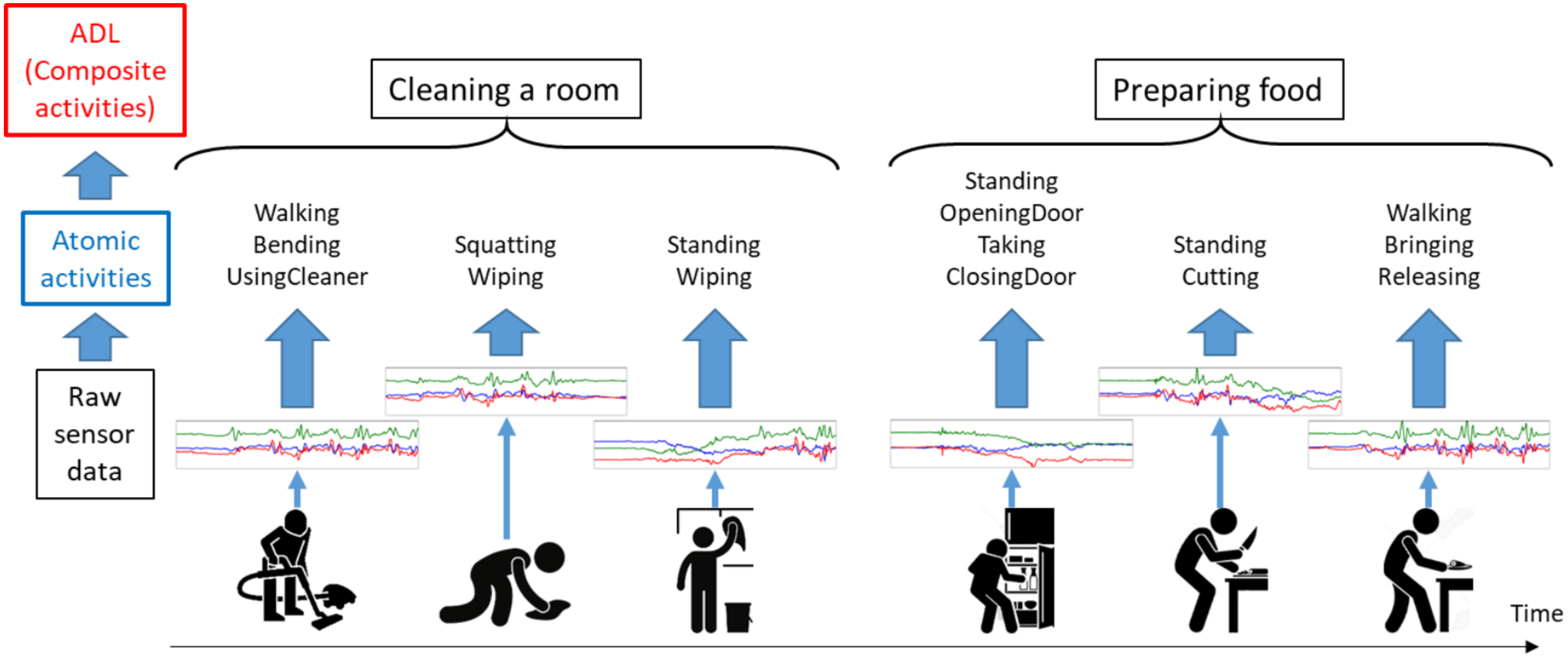
Applications

Recognition of Daily Activities

https://youtu.be/s5wZP4ArZtU



Application

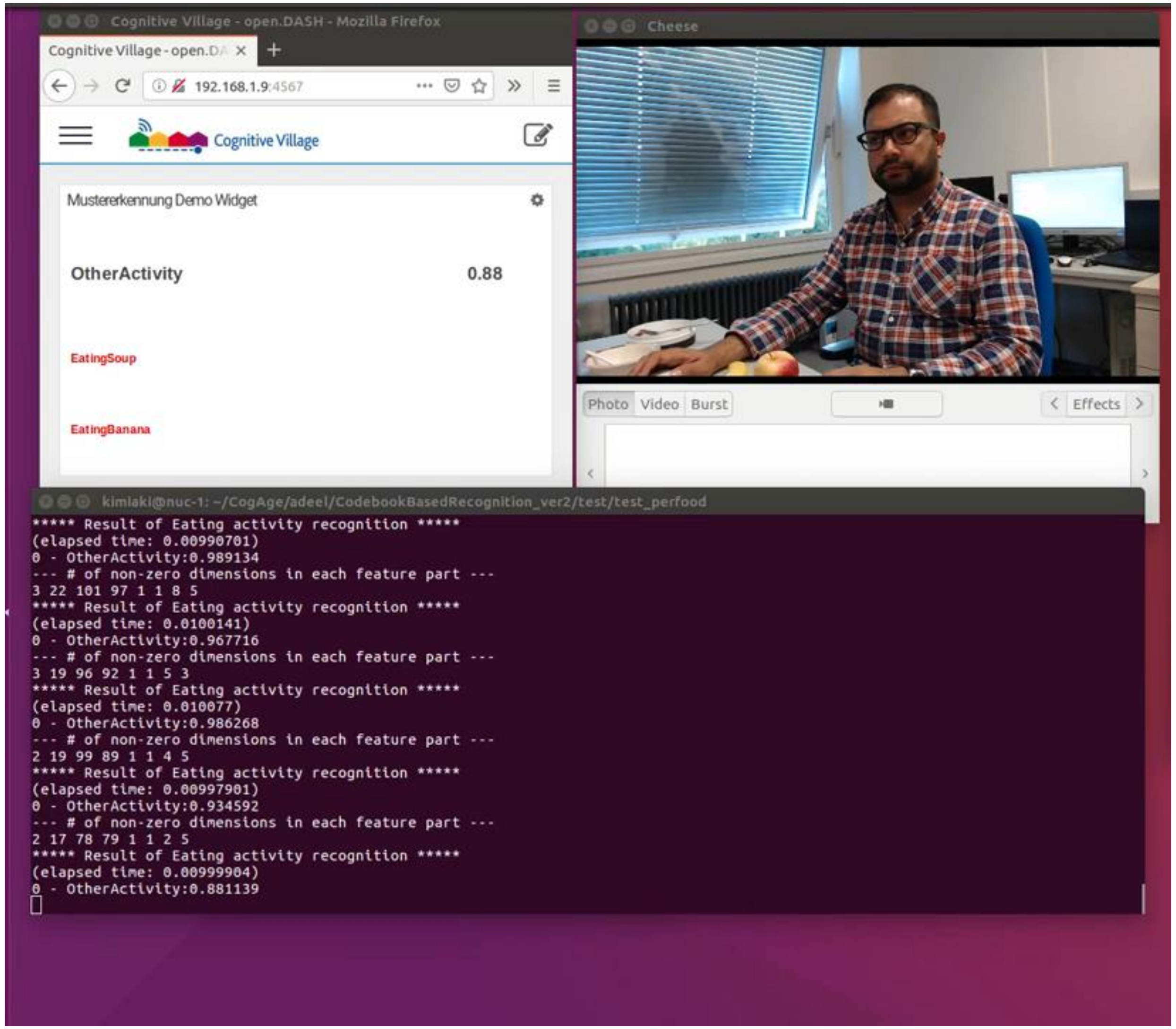


Recognition of Daily Activities

Applications

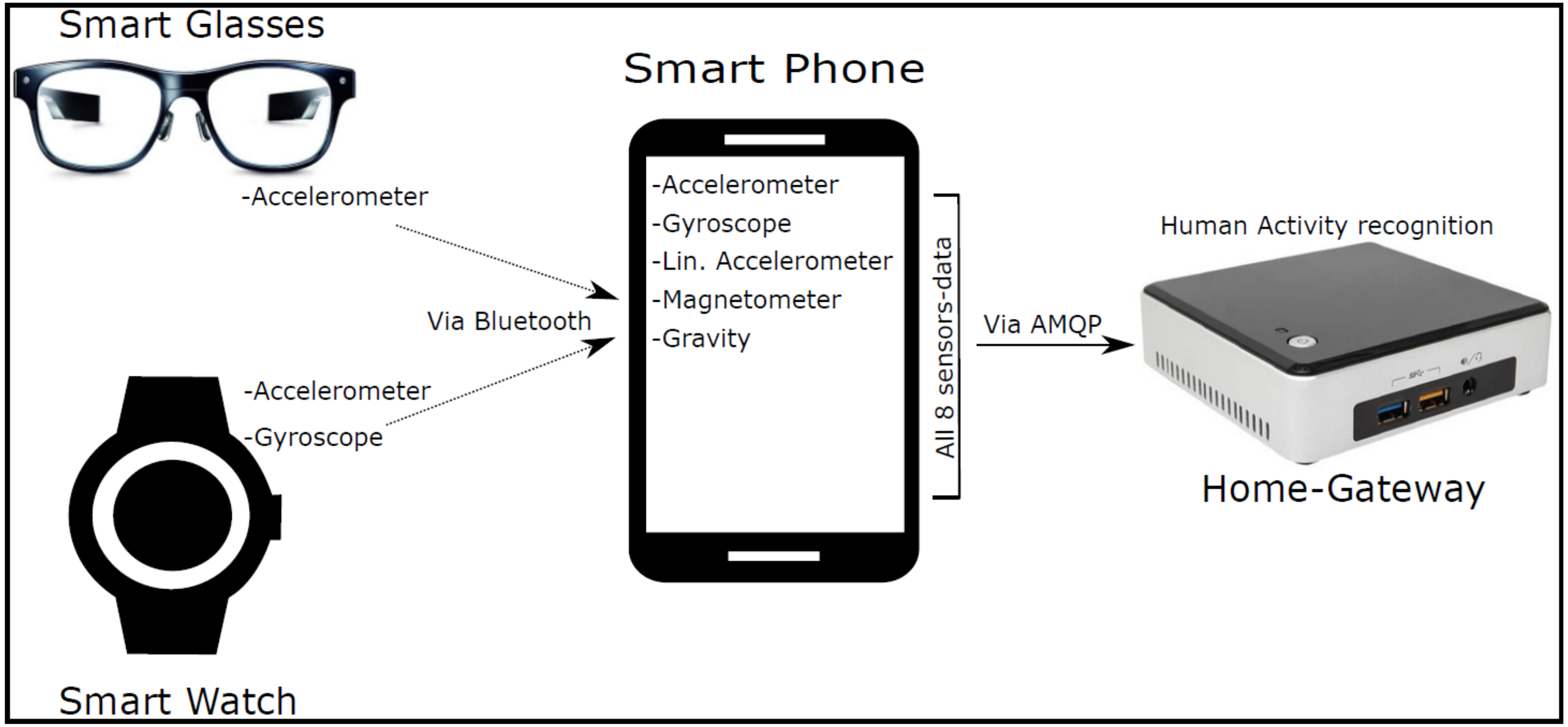
Recognition of Eating Activities

https://youtu.be/J4QLzRRmCY8



Current Final Year Projects

1. Sensor Data Acquisition System



2. Eating Activities Detection

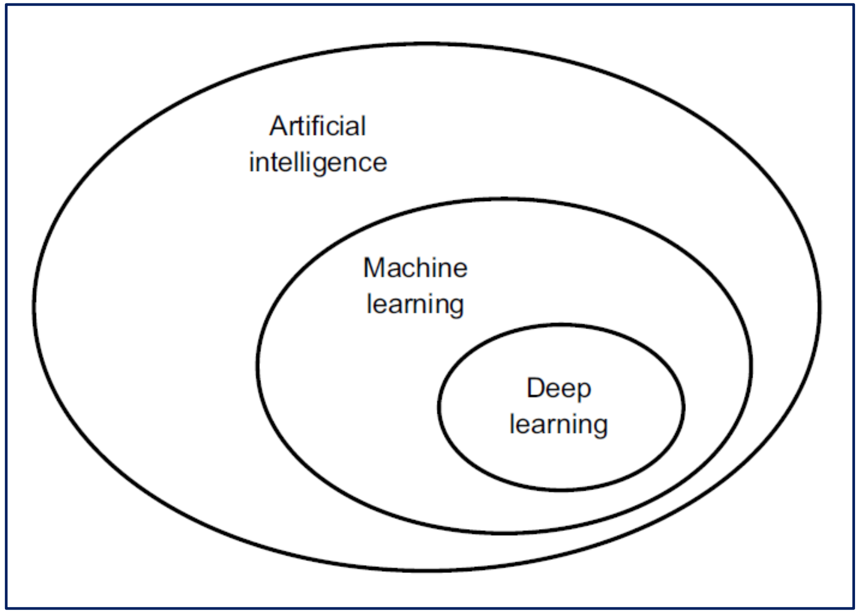
A Proposal for Final Year Project

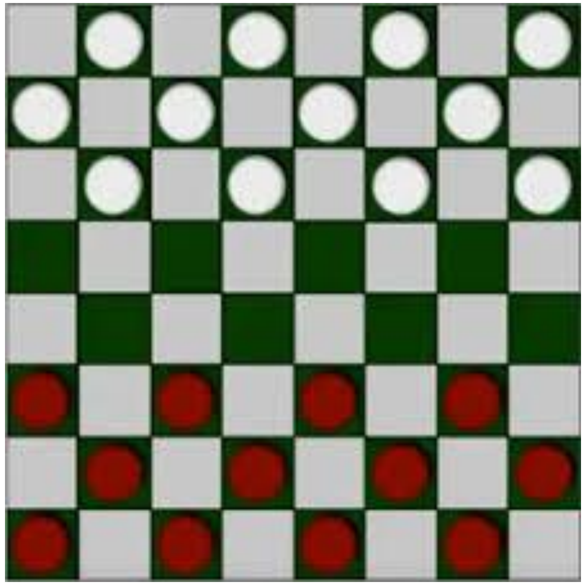
3. Detecting Genotype of Parkinson Patients

- Predicting Genotype based on Phenotype of Parkinson patients using Machine Learning
- Implementation and Comparison of Tabular Data Augmentation Techniques

What is Machine Learning?

- Machine learning (ML) is a branch of Artificial Intelligence (AI).
- Arthur Samuel (1959) defined ML as "Field of study that gives computers the ability to learn without being explicitly programmed"
  - Samuels wrote a checkers playing program
    - Had the program play 10000 games against itself
    - Work out which board positions were good and bad depending on wins/losses



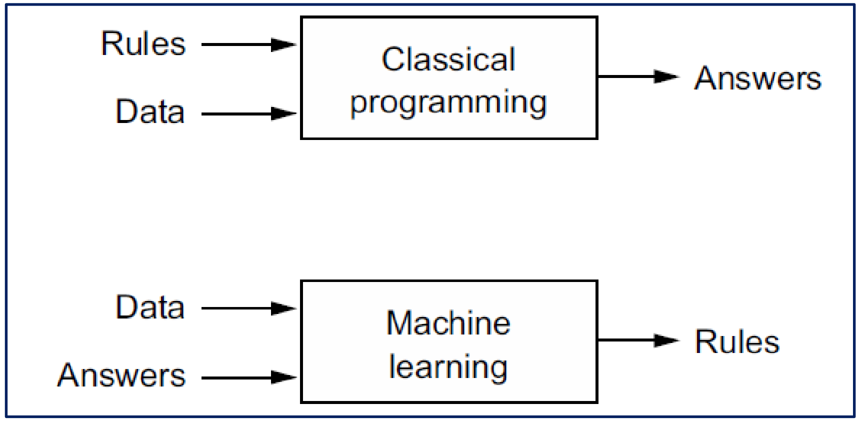


What is Machine Learning?

- Tom Michel (1999) defines ML as a well posed learning problem: "A computer program is said to learn 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."

The checkers example,

- E = 10000s games
- T is playing checkers
- P is probability of winning



Different Phases of Life-Cycle

1. • Data Acquisition → Tabular data, Image/video, Sensor data
2. • Data Preparation
3. • Feature Extraction → (1) Feature Engineering (2) Feature learning
4. • Train Model → LR, SVM, RF, ANN
5. • Test Model → For Evaluation and assessment
- • Evaluate and Improve

Types of Machine Learning

1
- **Supervised Machine Learning** assumes that a set of labelled training data is available and the classifier is designed by exploiting this a-priori known information.
- Two further types
  1
  - Regression
    - Linear Regression
    - Nonlinear Regression

  2
  - Classification
    - Logistic Regression
    - Naïve Bayes
    - Support Vector Machines etc

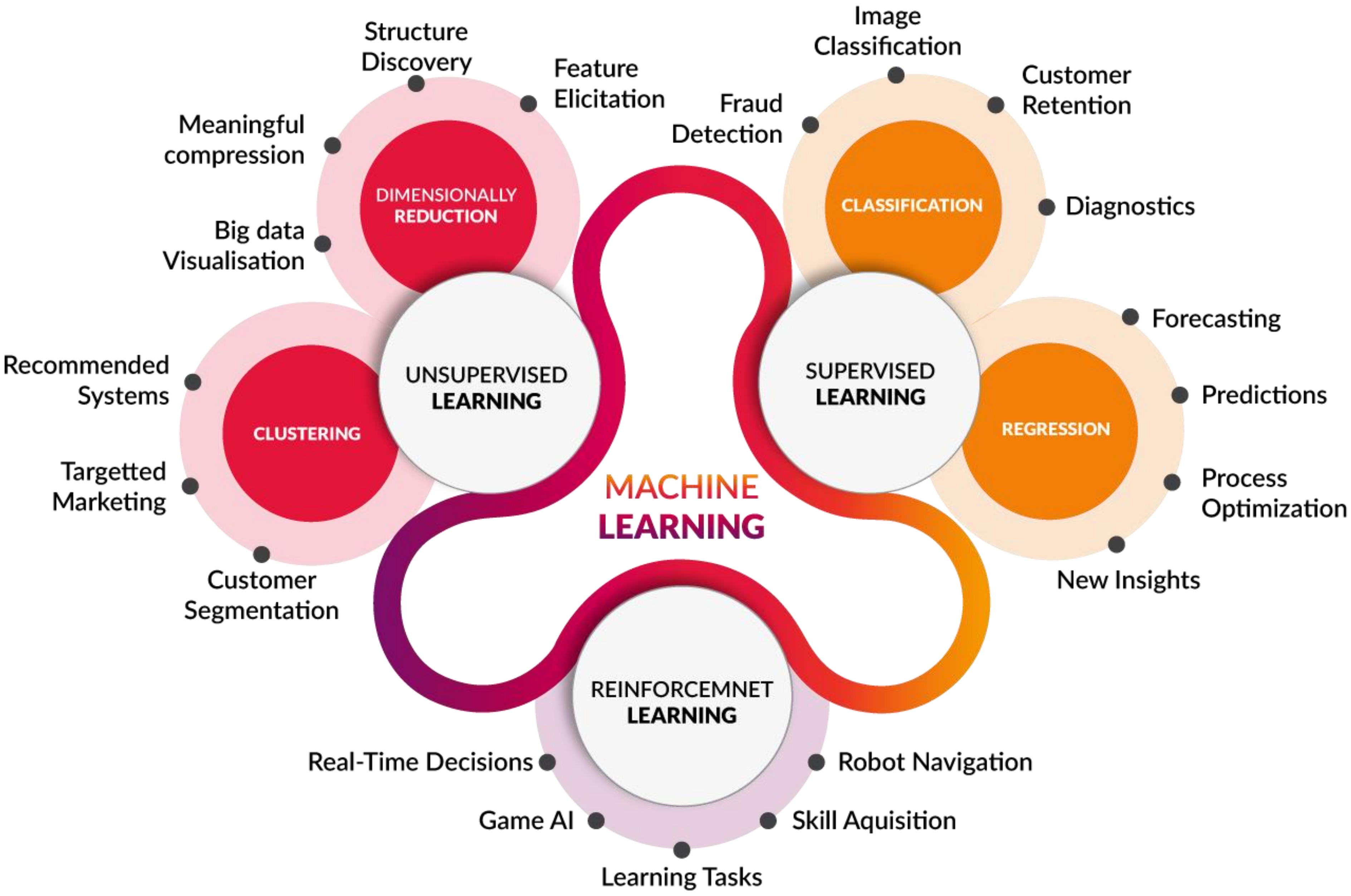
D.T / R.F

Types of Machine Learning

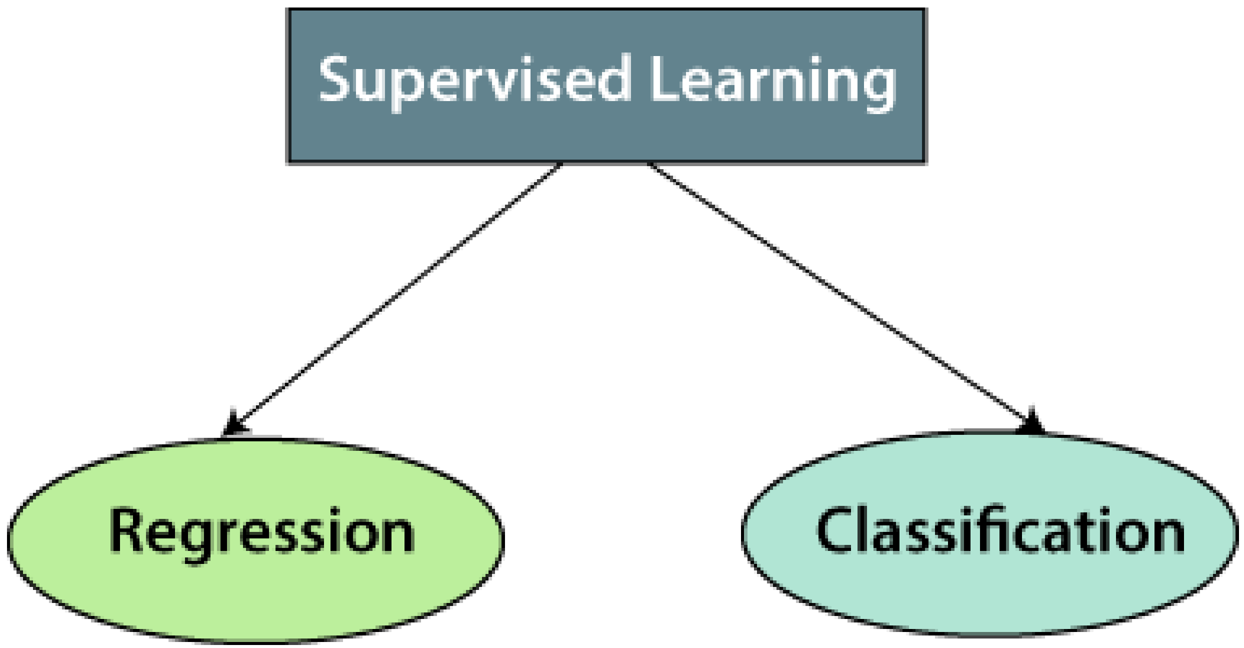
- **Unsupervised Machine Learning** clusters unlabeled training data described by feature vectors into similar groups
  - Clustering
    - K-Means Clustering
  - Dimensionality Reduction
    - Principal Component Analysis
    - Autoencoders

Types of Machine Learning

- In **Semi-supervised Machine Learning** the dataset contains both labeled and unlabeled examples. Usually, the quantity of unlabeled examples is much higher than the number of labeled examples. The goal of a semi-supervised learning algorithm is the same as the goal of the supervised learning algorithm.
- **Reinforcement Learning** solves a particular kind of problems where decision making is sequential, and the goal is long-term, such as game playing, robotics, resource management, or logistics.



Structure Discovery
Feature Elicitation
Meaningful compression
DIMENSIONALLY REDUCTION
Big data Visualisation
Image Classification
Customer Retention
Fraud Detection
CLASSIFICATION
Diagnostics
Recommended Systems
CLUSTERING
UNSUPERVISED LEARNING
Targetted Marketing
Customer Segmentation
SUPERVISED LEARNING
Forecasting
Predictions
REGRESSION
Process Optimization
New Insights
MACHINE LEARNING
REINFORCEMNET LEARNING
Real-Time Decisions
Robot Navigation
Game AI
Skill Aquisition
Learning Tasks



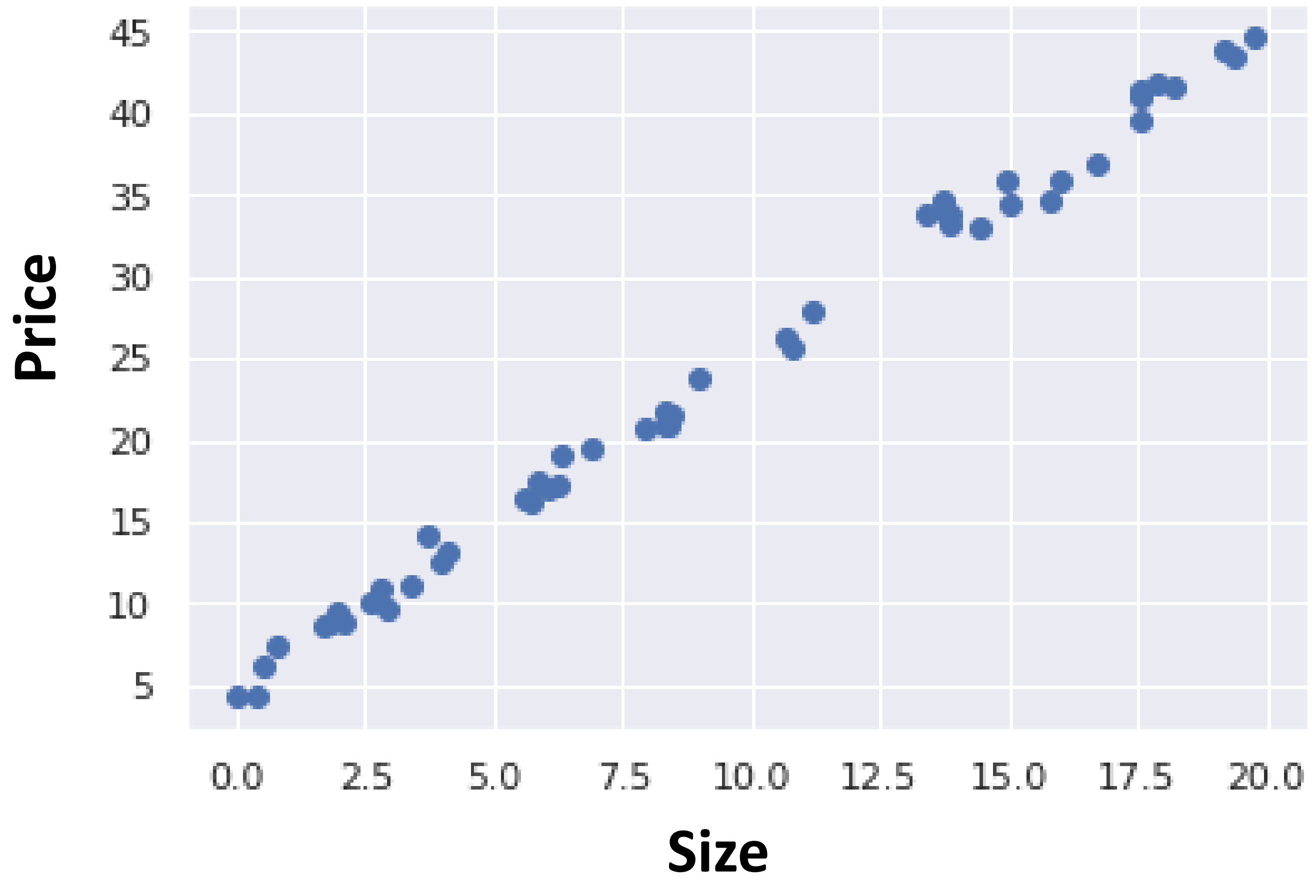
Supervised Learning
Regression
Classification

Regression

- A Supervised learning algorithm
- Taking input variables and trying to fit the output onto a continuous values.
- Linear regression with one variable is also known as "Univariate linear regression".
- Univariate linear regression is used when you want to predict a single output value y from a single input value x.
- The Hypothesis Function $y' = h\theta(x) = \theta_0 + \theta_1 x$
- Given the training data with right answers, predict the real-valued output for the test data.

Dataset and Plotted Graph

Input Data (x)	Correct Answer (y)
8.3	20.99
14.4	32.89
6.05	17.08
..	..



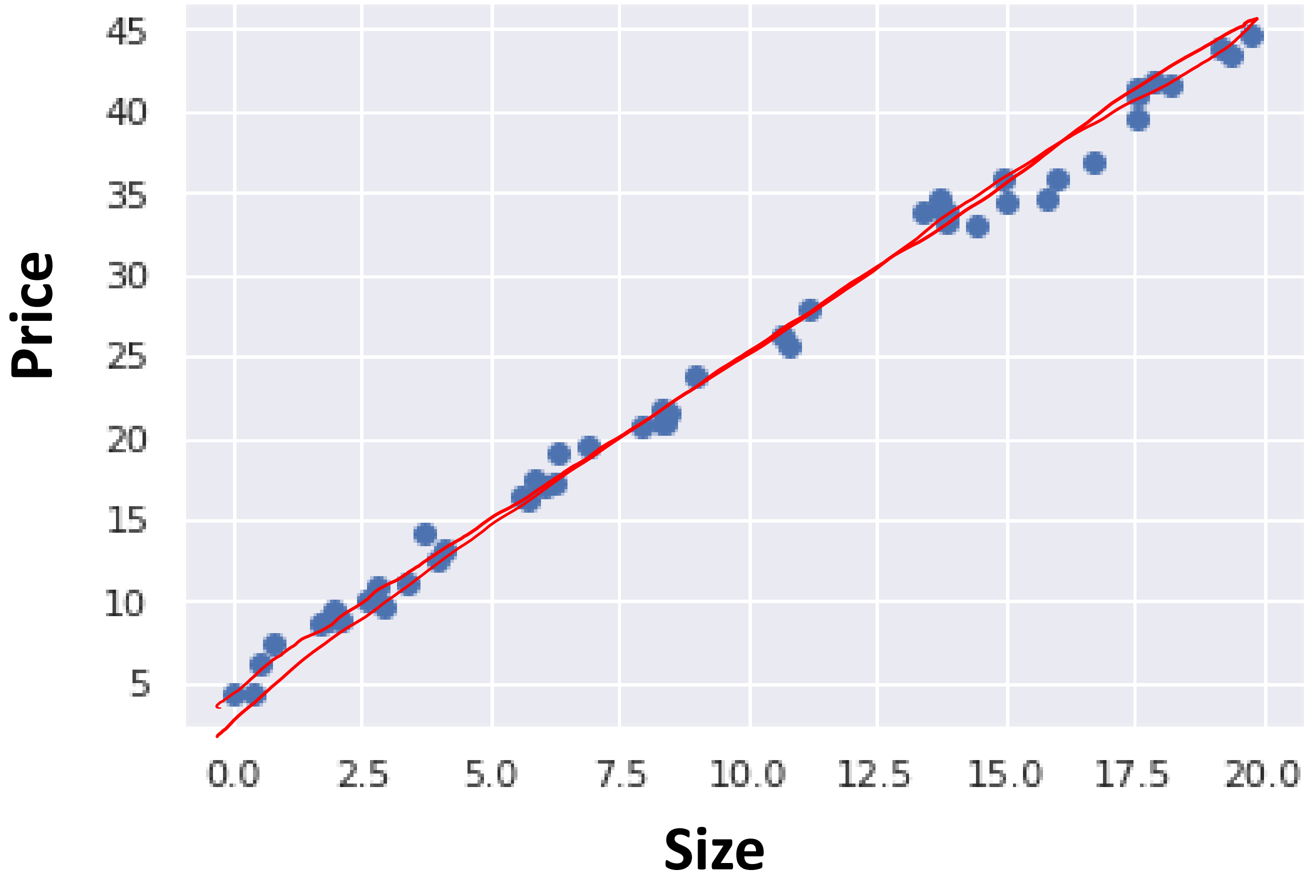
Dataset and Notations

- Notations
- m = Number of Training Examples
- **x** = Input Variable/ Features
- **y** = Output Variable / Target Value
- **(x,y)** is one training example
- **($x^{(i)}$,$y^{(i)}$)** is i^{th} training example
- **($x^{(1)}$,$y^{(1)}$) = (8.3, 20.99)**

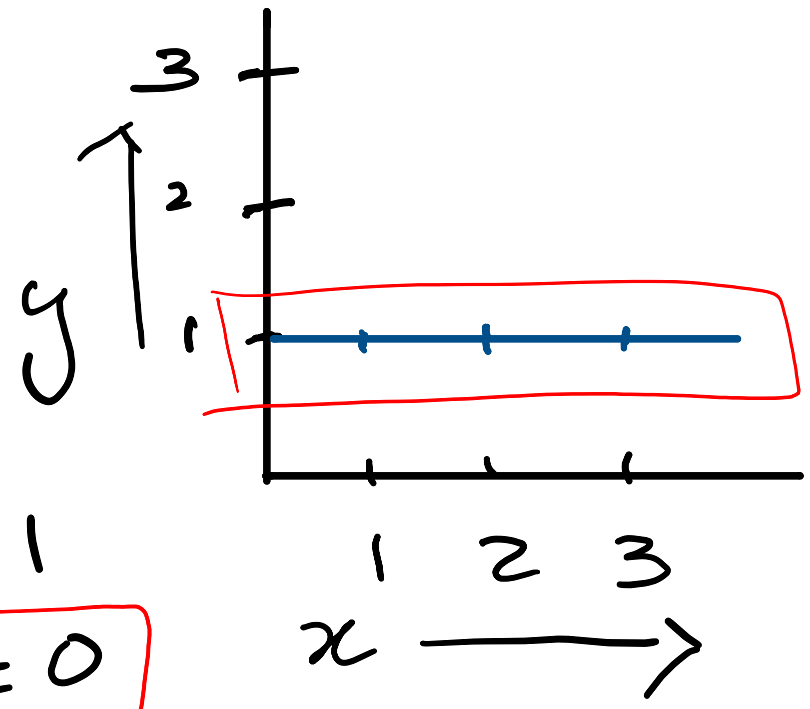
Input Data (x)	Correct Answer (y)
8.3	20.99
14.4	32.89
6.05	17.1
..	..

Linear Regression with One Variable

- This is like the equation of a straight line.
- We give $h\theta(x)$ values for θ_0 and θ_1 to get our estimated output y'.
- We are trying to create a function that will map out input data to our output data.

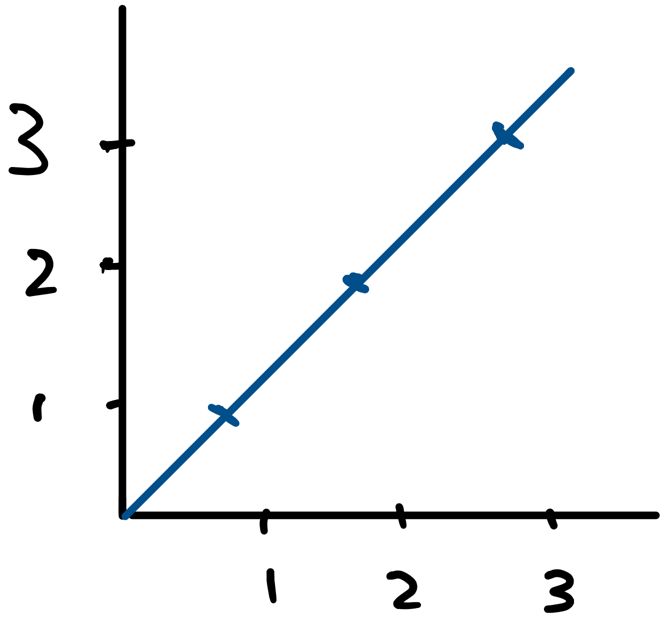


Linear Functions With Varying Values of ϴ



$\theta_0 = 1$

$\boxed{\theta_1 = 0}$



$\boxed{\theta_0 = 0}$

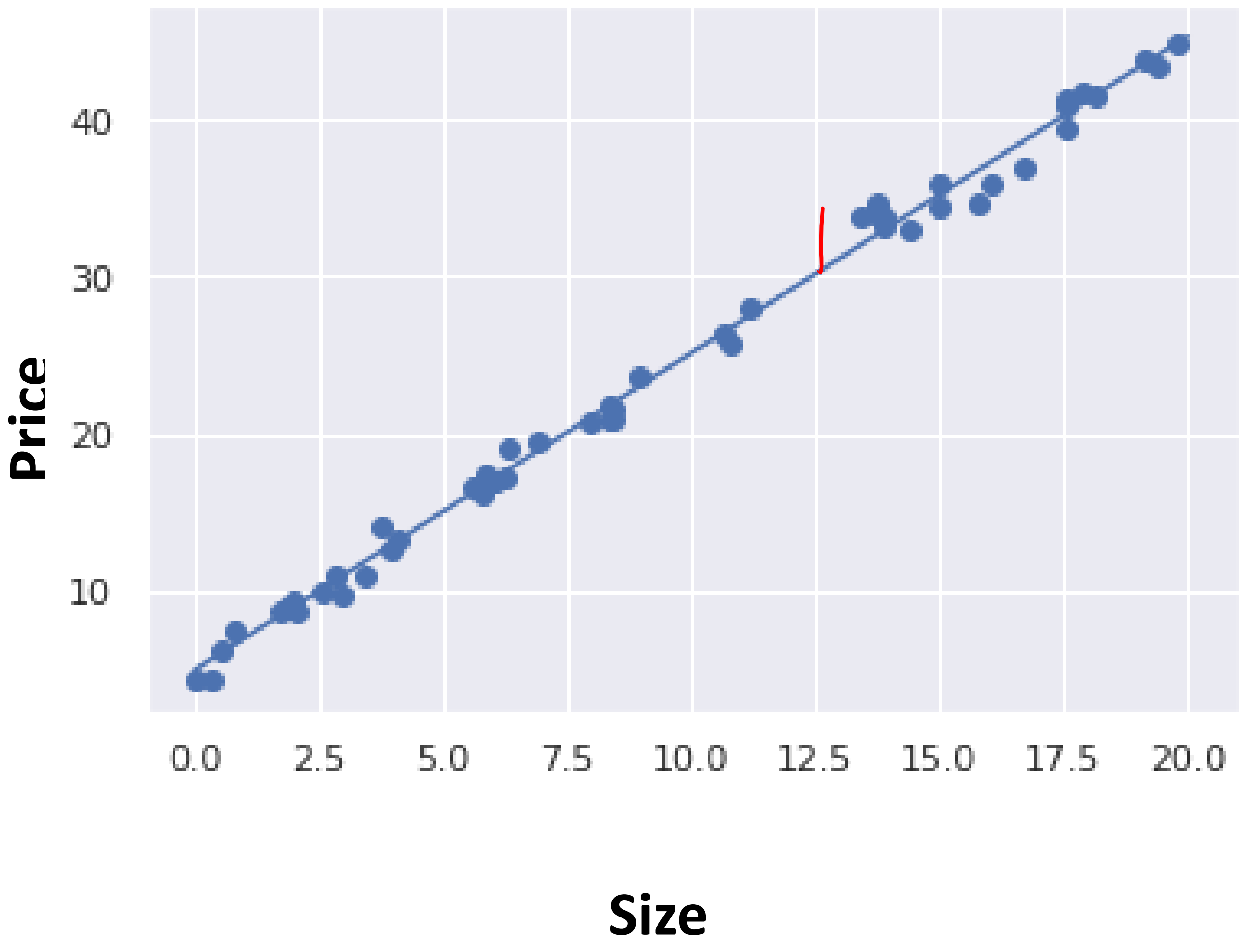
$\theta_1 = 1$

Linear Regression with One Variable

$$\overset{}{y'} = h\theta(x) = \overset{5}{\theta_0} + \overset{2\times 5}{\theta_1 x}$$

- Intercept: $\theta_0 = 5$
- Slope: $\theta_1 = 2$

Input Data (x)	Correct Answer (y)
5	15
10	25
15	35
..	..



Cost Function

- **Hypothesis Function**

$$y' = h\vartheta(x) = \vartheta_0 + \vartheta_1 x$$

- **Cost function** (to measure the performance of hypothesis function)

$$J(\vartheta_0, \vartheta_1) = \frac{1}{2m} \sum_{i=1}^{m} (y'^{(i)} - y^{(i)})^2 = \frac{1}{2m} \sum_{i=1}^{m} (h\vartheta(x^{(i)}) - y^{(i)})^2$$

Cost Function

Input Data (x)	Correct Answer (y)	Estimated Answer	Error
8.3	20.99	21.6	-0.61
14.4	32.89	33.8	-0.81
6.05	17.1	17.08	0.02
..	..	..	..

$$Mean\ Square\ Error\ (MSE) = J(\vartheta_0, \vartheta_1) = \frac{1}{2m} \sum_{i=1}^{n} (y^{(i)} - y'^{(i)})^2$$

Cost Function

- **Hypothesis Function**

$$y' = h\vartheta(x) = \vartheta_0 + \vartheta_1 x$$

- **Cost function** (to measure the performance of hypothesis function)

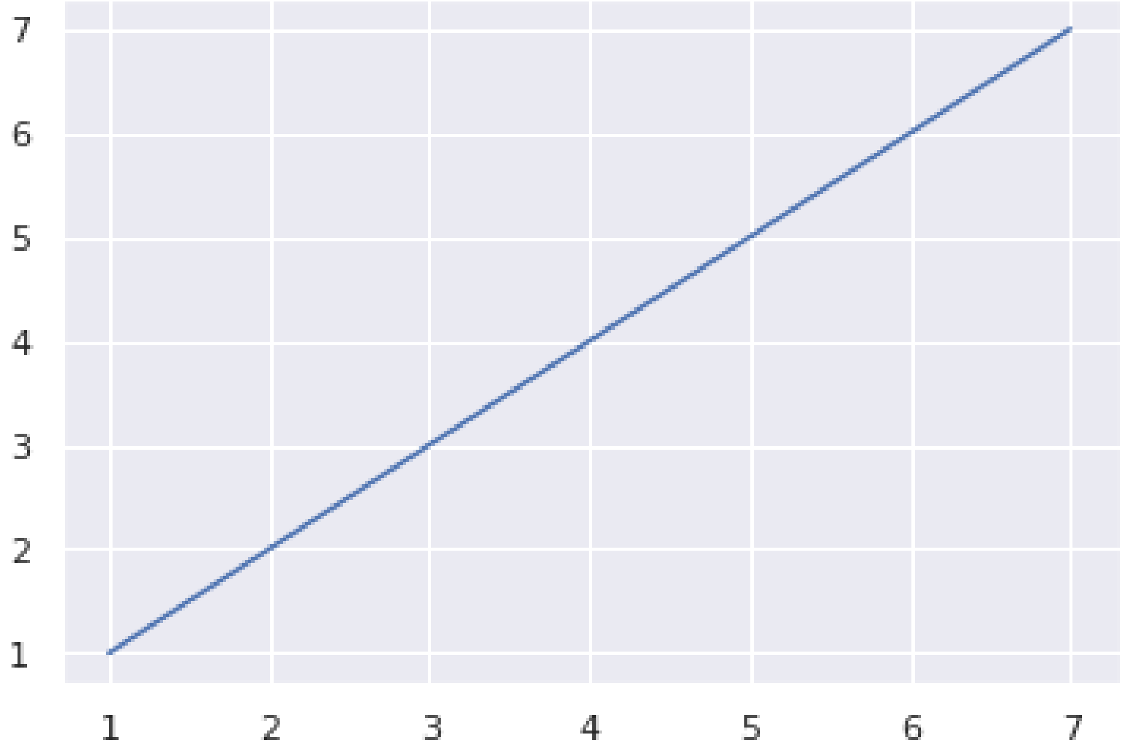
$$J(\vartheta_{0,}\vartheta_1) = \frac{1}{2m}\sum_{i=1}^{m}(\ y'^{\,(i)}\ -\ y^{\,(i)}\ )^2 = \frac{1}{2m}\sum_{i=1}^{m}(\ h\vartheta(x^{\,(i)})\ -\ y^{\,(i)}\ )^2$$

- **Objective:**

$$\min_{\vartheta_{0,}\vartheta_1} \mathrm{J}(\vartheta_{0,}\vartheta_1)$$

Cost Function - Example

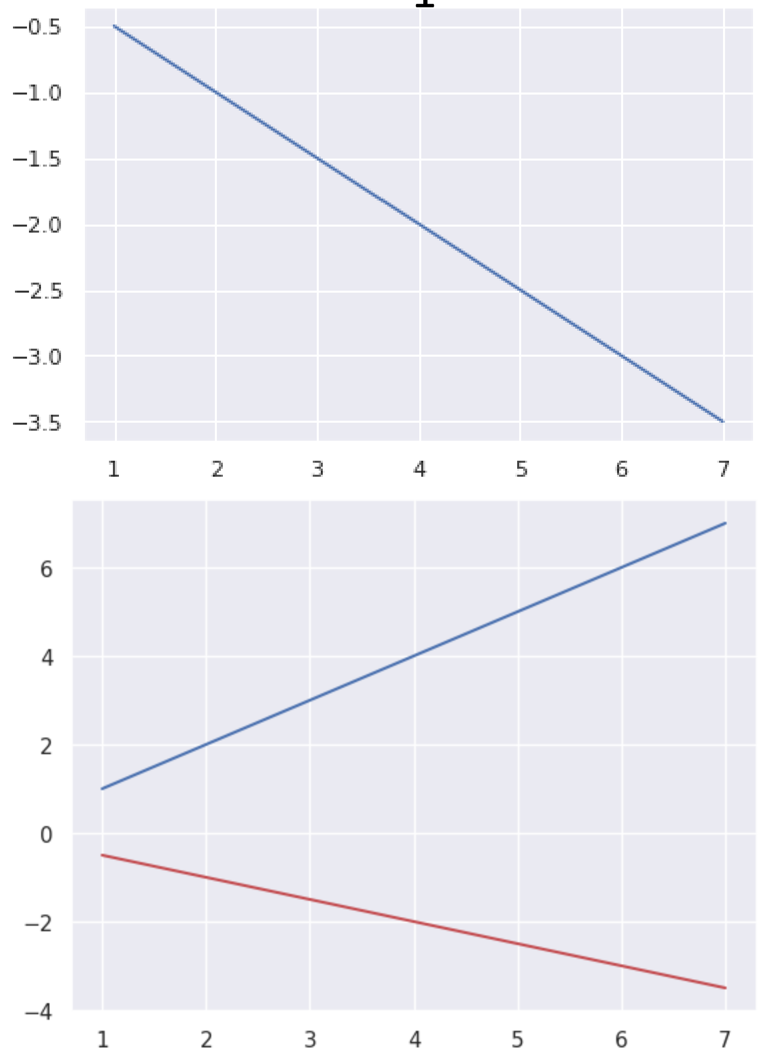
- **x** = [1, 2, 3, 4, 5, 6, 7]
- **y** = [1, 2, 3, 4, 5, 6, 7]
- $y' = h\theta(x) = \theta_0 + \theta_1 x$
- Assume $\theta_0 = 0$
- So, $y' = h\theta(x) = \theta_1 x$



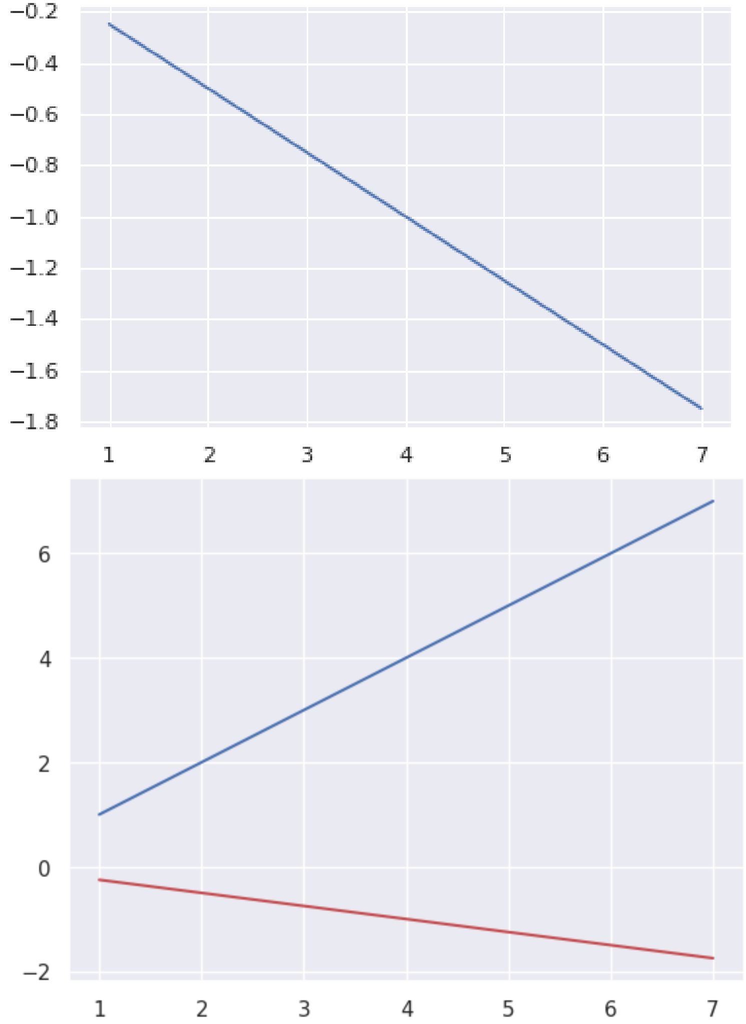
θ_1 = [-0.5, -0.25, 0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25]

Cost Function - Example

- $\vartheta_1 = -0.5$, $J(\vartheta_1) = 45.0$

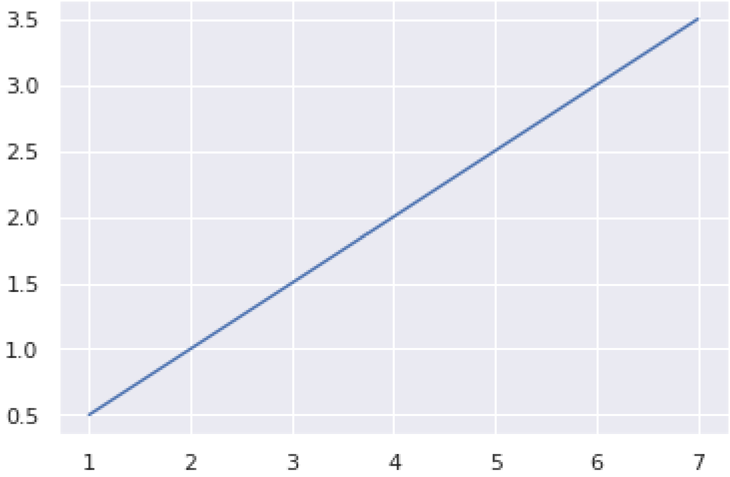


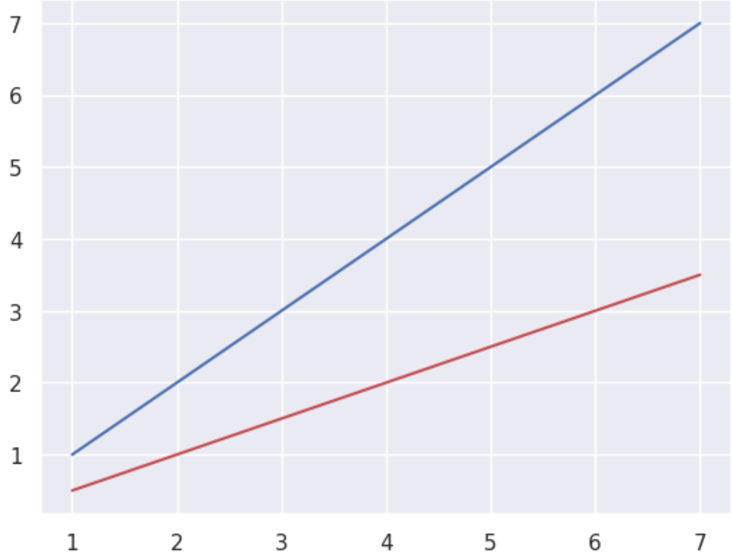
- $\vartheta_1 = -0.25$, $J(\vartheta_1) = 31.25$



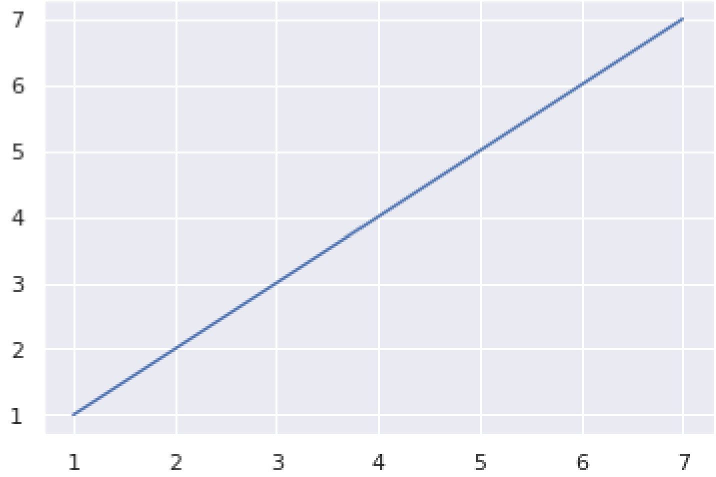
Cost Function - Example

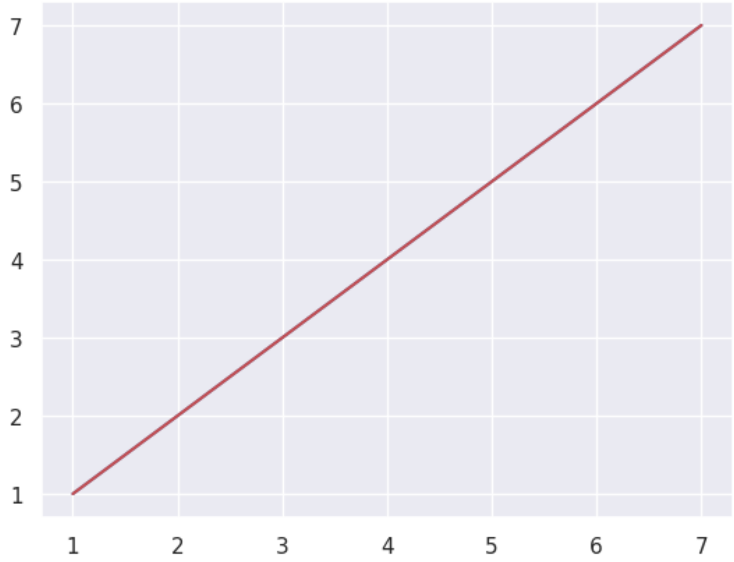
- ϑ_1 `= 0.5,` J(ϑ_1)= `5.0`





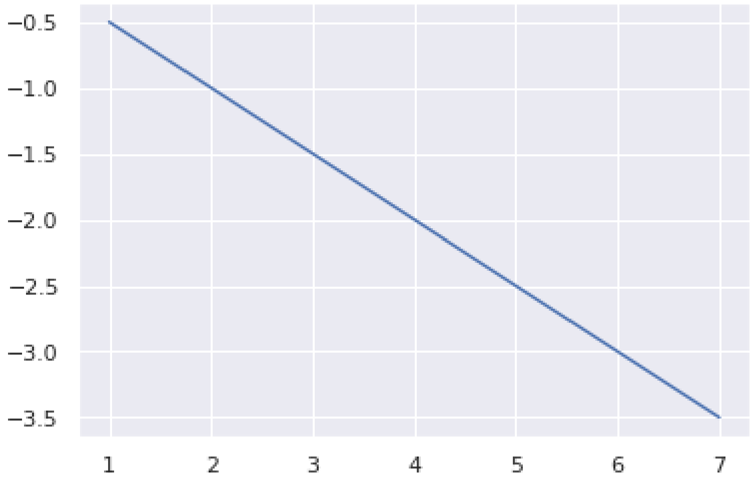
- ϑ_1 `= 1.0,` J(ϑ_1)= `0.0`



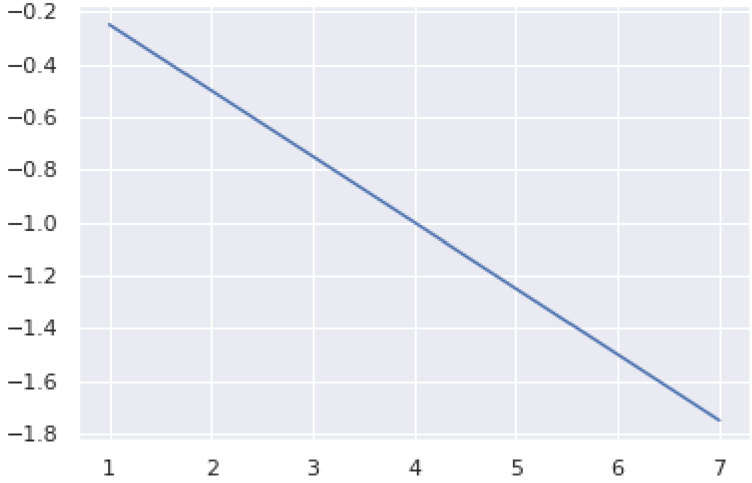


Cost Function - Example

- ϑ_1 = 1.5, J(ϑ_1)= 5.0

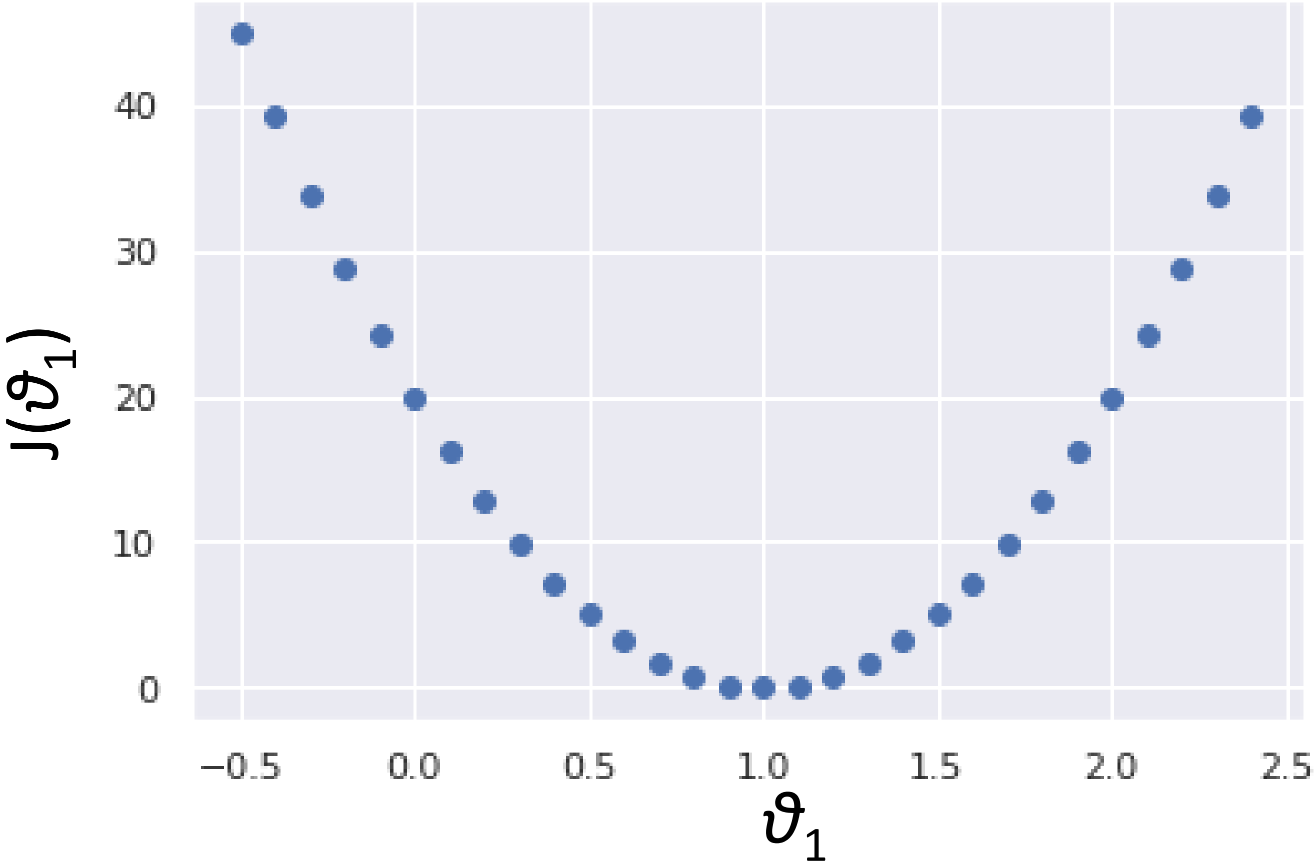


- ϑ_1 = 2.0, J(ϑ_1)= 20.0

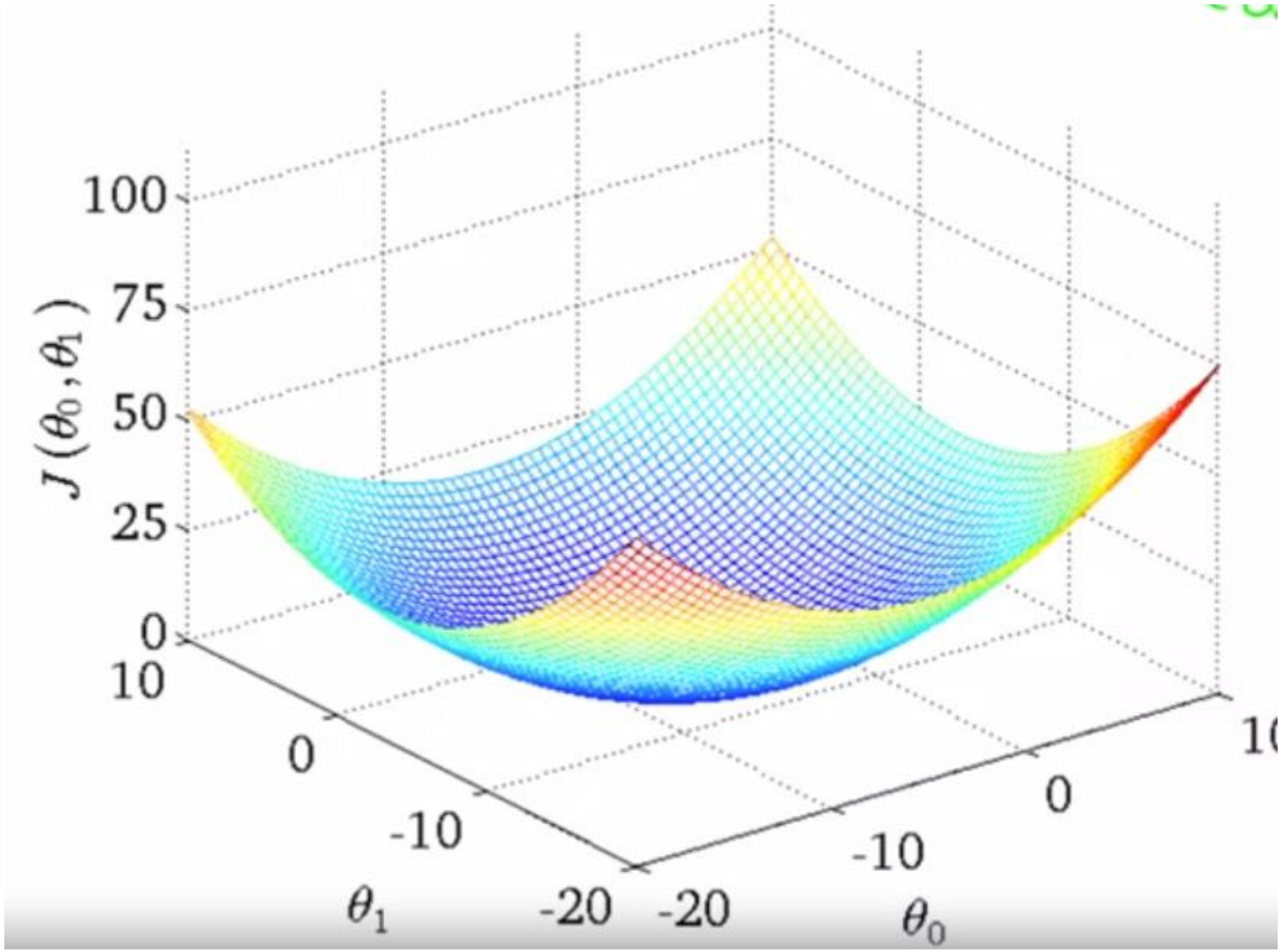


Graph of J(ϑ_1)

- θ_1 = [-0.5, -0.25, 0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25]
- $J(\theta_1)$ =[45.0, 31.25, 20.0, 11.25, 5.0, 1.25, 0.0, 1.25, 5.0, 11.25, 20.0, 31.25]

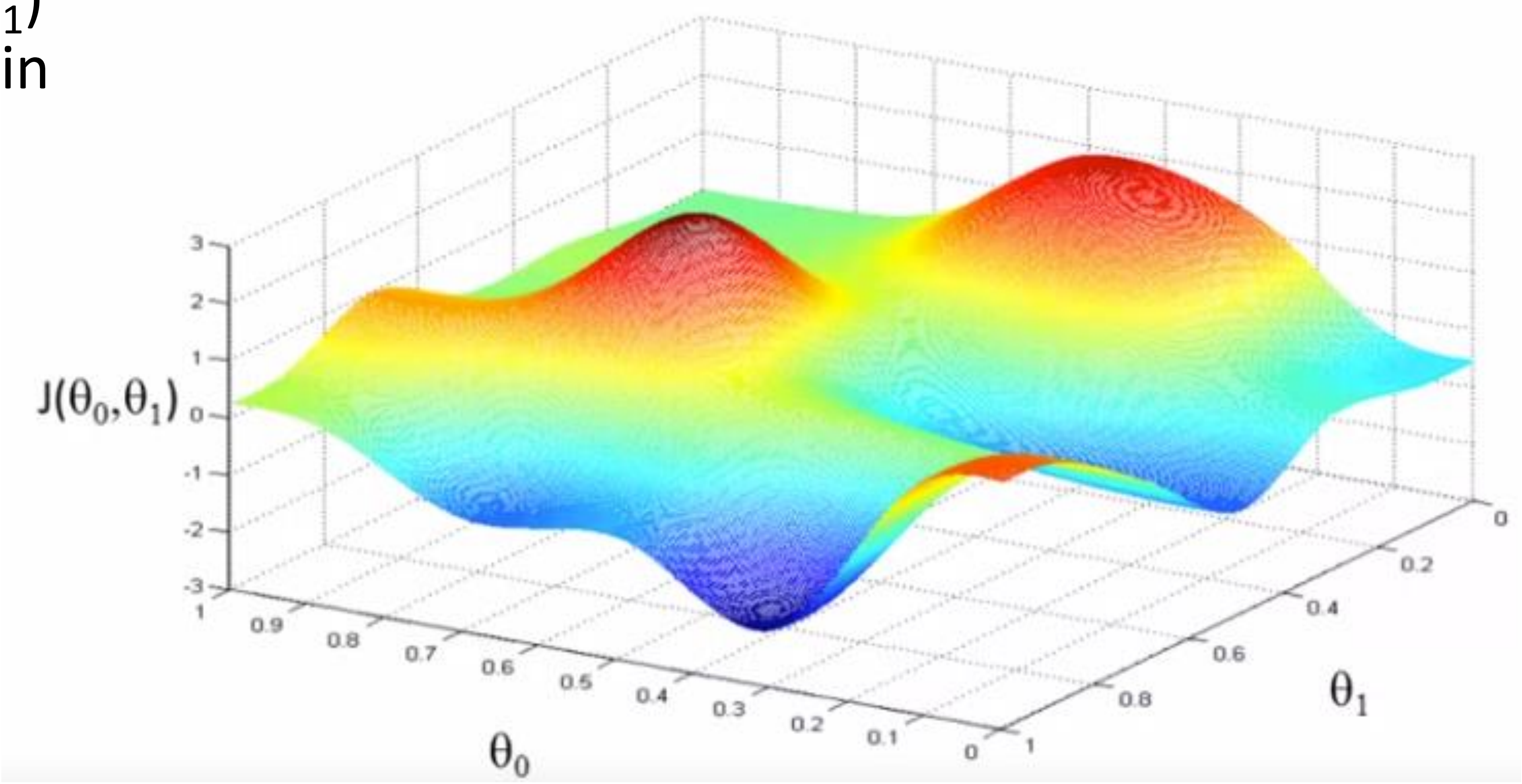


Graph of J($\vartheta_{0}, \vartheta_1$)

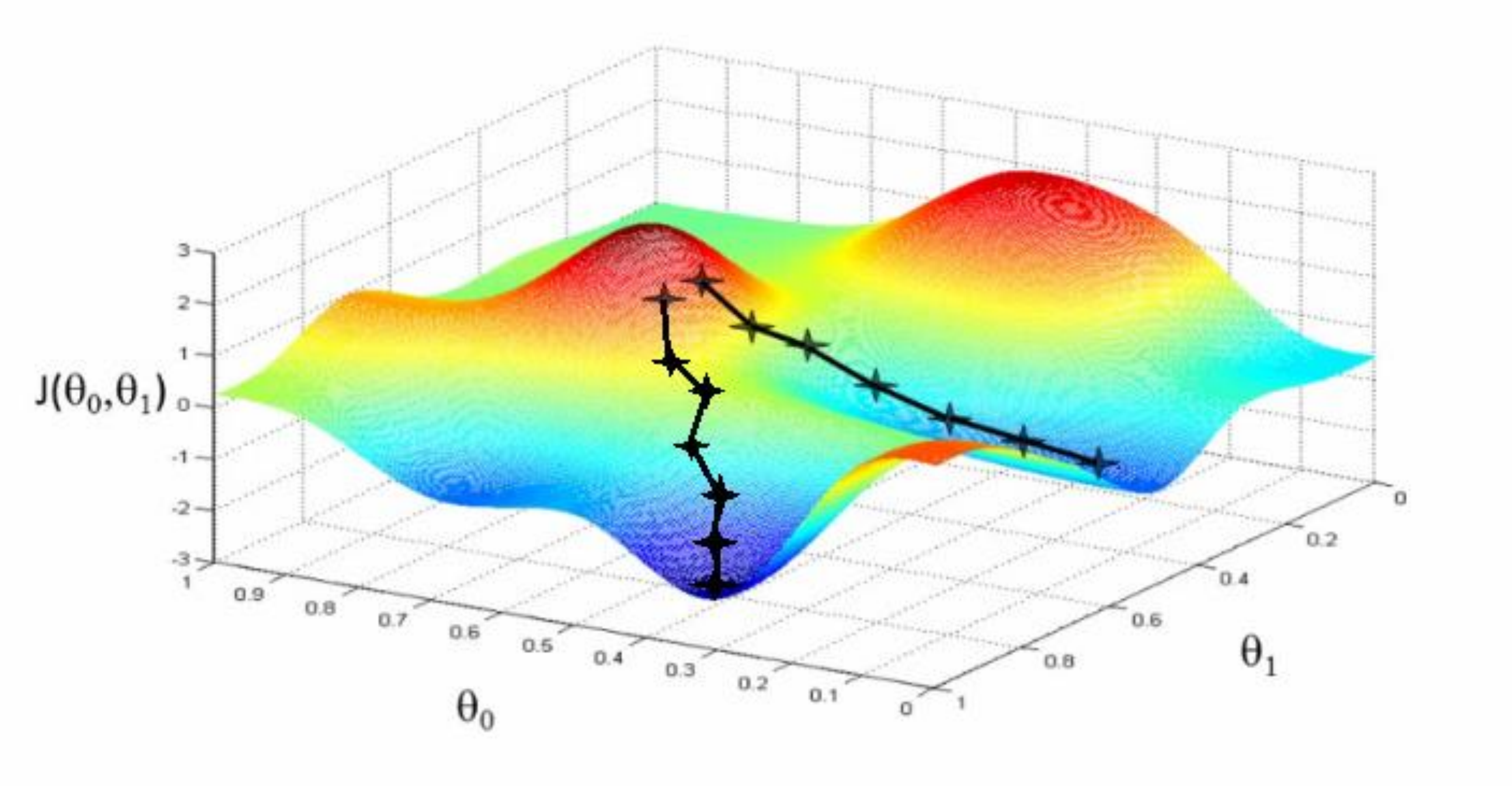


Gradient Descent Algorithm

- We have J(ϑ_0, ϑ_1) and we want min J(ϑ_0, ϑ_1)



Solving Minimization Problem



Derivatives

$f(x) = 4x$

$f(x) = x^3$

$f(x) = (x + 2)^4$

$f(x,y) = (3x + 2y + 2)^2$

Gradient Descent Algorithm

- $\vartheta_j \coloneqq \vartheta_j - \alpha \frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1)$ (for j = 0 and j = 1)
- $\frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1)$ is a partial derivative term
- Alpha is learning rate
- Simultaneous Update
- temp0 = $\vartheta_0 - \alpha \frac{\partial}{\partial \vartheta_0} J(\vartheta_0, \vartheta_1)$
- temp1 = $\vartheta_1 - \alpha \frac{\partial}{\partial \vartheta_1} J(\vartheta_0, \vartheta_1)$
- $\vartheta_0 \coloneqq$ temp0
- $\vartheta_1 \coloneqq$ temp1

Linear Regression with Gradient Descent

$$\vartheta_j := \vartheta_j - \alpha \frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1)$$

$$\frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1) = \frac{\partial}{\partial \vartheta_j} \left(\frac{1}{2m} \sum_{i=1}^{m} \left(h\vartheta(x^{(i)}) - y^{(i)} \right)^2\right)$$

$$\frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1) = \frac{\partial}{\partial \vartheta_j} \left(\frac{1}{2m} \sum_{i=1}^{m} \left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)} \right)^2\right)$$

Linear Regression with Gradient Descent

$$\frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1) = \frac{\partial}{\partial \vartheta_j} \left(\frac{1}{2m} \sum_{i=1}^{m} \left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)} \right)^2\right)$$

$$\frac{\partial}{\partial \vartheta_0} J(\vartheta_0, \vartheta_1) = \frac{\partial}{\partial \vartheta_0} \left(\frac{1}{2m} \sum_{i=1}^{m} \left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)} \right)^2\right)$$

$$\frac{\partial}{\partial \vartheta_0} J(\vartheta_0, \vartheta_1) = \frac{1}{m} \sum_{i=1}^{m} \left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)} \right)$$

$$\frac{\partial}{\partial \vartheta_1} J(\vartheta_0, \vartheta_1) = \frac{\partial}{\partial \vartheta_1} \left(\frac{1}{2m} \sum_{i=1}^{m} \left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)} \right)^2\right)$$

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Linear Regression with Gradient Descent

- Repeat until **converge**

$$\vartheta_0 := \vartheta_0 - \alpha \left(\frac{1}{m}\sum_{i=1}^{m}\left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)}\right)\right)$$

$$\vartheta_1 := \vartheta_1 - \alpha \left(\frac{1}{m}\sum_{i=1}^{m}\left(\vartheta_0 + \vartheta_1 x^{(i)} - y^{(i)}\right) x^{(i)}\right)$$

- Simultaneous update

Linear Regression with Multiple Features

- **Hypothesis Function**

$y' = h\vartheta(x) = \vartheta_0 + \vartheta_1 x_1 + \vartheta_1 x_1 + \vartheta_2 x_2 + \ldots + \vartheta_n x_n$

$y' = h\vartheta(x) = \vartheta_1 x_0 + \vartheta_1 x_1 + \vartheta_1 x_1 + \vartheta_2 x_2 + \ldots + \vartheta_n x_n$ *where* $x_1 = 1$

$y' = h\vartheta(x) = \theta^T X$

Simultaneous update

$$\vartheta_j \coloneqq \vartheta_j - \alpha \frac{\partial}{\partial \vartheta_j} J(\vartheta_0, \vartheta_1, \ldots, \vartheta_n)$$

$$\vartheta_j \coloneqq \vartheta_j - \alpha \frac{\partial}{\partial \vartheta_j} J(\theta)$$

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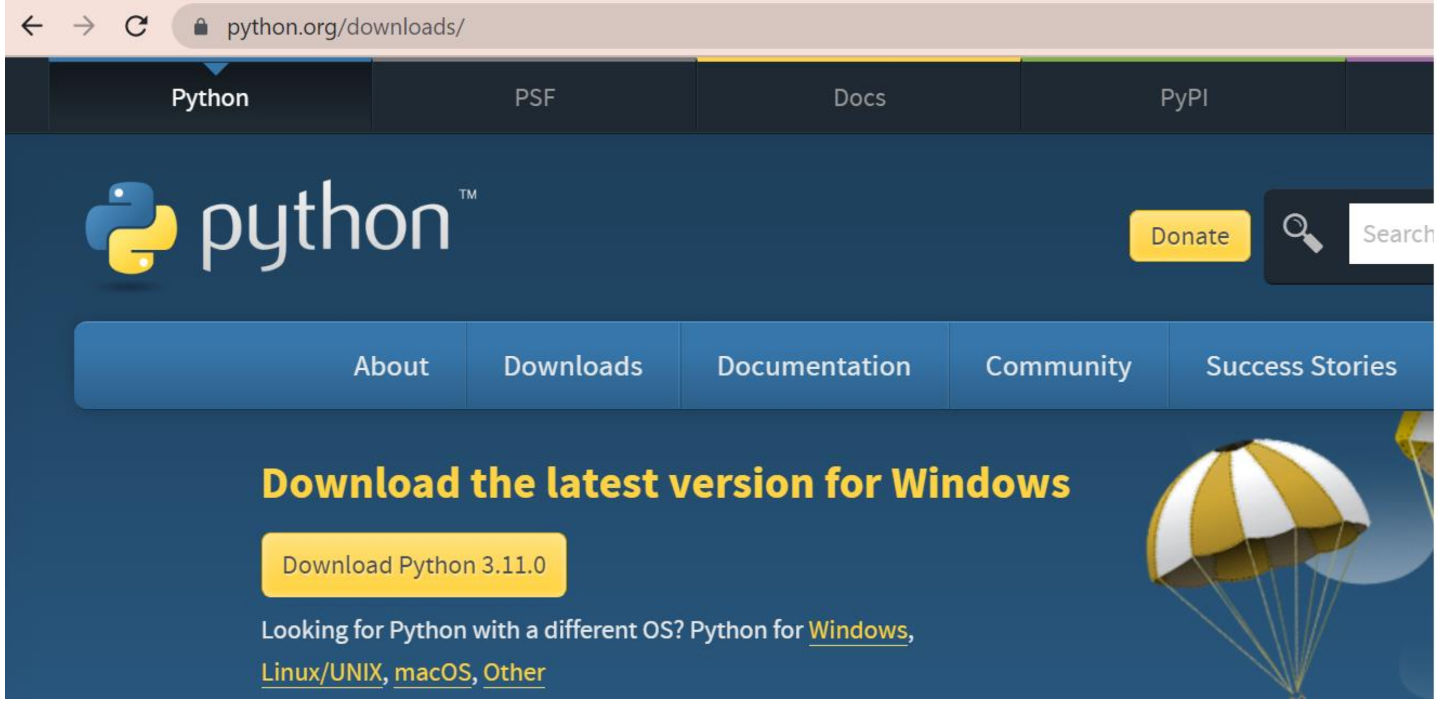

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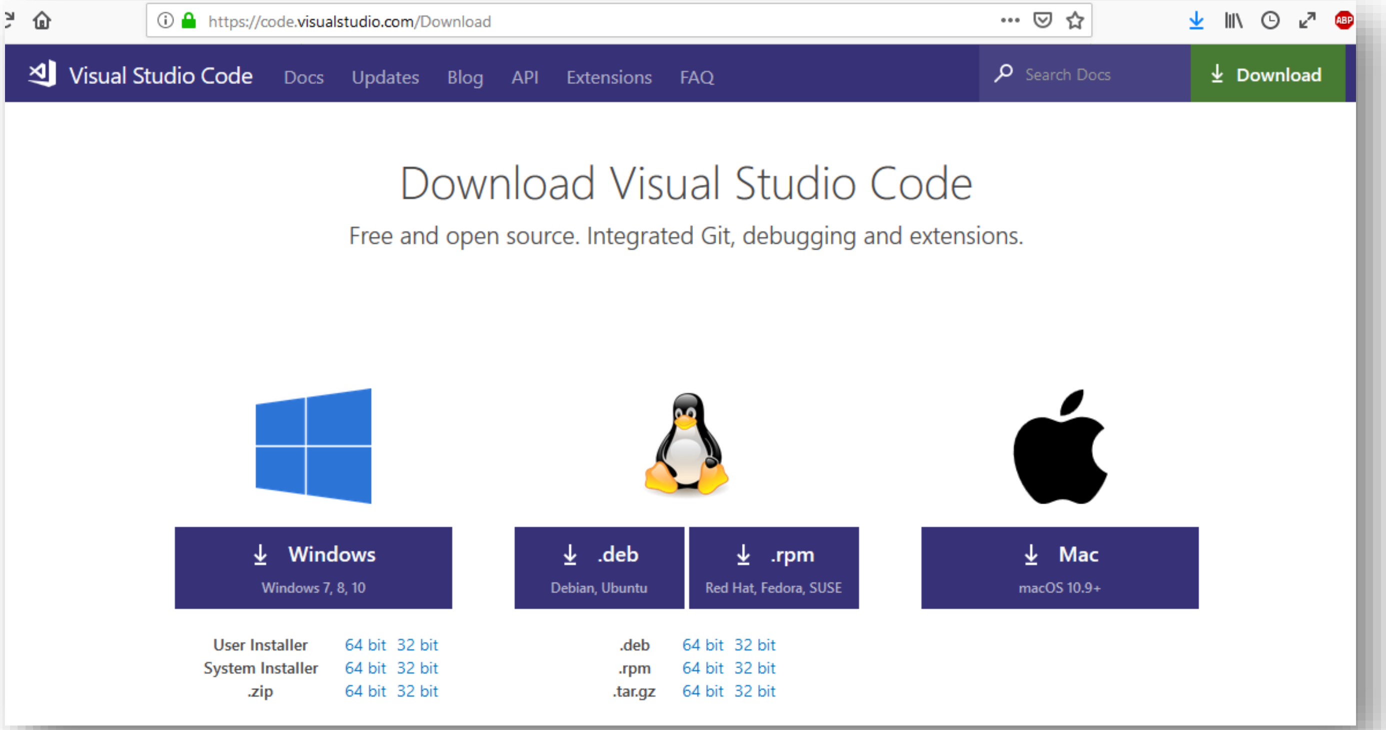

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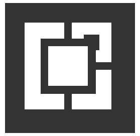

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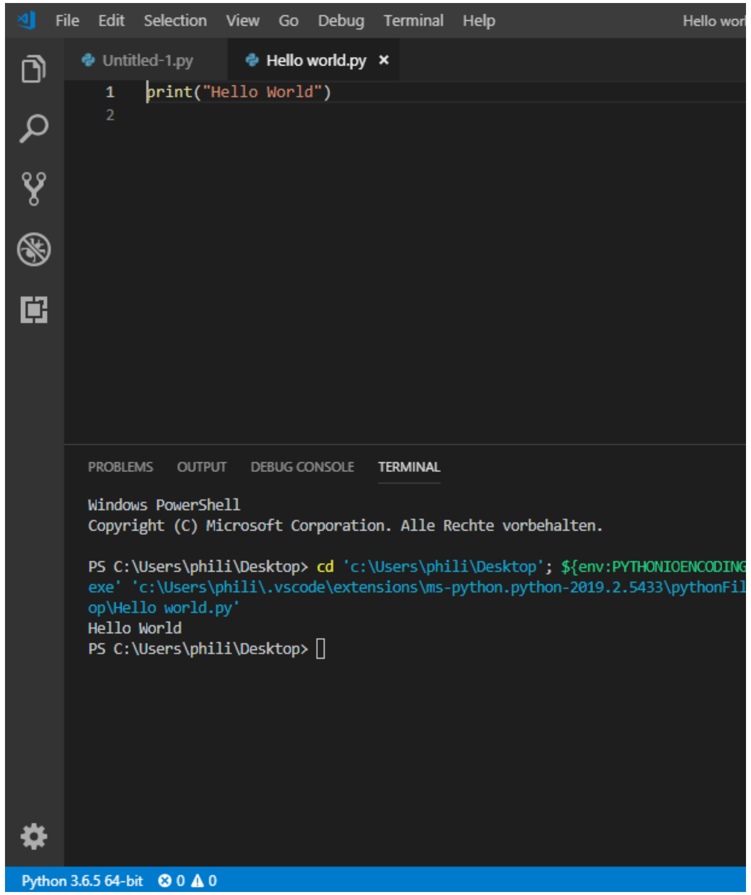

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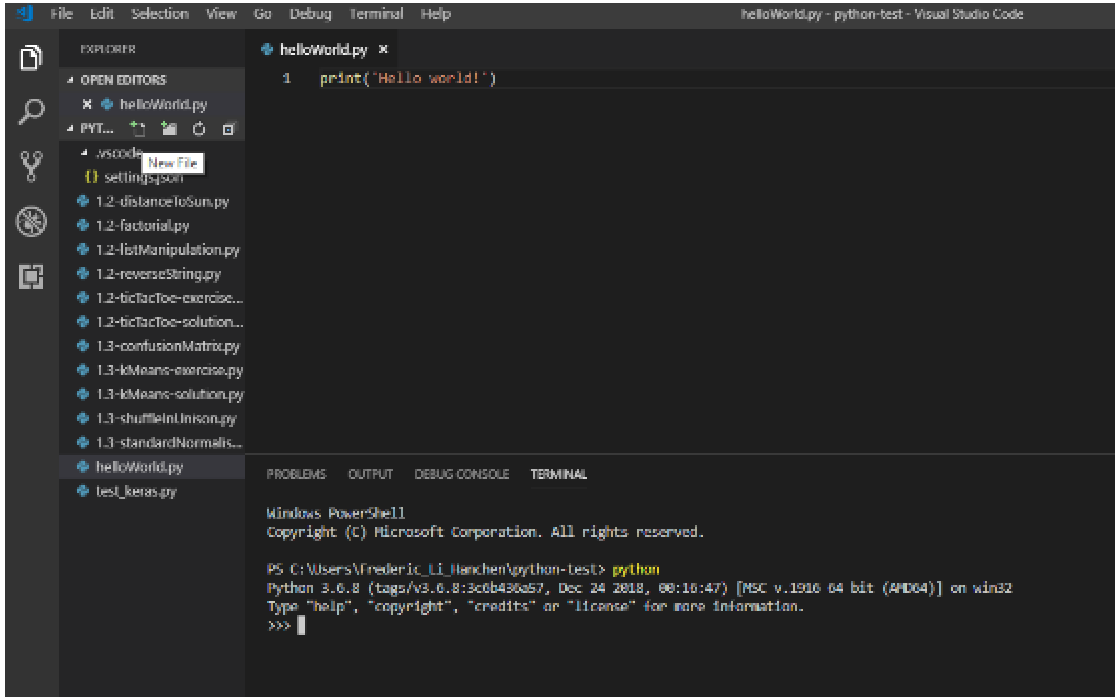

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assert	finally	or
break	for	pass
class	from	print
continue	global	raise
def	if	return
del	import	try
elif	in	while
else	is	with
except	lambda	yield

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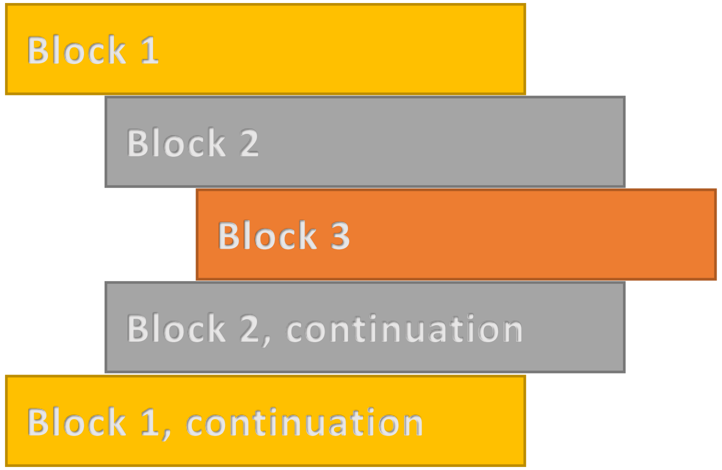

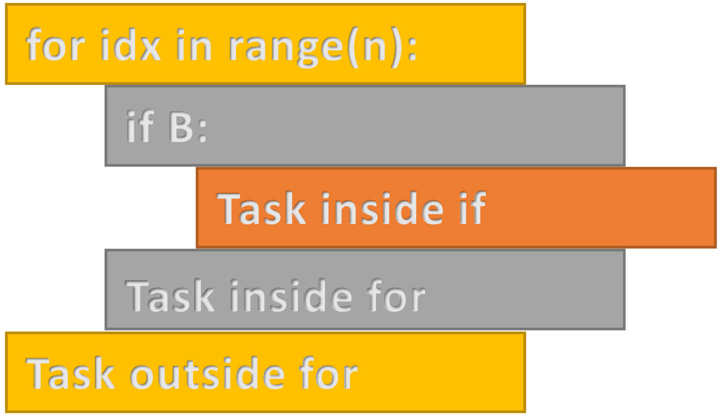

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- No type needed
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- delete entire variables: *del *variable name**

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# A string
name = "John"
# one line
counter, miles, name = 100, 1000.0, "John"
# Assign single value to several variables
a = b = c = 1
# Delete a variable
del a
```

Standard data types

- Python has six standard data types
  - Numbers
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  - String
  - List
  - Tuple
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- For numbers: integer, float, complex
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Lists

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- Iterates over the items of any sequence
- Iterate over a slice copy of the entire list with *list[:]*

```
list = ['element1', 'element2', 'element3']
for element in list:
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- Iterate over a sequence of numbers: *range* - function

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for i in range(5): *
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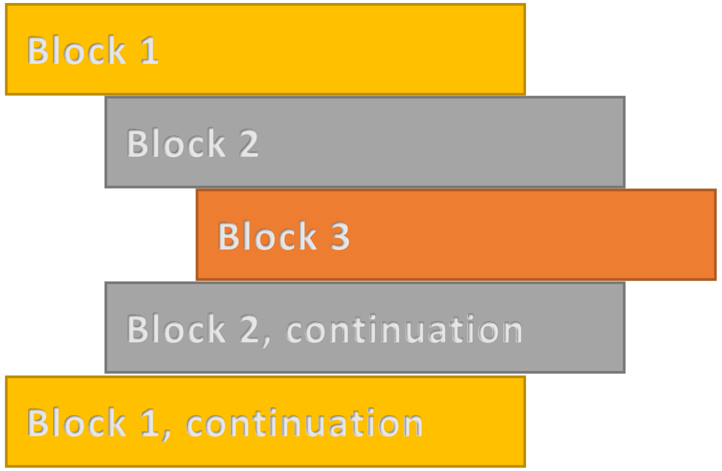

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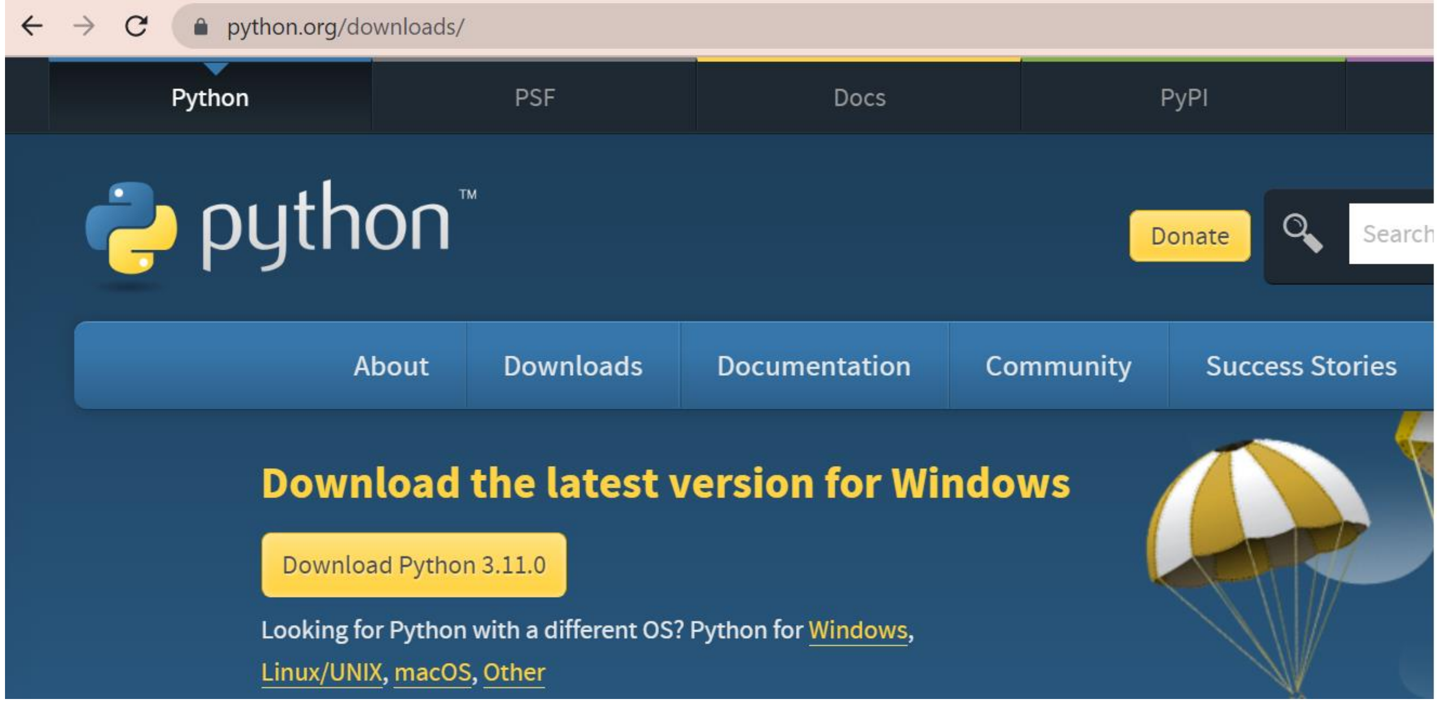

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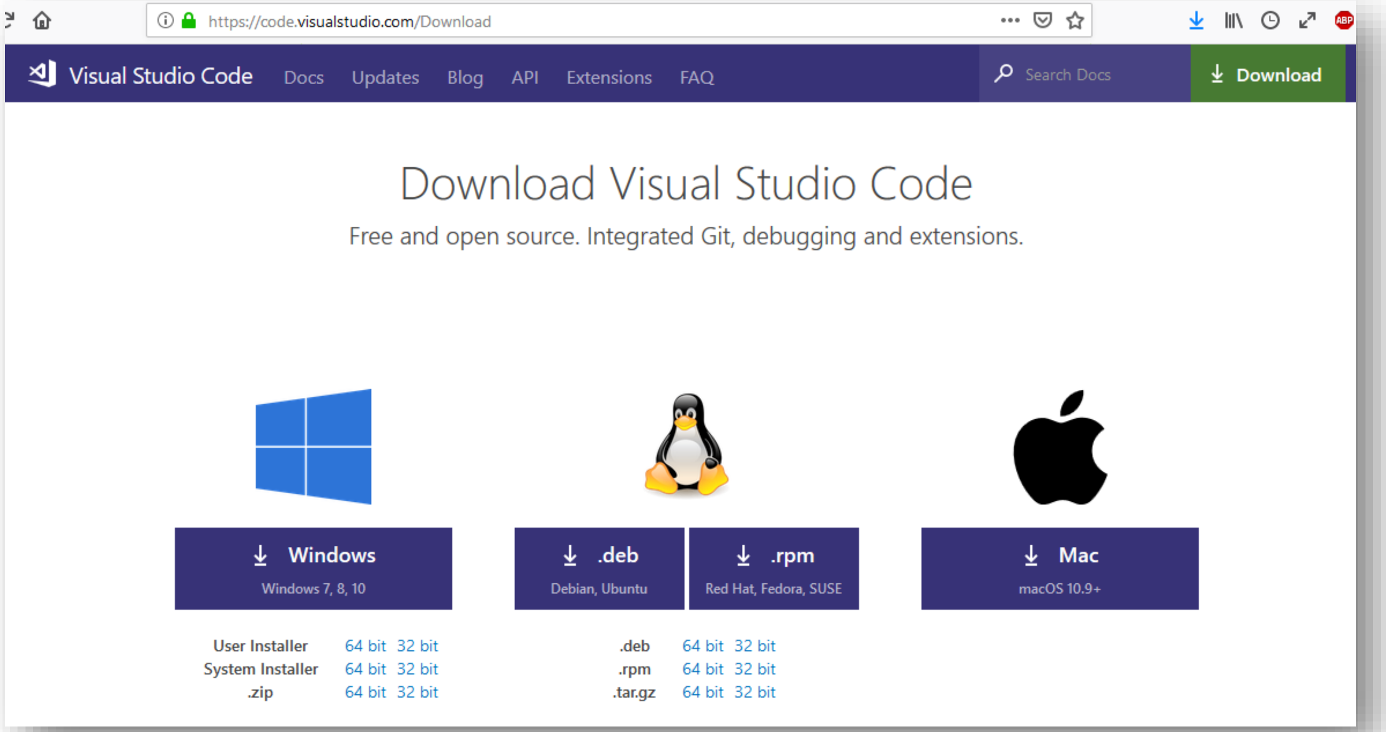

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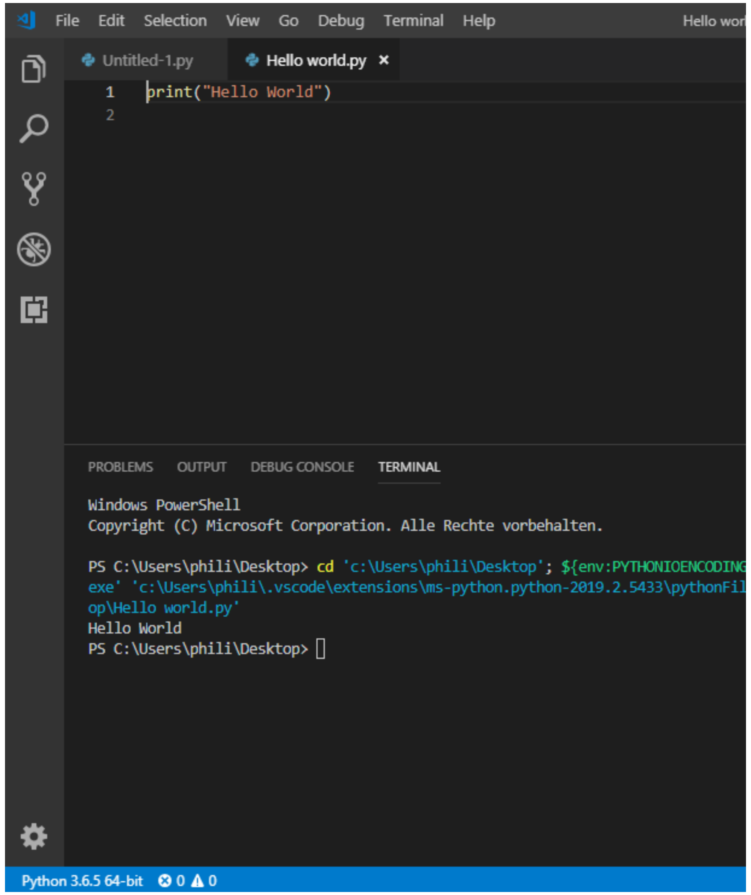

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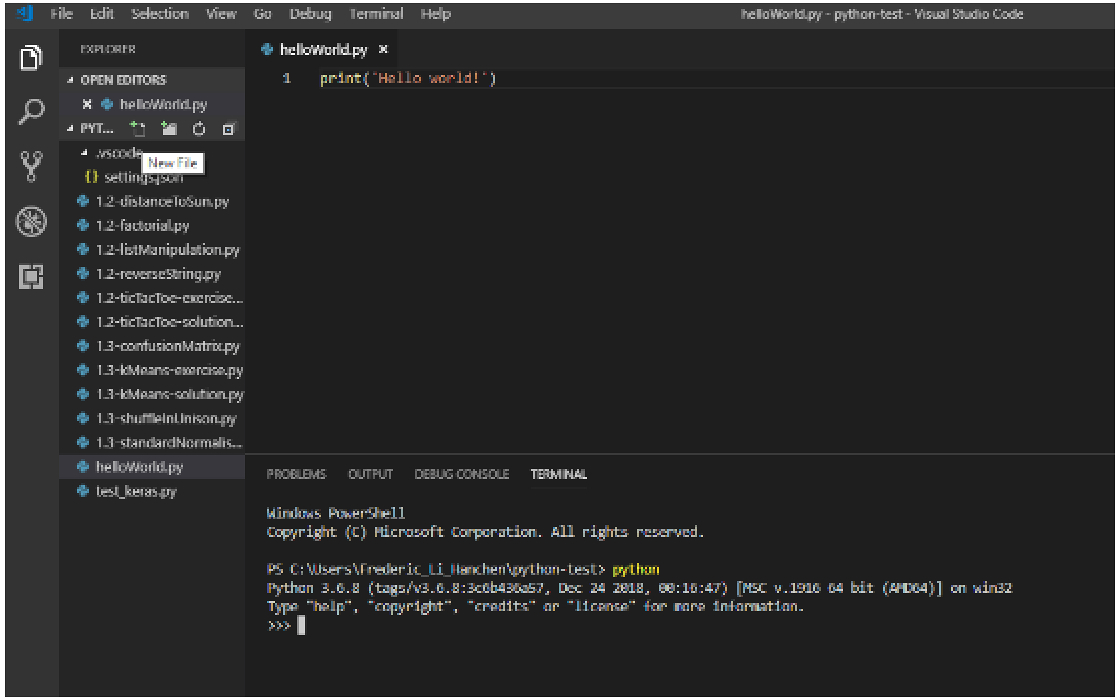

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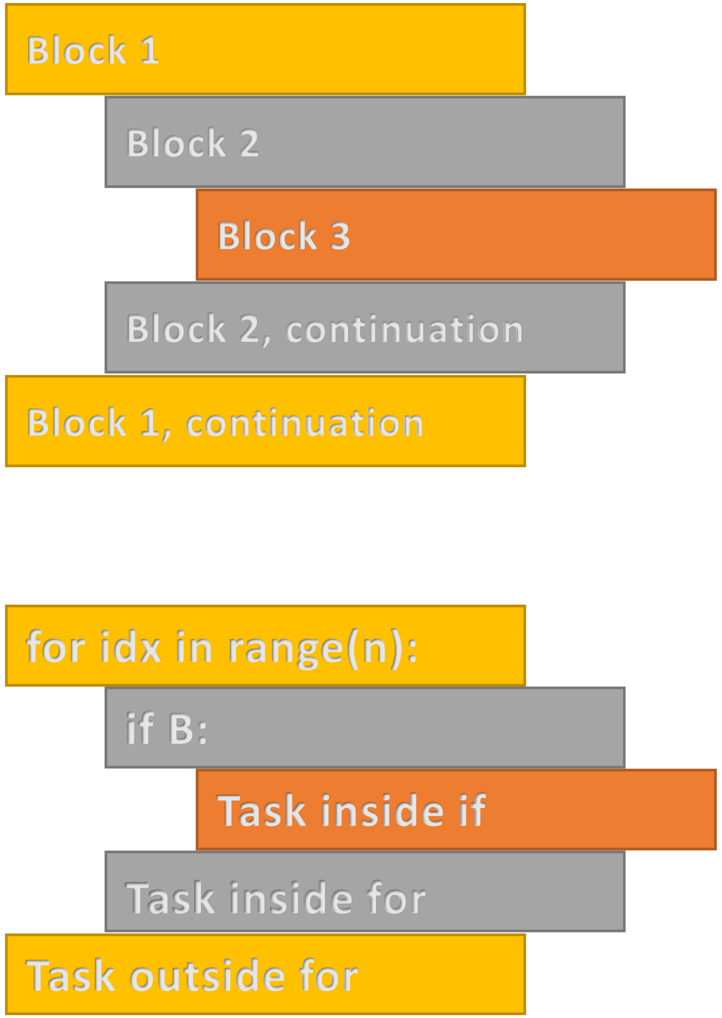

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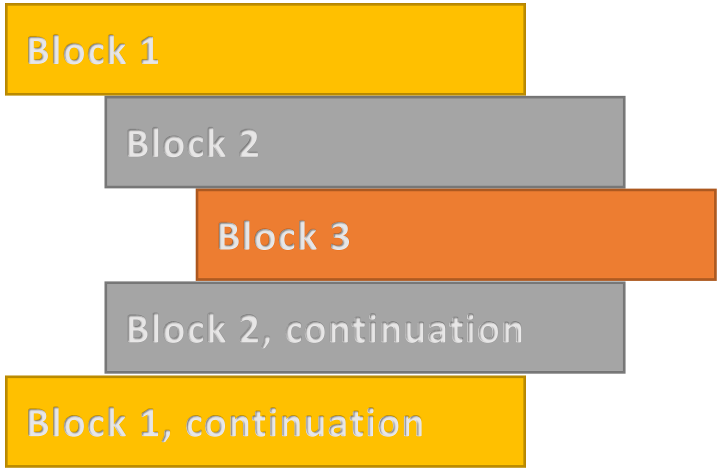

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Linear Algebra review (optional)

Matrices and vectors

Courtesy: Andrew Ng

Matrix: Rectangular array of numbers:

Dimension of matrix: number of rows x number of columns

Matrix Elements (entries of matrix)

$$A = \begin{bmatrix} 1402 & 191 \\ 1371 & 821 \\ 949 & 1437 \\ 147 & 1448 \end{bmatrix}$$

$A_{ij} =$ "i, j entry" in the i^{th} row, j^{th} column.

Vector: An n x 1 matrix.

$$y = \begin{bmatrix} 460 \\ 232 \\ 315 \\ 178 \end{bmatrix}$$

$y_i = i^{th}$ element

1-indexed vs 0-indexed:

$$y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} \qquad y = \begin{bmatrix} y_0 \\ y_1 \\ y_2 \\ y_3 \end{bmatrix}$$

Linear Algebra review (optional)

Addition and scalar multiplication

Matrix Addition

$$\begin{bmatrix} 1 & 0 \\ 2 & 5 \\ 3 & 1 \end{bmatrix} + \begin{bmatrix} 4 & 0.5 \\ 2 & 5 \\ 0 & 1 \end{bmatrix} =$$

$$\begin{bmatrix} 1 & 0 \\ 2 & 5 \\ 3 & 1 \end{bmatrix} + \begin{bmatrix} 4 & 0.5 \\ 2 & 5 \end{bmatrix} =$$

Scalar Multiplication

$$3 \times \begin{bmatrix} 1 & 0 \\ 2 & 5 \\ 3 & 1 \end{bmatrix} =$$

$$\begin{bmatrix} 4 & 0 \\ 6 & 3 \end{bmatrix} / 4 =$$

Combination of Operands

$$3 \times \begin{bmatrix} 1 \\ 4 \\ 2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 5 \end{bmatrix} - \begin{bmatrix} 3 \\ 0 \\ 2 \end{bmatrix} /3$$

Linear Algebra review (optional)

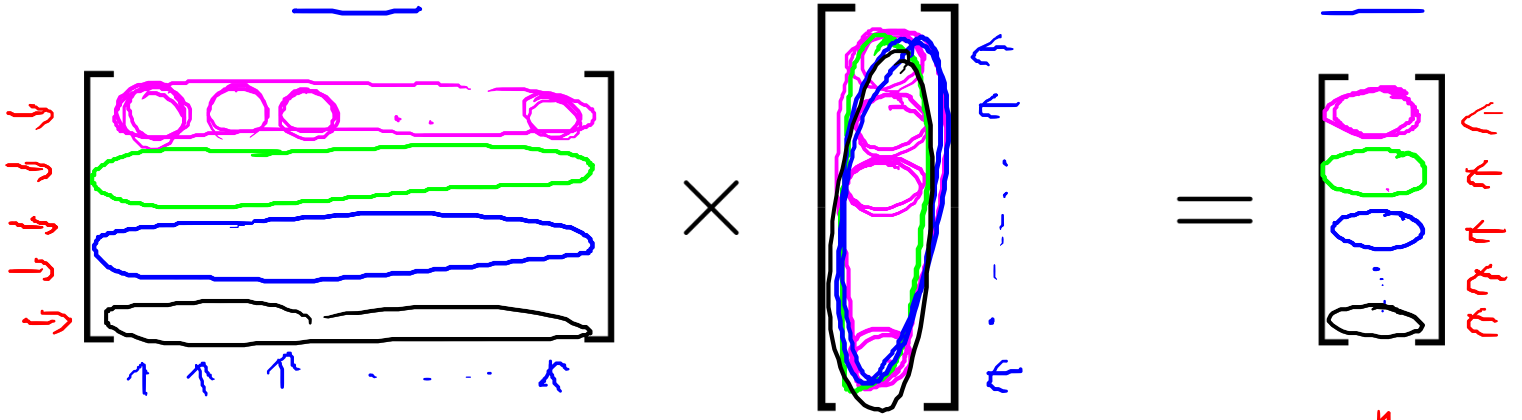
Matrix-vector multiplication

Example

$$\begin{bmatrix} 1 & 3 \\ 4 & 0 \\ 2 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 5 \end{bmatrix} =$$

Details:

$$A \times x = y$$



m x n matrix (m rows, n columns)

n x 1 matrix (n-dimensional vector)

m-dimensional vector

To get y_i, multiply A's i^{th} row with elements of vector x, and add them up.

Example

$$\begin{bmatrix} 1 & 2 & 1 & 5 \\ 0 & 3 & 0 & 4 \\ -1 & -2 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 3 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} \boxed{14} \\ \boxed{13} \\ \boxed{-7} \end{bmatrix} = \begin{bmatrix} 14 \\ 13 \\ -7 \end{bmatrix}$$

$\boxed{3} \times 4$ $\quad$ 4×1 $\quad$ 3×1

$$1 \times 1 + 2 \times 3 + 1 \times 2 + 5 \times 1 = 14$$

$$0 \times 1 + 3 \times 3 + 0 \times 2 + 4 \times 1 = 13$$

$$-1 \times 1 + (-2) \times 3 + 0 \times 2 + 0 \times 1 = -7$$