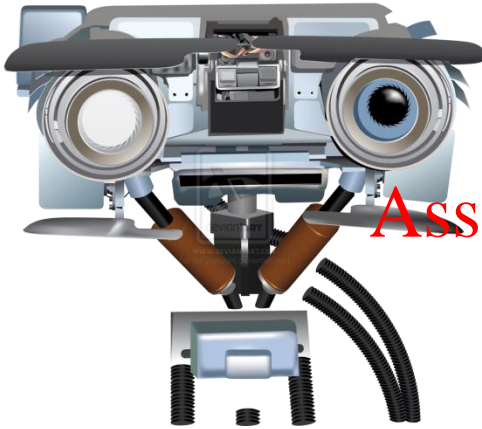


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# Machine Learning Introduction

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<https://powcoder.com>

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Slides adapted from Kate Saenko

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about me

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A.S., MCC



B.S. & PhD, UIUC



At BU 2018-  
Tenure Track 2020-

<https://powcoder.com>

## • Research: Artificial Intelligence

### – Deep Learning for Vision

- Vision and language understanding
- Representation learning, Explainable AI, Efficient Neural Networks

# Assignment Project Exam Help

## Today

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- What is machine learning?
- Supervised learning intro
- Course logistics

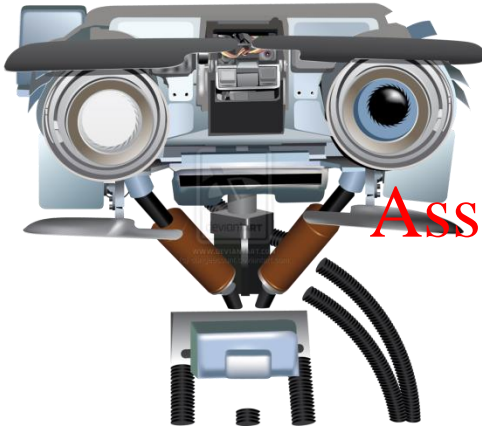
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# Machine Learning:

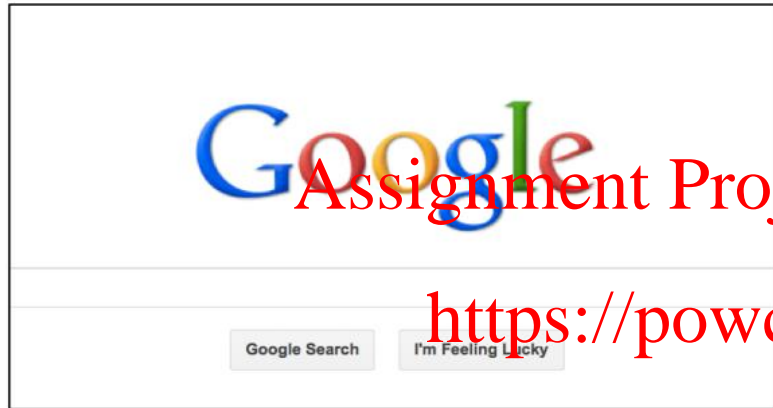
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Why do we need it?

- Help automate boring, hard tasks
- Hard to program computer directly to do the task  
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- Instead, program a computer to **learn** from examples  
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- Often use “big data” examples



# Machine Learning:

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used in lots of ways in our everyday life!



## Other Movies You Might Enjoy



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ML wins Jeopardy!



# Machine Learning in Real Life:

## Smart Cars



- Stanford/Google one of the first to develop self-driving cars
- Cars “see” using many sensors: radar, laser, cameras



# Machine Learning in Real Life: Medical and Scientific Data





# Machine Learning in Real Life: Robotics

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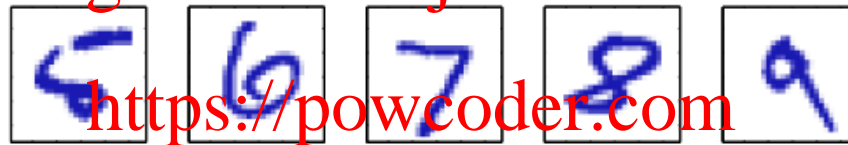
# Machine Learning in Real Life:

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Image Classification

handwritten digits



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<https://powcoder.com>

face tagging on social media



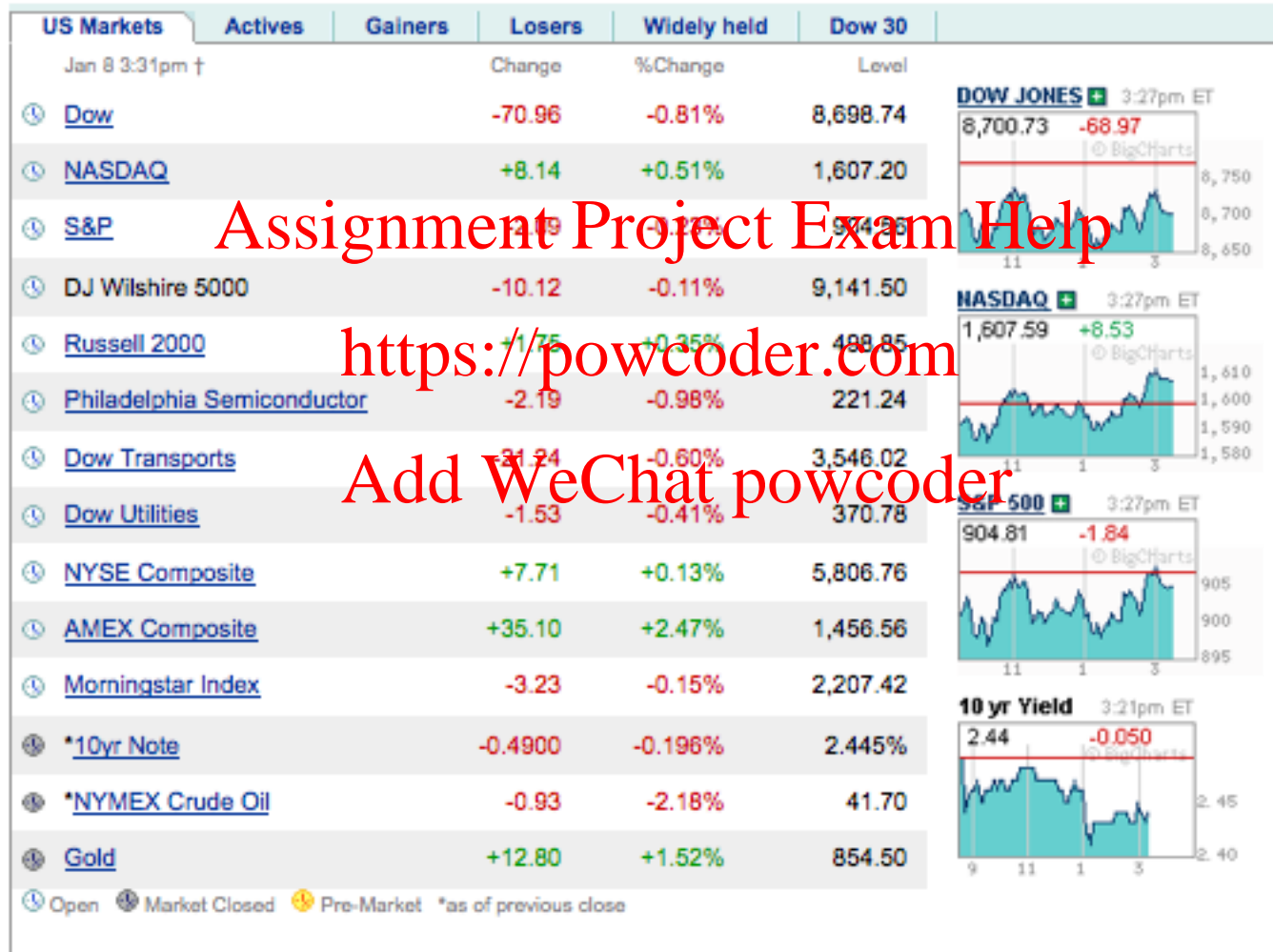
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## Machine Learning in Real Life:

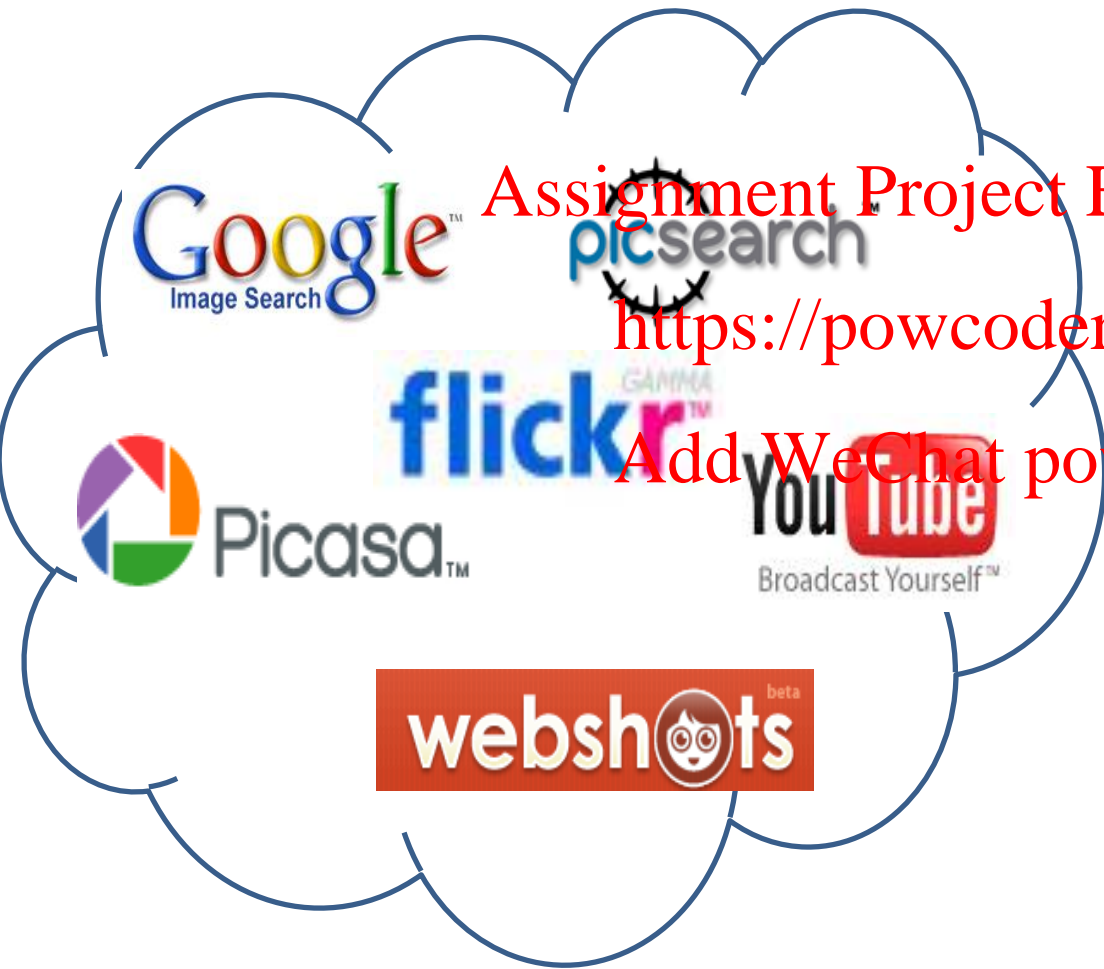
### Add WeChat powcoder

### Computational Finance



# Machine Learning from Big Data

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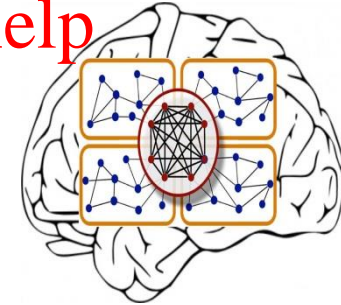


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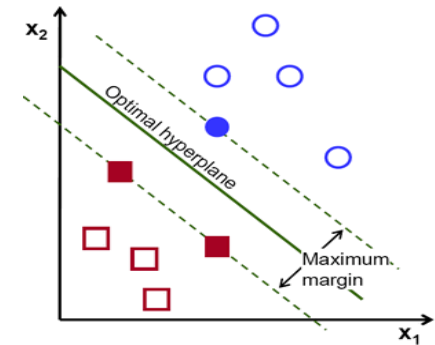
<https://powcoder.com>

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Artificial Neural Network

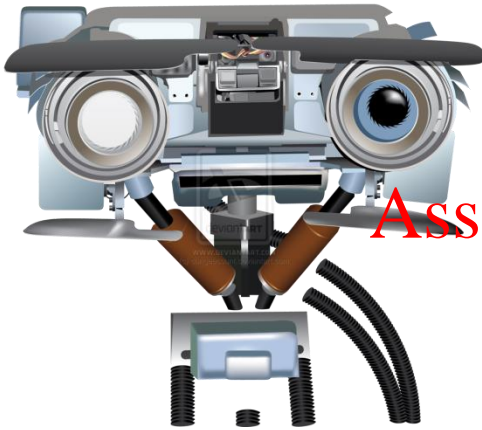


Support Vector Machine



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# Introduction: What is Machine Learning?

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# Assignment Project Exam Help

# Machine Learning

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- Branch of Artificial Intelligence
- *“creating machine algorithms that can learn from data”*

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- Closely related to <https://powcoder.com>

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  - Pattern recognition
  - Data Mining
  - Big Data
  - Deep learning

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## Types of learning

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- Supervised
- Unsupervised
- Reinforcement

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# Supervised Learning

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- Given a **training set** consisting of inputs and outputs, learn to map novel inputs to outputs

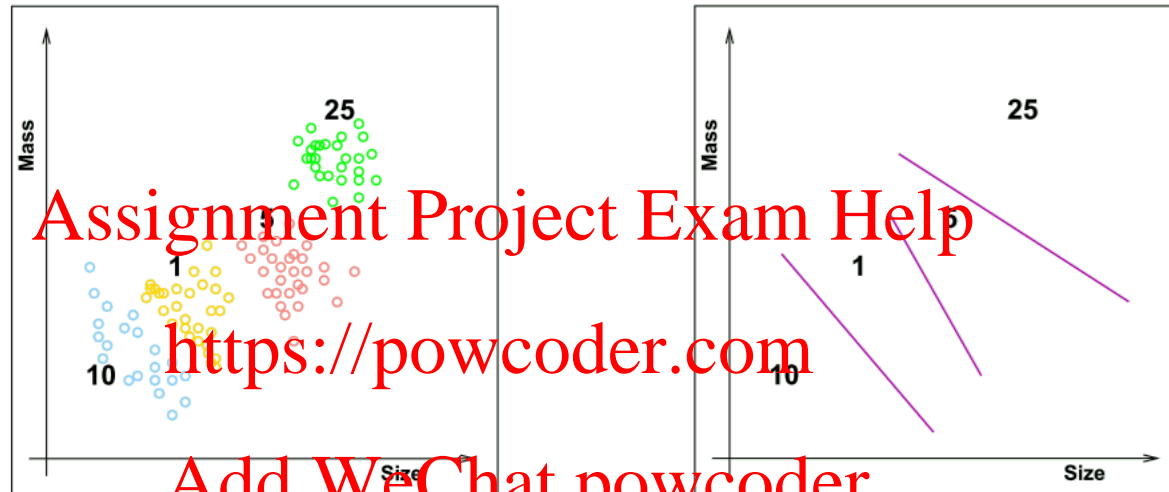
- The novel inputs are called a **test set**

- Outputs can be

- Categorical (**classification**)
- Continuous (**regression**)

# Example of Supervised Learning

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recognize coins

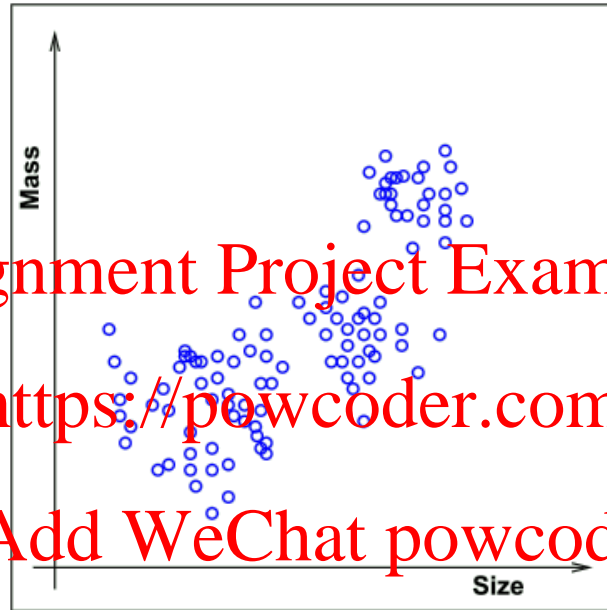


- Given training set consisting of coin denomination (penny, nickel, dime, quarter), mass and size
- Learn to predict denomination
- What is input? Output?

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## Unsupervised Learning

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- Given training set consisting of ~~coin denomination~~ (~~penny, nickel, dime, quarter~~) mass and size
- Learn... something?



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# Reinforcement Learning

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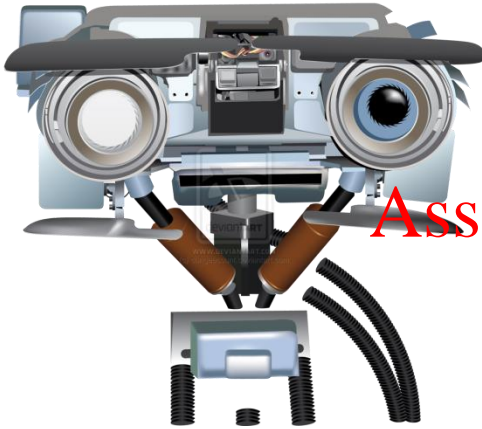
learn to pick up coins



- Given only input, but can take action
- Predict output (action), get a reward for it

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# Supervised Learning

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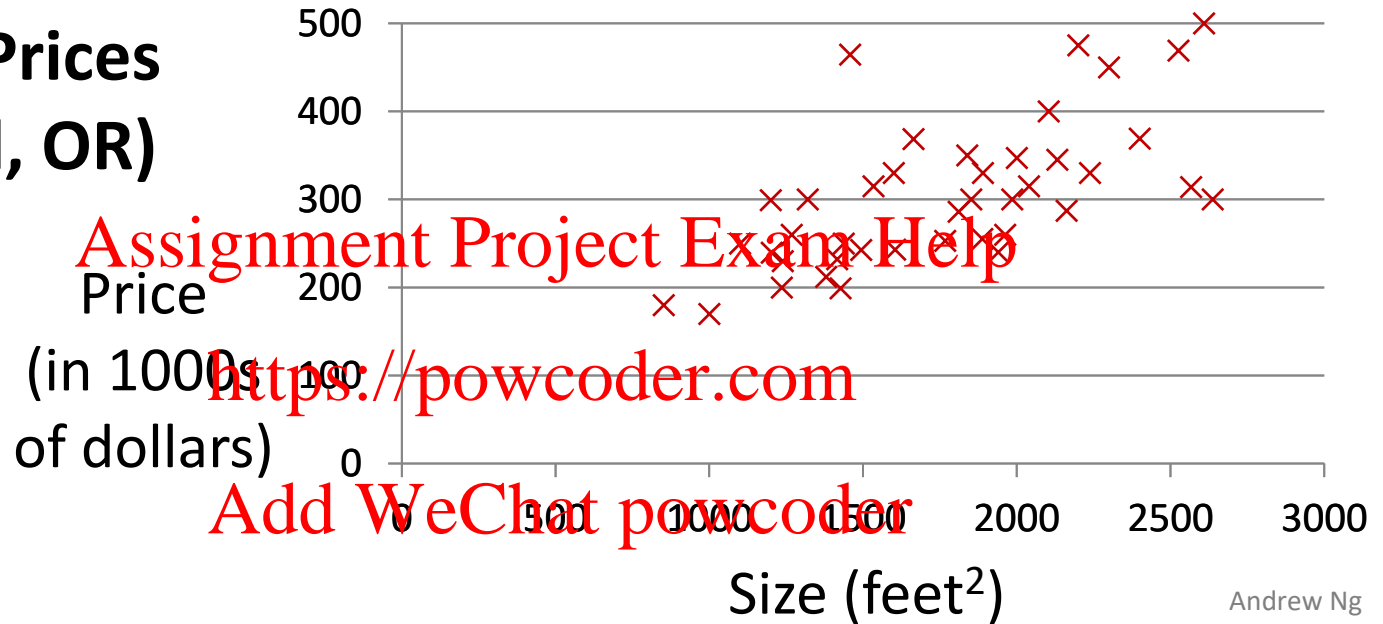
Cost functions

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## Example: house price prediction

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### Housing Prices (Portland, OR)



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# Assignment Project Exam Help

## Supervised Learning

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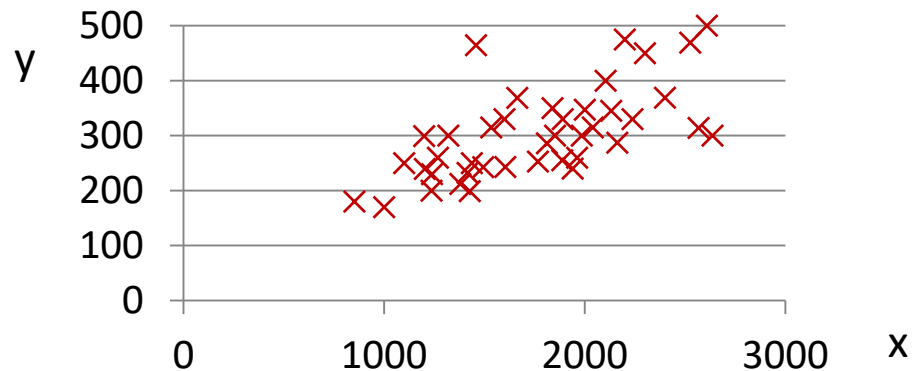
### What should the learner be??

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Want:



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# Assignment Project Exam Help

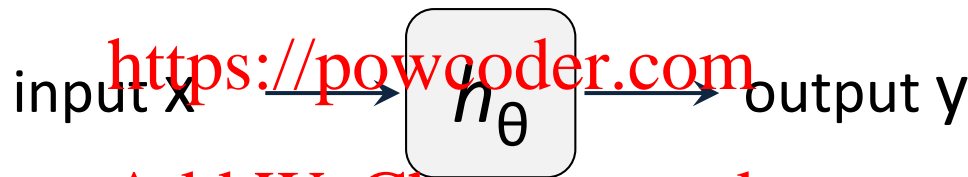
## Hypothesis $h$

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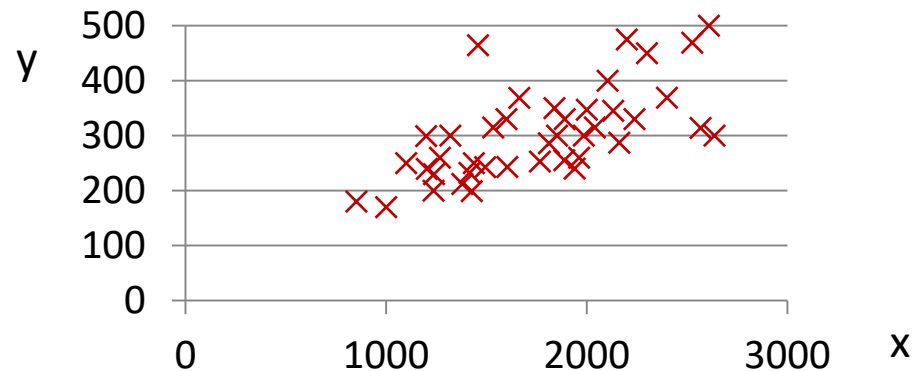
$h$  : a function parametrized by  $\vartheta$

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Want:



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# Assignment Project Exam Help

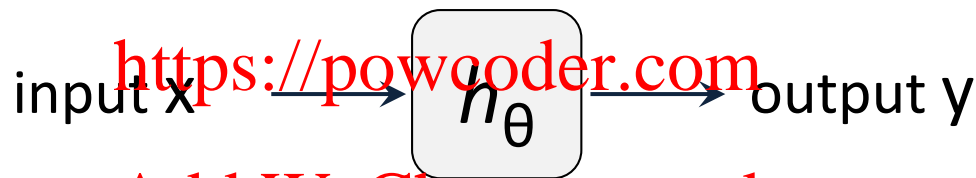
## How to learn $\vartheta$ ?

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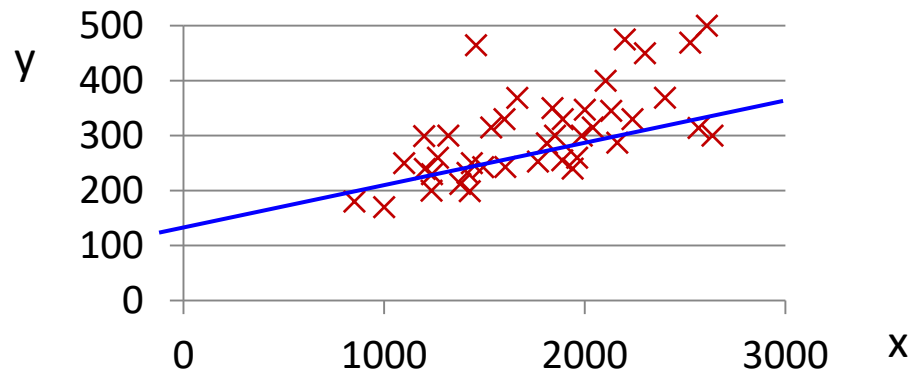
**Given:** Training Set  $\{x^i, y^i\}$  **But what if  $y \neq y^i$  ??**

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**Want:**



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# Assignment Project Exam Help

## Cost function

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Given:

Training Set  $\{x^i, y^i\}$

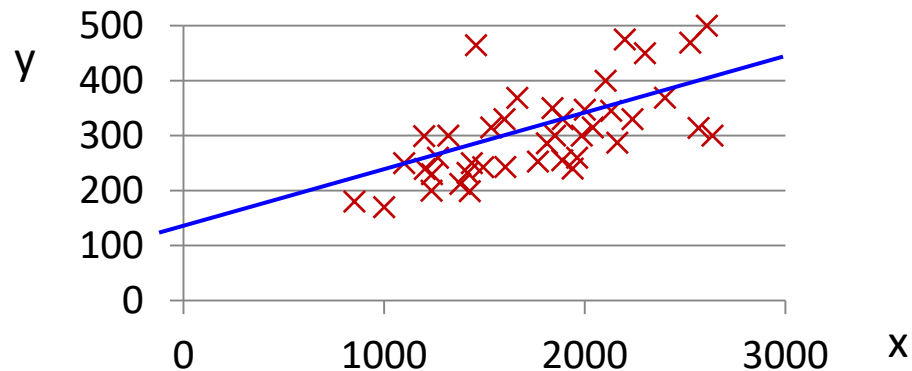
Cost function  $\text{Cost}(y, y^i)$

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**learning == minimizing cost**

<https://powcoder.com>

Want:



# Assignment Project Exam Help

## Supervised Learning

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**Given:** Training Set  $\{x^i, y^i\}$

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learning = minimizing cost

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**Learn  $\theta^*$ :**  $\min_{\theta} \text{Cost}(h_{\theta}(x), y)$

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**Want:** input  $x^i$   $\longrightarrow$   $h_{\theta^*}$   $\longrightarrow$  output  $y$

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## Training set

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Training set:

Size in feet <sup>2</sup> (x)	Price (\$) in 1000's (y)
2104	460
1416	232
1534	315
852	178
...	...

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<https://powcoder.com>

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Notation:

$m$  = Number of training examples

$x^{(i)}$  = “input” variable / features

$y^{(i)}$  = “output” variable / “target” variable

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## What should $h$ be?

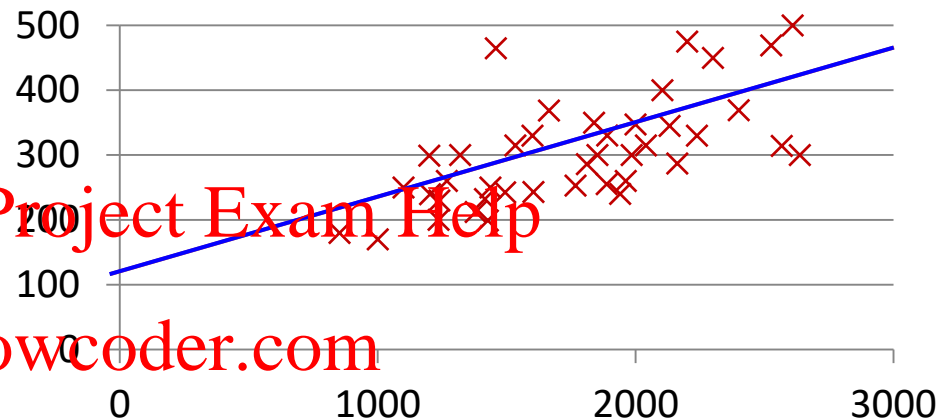
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Linear hypothesis:

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

$\theta_i$ 's: Parameters

<https://powcoder.com>



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$$\min_{\theta} \text{Cost}(h_{\theta}, \{x^i, y^i\})$$

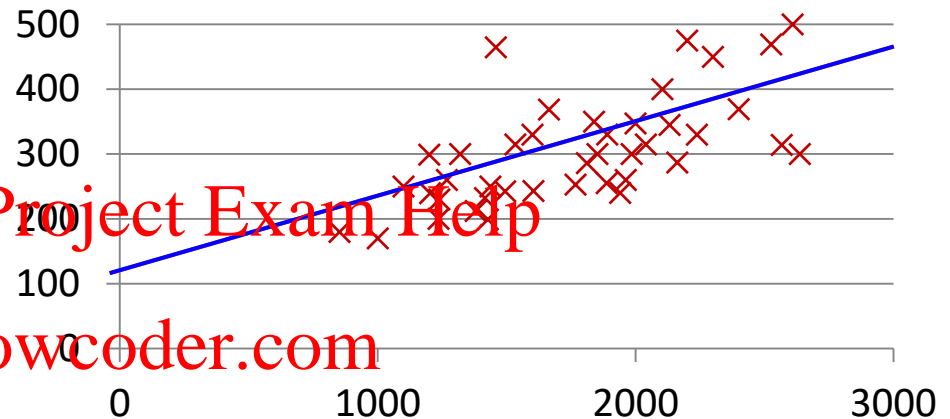


# What's a good cost function for this problem?

Hypothesis:

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

$\theta_i$ 's: Parameters



How about “Sum of squared differences”

Cost Function:

$$J(\theta_0, \theta_1) = \frac{1}{2m} \sum_{i=1}^m (h_{\theta}(x^{(i)}) - y^{(i)})^2$$

Goal: minimize  $J(\theta_0, \theta_1)$   
 $\theta_0, \theta_1$

# Assignment Project Exam Help

## 2-dimensional $\theta$

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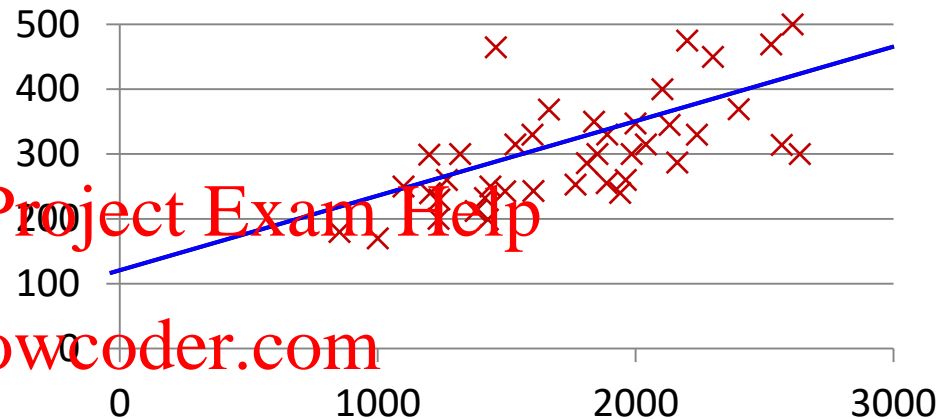
Hypothesis:

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

$\theta_i$ 's:

Parameters

<https://powcoder.com>



Cost Function:

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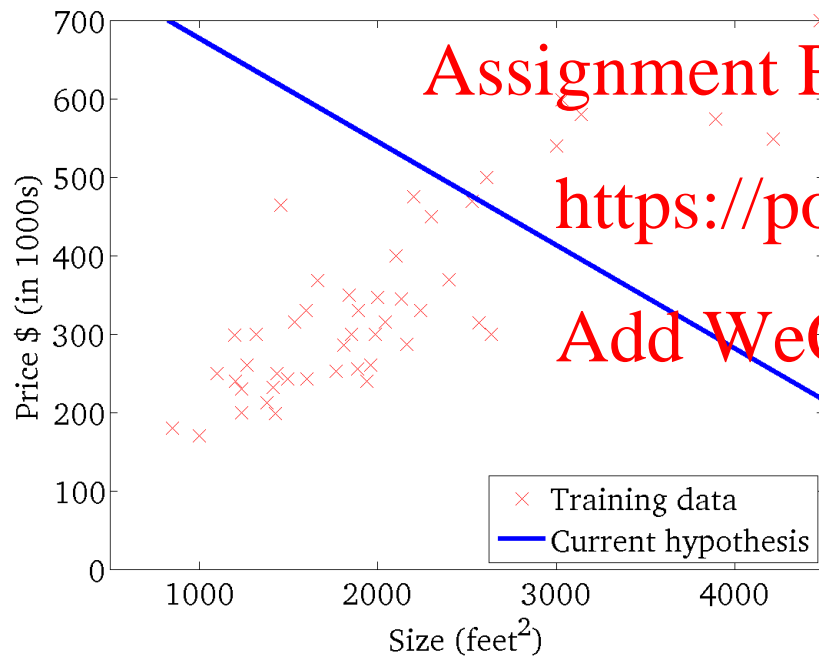
$$J(\theta_0, \theta_1) = \frac{1}{2m} \sum_{i=1}^m (h_{\theta}(x^{(i)}) - y^{(i)})^2$$

# Assignment Project Exam Help

## Plotting cost for 2-dimensional $\theta$

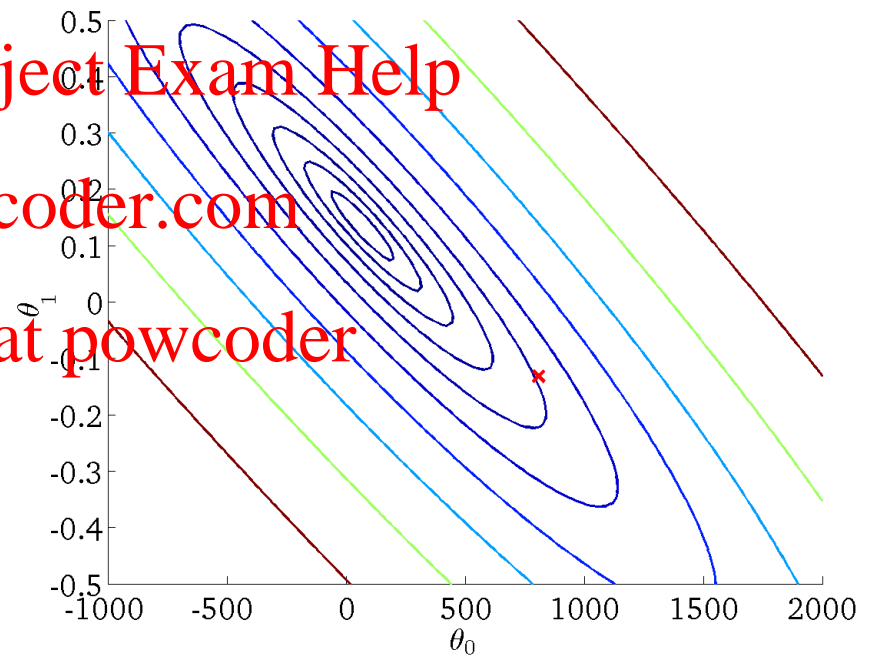
$$h_{\theta}(x)$$

(for fixed  $\theta_0, \theta_1$ , this is a function of  $x$ )



$$J(\theta_0, \theta_1)$$

(function of the parameters  $\theta_0, \theta_1$ )

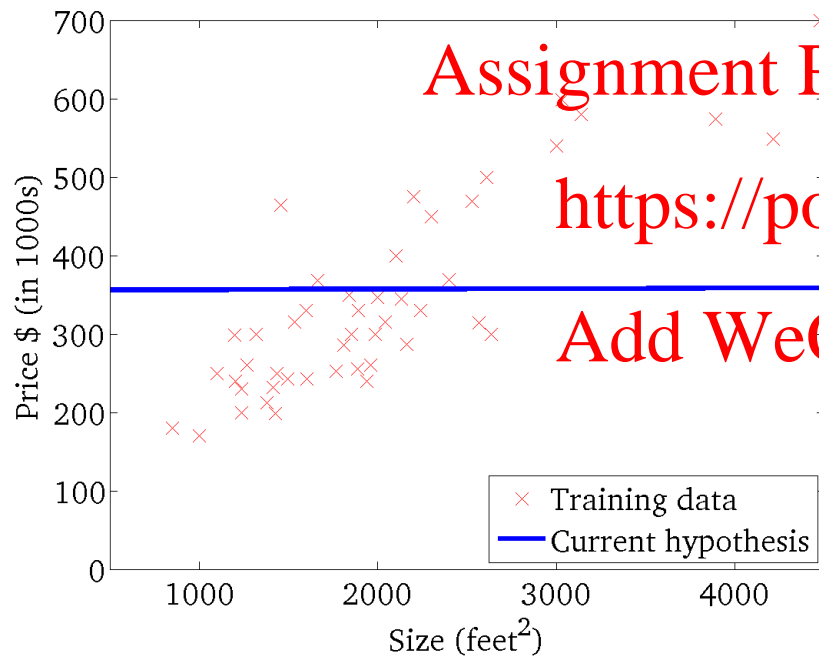


# Assignment Project Exam Help

## Plotting cost for 2-dimensional $\theta$

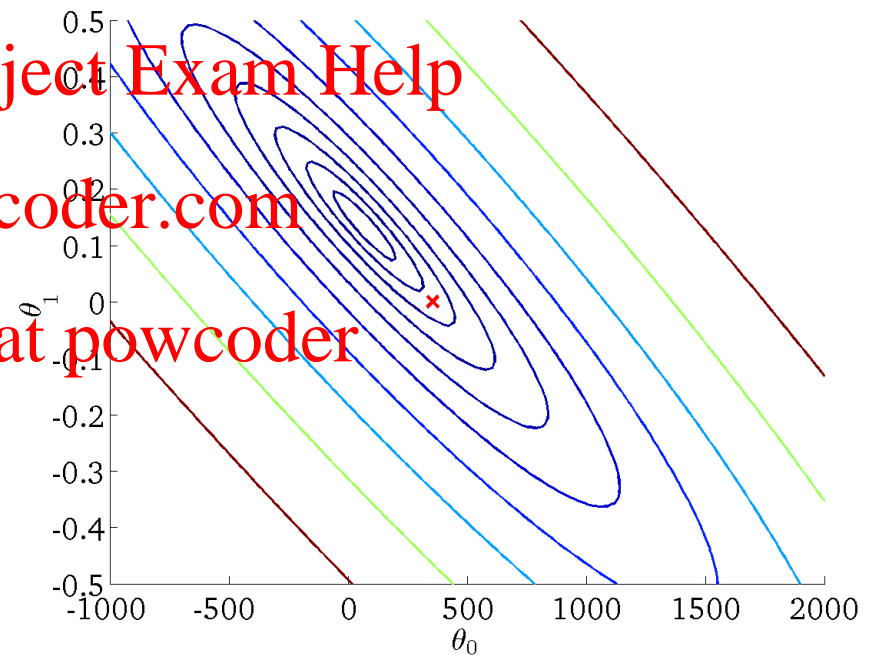
$$h_{\theta}(x)$$

(for fixed  $\theta_0, \theta_1$ , this is a function of  $x$ )



$$J(\theta_0, \theta_1)$$

(function of the parameters  $\theta_0, \theta_1$ )



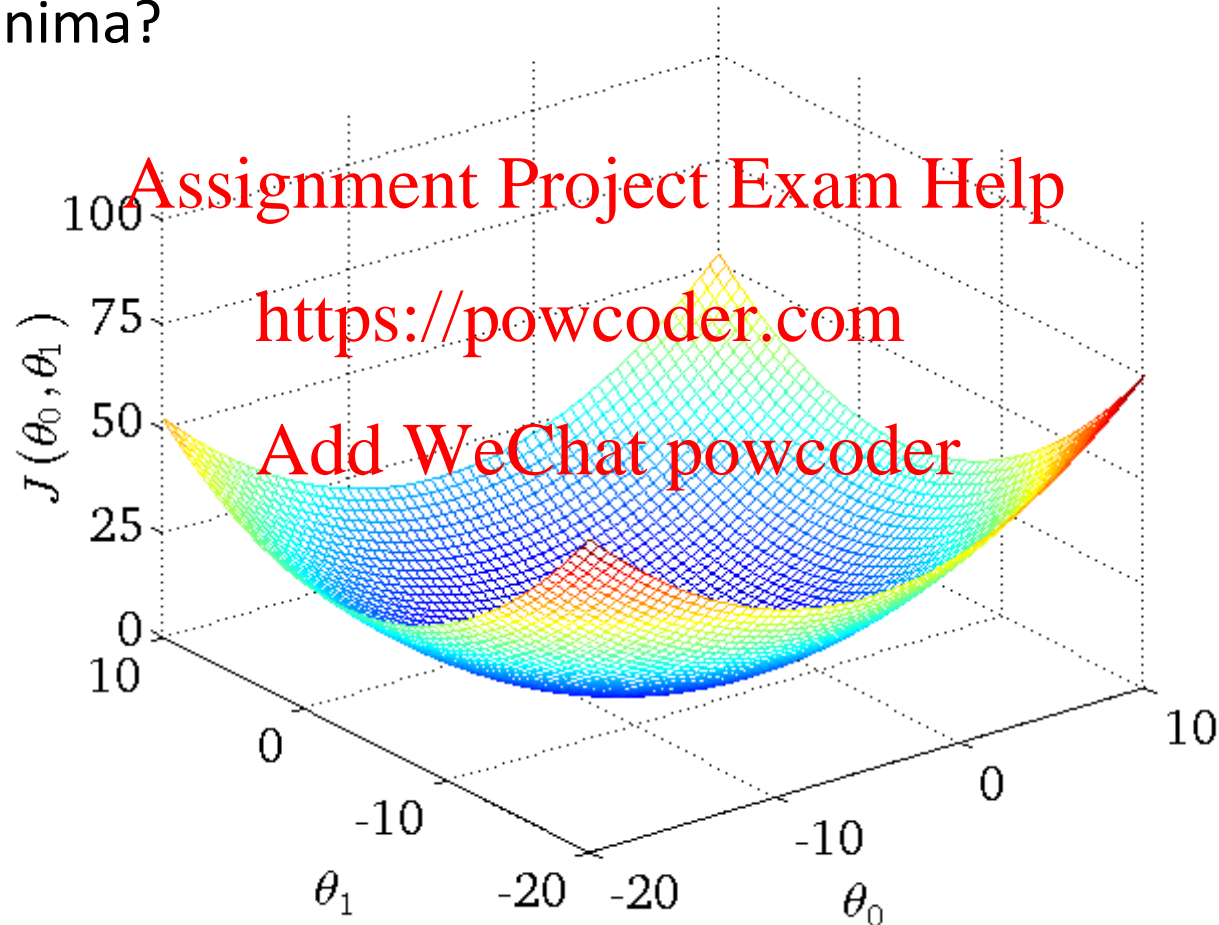
Note, squared loss cost is convex in parameters

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## SSD cost function is convex

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Minima?

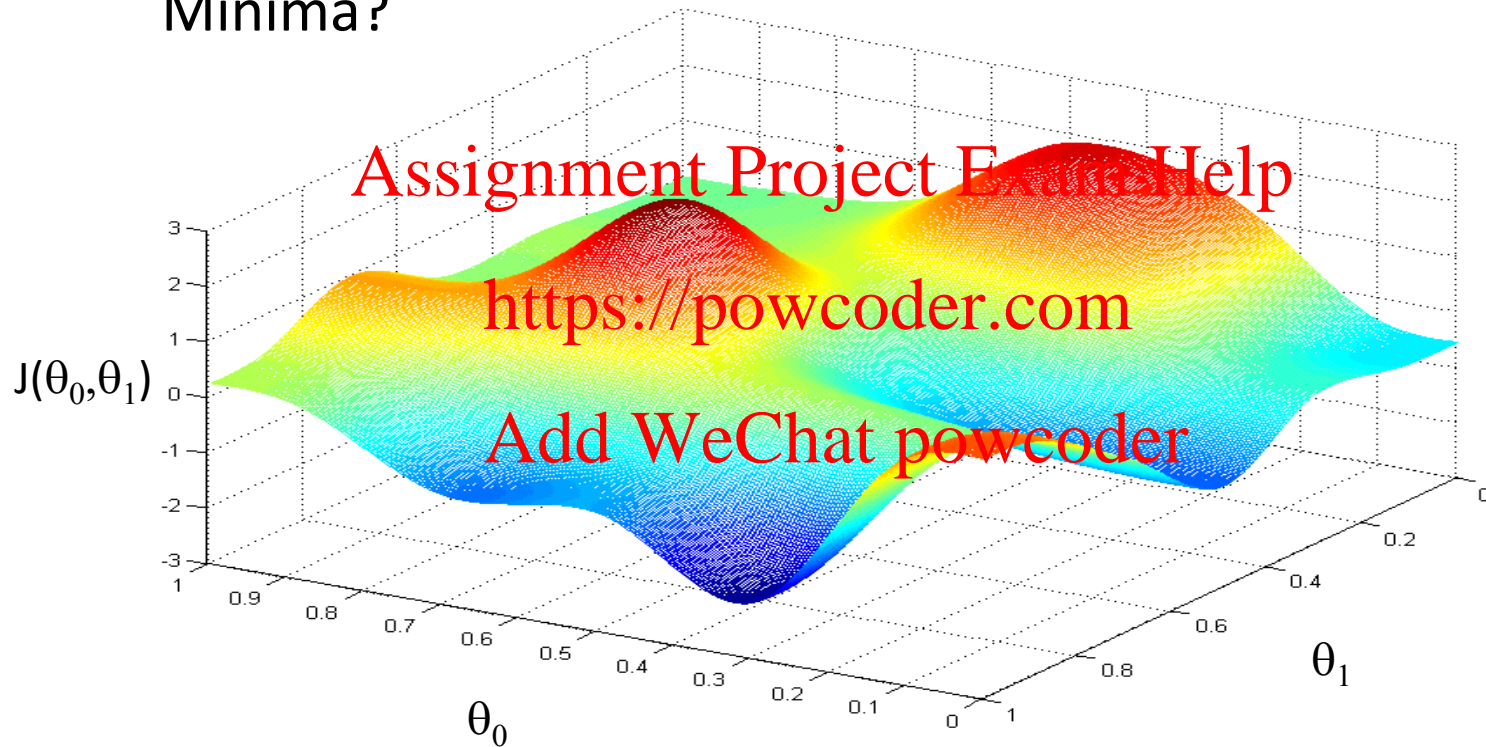


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## Non-convex cost function

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Minima?





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Later

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- How to minimize the SSD cost function
  - Direct solution
  - Indirect solution

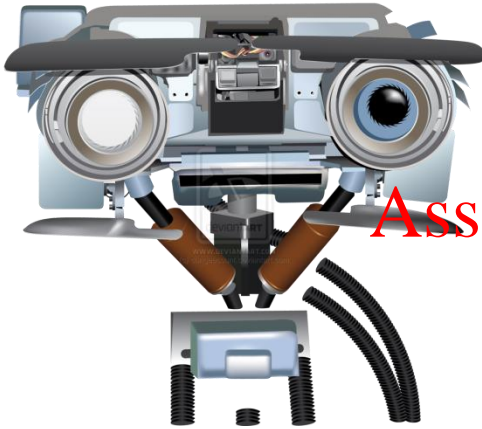
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## Introduction: Course Overview

<https://powcoder.com>

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# Assignment Project Exam Help

## Class website

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- Main class website

<https://piazza.com/bu/fall2020/cs542/home>

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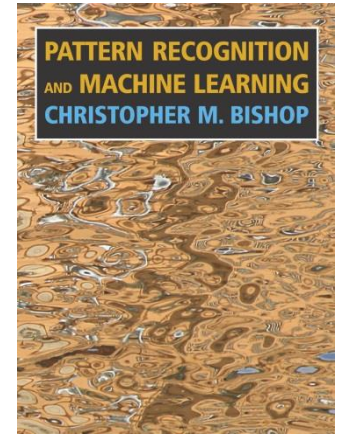
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# Assignment Project Exam Help

## Textbook

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- Required textbook

Bishop, C. M. [Pattern Recognition and Machine Learning](#). Springer. 2007

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- Other suggested textbooks

Duda, R.O., Hart, P.E., and Stork, D.G. [Pattern Classification](#). Wiley-Interscience. 2nd Edition. 2001.

Marsland, S. [Machine Learning: An Algorithmic Perspective](#). CRC Press. 2009. Theodoridis, S. and Koutroumbas, K. [Pattern Recognition. Edition 4](#). Academic Press, 2008.

Russell, S. and Norvig, N. [Artificial Intelligence: A Modern Approach](#). Prentice Hall Series in Artificial Intelligence. 2003.

Bishop, C. M. [Neural Networks for Pattern Recognition](#). Oxford University Press. 1995.

Hastie, T., Tibshirani, R. and Friedman, J. [The Elements of Statistical Learning](#). Springer. 2001.

Koller, D. and Friedman, N. [Probabilistic Graphical Models](#). MIT Press. 2009.

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## Problem Sets

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- Weekly problems sets
  - Python coding problems
  - Written math problems
  - Important to prepare you for the exams!
- Self-graded
  - you will submit code, answers, and your own grade
  - we will randomly check to verify

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# Assignment Project Exam Help

## Class Challenge



Individual end-of-term project

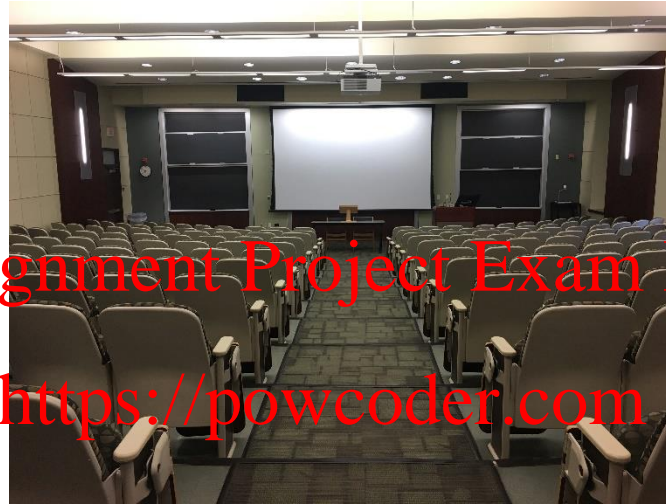
- Based on a real-world problem, hosted as a Kaggle-like challenge for our class
- Goal is to design a machine learning approach and apply it to the problem

- Deliverables: github

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## Lecture Class Rotations

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CIS 522 - 32 student capacity

- As of yesterday, 63 students have indicated they might attend in-person (or have not responded to the poll)
- Check Piazza for rotations before coming to class as they may shift during the semester
- Wipe down chairs before sitting down
- Wear a mask and be prepared to show your badge



# Assignment Project Exam Help

## Discussion/Lab Rotations

- Check Piazza for rotations before coming to class as they may shift during the semester
- As of yesterday, A3 and A4 require rotations, A2 and A5 don't need rotations (but may change, email me if you would like to change sections)
- Only attend the discussion section that you are registered for (especially if you want to attend in-person)
- Wipe down chairs before sitting down
- Wear a mask and be prepared to show your badge

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Next Class

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## Preliminaries

*review of expected mathematical skills for the course*

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- Reference reading on matrix calculus and linear algebra can be found [here](#)
- [Matrix derivatives cheat sheet](#)
- also see <http://www.matrixcalculus.org/>

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## Questions

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