Introduction to Machine Learning Homework 1 Announcement

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Lastest update: 2023/09/27 13:00

Homework 1

- Deadline: 23:59, Oct. 10th (Tue), 2023
- Coding (50%): Implement linear regression by only using **numpy.**
    - Submit your python file (.py).
    - Answer the questions (by screenshots) in the report (.pdf).
- Handwritten Questions (50%): Answer questions about linear regression.
    - Answer the questions (handwritten, typed, digital, etc.) in the report.

Links

- Questions: Link
- Sample code: Link
- Dataset: Link
- Report template: Link

Environment

- Python version: 3.8 or newer
- Tips
  - We recommend that you use **virtual environments** when implementing your homework assignments.
  - Here are some popular virtual environment management tools:
    - Conda
    - Miniconda
    - virtualenv

Numpy

- Build-in array operations.
- Numpy Tutorial: [Link]

```python
a = np.array([1, 2, 3])
b = np.array([4, 5, 6])
for i in range(a.shape[0]):
    a[i] *= b[i]
print(a)
# a = [ 4 10 18]
```

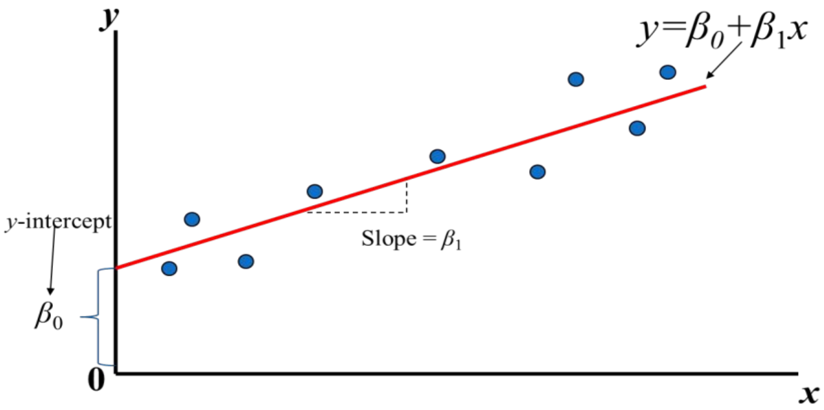
```python
a = np.array([1, 2, 3])
b = np.array([4, 5, 6])
a *= b
print(a)
# a = [ 4 10 18]
```

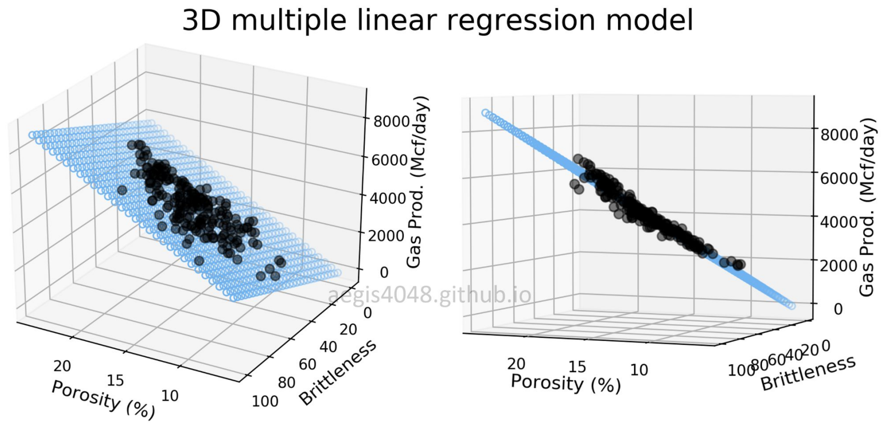
```python
import math
a = np.array([1, 4, 9])
for i in range(a.shape[0]):
    a[i] = math.sqrt(a[i])
print(a)
# a = [1 2 3]
```

```python
a = np.array([1, 4, 9])
a = np.sqrt(a)
print(a)
# a = [1 2 3]
```

Linear Regression

- Find the best value of the weights and the intercept





https://aegis4048.github.io/mutiple_linear_regression_and_visualization_in_python

How to find β0 and β1?

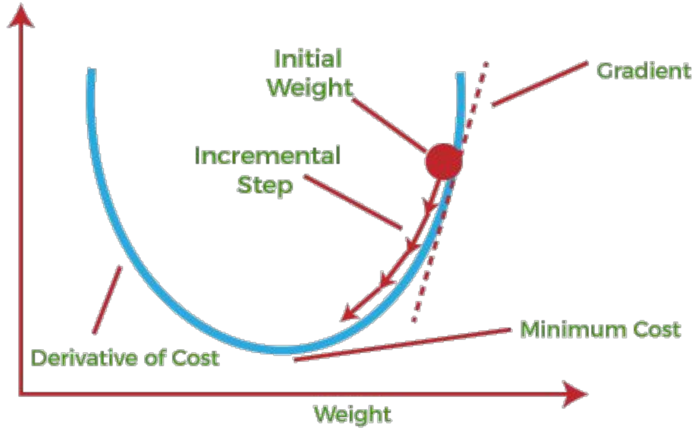
- Closed-form solution

$$\hat{\beta} = (X^T.X)^{-1}X^T.Y$$

- How about a large dataset?
  - high dimensional data
  - huge amount of data

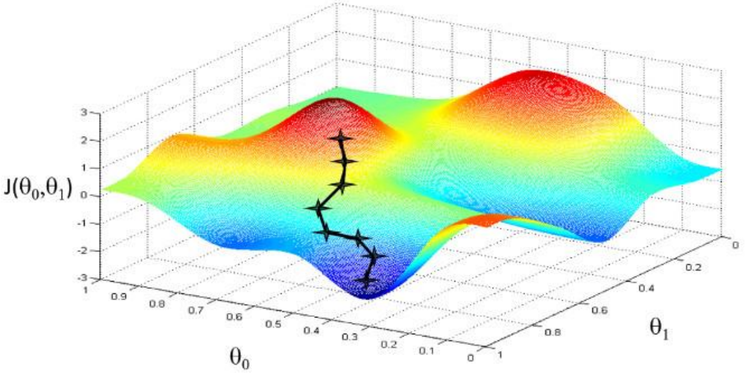
How to find β0 and β1?

- [Gradient Descent]



Gradient Descent

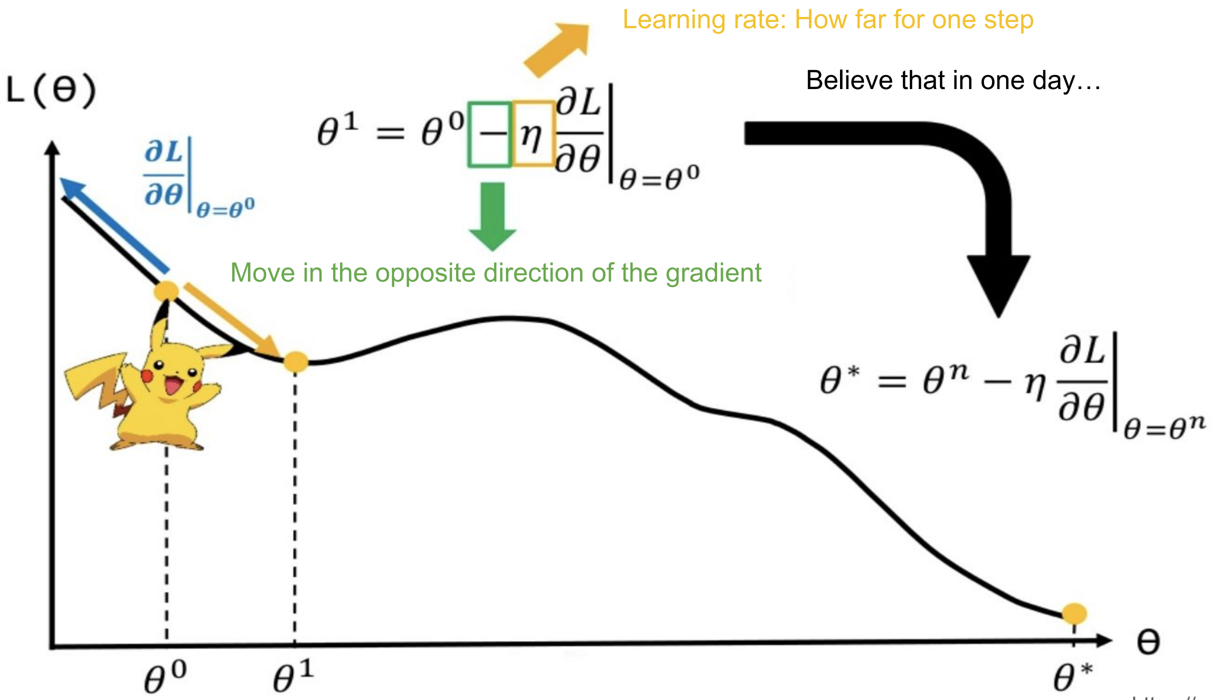
- x-axis and y-axis: the value of weights
- z-axis: the value of loss of the corresponding weights
- Goal: Find the weights that minimize the value of loss



https://www.linkedin.com/pulse/gradient-descent-visualization-python-ibrahim-sobh/

Gradient Descent

- Learning rate



https://www.youtube.com/watch?v=yKKNr-QKz2Q

Dataset

- Student Performance Dataset
- Features
  - Hour Studied
  - Previous Score
  - Sleep Hours
  - Sample Question Papers Practiced
- Target
  - Performance Index (higher means better performance)

Linear Regression – Closed-form Solution

- Requirements
  - Implement Linear Regression by closed-form solution.
- Grading Criteria
  - (10%) Show the weights and intercepts of your linear model.
- Tips
  - There is only one answer, You can check your answer by yourself using third-party libraries (such as scikit-learn).

Linear Regression – Gradient Descent

- Requirements
    - Update your weights and intercept by gradient descent (you can implement mini-batch gradient descent or stochastic gradient descent if you want).
    - Use MSE (Mean Square Error) as your loss function.

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2$$

    - Tune the **learning rate** and **epoch** hyper-parameters (and **batch size** if you implement mini-batch gradient descent) to make your testing MSE loss as closed as the closed-form solution.

Linear Regression – Gradient Descent

- Grading Criteria
  - (10%) Show the weights and intercepts of your linear model.
  - (10%) Plot the learning curve. (x-axis=epoch, y-axis=training loss)
  - (20%) Show your error rate between your closed-form solution and the gradient descent solution.

  error rate: (gradient_descent_loss - closed_form_loss) / closed_form_loss * 100

Points	**error rate**
20	**< 0.5%**
15	**< 1%**
10	**< 3%**
5	**< 5%**
0	**>= 5%**

Linear Regression – Gradient Descent

- Tips
    - Finding suitable hyper-parameters may cost you some time. Be patient!

Code Output

- Do not modify the main function architecture.
- Your code output will look like this:

```
Closed-form Solution
Weights: [redacted], Intercept: [redacted]
Gradient Descent Solution
Weights: [redacted], Intercept: [redacted]
Error Rate: 0.3%
```

Report

- Please follow the report template format.
- Link

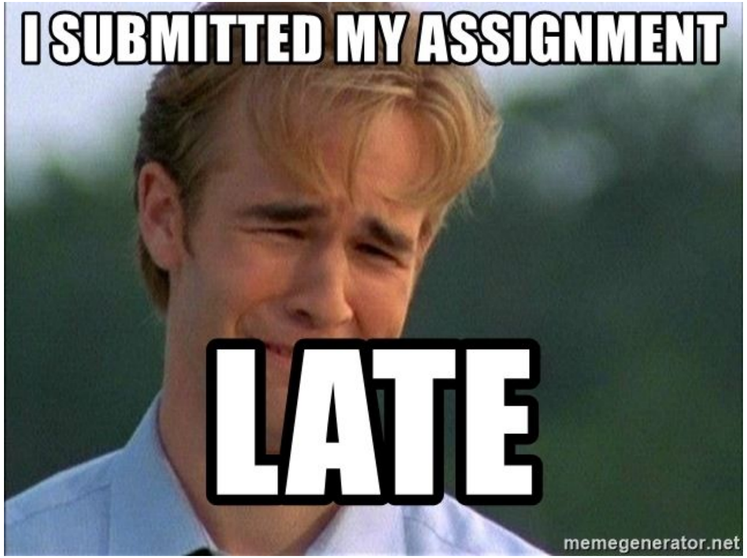
Submission

- Compress your code and report into a **.zip file** and submit it on E3.
- <STUDENT ID>_HW1.zip
  - <STUDENT ID>_HW1.py
  - <STUDENT ID>_HW1.pdf (do not submit .doc, .docx or others format)

```
 zip 0716040.zip 0716040_HW1.py 0716040_HW1.pdf
adding: 0716040_HW1.py (stored 0%)
adding: 0716040_HW1.pdf (deflated 10%)
```

Late policy

- We will deduct a late penalty of 20 points per additional late day.
- For example, If you get 90 points but delay for two days, your will get only 50 points!



FAQs

- Why can’t my gradient descent model converge?
  - Make sure you calculate the gradients correctly.
  - Use smaller learning rate.
- Can I use deep learning frameworks such as TensorFlow, PyTorch or other library such as math?
  - **No!** In HW1, you are request using only Numpy to implement linear regression and gradien descent. You can use matplotlib to plot the results.
- If you have other questions, ask on **E3 forum** first! We will reply as soon as possible.

Have Fun!