



## Pulsed Neural Networks

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#### Overview



Challenging Problems

**Artificial Neural Networks** 

Learning

**Dynamic Networks** 

Pulsed Networks

**Applications** 





# Challenging Problems



### Challenging Problems



Image recognition in varied settings

Speech recognition in noise

Robotic control and navigation









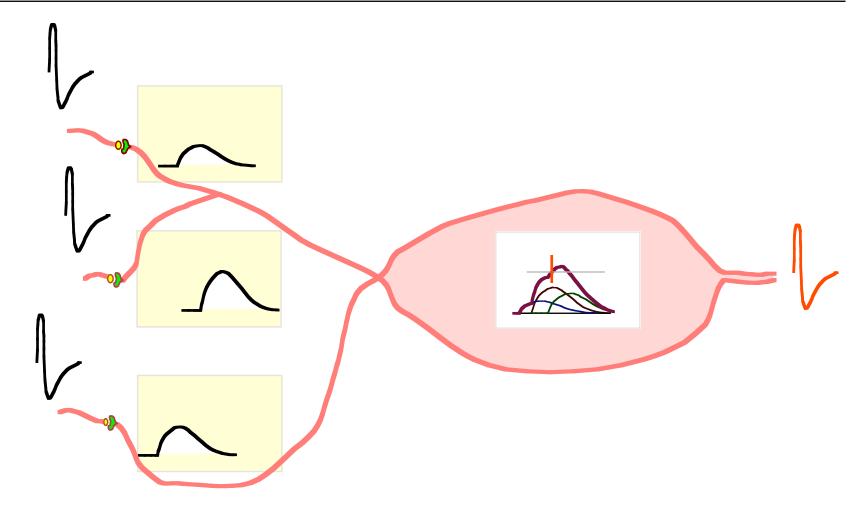


## Artificial Neural Networks



## Biological Neuron

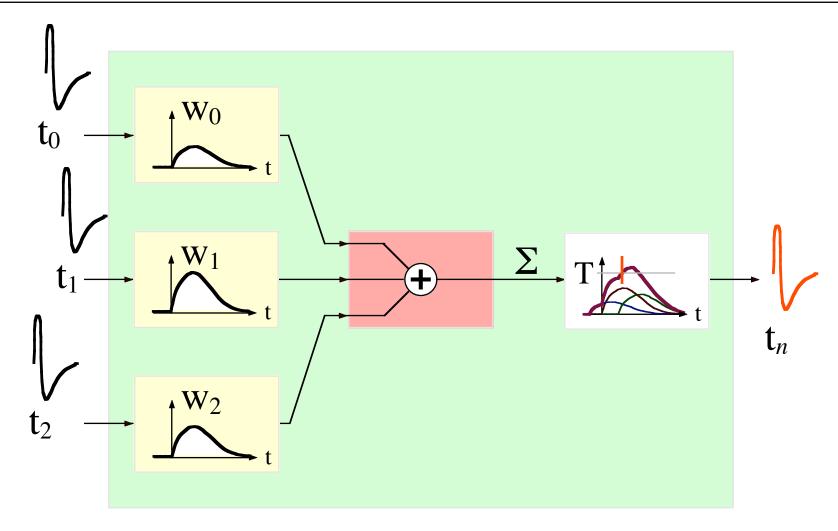






### Biological Neuron

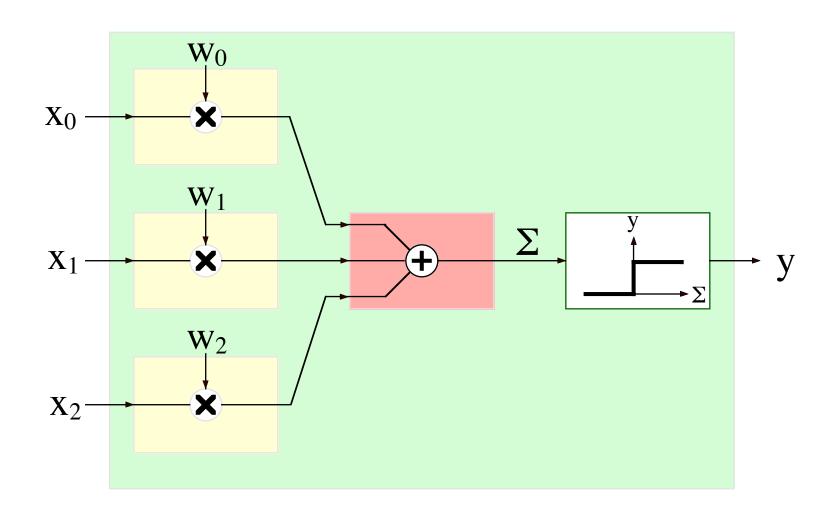






### Perceptron

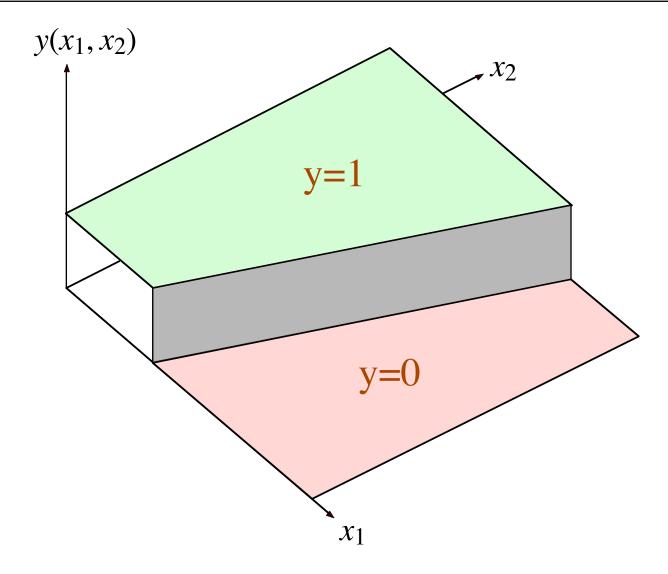






### Perceptron Response

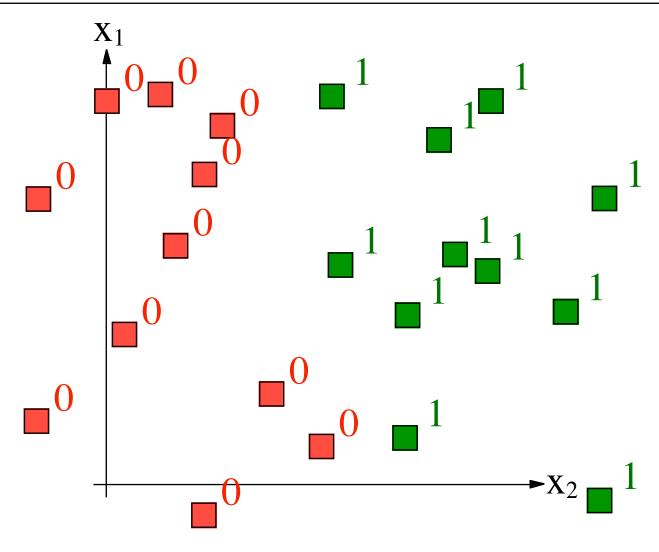






### Linear Separability

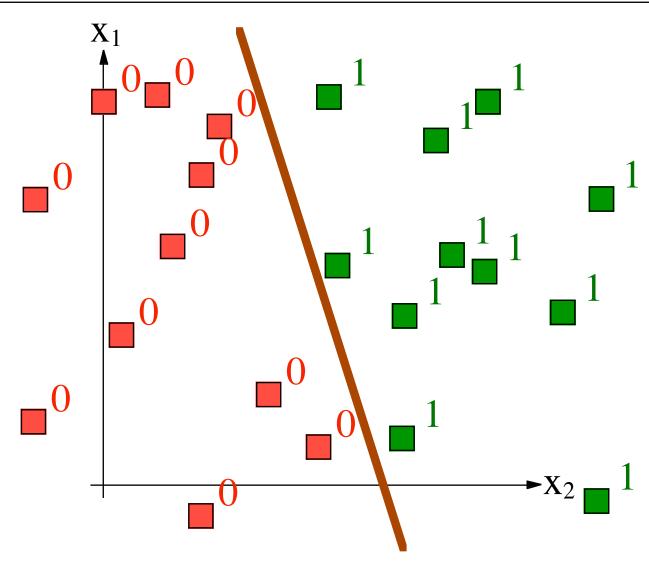






## Linear Separability

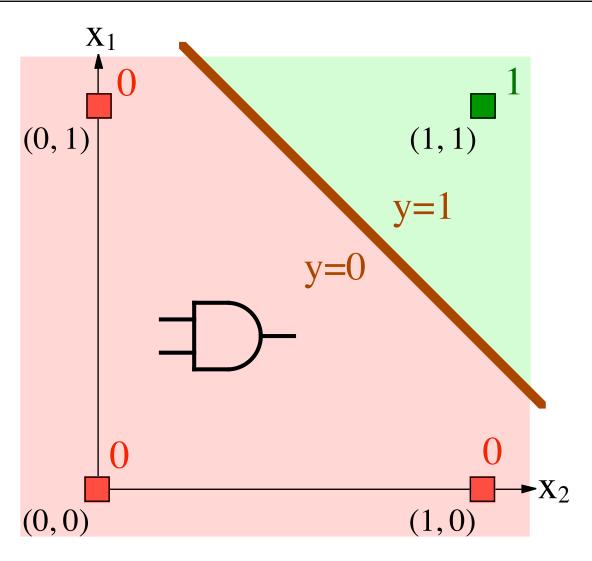






### Logic Gates

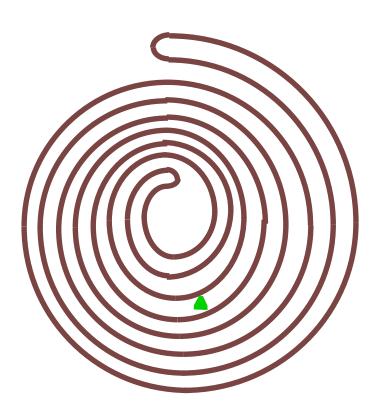






## Parallel Processing

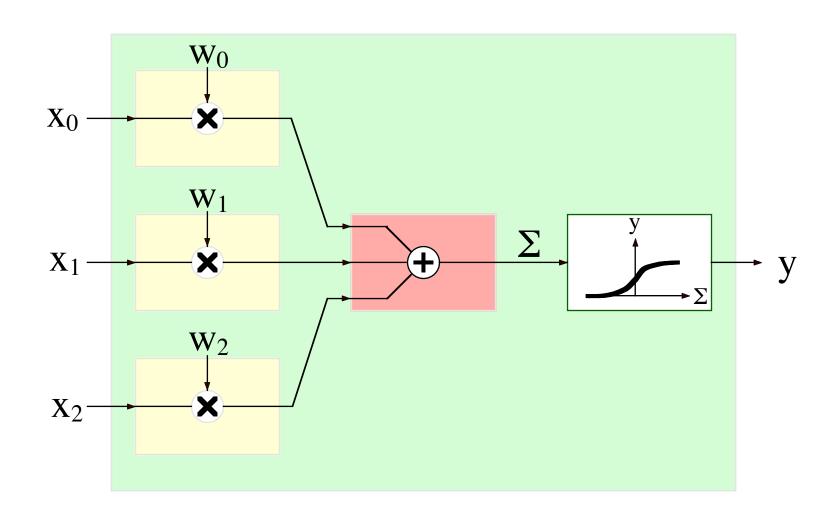






### Sigmoid Neuron

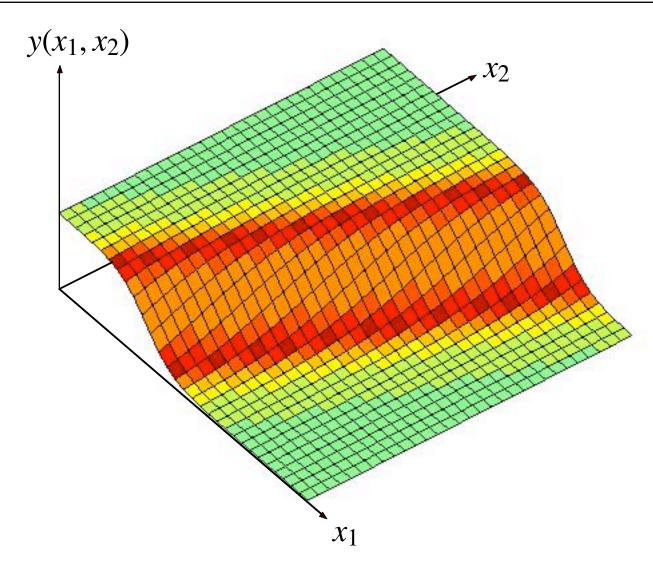






### Sigmoid Neuron Response

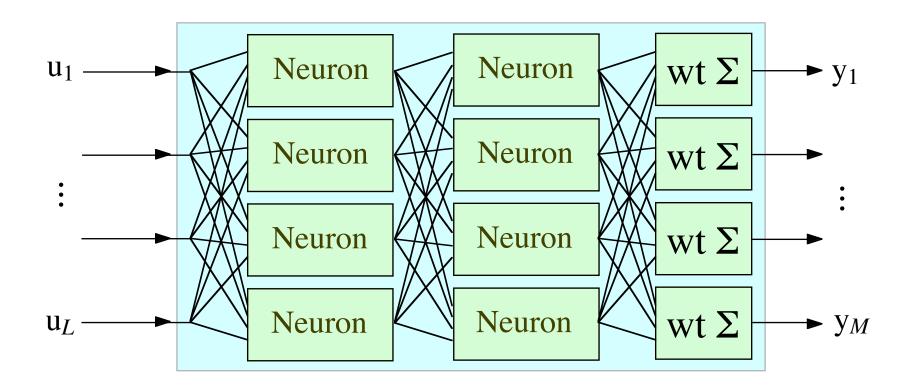






#### Neural Network

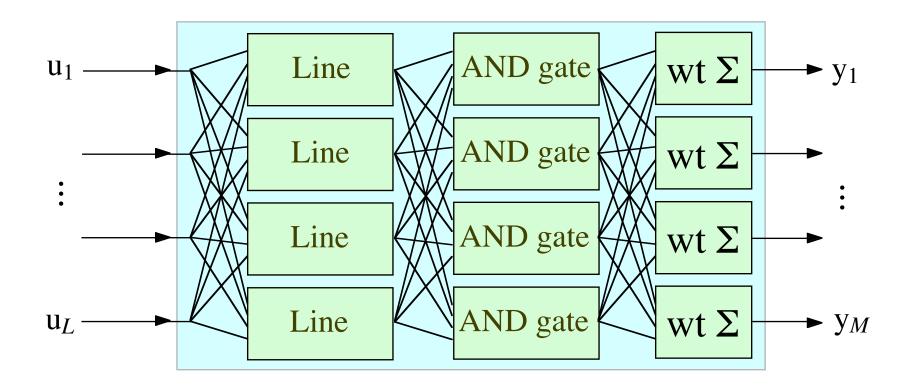






#### Neural Network

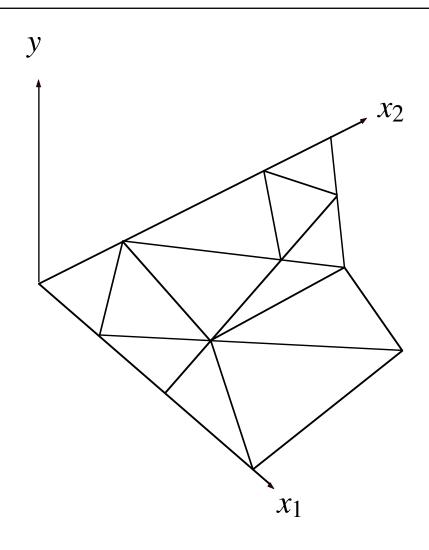






# Universal Approximation

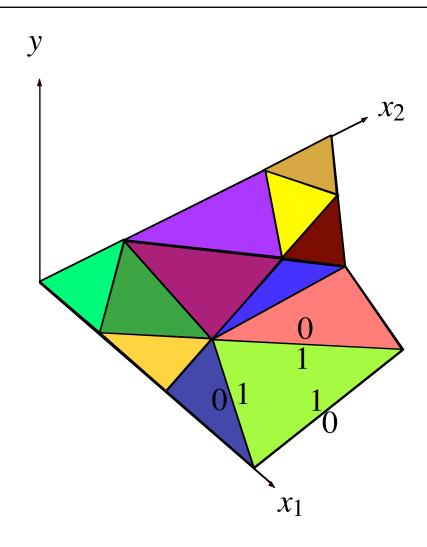






# Universal Approximation

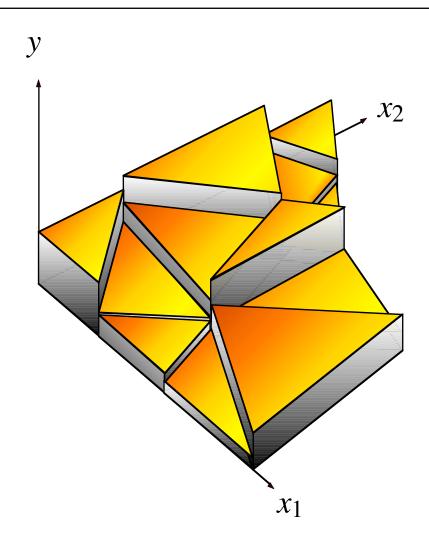






## Universal Approximation

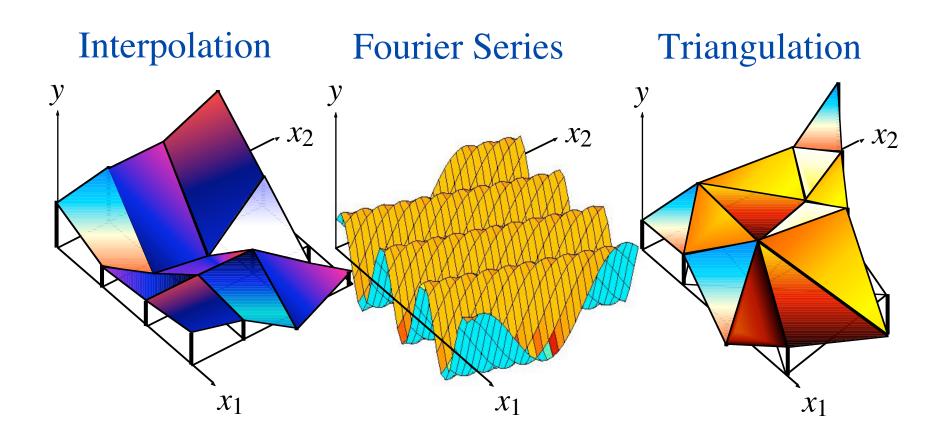






## **Function Approximations**





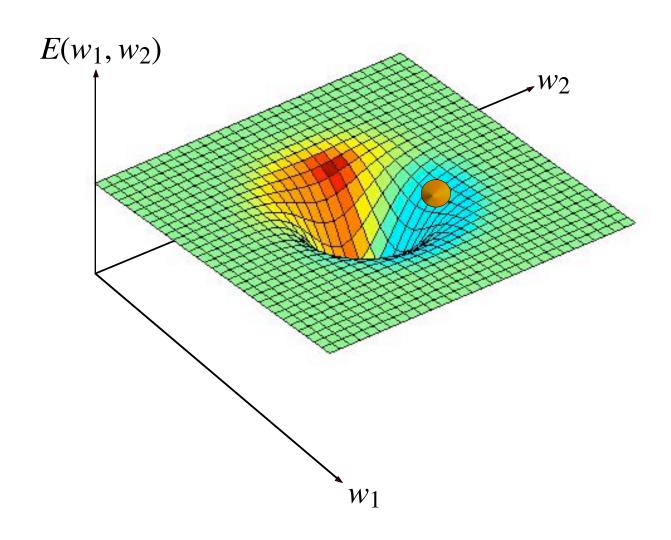




# Learning

### **Gradient Descent**

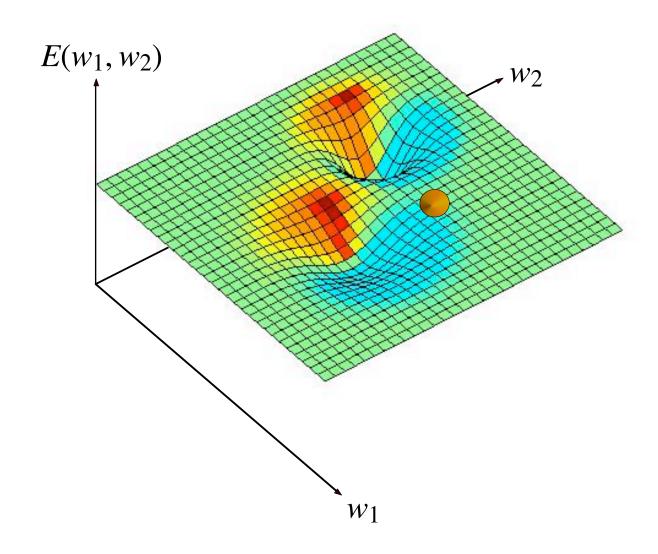






### Local Minima

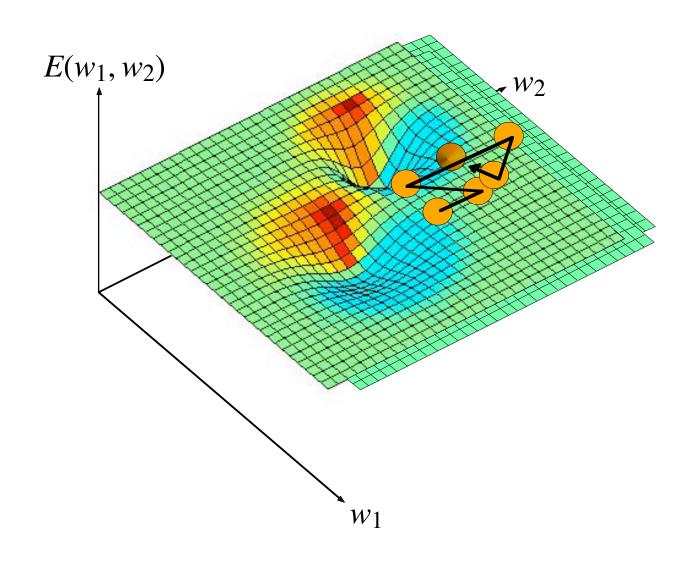






### Backward-Error Propagation







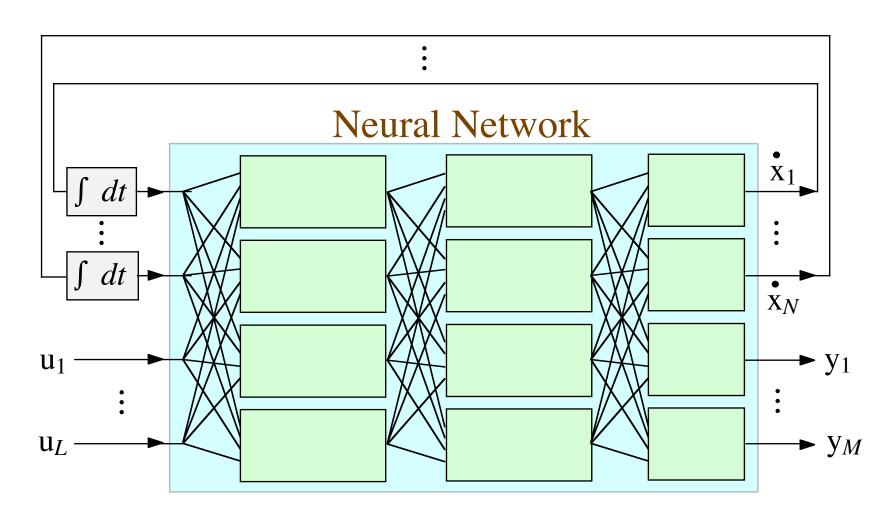


# Dynamic Networks



### Dynamic Networks

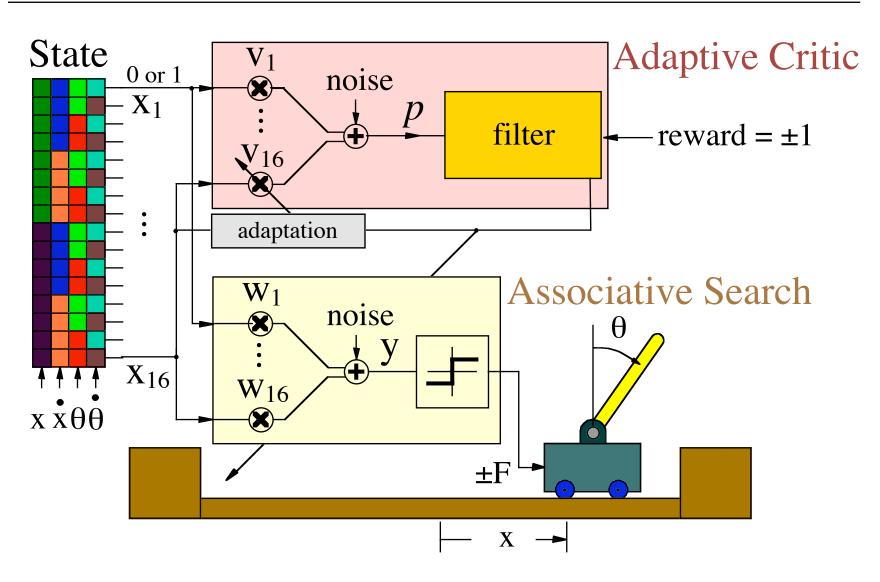






### Learning through Time

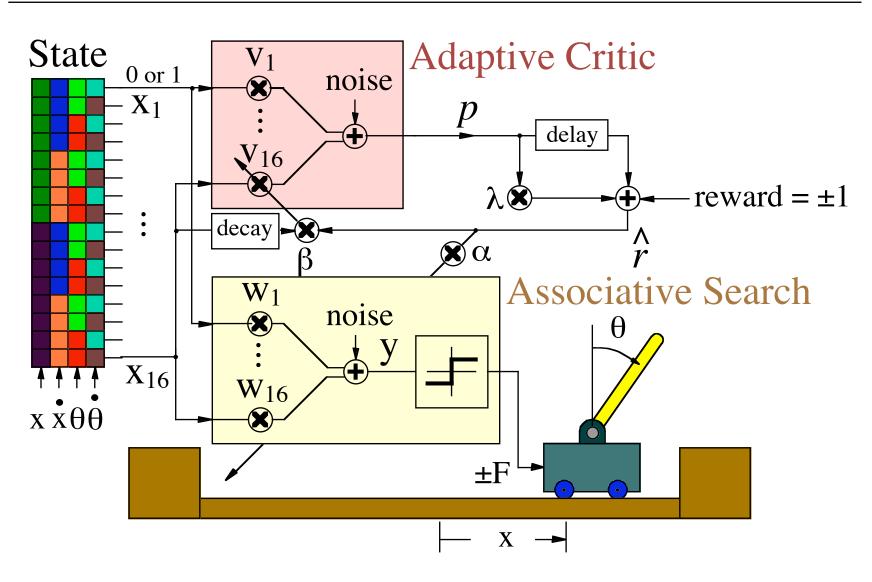






### Learning through Time







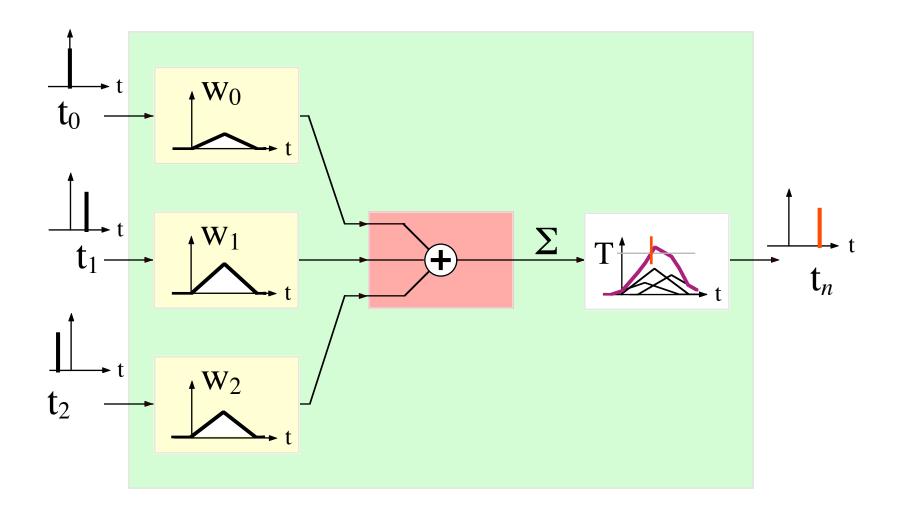


# Pulsed Networks



### Pulsed Neuron

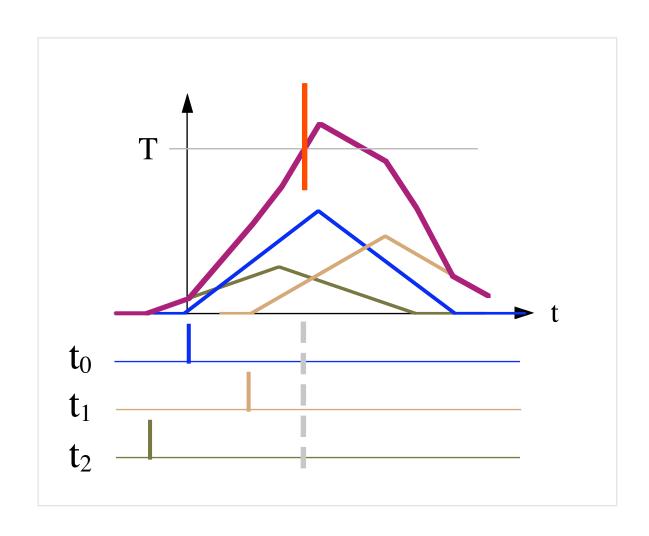






## Pattern Processing

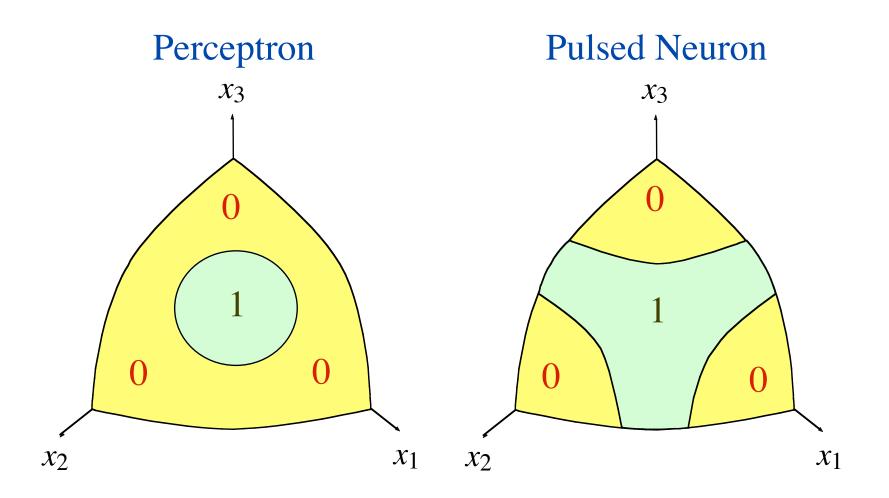






### Response Regions

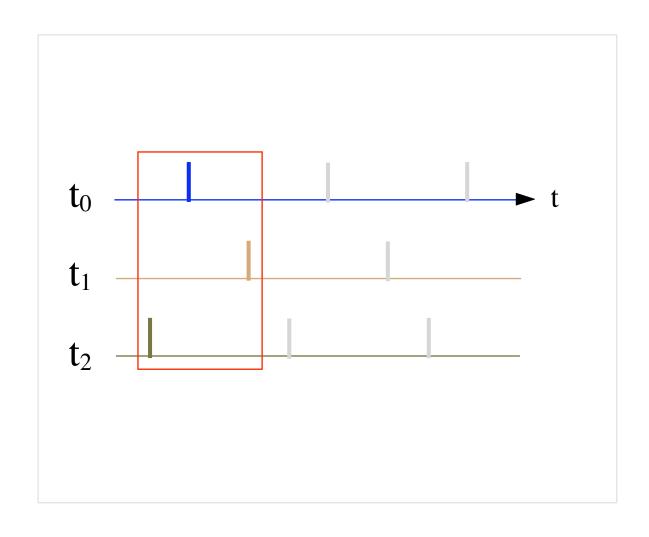






#### Pattern Windows

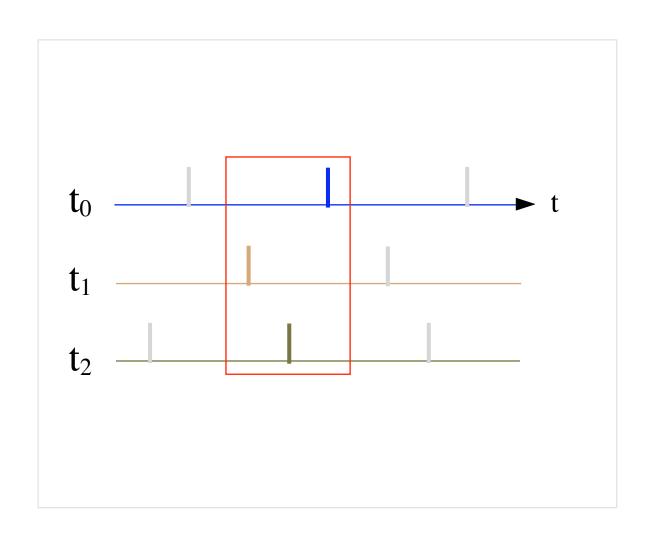






## Pattern Processing

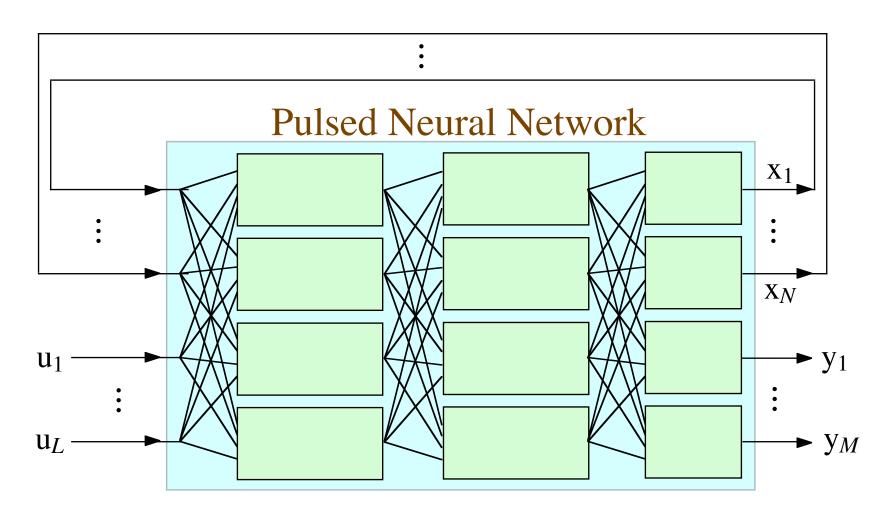






### Dynamic Pulsed Networks







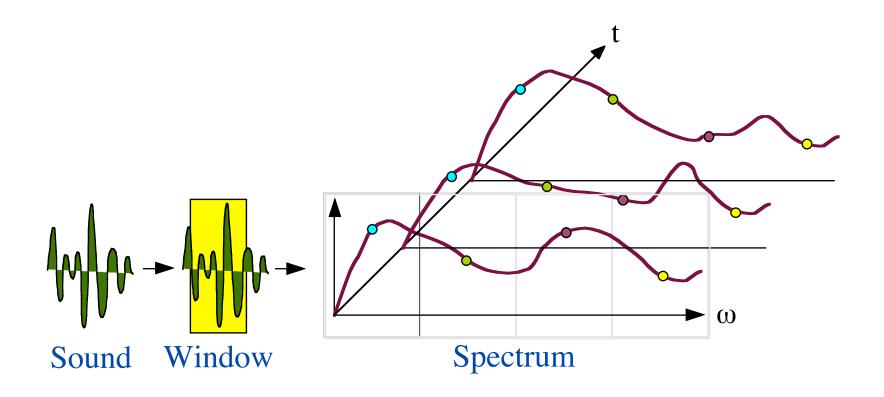


# Applications



## Speech Recognition

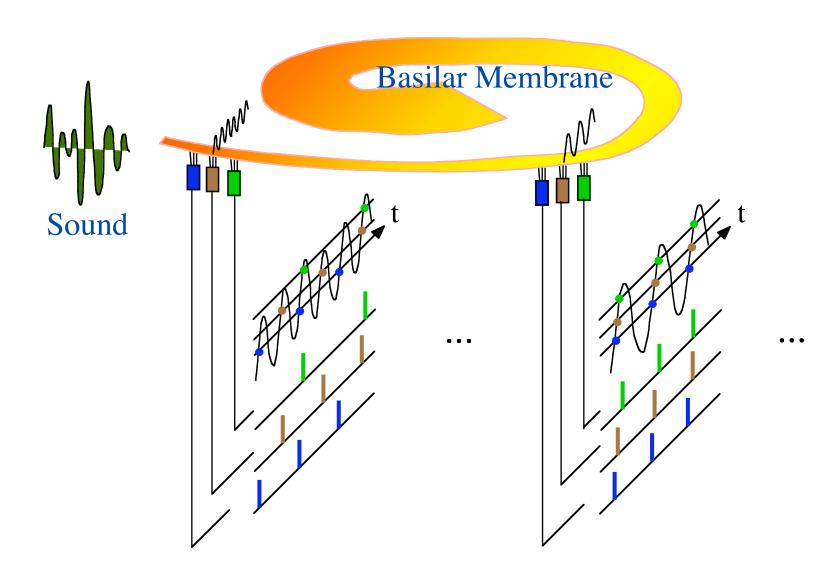






### **Auditory System**







### Research Opportunities



Mathematically describe pattern processing

Devise pattern-learning algorithms

**Build circuits** 

