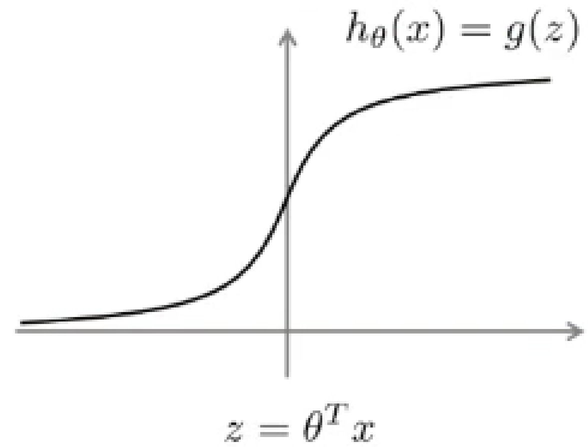
Machine Learning

Support Vector Machines

Large Margin Intuition

Alternative view of logistic regression

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



If y=1 we want $h_\theta(x) \approx 1, \theta^T x >> 0$

If y=0 we want $h_\theta(x) \approx 0, \theta^T x << 0$

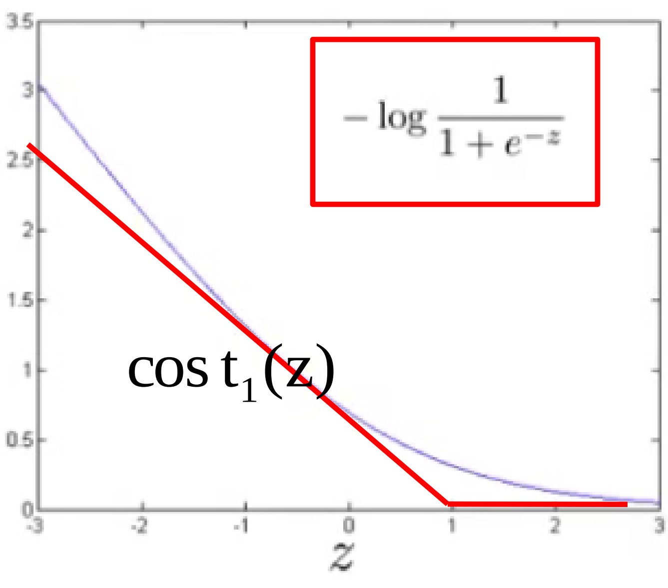
Alternative view of logistic regression

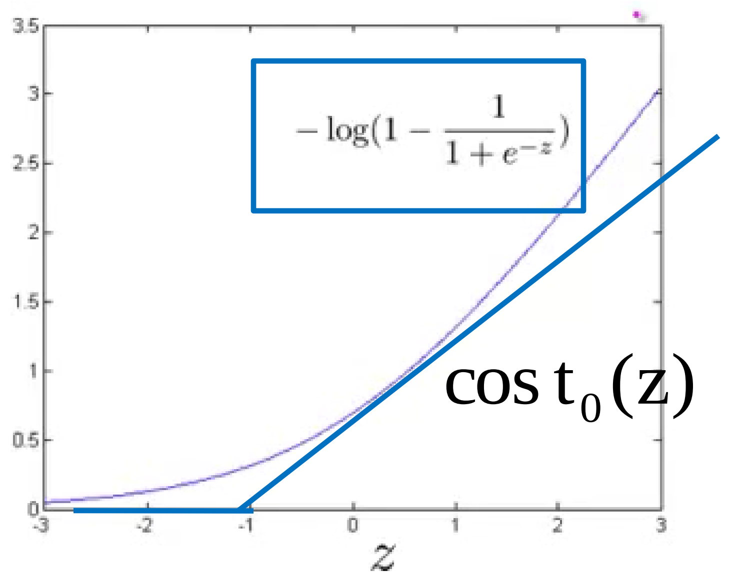
Cost of example: $-(y\log h_\theta(x)+(1-y)\log(1-h_\theta(x)))$

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

If y=1 (want $\theta^T x >> 0$):

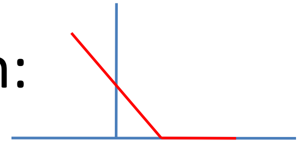
If y=0 (want $\theta^T x << 0$):

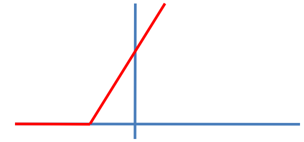




Support vector machine

Logistic regression:





$$\min_\theta \frac{1}{m}\underbrace{\left[\sum_{i=1}^{m} y^{(i)}\Big(\underbrace{-\log h_\theta(x^{(i)})}_{\cos t_1(\theta^T x^{(n)})}\Big) + (1-y^{(i)})\underbrace{\log(1-h_\theta(x^{(i)}))}_{\cos t_0(\theta^T x^{(n)})}\right]}_{A} + \underbrace{\frac{\lambda}{2m}\sum_{j=1}^{n}\theta_j^{\,2}}_{B}$$

Support vector machine

$$\min_\theta \frac{1}{\cancel{m}}\left[\sum_{i=1}^{m} y^{(i)}\cos t_1(\theta^T x^{(n)}) + (1-y^{(i)})\cos t_0(\theta^T x^{(n)})\right] + \frac{\lambda}{2\cancel{m}}\sum_{j=1}^{n}\theta_j^{\,2}$$

$$A + \lambda B \qquad C = \frac{1}{\lambda}$$

$$CA + B$$

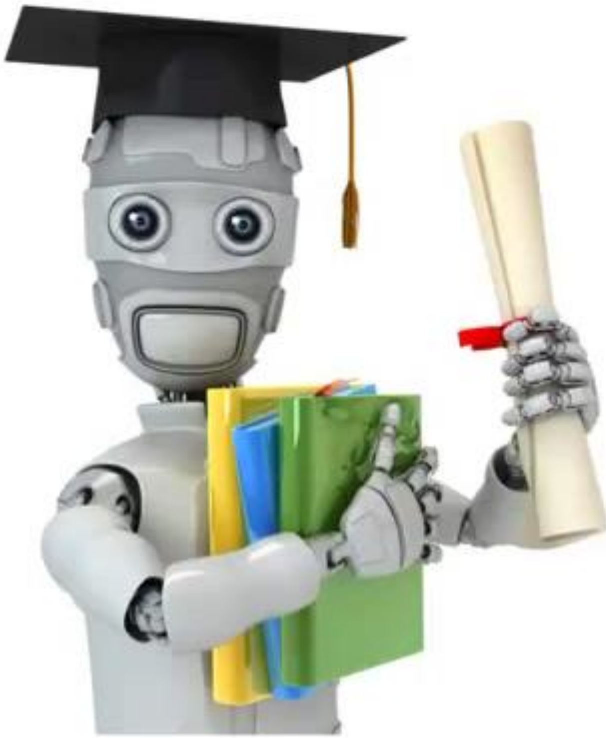
$$\min_\theta C\left[\sum_{i=1}^{m} y^{(i)}\cos t_1(\theta^T x^{(n)}) + (1-y^{(i)})\cos t_0(\theta^T x^{(n)})\right] + \frac{1}{2}\sum_{j=1}^{n}\theta_j^{\,2}$$

SVM hypothesis

$$\min_{\theta} C\left[\sum_{i=1}^{m} y^{(i)} \cos t_1(\theta^T x^{(n)}) + (1 - y^{(i)}) \cos t_0(\theta^T x^{(n)})\right] + \frac{1}{2}\sum_{j=1}^{n} \theta_j{}^2$$

Hypothesis:

$$h_\theta(x) = \begin{cases} 1.......\text{if } (\theta^T x \geq 0) \\ 0......\text{otherwise} \end{cases}$$



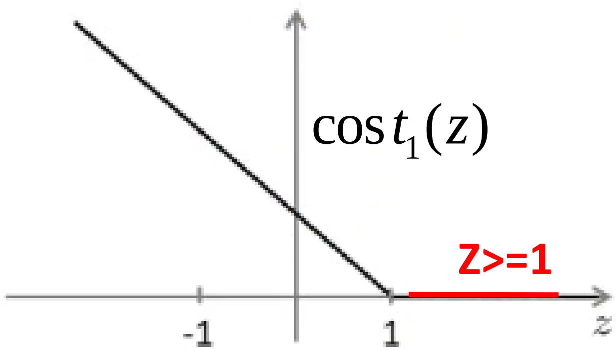
Machine Learning

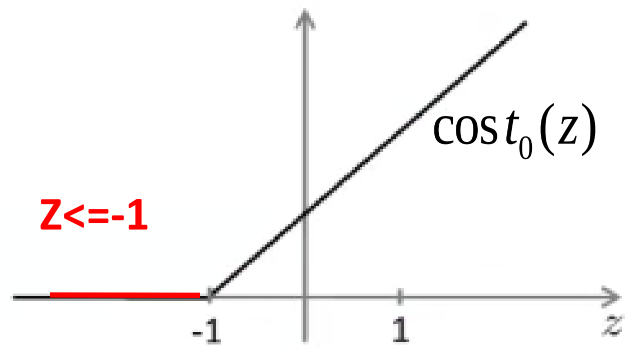
Support Vector Machines

Optimization objective

Support Vector Machine

$$\min C\sum_{i=1}^{m}[y^{(i)}\cos t_1(\theta^T x^{(i)})+(1-y^{(i)})\cos t_0(\theta^T x^{(i)})]+\frac{1}{2}\sum_{j=1}^{n}\theta_j{}^2$$





If y=1 ,we want $\theta^T x \ge 1$ (not just>=0) $\theta^T x \ge \cancel{0}$ 1

If y=0 ,we want $\theta^T x \le -1$ (not just<0) $\theta^T x \le \cancel{0}$ -1

SVM Decision Boundary

$$\min C\sum_{i=1}^{m}[y^{(i)}\cos t_1(\theta^T x^{(i)})+(1-y^{(i)})\cos t_0(\theta^T x^{(i)})]+\frac{1}{2}\sum_{j=1}^{n}\theta_j^{\,2}$$

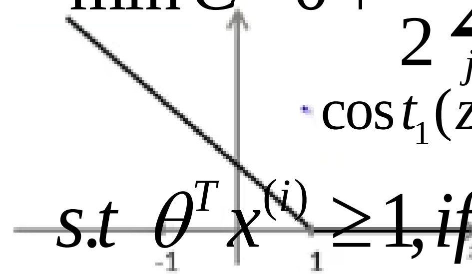
C is very large

=0

$$\min C*0+\frac{1}{2}\sum_{j=1}^{n}\theta_j^{\,2}$$

Whenever $y^{(i)}=1$

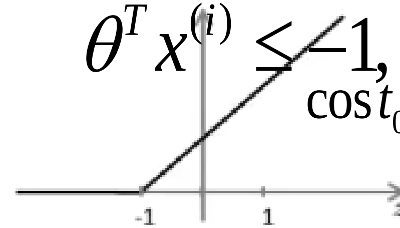
$$\theta^T x \geq 1$$



$\cos t_1(z)$

$$s.t\ \ \theta^T x^{(i)} \geq 1, if\,(y^{(i)}=1)$$

$$\theta^T x^{(i)} \leq -1, if\,(y^{(i)}=0)$$

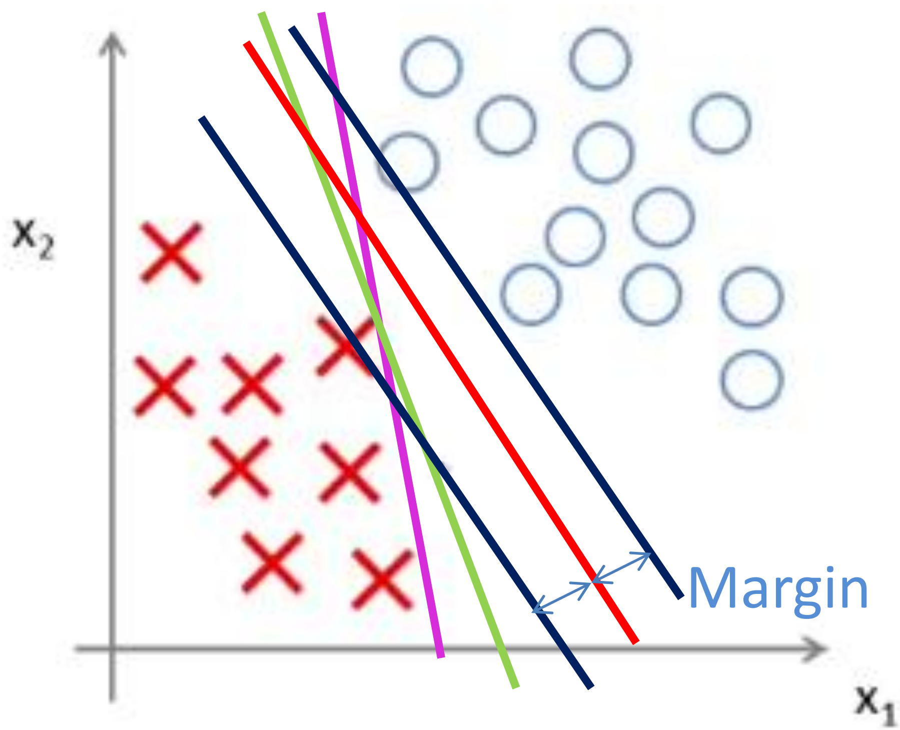


$\cos t_0(z)$

Whenever $y^{(i)}=0$

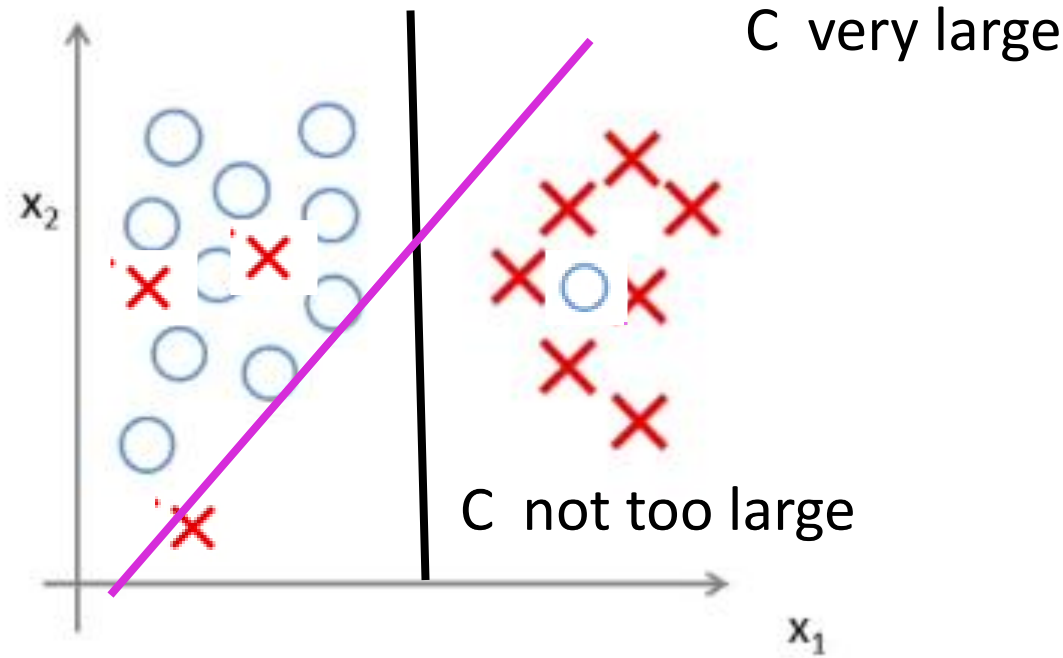
$$\theta^T x \leq -1$$

SVM Decision Boundary:Linearly separable case



Large margin classifier

Large margin classifier in presence of outliers



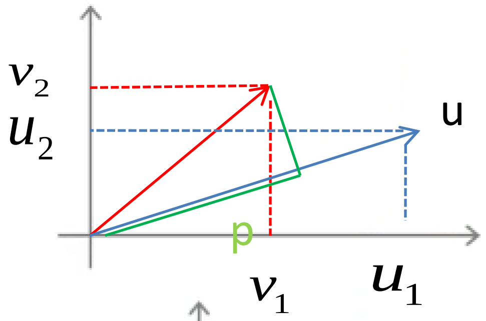
Machine Learning

Support Vector Machines

The mathematics behind large margin classification (optional)

Vector Inner Product

$$u = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \qquad v = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

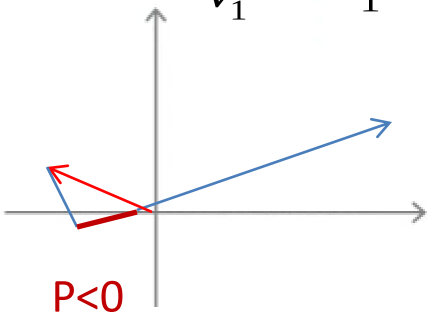


$$u^T v = ?$$

P =length of projection of v onto u

$$u^T v = p.\|u\| \qquad = v^T u$$

$$= u_1 v_1 + u_2 v_2$$



SVM Decision Boundary

$$\min \frac{1}{2}\sum_{j=1}^{n}\theta_j^{\ 2} = \frac{1}{2}(\theta_1^{\ 2}+\theta_2^{\ 2}) = \frac{1}{2}(\sqrt{\theta_1^{\ 2}+\theta_2^{\ 2}})^2 = \frac{1}{2}\|\theta\|^2$$

$$s.t \quad \theta^T x^{(i)} \ge 1 \quad if, y^{(i)} = 1$$

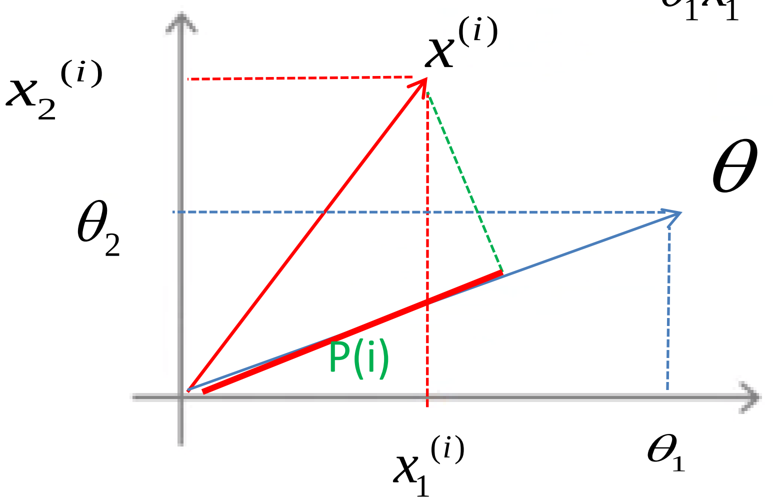
$$\theta^T x^{(i)} \le -1 \quad if, y^{(i)} = 0$$

$$simplification: \theta_0 = 0, n = 2$$

$$\theta^T x_2^{(i)} = P^{(i)}\|\theta\|$$
$$= \theta_1 x_1^{(i)} + \theta_2 x_2^{(i)}$$

$$\theta^T x^{(i)} = ?$$

$$u^T v$$



SVM Decision Boundary

$$\min \frac{1}{2}\sum_{j=1}^{n}\theta_j^{\,2} \;=\frac{1}{2}\|\theta\|^2$$

$$s.t\; P^{(i)}\|\theta\| \ge 1 \; if, y^{(i)} = 1$$

$$P^{(i)}\|\theta\| \le -1 \; if, y^{(i)} = 0$$

Where $p^{(i)}$ is the projection of $\chi^{(i)}$ onto the vector θ

$$simplification: \theta_0 = 0$$

$$P^{(1)}\|\theta\| \ge 0$$