



# High Dimensionality

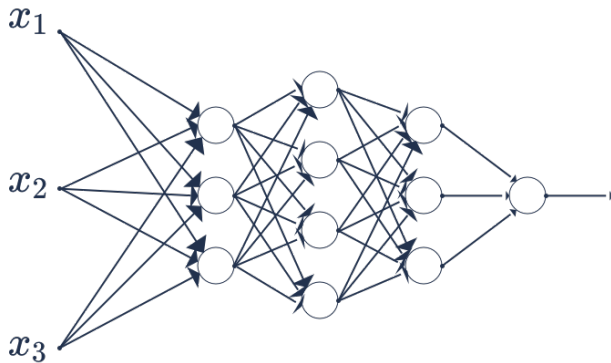
Higher Dimensionality →

More Data ↓

Feature 1	Feature 2	Feature 3	Feature 4
Value 1, 1	Value 1, 2	Value 1, 3	Value 1, 4
Value 2, 1	Value 2, 2	Value 2, 3	Value 2, 4
Value 3, 1	Value 3, 2	Value 3, 3	Value 3, 4
Value 4, 1	Value 4, 2	Value 4, 3	Value 4, 4
Value 5, 1	Value 5, 2	Value 5, 3	Value 5, 4
Value 6, 1	Value 6, 2	Value 6, 3	Value 6, 4

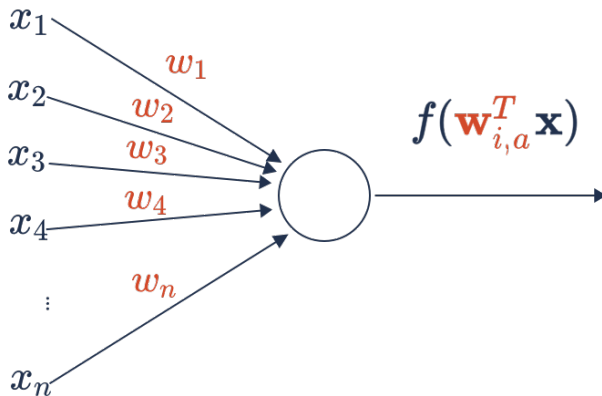
$$\begin{aligned} \min_{\mathbf{W}} \quad & \|\mathbf{X} - \mathbf{W}\mathbf{W}^T\mathbf{X}\|_F^2, \\ \text{s.t.} \quad & \mathbf{W}^T\mathbf{W} = \mathbf{I}. \end{aligned}$$

# Neural Network



# Neuron

$$g_{i,a}(\mathbf{x}) = f(\mathbf{w}_{i,a}^T \mathbf{x}),$$



# 2-Layer Simple Network

Assuming we use an identity activation function,  $f(\mathbf{X}) = \mathbf{X}$ .

$$g_j(\mathbf{X}) = \mathbf{W}_j^T \mathbf{W}_i^T \mathbf{X},$$

# 2-Layer Simple Network

Supervised:

$$\min_{\mathbf{W}} \|\mathbf{y} - \hat{\mathbf{y}}\|_p^p.$$

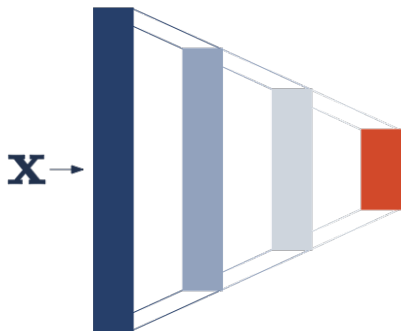
Unsupervised 2-Layer Simple Network:

$$\min_{\mathbf{W}} \|\mathbf{X} - \mathbf{W}_j^T \mathbf{W}_i^T \mathbf{X}\|_F^2.$$

PCA:

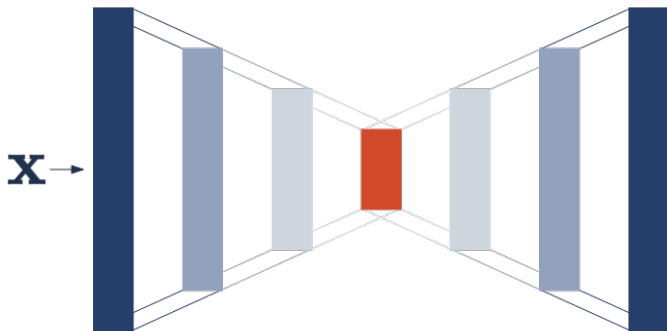
$$\begin{aligned} \min_{\mathbf{W}} \|\mathbf{X} - \mathbf{W}\mathbf{W}^T \mathbf{X}\|_F^2, \\ \text{s.t. } \mathbf{W}^T \mathbf{W} = \mathbf{I}. \end{aligned}$$

# Autoencoders

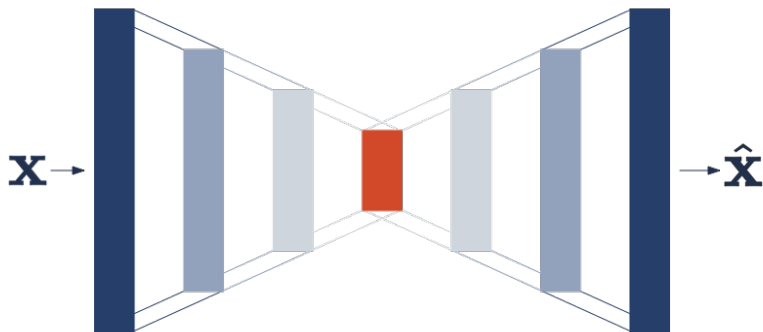




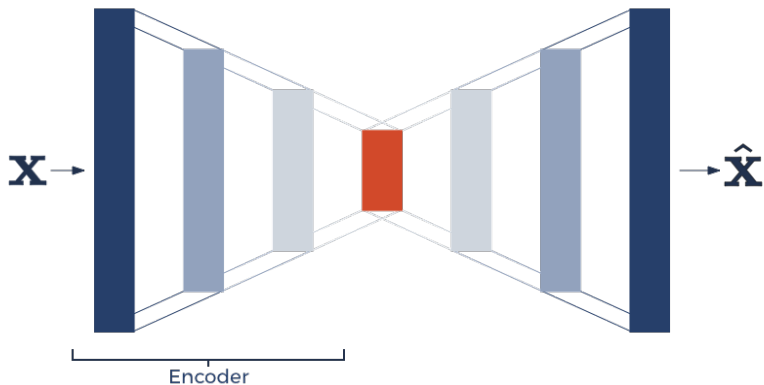
# Autoencoders



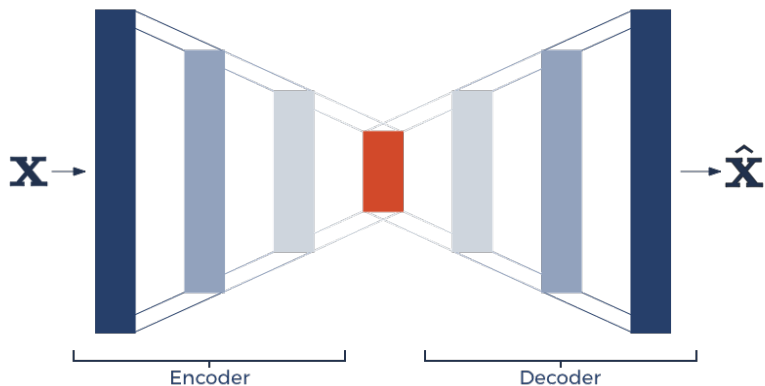
# Autoencoders



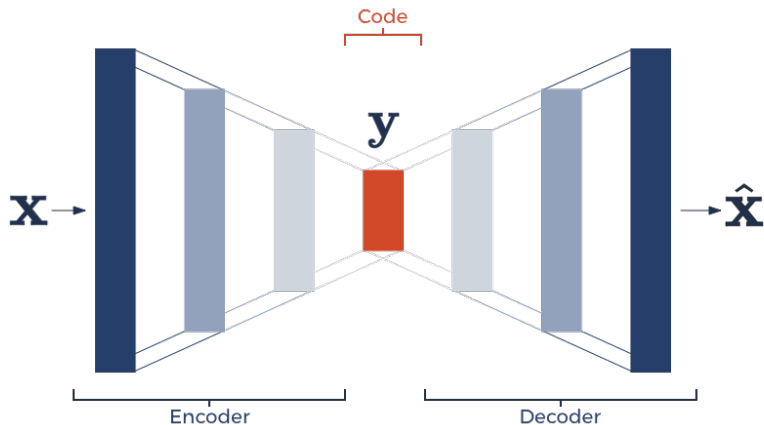
# Autoencoders



# Autoencoders



# Autoencoders



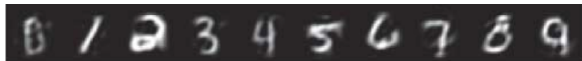
# Autoencoder Performance vs PCA



Original



30-dim  
Autoencoder



PCA

# Variations on Autoencoders

- Sparse Autoencoders
- Denoising Autoencoders
- Stacked Autoencoders

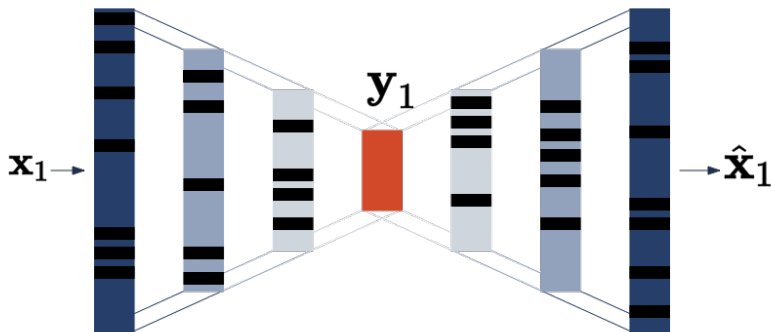
# Sparse Autoencoders

$$\hat{\rho}_{ia} = \frac{1}{n} \sum_{i=1}^n f(\mathbf{w}_{i,a}^T \mathbf{x}_{i-1}),$$

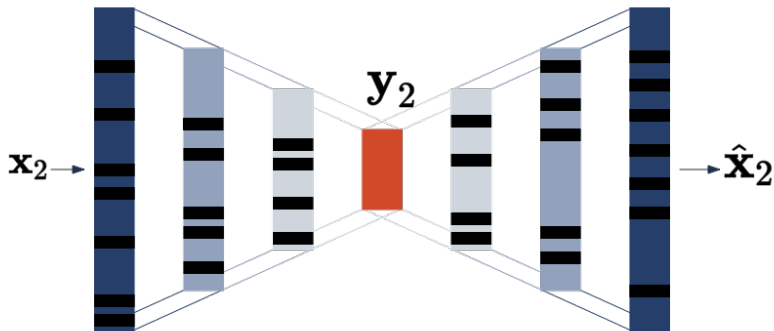
where  $n$  is the number of datapoints, and  $\mathbf{x}_{i-1}$  is the output from the previous layer to  $i$ .



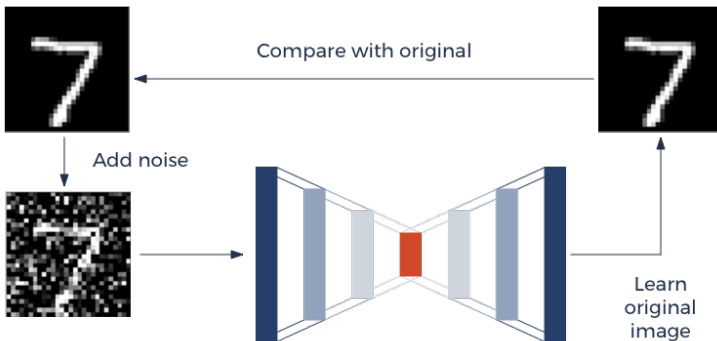
# Sparse Autoencoders



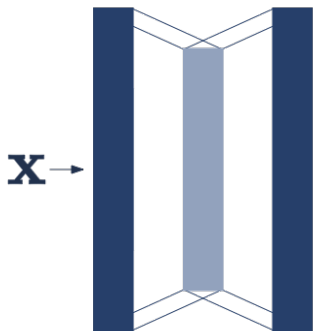
# Sparse Autoencoders



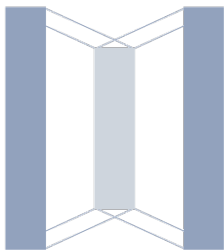
# Denoising Autoencoders



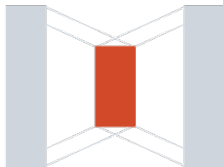
# Stacked Autoencoders



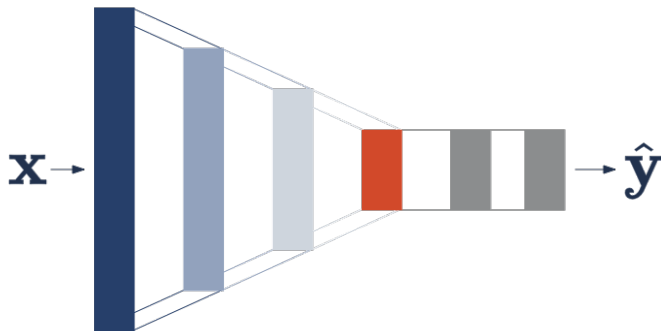
# Stacked Autoencoders



# Stacked Autoencoders



# Stacked Autoencoders



# Questions



These slides are designed for educational purposes, specifically the CSCI-470 Introduction to Machine Learning course at the Colorado School of Mines as part of the Department of Computer Science.

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