Pulsed Neural Networks

Neil E. Cotter

ECE Department
University of Utah
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
Perceptron

\[ y = \sum w_i x_i \]
Perceptron Response

\[ y(x_1, x_2) \]

\[ y = 1 \]

\[ y = 0 \]
Linear Separability
Logic Gates

\[(1, 1)\]

\[(0, 1)\]

\[(0, 0)\]

\[(1, 0)\]

\[y=1\]

\[y=0\]

\[x_1\]

\[x_2\]
Sigmoid Neuron

\[ y = \sigma(\sum w_i x_i) \]

where \( \sigma \) is the sigmoid function.

\[ \sigma(z) = \frac{1}{1 + e^{-z}} \]
Sigmoid Neuron Response

\[ y(x_1, x_2) \]
Neural Network
Neural Network
Universal Approximation
Universal Approximation

\[ y = x_1^2 \]
Learning
Gradient Descent

\[ E(w_1, w_2) \]
Local Minima

\[ E(w_1, w_2) \]
Backward-Error Propagation

\[ E(w_1, w_2) \]

\[ w_1 \]

\[ w_2 \]
Dynamic Networks
Dynamic Networks

Neural Network

\[ \frac{\text{\(u_1\)}}{	ext{\(\int dt\)}} \quad \frac{\text{\(u_L\)}}{	ext{\(\int dt\)}} \]

\[ \text{\(x_1\)} \quad \text{\(x_N\)} \]

\[ \text{\(y_1\)} \quad \text{\(y_M\)} \]
Learning through Time

Adaptive Critic

Associative Search

State

$0 \text{ or } 1$

$x \times 1$

$x_1$

$x_1$

$x \times 1$

$V_1$

$V_{16}$

noise

$p$

filter

reward $= \pm 1$

adaptation

$W_1$

$W_{16}$

noise

$y$

$x \times \theta \times \theta$

$x \times \theta \times \theta$

$\theta$

$\pm F$

$x$

$x$

$\theta$
Learning through Time

State

Adaptive Critic

Associative Search

\[ x \times \theta \theta \]

\[ 0 \text{ or } 1 \]

\[ X_1 \]

\[ V_1 \]

\[ V_{16} \]

noise

delay

\[ p \]

\[ \lambda \times \]

\[ \alpha \]

\[ \beta \]

\[ \gamma \]

\[ r \]

\[ \text{reward} = \pm1 \]

\[ w_1 \]

\[ v_1 \text{ } \text{ noise} \]

\[ v_{16} \text{ noise} \]

\[ y \]

\[ W_1 \]

\[ W_{16} \]

\[ \pm F \]

\[ \theta \]

\[ x \]

\[ X_16 \]
Pulsed Networks
Pulsed Neuron

\[ t \]

\[ t_0 \]

\[ t_1 \]

\[ t_2 \]

\[ t_\Sigma \]

\[ t_n \]
Pattern Windows
Dynamic Pulsed Networks

Pulsed Neural Network

\( u_1 \rightarrow x_1 \rightarrow x_N \rightarrow y_1 \rightarrow y_M \)

\( u_L \rightarrow x_1 \rightarrow x_N \rightarrow y_1 \rightarrow y_M \)
Applications
Speech Recognition

Sound → Window → Spectrum
Mathematically describe pattern processing

Devise pattern-learning algorithms

Build circuits