Sid

# Debugging learning algorithm

- more training examples → 1
- $\underbrace{\text{smaller}}_{1}$ / $\underbrace{\text{greater}}_{2}$ features
- polynomial features → 2
- $\underbrace{\text{decreasing}}_{2}$ / $\underbrace{\text{increasing}}_{1}$ $\lambda$

1) fix high variance
2) Fix high bias

# ML Diagnostic

- test to gain insight to learning algorithm and how to improve performance.

# Evaluate Hypothesis

- Split data into training & test set
- learn $\theta$ from training
- Compute test error ($J_{test}(\theta)$)

| (70%) Training | (30%) Test |
| --- | --- |
| $(x^{(1)}, y^{(1)})$ | $(x_{test}^{(1)}, y_{test}^{(1)})$ |
| $(x^{(2)}, y^{(2)})$ | $(x_{test}^{(2)}, y_{test}^{(2)})$ |
| $\vdots$ | $\vdots$ |
| $(x^{(m)}, y^{(m)})$ | $(x_{test}^{(m_{test})}, y_{test}^{(m_{test})})$ |

- Misclassification error

$$\text{error}(h_\theta(x), y) = \begin{cases} 1 & h_\theta(x) \geq 0.5,\ y=0 \\ & h_\theta(x) < 0.5,\ y=1 \\ 0 & \text{(otherwise)} \end{cases}$$

$$\text{Test Error} = \frac{1}{m_{test}} \sum_{i=1}^{m_{test}} \text{error}\left(h_\theta(x_{test}^{(i)}),\ y_{test}^{(i)}\right)$$

## Model Selection:

- Training (60%) $\rightarrow$ optimize parameters $(\theta)$ for each 'd'
- Cross Validation (20%) $\rightarrow$ Find 'd' w/ least error $(J_{cv}(\theta))$
- Test (20%) $\rightarrow$ generalization error : $J_{test}(\theta^{(d)})$

d=1 1) $h_\theta(x) = \theta_0 + \theta_1 x \rightarrow \theta^{(1)} \rightarrow J_{cv}(\theta^{(1)})$

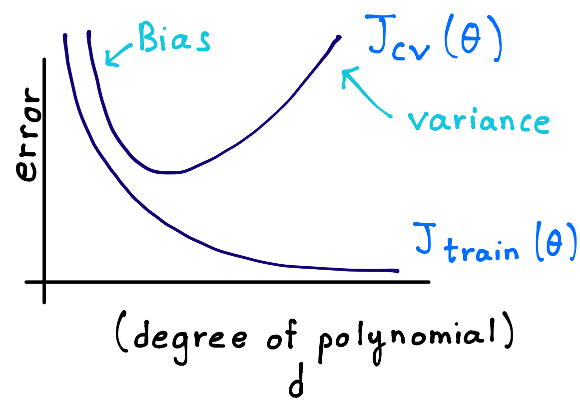
d=2 2) $h_\theta(x) = \theta_0 + \theta_1 x + \theta_2 x^2 \rightarrow \theta^{(2)} \rightarrow J_{cv}(\theta^{(2)})$

⋮

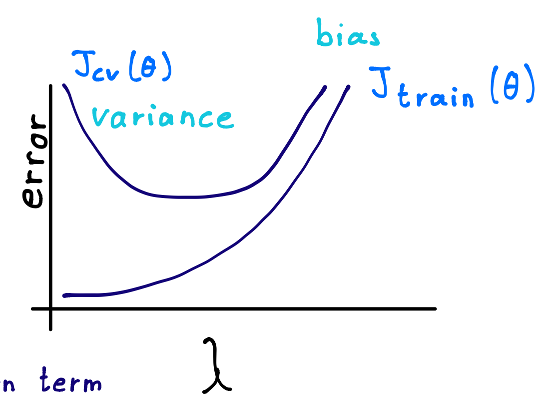
d) $h_\theta(x) = \theta_0 + \theta_1 x + \dots + \theta_d x^d \rightarrow \theta^{(d)} \rightarrow J_{cv}(\theta^{(d)})$

## Bias vs Variance

- High bias (underfit)
  - $J_{train}(\theta)$ is high
  - $J_{cv}(\theta) \approx J_{train}(\theta)$
- High variance (overfit)
  - $J_{train}(\theta)$ is low
  - $J_{cv}(\theta) >> J_{train}(\theta)$




## Regularization & bias/variance
(prevent overfitting)

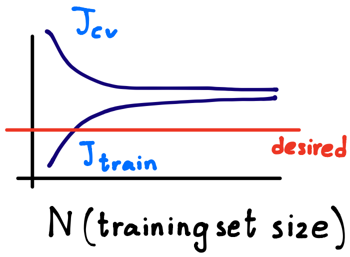



$$J(\theta) = \frac{1}{2m}\sum_{i=1}^{m}(h_\theta(x^{(i)}) - y^{(i)})^2 + \frac{\lambda}{2m}\sum_{j=1}^{n}\theta_j^2$$

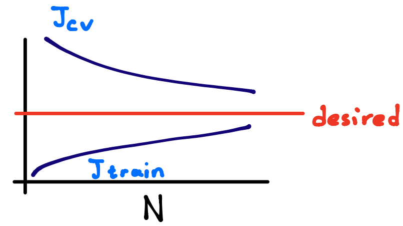
$J_{train}(\theta)$, $J_{cv}(\theta)$, $J_{test}(\theta)$ : No regularization term

Learning Curve

- High Bias




- High Variance




× more training data ✓