

Entropy of a dataset with C classes

$$H(S) = - \sum_{i=1}^C p_i \log_2 p_i$$

Entropy of the dataset after splitting from feature x

$$H(S|x) = \sum_{c \in x} P(c) \cdot H(c)$$

Information gain of splitting from feature x

$$IG(S, x) = H(S) - H(S|x)$$

Gini impurity

$$G = 1 - \sum_{i=1}^C P(i)^2$$

$$\text{or } G = \sum_{i=1}^C P(i) (1 - P(i))$$

Linear regression

Hypothesis (Final hypothesis)

$$g(x) = \theta^0 + \theta^1 x$$

Error

$$\text{Error} = [h(x) - y]^2$$

Cost function

$$J(\theta^0, \theta^1) = \frac{1}{2N} \sum_{i=1}^N (h(x_i) - y_i)^2$$

Gradient Descent

1. Repeat

$$2. \theta^j = \theta^j - \alpha \frac{dJ(\theta^0, \theta^1)}{d\theta^j}$$

3. Until converge

Batch gradient descent

1. Repeat

$$2. \theta_0 = \theta_0 - \frac{\alpha}{N} \sum_{i=1}^N (h(x_i) - y_i)$$

$$3. \theta_1 = \theta_1 - \frac{\alpha}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i$$

4. Until converge

$$h(x) = \theta^0 + \theta^1 x$$

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Multivariate linear regression

Hypothesis function

$$g(x) = \theta^0 x^0 + \theta^1 x^1 + \theta^2 x^2 + \dots + \theta^d x^d$$

where $x^0 = 1$

$$g(x) = \theta^T x \Rightarrow \theta = \begin{bmatrix} \theta^0 \\ \theta^1 \\ \vdots \\ \theta^d \end{bmatrix} \quad x = \begin{bmatrix} x^0 \\ x^1 \\ \vdots \\ x^d \end{bmatrix}$$

Cost function

$$J(\theta^0, \theta^1, \dots, \theta^d) = \frac{1}{2N} \sum_{i=1}^N (\theta^T x_i - y_i)^2$$

Gradient descent

1. Repeat

$$2. \theta^0 = \theta^0 - \frac{\alpha}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^0$$

$$3. \theta^1 = \theta^1 - \frac{\alpha}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^1$$

$$4. \theta^d = \theta^d - \frac{\alpha}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^d$$

5. Until converge.

Normal equations

Normal equations

Cost function

$$J(\theta^0, \theta^1, \dots, \theta^d) = \frac{1}{2N} \|x\theta - y\|^2$$

Compute θ

$$\theta = (X^T X)^{-1} X^T y$$

$$X = \begin{bmatrix} x_1^T & \dots & x_n^T \\ \vdots & & \vdots \end{bmatrix} \quad \theta = \begin{bmatrix} \theta^1 \\ \theta^2 \\ \vdots \\ \theta^d \end{bmatrix}$$

$$y = [y_1, y_2, \dots, y_n]$$

Logistic regression

$$k(x) = h(g(x))$$

↑ Classification hypothesis ↑ Restrictive function/logistic function ↑ Linear regression hypothesis.

$$g(x) = \theta^T x$$

Logistic function/Sigmoid function

$$g_0(x) = \frac{1}{1 + e^{-\theta^T x}}$$

Cost function

$$J(\theta) = -\frac{1}{N} \left[\sum_{i=1}^N y_i \log(h_\theta(x_i)) + (1-y_i) \log(1-h_\theta(x_i)) \right]$$

Gradient descent

1. Repeat

$$2. \theta^j = \theta^j - \alpha \frac{dJ(\theta)}{d\theta^j}$$

3. Until converge

For any j

$$\frac{dJ(\theta)}{d\theta^j} = \frac{1}{N} \sum_{i=1}^N (h_\theta(x_i) - y_i) x_i^j$$

Regularization

$$\text{where } h_\theta(x_i) = \frac{1}{1 + e^{-\theta^T x}}$$

Cost function

$$J(\theta) = \frac{1}{2N} \left[\sum_{i=1}^N (h_\theta(x_i) - y_i)^2 + \lambda \sum_{i=1}^N \theta_i^2 \right]$$

↑ regularization parameter

Gradient descent with regularization

1. Repeat

$$2. \theta^0 = \theta^0 - \alpha \frac{1}{N} \sum_{i=1}^N (h_\theta(x_i) - y_i) x_i^0$$

$$3. \theta^j = \theta^j - \alpha \left(\frac{1}{N} \sum_{i=1}^N (h_\theta(x_i) - y_i) x_i^j + \frac{\lambda}{N} \theta^j \right)$$

4. Until converge

$$\theta^j = \theta^j \left(1 - \frac{\alpha \lambda}{N} \right) - \frac{\alpha}{N} \sum_{i=1}^N (h_\theta(x_i) - y_i) x_i^j$$

$$\text{Usually } 0 < \left(1 - \frac{\alpha \lambda}{N} \right) < 1$$

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Logistic regression with regularization

Cost function

$$J(\theta) = -\frac{1}{N} \left[\sum_{i=1}^N y_i \log(h_{\theta}(x_i)) + (1-y_i) \log(1-h_{\theta}(x_i)) \right] + \frac{\lambda}{2N} \sum_{j=1}^d \theta_j^2$$

Gradient descent

1. Repeat

$$2. \theta^0 = \theta^0 - \alpha \frac{1}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^0$$

$$3. \theta^j = \theta^j - \alpha \left(\frac{1}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^j + \frac{\lambda}{N} \theta^j \right)$$

4. Until converge

$$\theta^j = \theta^j \left(1 - \alpha \frac{\lambda}{N} \right) - \alpha \frac{1}{N} \sum_{i=1}^N (h(x_i) - y_i) x_i^j$$

Usually $0 < (1 - \alpha \frac{\lambda}{N}) < 1$