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Neural Networks and Sensor Fusion

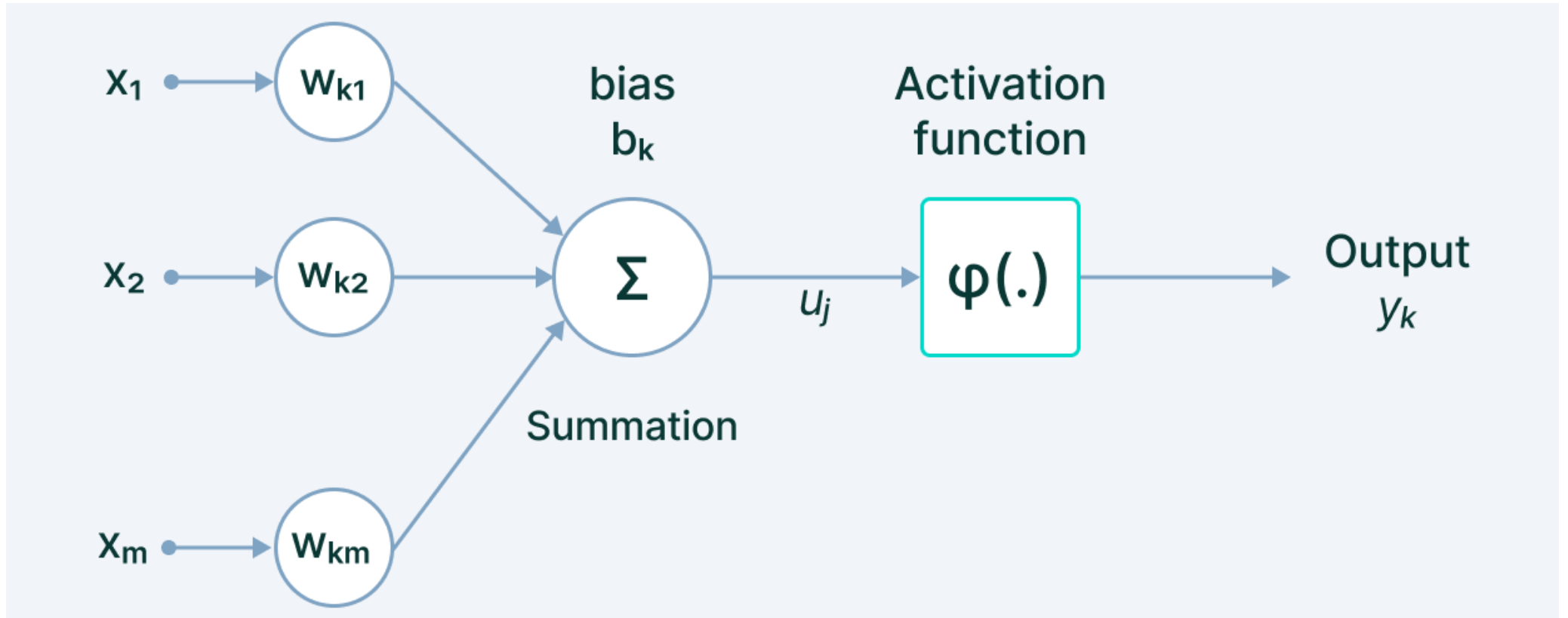
Aprendizaje Automático Embebido

Somos Innovación Tecnológica con *Sentido Humano*



Alcaldía de Medellín

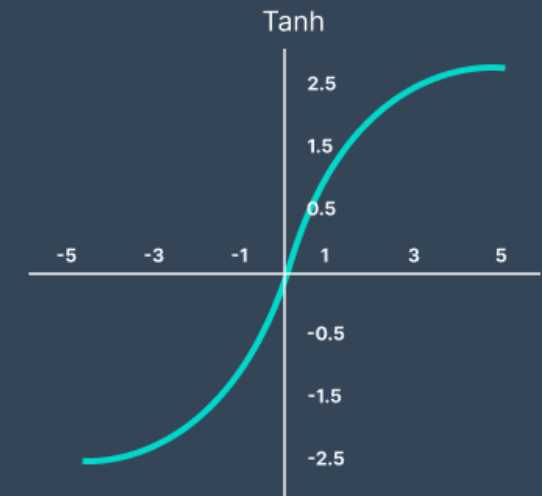
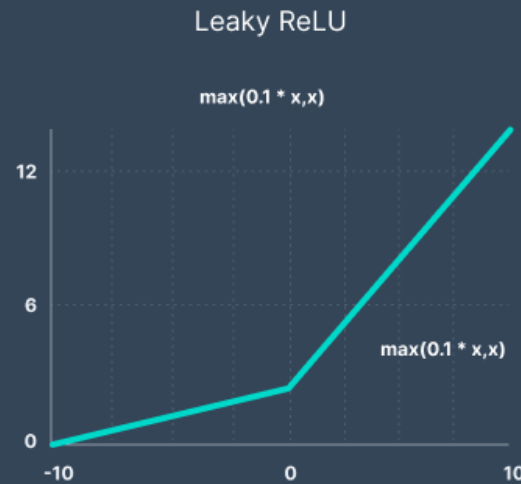
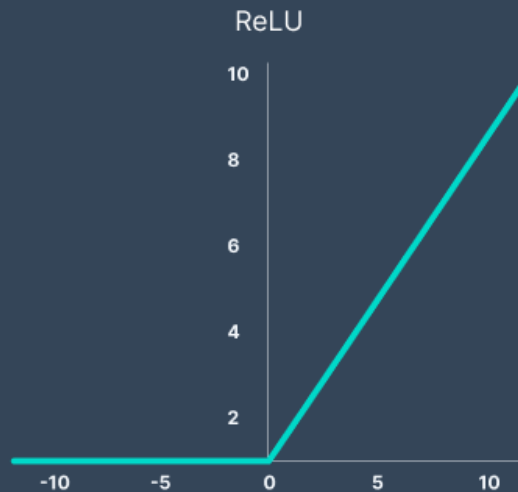
Neural Networks - Basic Unit



$$u_k = \mathbf{w}_k^T \mathbf{x} + b_k$$

$$y_k = \varphi(u_k)$$

Neural Networks – Activation functions

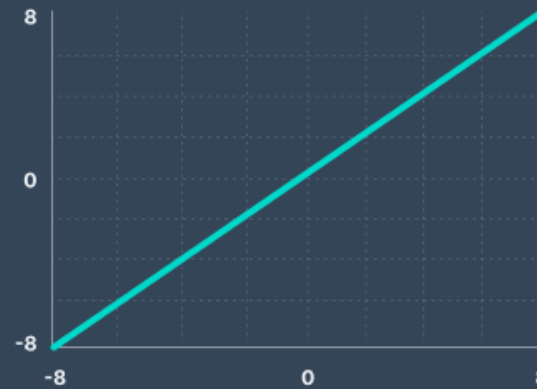


Neural Networks – Activation functions

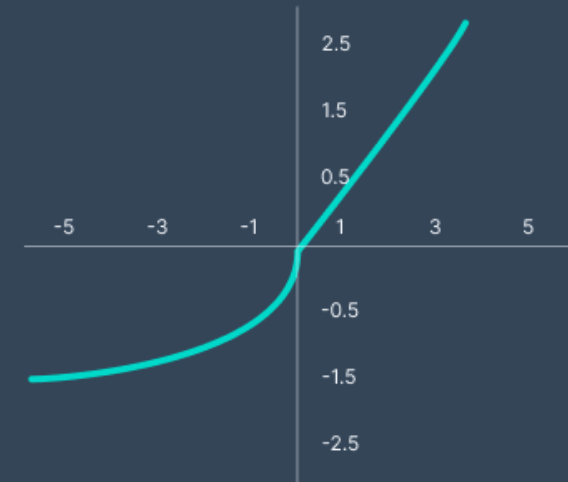
Binary Step Function



Linear

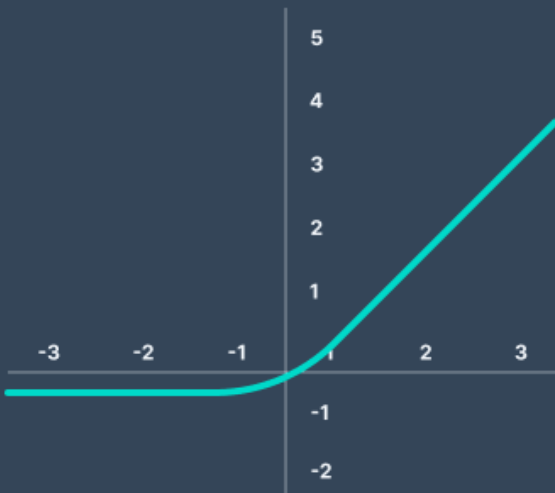


SELU

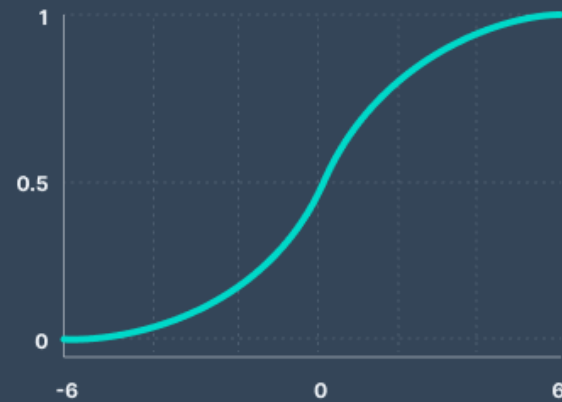


Neural Networks – Activation functions

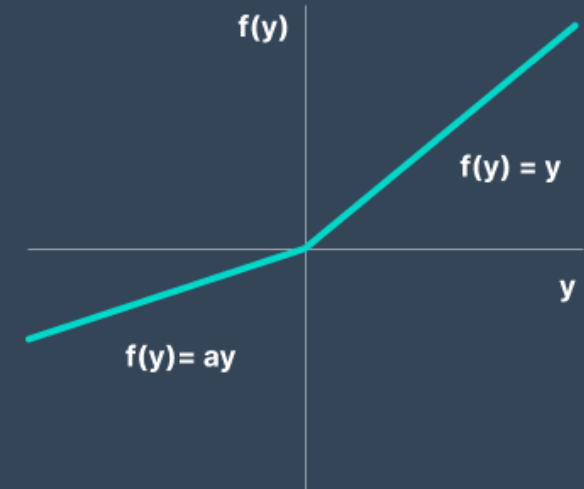
ELU



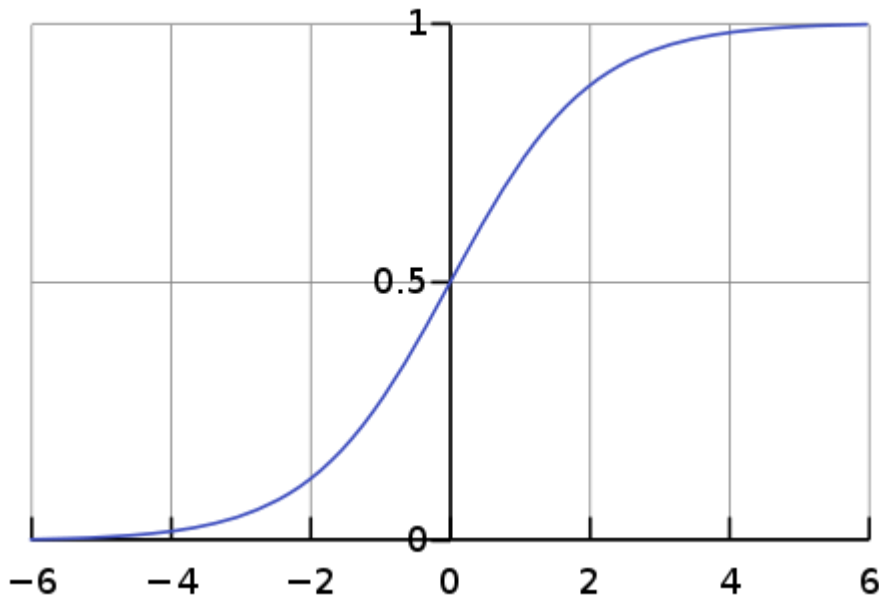
Sigmoid / Logistic



Parametric ReLU



Neural Network - SoftMax



$$P(y = j \mid \mathbf{x}) = \frac{e^{\mathbf{x}^T \mathbf{w}_j}}{\sum_{k=1}^K e^{\mathbf{x}^T \mathbf{w}_k}}$$

Neural Network - SoftMax

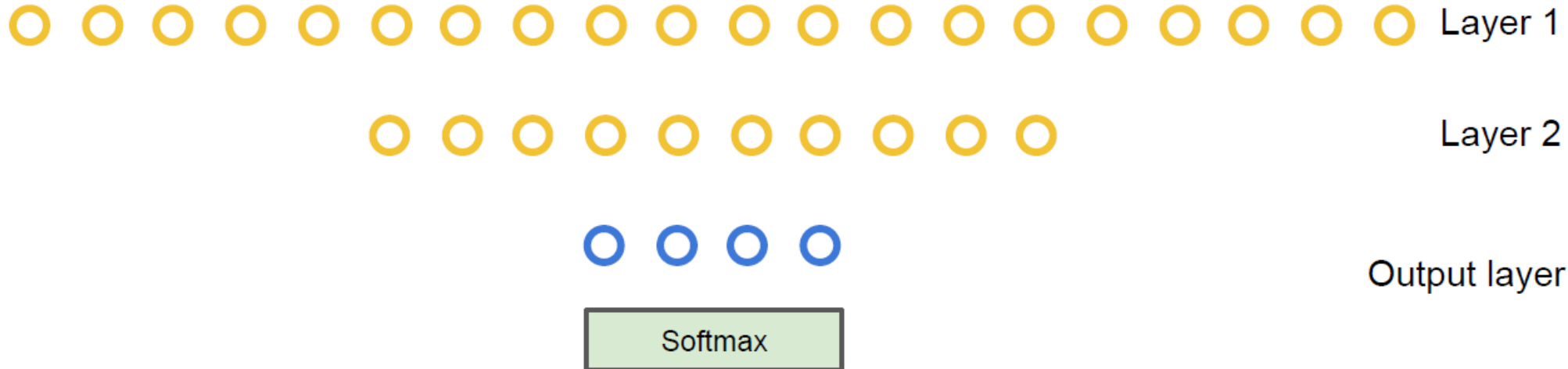
$$P(y = j \mid \mathbf{x}) = \frac{e^{\mathbf{x}^T \mathbf{w}_j}}{\sum_{k=1}^K e^{\mathbf{x}^T \mathbf{w}_k}}$$

$$\begin{aligned} \begin{bmatrix} P(\text{cat}) \\ P(\text{dog}) \end{bmatrix} &= \sigma \left(\begin{bmatrix} 1.2 \\ 0.3 \end{bmatrix} \right) \\ &= \begin{bmatrix} \frac{e^{1.2}}{e^{1.2} + e^{0.3}} \\ \frac{e^{0.3}}{e^{1.2} + e^{0.3}} \end{bmatrix} \\ &= \begin{bmatrix} 0.71 \\ 0.29 \end{bmatrix} \end{aligned}$$

Neural Network - Accelerometer

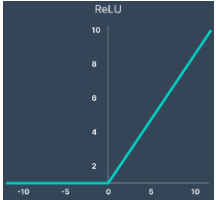
Features

accX RMS
accX Peak 1 Freq
accX Peak 1 Height
accX Peak 2 Freq
accX Peak 2 Height
accX Peak 3 Freq
accX Peak 3 Height
accX Spec Pow 0.1-0.5
accX Spec Pow 0.5-1.0
accX Spec Pow 1.0-2.0
accX Spec Pow 2.0-5.0
accY RMS
accY Peak 1 Freq
accY Peak 1 Height
accY Peak 2 Freq
accY Peak 2 Height
accY Peak 3 Freq
accY Peak 3 Height
accY Spec Pow 0.1-0.5
accY Spec Pow 0.5-1.0
accY Spec Pow 1.0-2.0
accY Spec Pow 2.0-5.0
accZ RMS
accZ Peak 1 Freq
accZ Peak 1 Height
accZ Peak 2 Freq
accZ Peak 2 Height
accZ Peak 3 Freq
accZ Peak 3 Height
accZ Spec Pow 0.1-0.5
accZ Spec Pow 0.5-1.0
accZ Spec Pow 1.0-2.0
accZ Spec Pow 2.0-5.0



Neural Network - Accelerometer

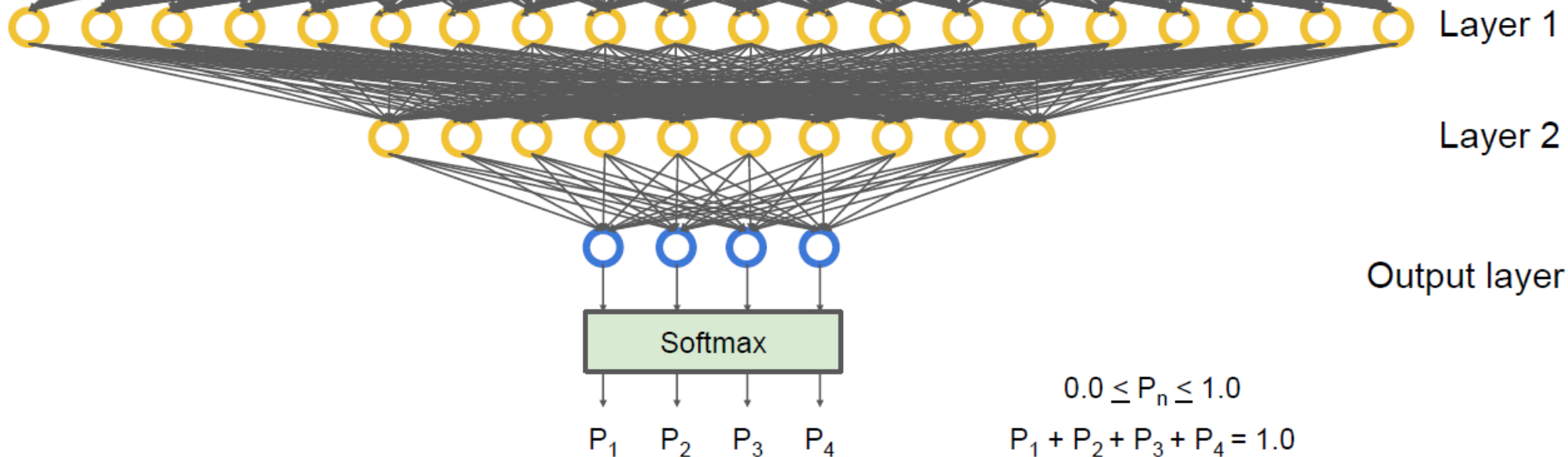
$$\mathbf{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_{33} \end{bmatrix}$$



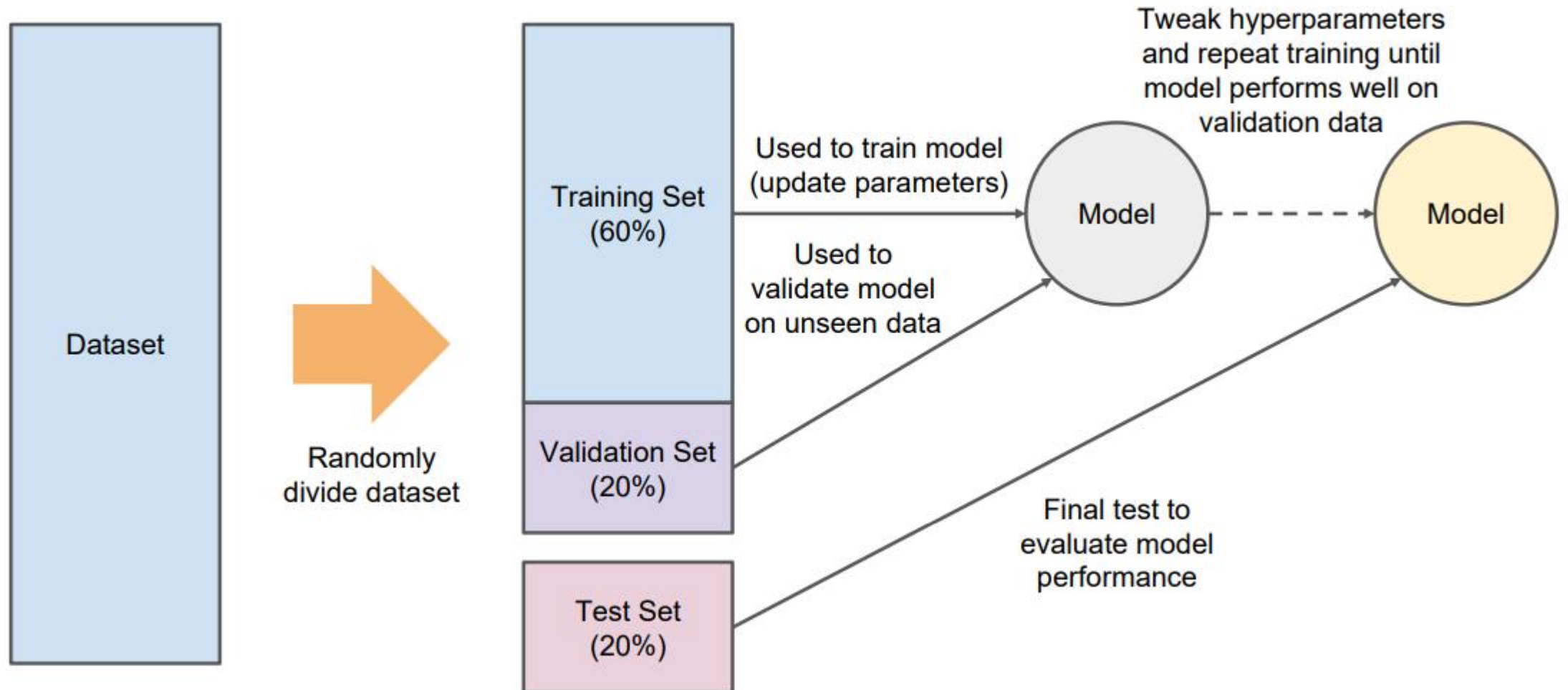
Features																																
accX RMS	accX Peak 1 Freq	accX Peak 1 Height	accX Peak 2 Freq	accX Peak 2 Height	accX Peak 3 Freq	accX Peak 3 Height	accX Spec Pow 0.1-0.5	accX Spec Pow 0.5-1.0	accX Spec Pow 1.0-2.0	accX Spec Pow 2.0-5.0	accY RMS	accY Peak 1 Freq	accY Peak 1 Height	accY Peak 2 Freq	accY Peak 2 Height	accY Peak 3 Freq	accY Peak 3 Height	accY Spec Pow 0.1-0.5	accY Spec Pow 0.5-1.0	accY Spec Pow 1.0-2.0	accY Spec Pow 2.0-5.0	accZ RMS	accZ Peak 1 Freq	accZ Peak 1 Height	accZ Peak 2 Freq	accZ Peak 2 Height	accZ Peak 3 Freq	accZ Peak 3 Height	accZ Spec Pow 0.1-0.5	accZ Spec Pow 0.5-1.0	accZ Spec Pow 1.0-2.0	accZ Spec Pow 2.0-5.0

$$y_k = \varphi(\mathbf{w}_k^T \mathbf{x} + b_k)$$

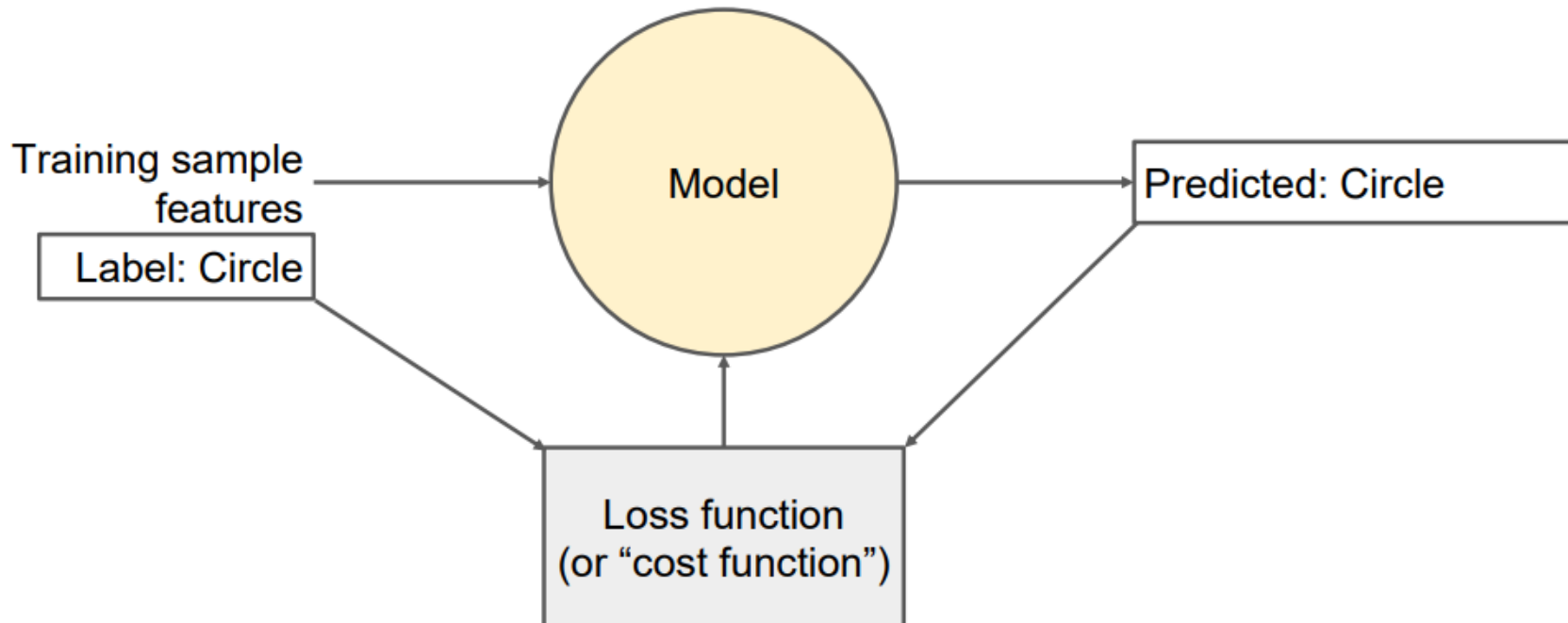
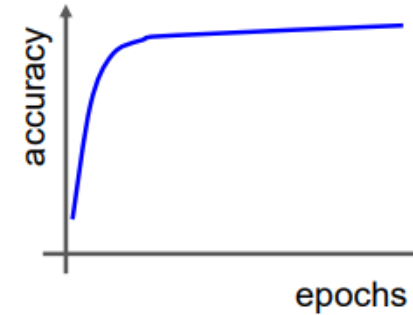
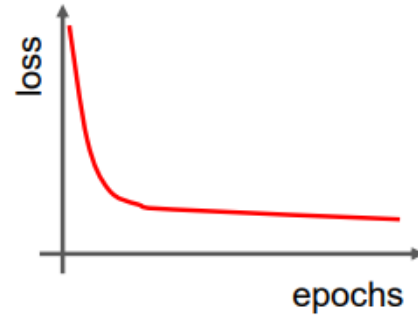
$$\mathbf{y} = \varphi(\mathbf{W}\mathbf{x} + \mathbf{b})$$



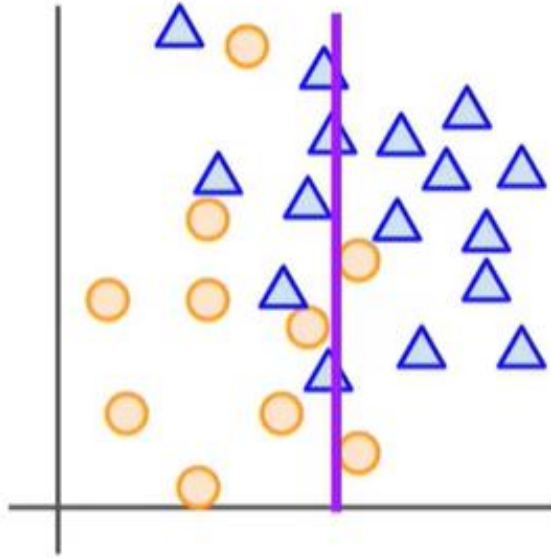
Neural Network - Setup



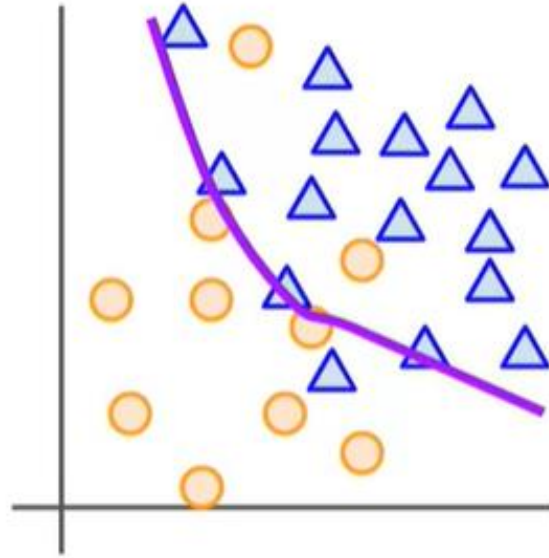
Neural Network - Training



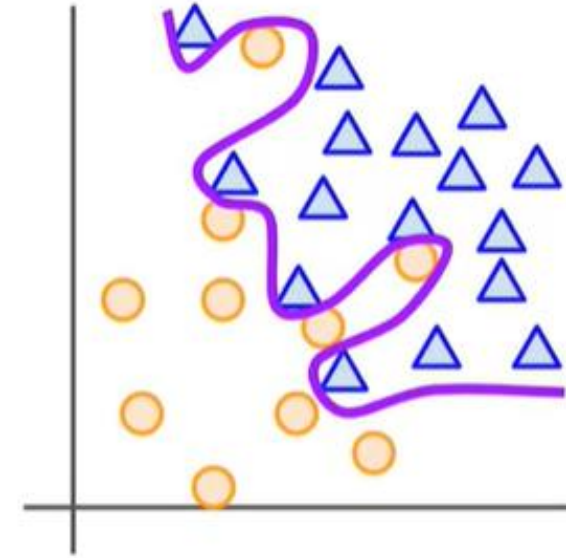
Overfitting



Underfit: Model fails to capture trends in the data

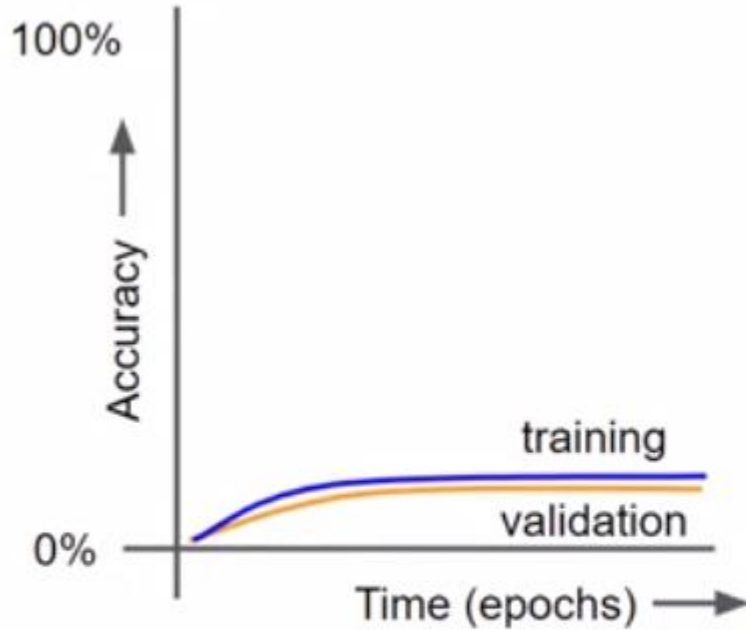


Good fit: Model captures trends and can generalize to unseen data

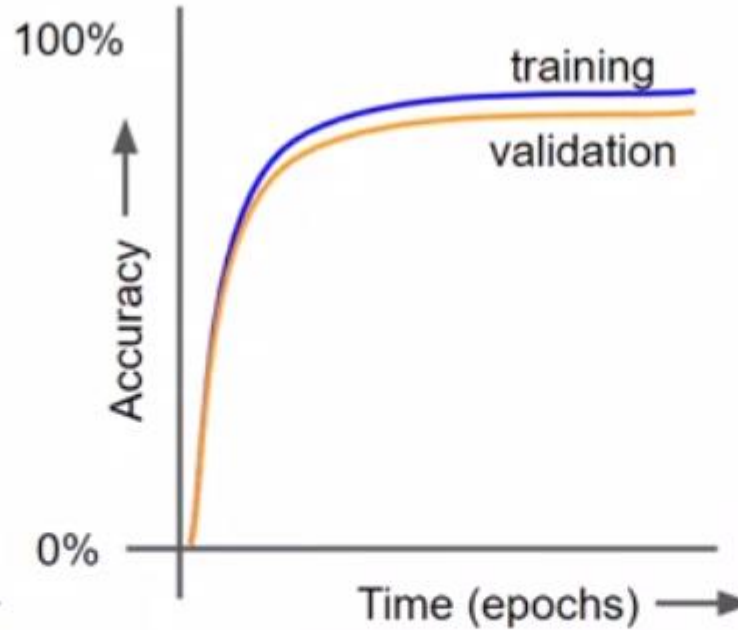


Overfit: Model captures training data trends but fails on unseen data

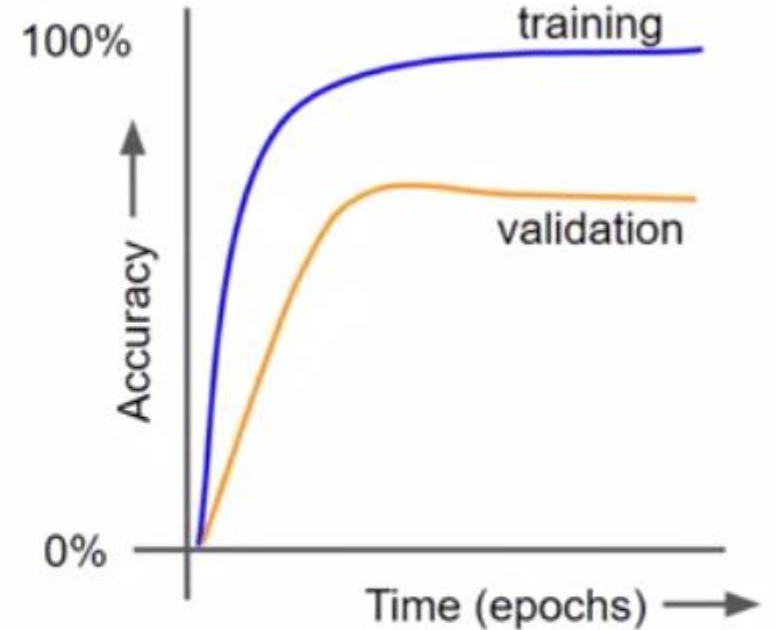
Neural Network – Underfit and Overfit



Underfit: Model performs poorly on training and validation data

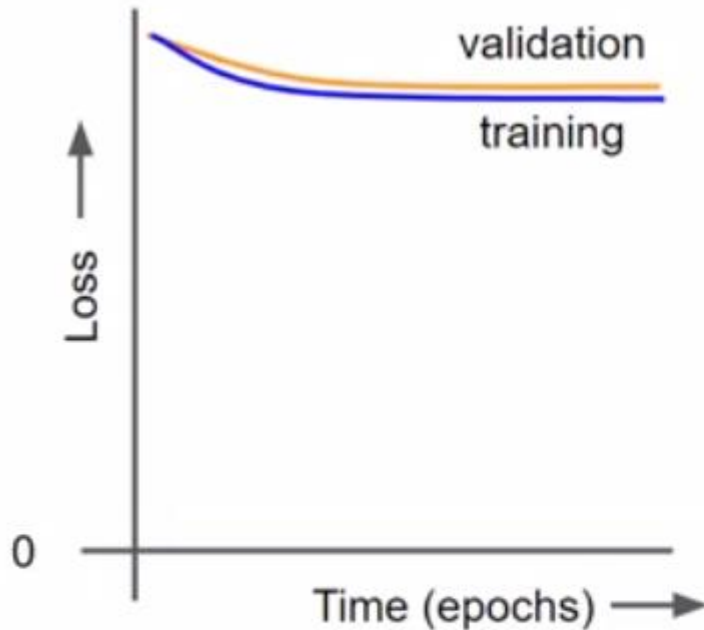


Good fit: Model generalizes well from training to validation data

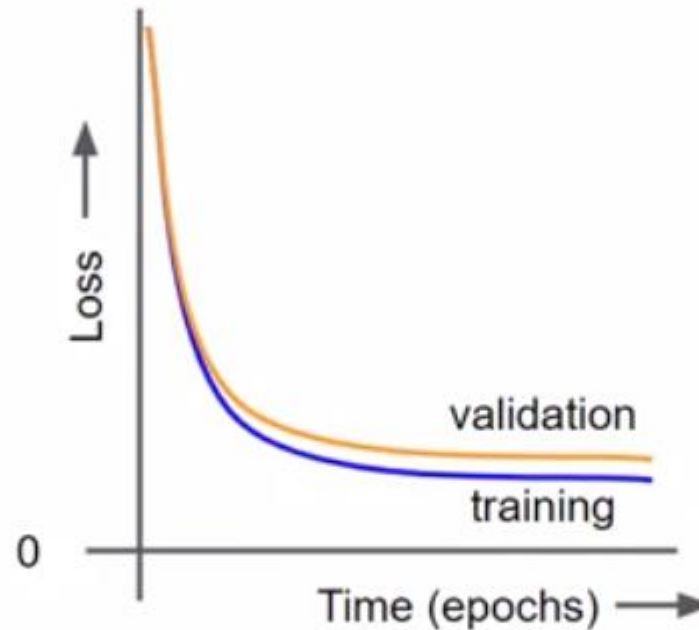


Overfit: Model predicts training data well but fails to generalize to validation data

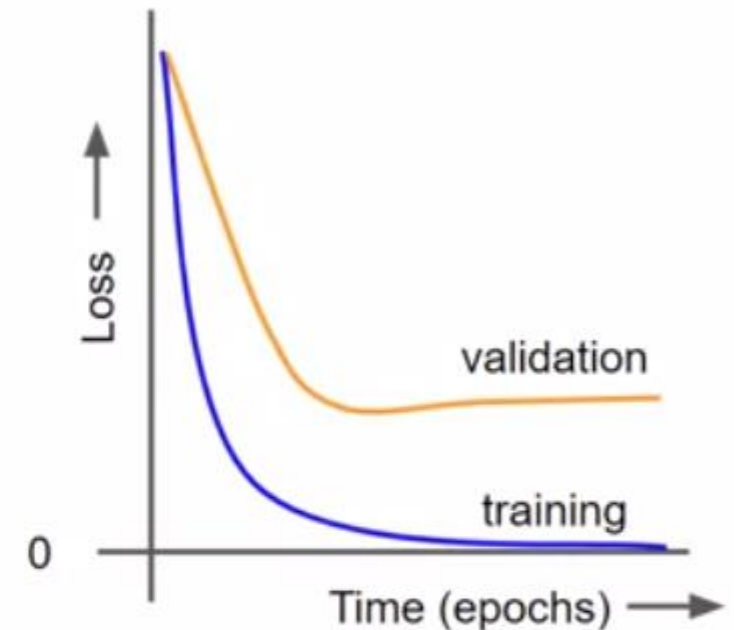
Neural Network – Underfit and Overfit



Underfit: Model performs poorly on training and validation data

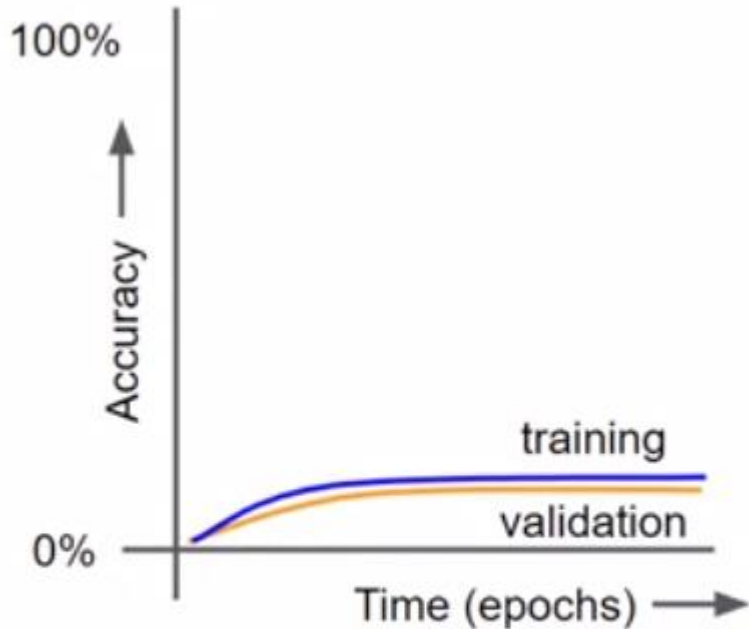


Good fit: Model generalizes well from training to validation data



Overfit: Model predicts training data well but fails to generalize to validation data

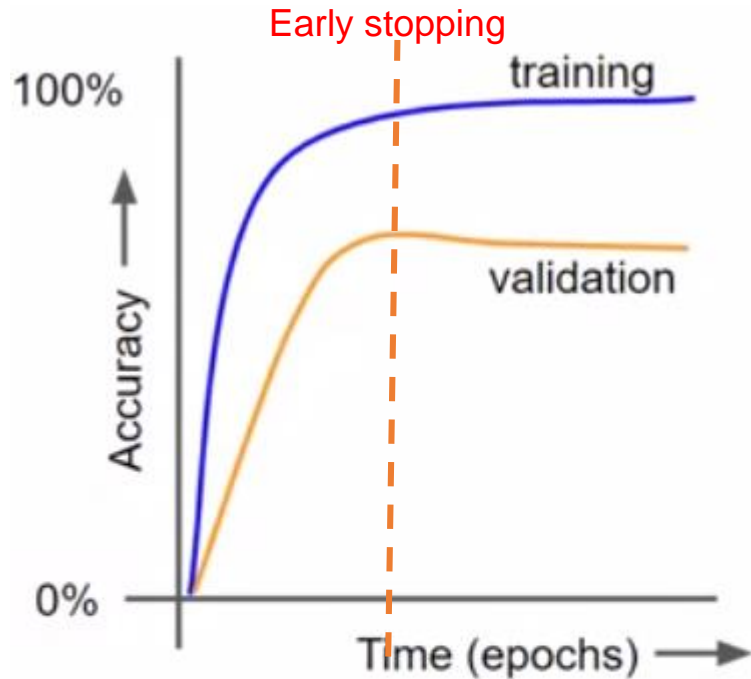
Neural Network – Fix Underfit



Underfit: Model performs poorly on training and validation data

- Get more data.
- Try different features or more features.
- Train for longer.
- Try more complex model (more layers, more nodes, etc.)

Neural Network – Fix Overfit



Overfit: Model predicts training data well but fails to generalize to validation data

- Get more data.
- Early stopping.
- Reduce model complexity.
- Add regularization terms.
- Add dropout layers (for neural networks).



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¡Gracias!

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