

## SUPERVISED LEARNING

- \* Regression Problem
- Classification Problem

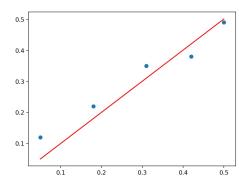
# UNSUPERVISED LEARNING

- Clustering Problem
- \* Cocktail Party Problem



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# TOPICS (W1)

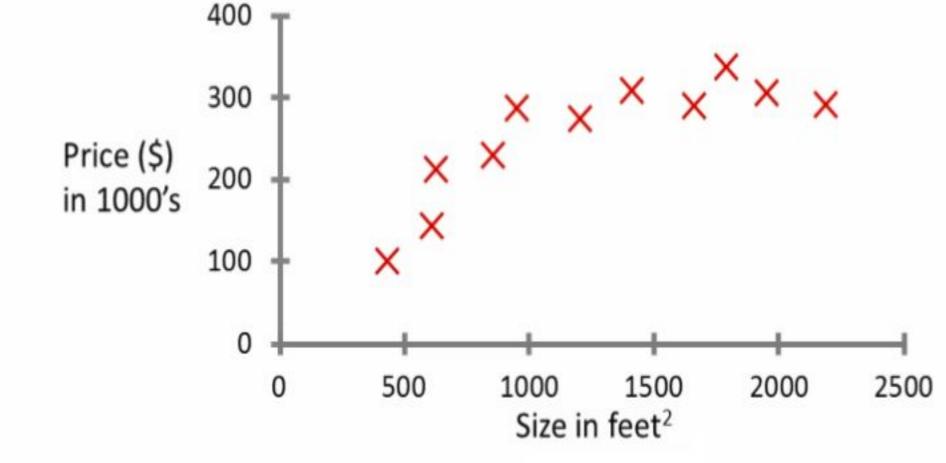
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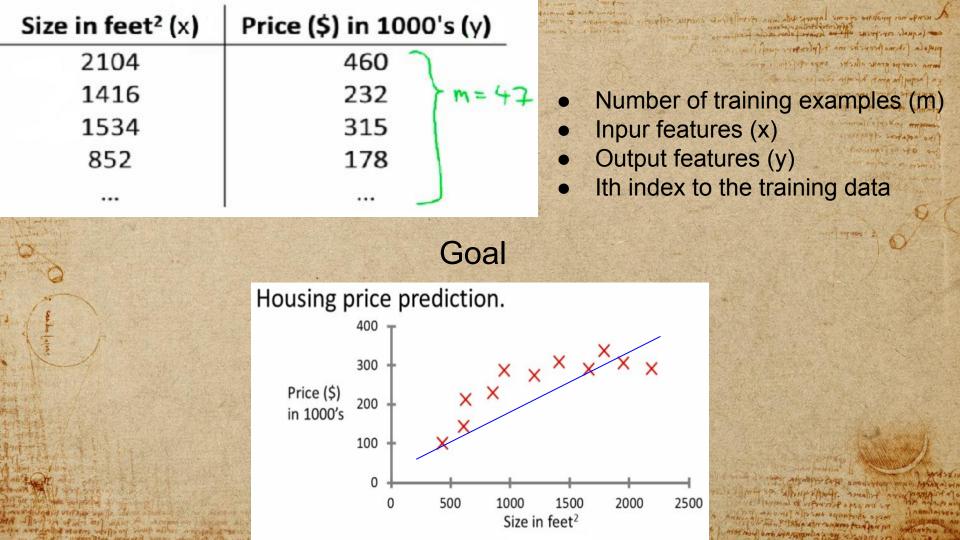
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- Linear Regression (Univariate)
  - \* Model Representation
  - \* Cost function
  - \* Gradient descent
  - Linear Algebra
    - \* Matrices and Vectors.
    - \* Matrix & Vector Addition and Multiplication
    - \* Matrix Inverse and Transpose

# Housing price prediction.



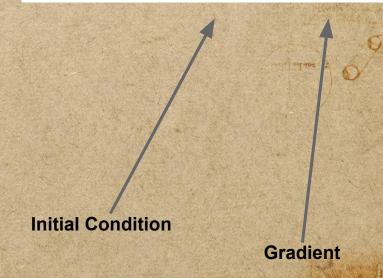


# MODEL REPRESENTATION (UNIVARIATE)

- Define a hypothesis (h)
- Whereas:
  - Theta (sub-0) is the zero condition
  - Theta (sub-0) is the gradient
- x is some arbitrary variable
- The function uses parameters learned by the system to give a prediction

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

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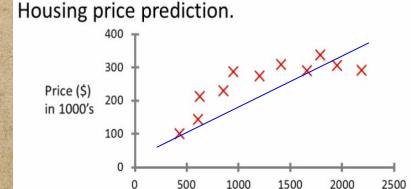


# REFINED OBJECTIVE

- Using different values for Theta, define a cost function to best fit the line to the data
- Generate parameters such that:
  - The hypothesis (h) is very close to the actual (y) value
- Minimize the squared difference between h(x) and y for every sample

#### **More Formally**

$$\frac{1}{2m} \sum_{i=1}^{m} \left( h_{\hat{\theta}}(x^{i}) - y^{i} \right)^{2}$$



Size in feet<sup>2</sup>

#### COST FUNCTION

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Minimize the cost function for all the training data

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$$\int \left(\theta_{a}/\theta_{i}\right) = \frac{1}{2m} \sum_{i=1}^{m} \left(h_{a}(x^{i}) - y^{i}\right)^{2}$$

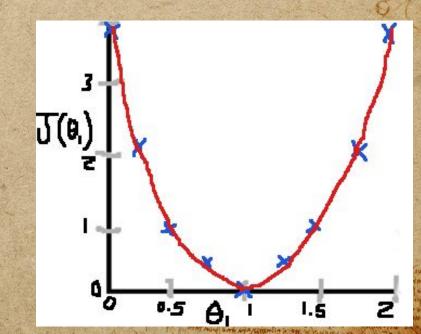
### **EXAMPLE 1**

- Minimize the cost function
  - Assume theta (sub-0) = 0

$$h_{\theta}(x) = \frac{1}{2} + \frac{1}{2}x$$
 $\theta_{i} = 0$ 

$$h_{\theta}(x) = \frac{1}{2} \times \frac{1}{2} \left( h_{\theta}(x^{i}) - y^{i} \right)^{2}$$

$$\theta_{i} \text{ is the gradient}$$



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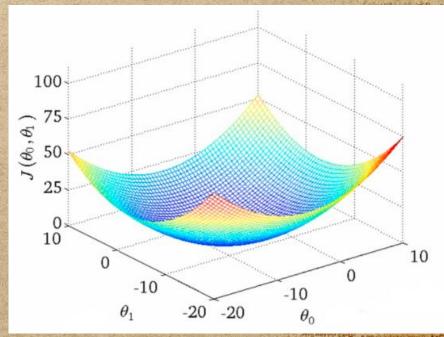
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#### **EXAMPLE 2**

- Minimize the cost function
  - Assume theta (sub-0) = 0

$$\overline{\int}(\theta_{a}/\theta_{i}) = \frac{1}{2m} \sum_{i=1}^{m} \left(h_{\theta}(x^{i}) - y^{i}\right)^{2}$$



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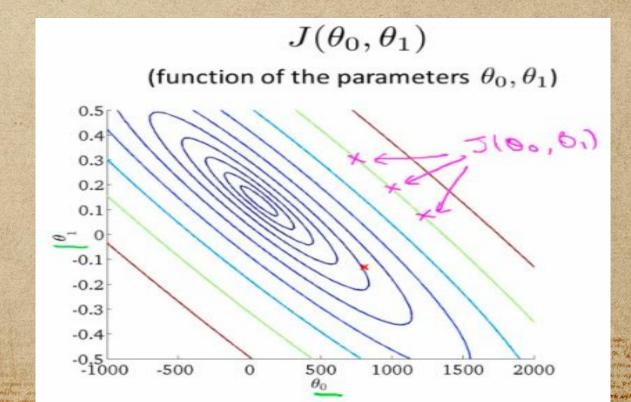
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# **EXAMPLE 2 (continued)**

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Use a contour plot to visualize the cost function



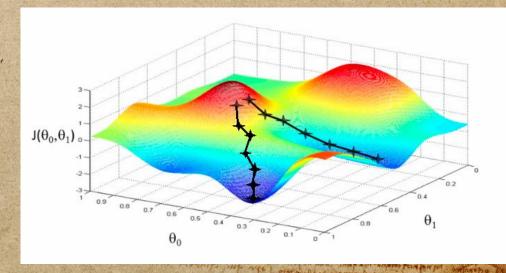
## GRADIENT DESCENT

Used to minimize the cost function with N parameters given by:

$$J(\theta_{o},\theta_{i},...,\theta_{n})$$

#### Algorithm

- Make an initial guess
- Change the parameters in order to reduce the cost function at each step
- Repeat until convergence at a local minimum



# GRADIENT DESCENT (CONTINUED)

#### More Formally: (repeat the following step)

$$\Theta_{j} = \Theta_{j} - \alpha \frac{\partial}{\partial \theta_{j}} J(\Theta_{\bullet}, A)$$
(for  $j = 0$  and  $j = 1$ )

Simultaneously update the parameters

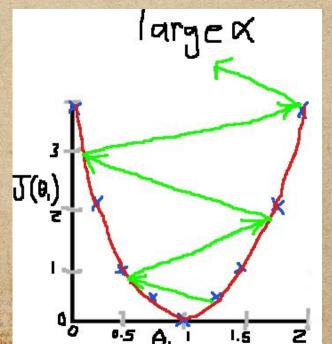
- α (alpha) is the learning rate
  - Controls the step size

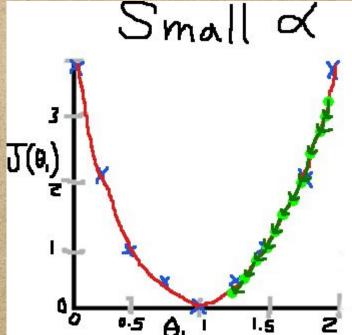
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# Choosing an Optimal Learning Rate Consider J (5,)





# Derivation of the Cost Function

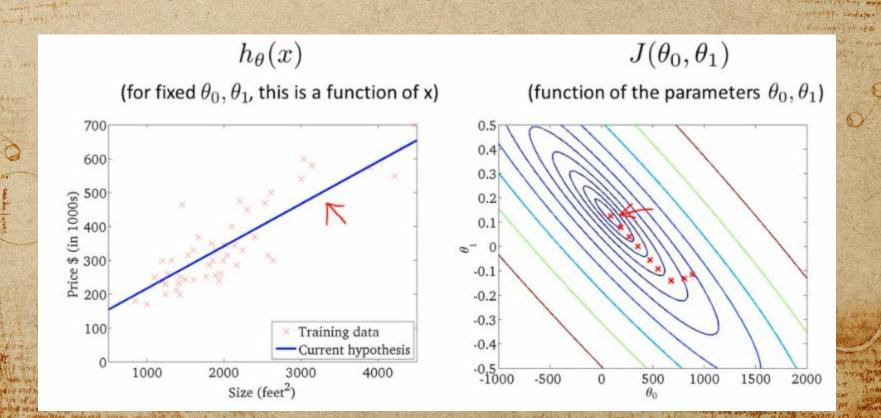
$$\frac{\partial}{\partial \theta_{i}} J(\theta_{0}, \theta_{i}) = \frac{\partial}{\partial \theta_{i}} \cdot \frac{1}{2m} \sum_{i=1}^{m} (h_{\theta}(x^{i}) - y^{i})^{2}$$

$$= \frac{\partial}{\partial \theta_{i}} \frac{1}{2m} \sum_{i=1}^{m} (\theta_{0} + \theta_{i} x^{i} - y^{i})^{2}$$

$$= \left(\frac{\partial}{\partial \theta_{i}} h_{\theta}(x^{i})\right) \frac{1}{m} \sum_{i=1}^{m} (h_{\theta}(x^{i}) - y^{i})$$

# Derivation of the Cost Function (continued)

The linear regression function is always a convex function with one minimum



## Fun Fact

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Batch Gradient Descent: Iterating over all the training data at every step.

Numerical solutions exist (**Normal Equations**), but don't scale as well.

# SYSTEM OF LINEAR EQUATIONS

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 $y = 2x_1 - 2x_3$   
 $y = x_2 + x_3$ 

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#### System of Equations

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#### Coefficient Matrix

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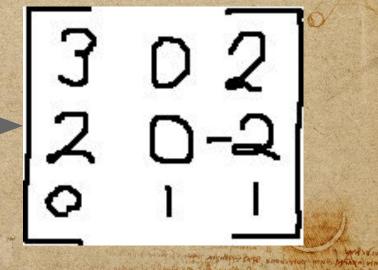
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#### **Properties:**

- 1s along the diagonal
- Same number of rows and columns

#### Facts:

- It is the optimal end form of row reduced augment matrices
- It is used as one way of calculating a matrix's inverse

#### Identity Matrix (3x3)

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System of Equations

Augmented Matrix

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$$3x_1 + 2x_3 = 0$$
  
 $2x_1 - 2x_3 = 0$   
 $x_2 + x_3 = 0$ 

#### **Matrix Operations**

- Swap 2 rows
- Multiple a row by a scalar
- Add 2 rows together to re-write that row

#### **Matrix Operations to RREF:**

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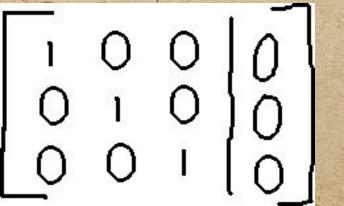
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- $r1 + r2 \rightarrow r1$
- $(1/5) * r1 \rightarrow r1$
- $(-2) * r1 + r2 \rightarrow r2$
- $(-1/2)*r2 \rightarrow r2$
- r1 ←→ r3
- $(-1) * r3 + r2 \rightarrow r2$



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# VECTORS

#### **EXAMPLES**

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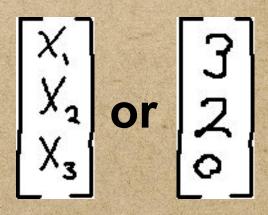
#### **Properties:**

N x 1 matrix

#### Facts:

 Can be used to express a system of linear equations

$$AX = \underline{b}$$



3x1 3x1

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#### Matrix Operations to RREF:

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- $r1 + r2 \rightarrow r1$
- $(1/5) * r1 \rightarrow r1$
- $(-2) * r1 + r2 \rightarrow r2$
- $(-1/2)*r2 \rightarrow r2$
- $r1 \longleftrightarrow r3$
- $(-1) * r3 + r2 \rightarrow r2$

#### APPLICATION

House sizes:

$$\begin{cases}
\frac{2104}{1416} \\
\frac{1534}{852}
\end{cases}$$

X

Have 3 competing hypotheses:

$$1(h_{\theta}(x) = -40 + 0.25x$$

2. 
$$h_{\theta}(x) = 200 + 0.1x$$

3. 
$$h_{\theta}(x) = -150 + 0.4$$

Matrix

$$\begin{bmatrix} 1 & 2104 \\ 1 & 1416 \\ 1 & \overline{1534} \\ 1 & 852 \end{bmatrix}$$

Matrix

$$\begin{bmatrix} -150 \\ 0.4 \end{bmatrix} =$$

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#### SOURCES

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- http://www.holehouse.org/mlclass/01 02 Introduction regression analysis and gr.html
- https://www.mathsisfun.com/algebra/matrix-inverse-row-operations-gauss-jordann.html
- cs.oswego.edu/~kzeller