DLP Driven, Learning, Optical Neural Networks

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SPRP506

Neural Network Applications

- **Stock Prediction:** Currency, Bonds, S&P 500, Natural Gas
- **Business:** Direct mail, Credit Scoring, Appraisal, Summoning Juries
- **Medical:** Breast Cancer, Heart Attack Diagnosis, ER Test Ordering
- **Sports:** Horse and Dog Racing
- **Science:** Solar Flares, Protein Sequencing, Mosquito ID, Weather
- **Manufacturing:** Welding Quality, Plastics or Concrete Testing
- **Pattern Recognition:** Speech, Article Class., Chem. Drawings
- **No Optical Applications:** Starting with Boolean

Most from www.calsci.com/Applications.html

Optical Computing & Neural Networks

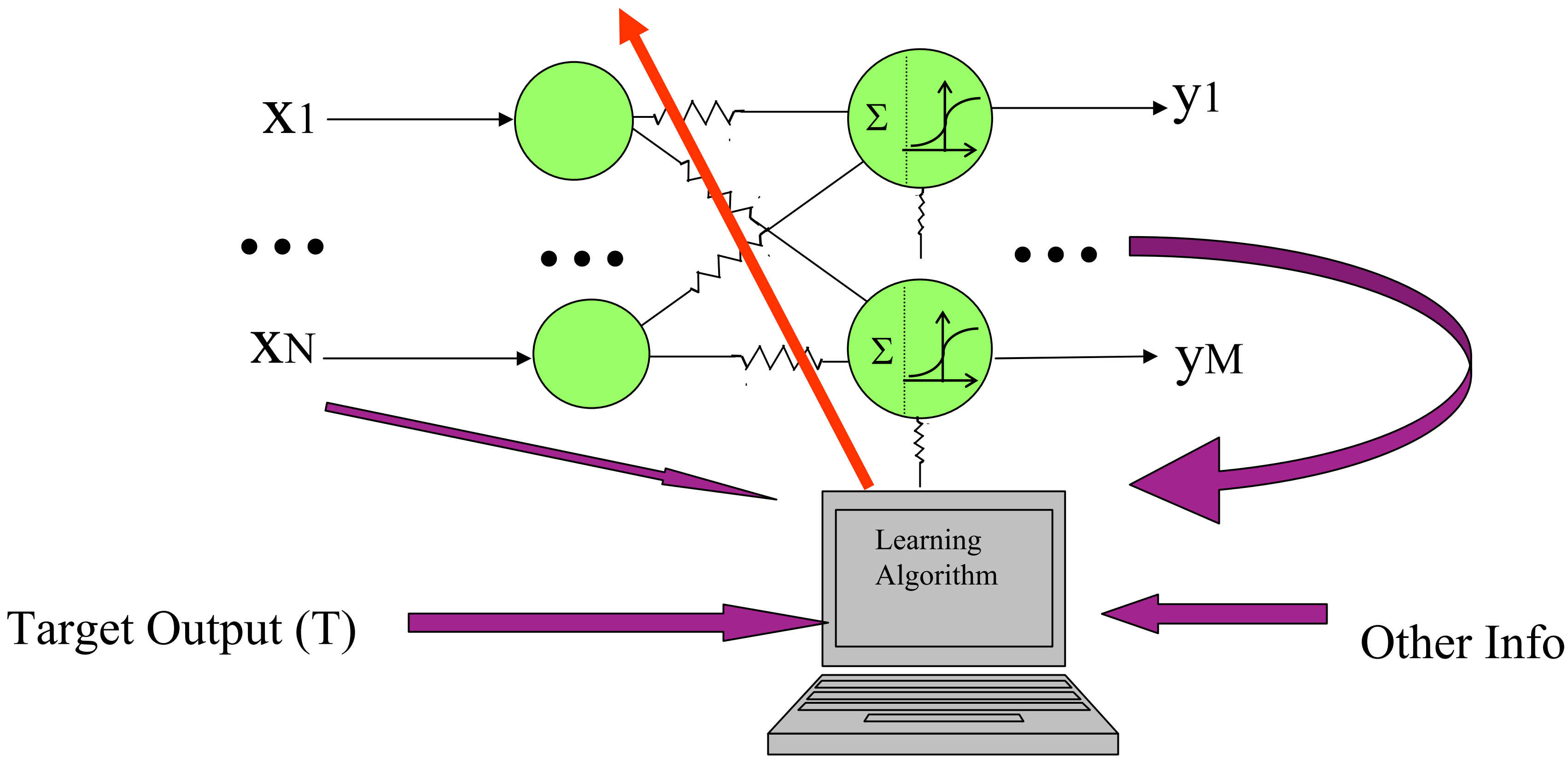
- **Optical Parallel Processing Gives Speed**
  - Lenslet’s Enlight 256—8 Giga Multiply and Accumulate per second
  - Order 10^{11} connections per second possible with holographic attenuators
- **Neural Networks**
  - Parallel versus Serial
  - Learn versus Program
  - Solutions beyond Programming
  - Deal with Ambiguous Inputs
  - Solve Non-Linear problems
  - Thinking versus Constrained Results

Optical Neural Networks

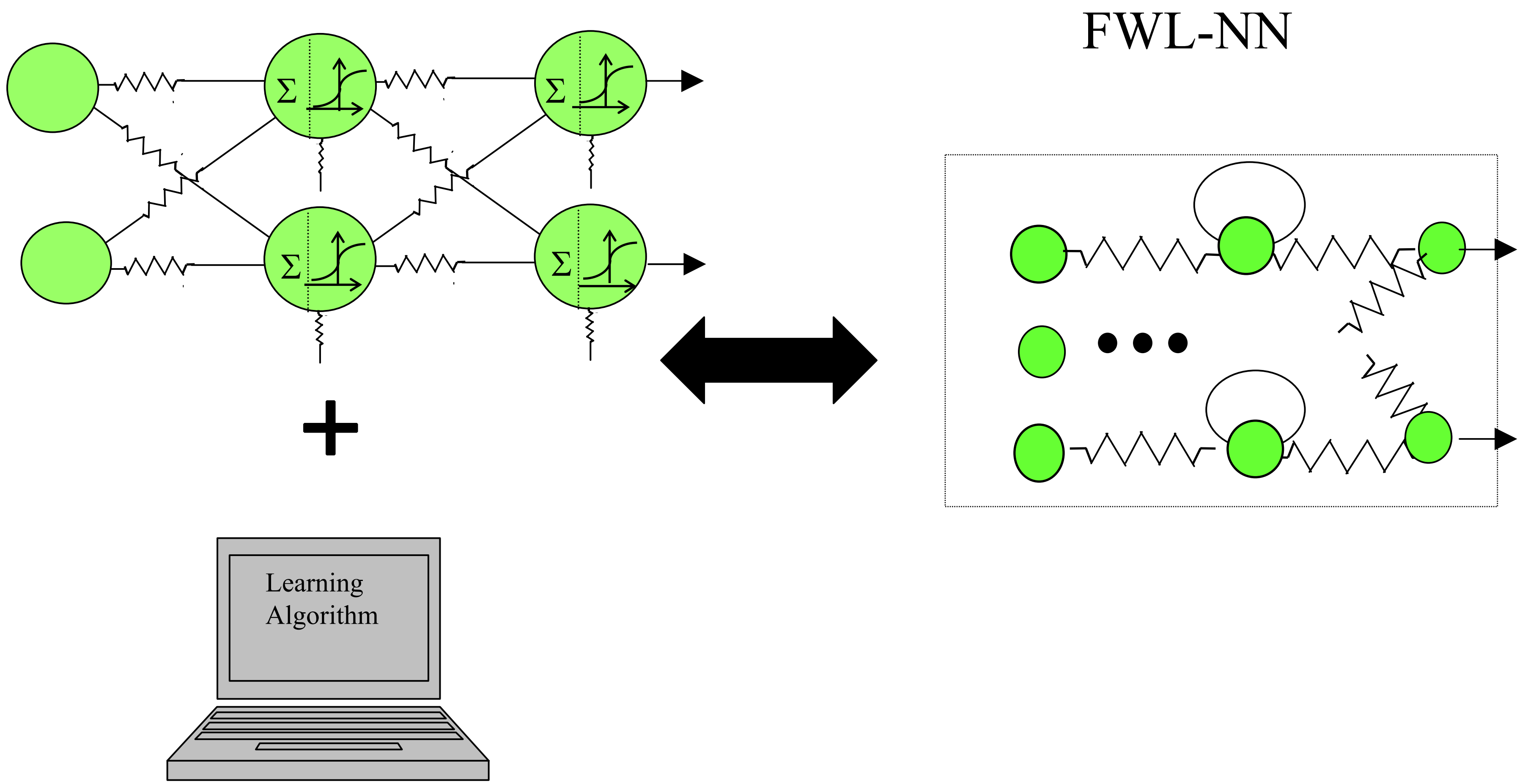
- Sources are modulated light beams (pulse or amplitude)
- Synaptic Multiplications are due to attenuation of light passing through an optical medium
- Geometric or Holographic
- Target neurons sum signals from many source neurons.
- Squashing by operational-amps or nonlinear optics

Standard Neural Net Learning

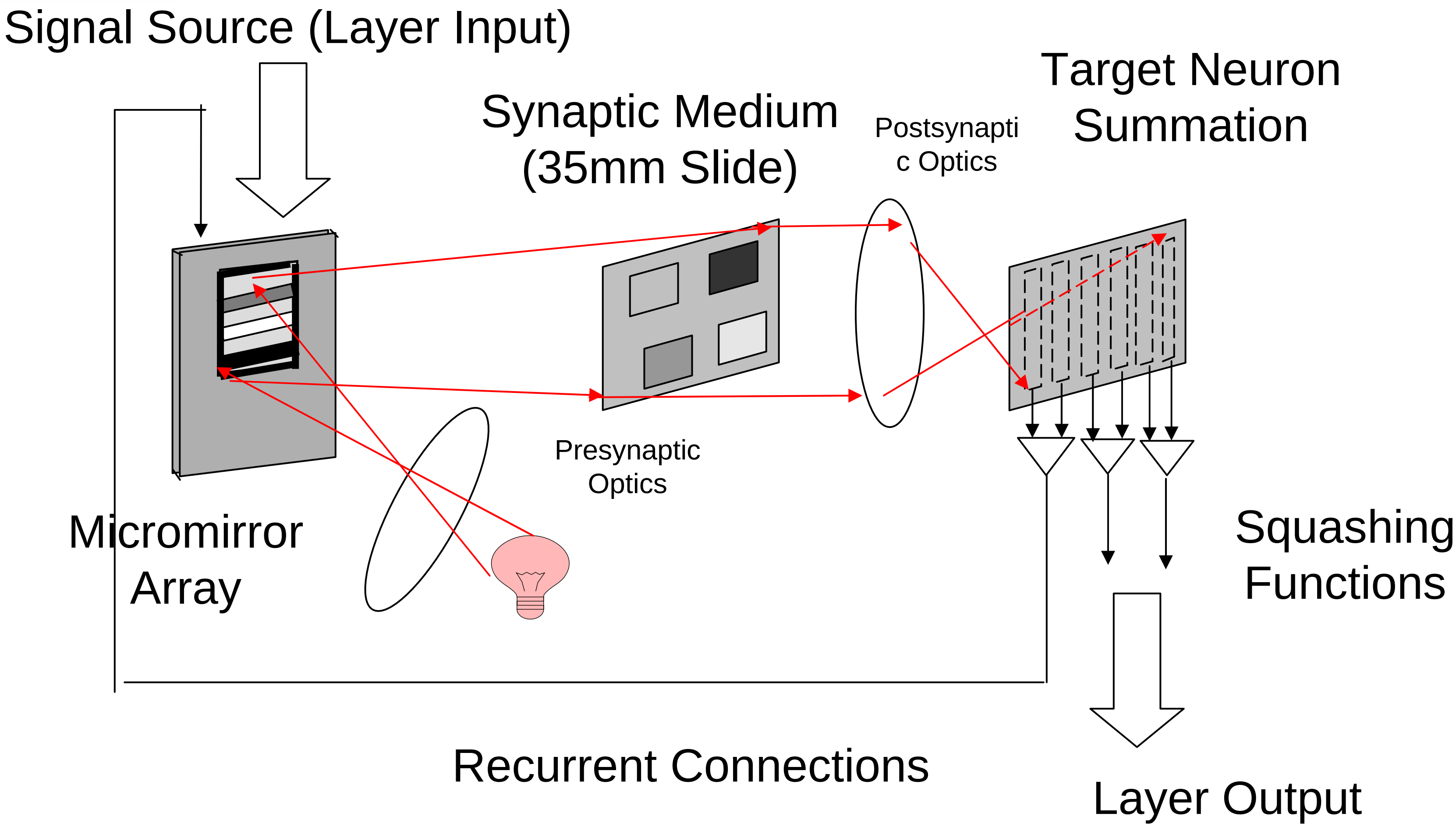
- We use a Training or Learning algorithm to adjust the weights, usually in an iterative manner.



FWL-NN Is Equivalent to a Standard Neural Network + Learning Algorithm

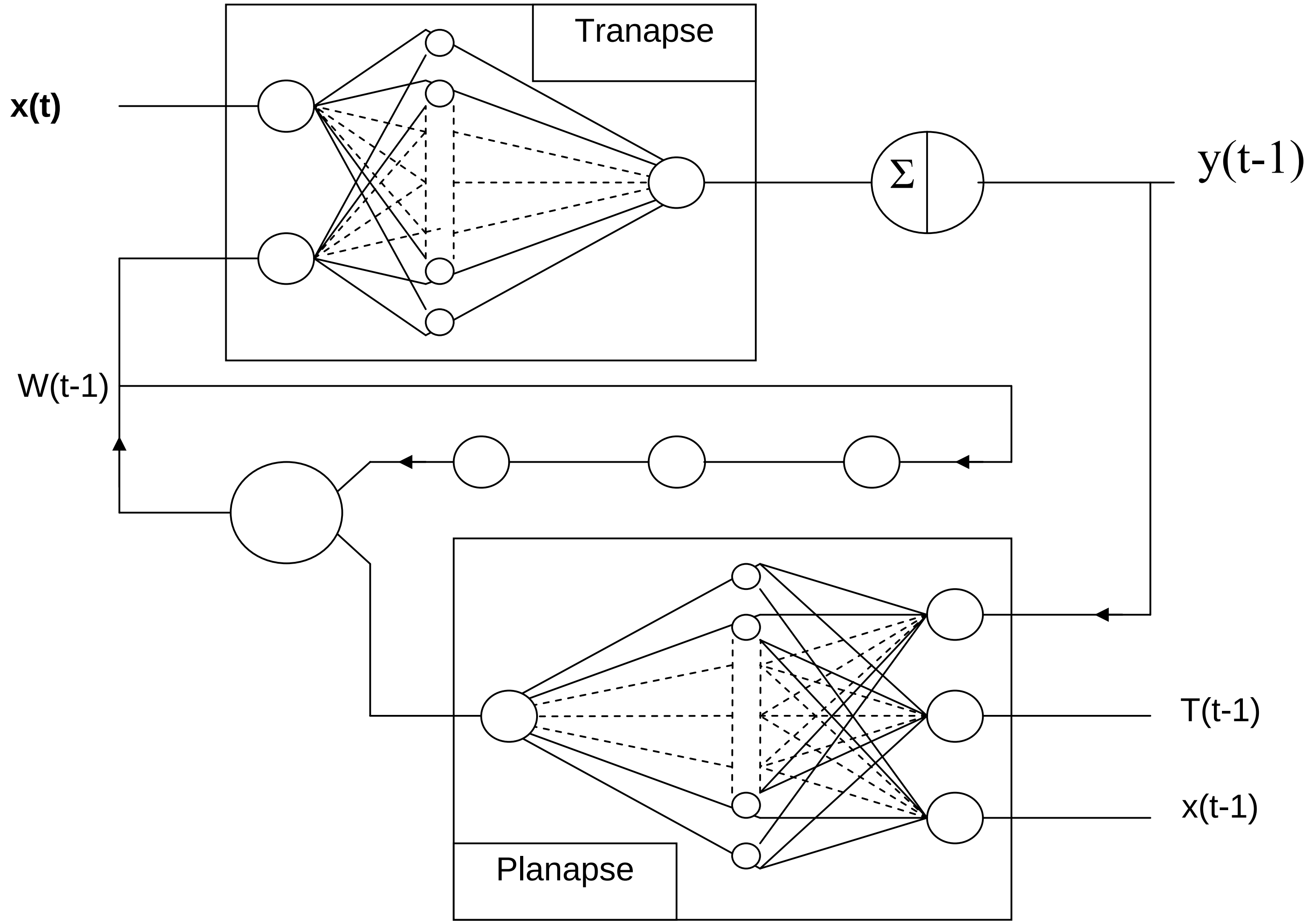


Optical Recurrent Neural Network



A Single Layer of an Optical Recurrent Neural Network. Only four synapses are shown. Actual networks will have a large number of synapses. A multi-layer network has several consecutive layers.

Optical Fixed-Weight Learning Synapse

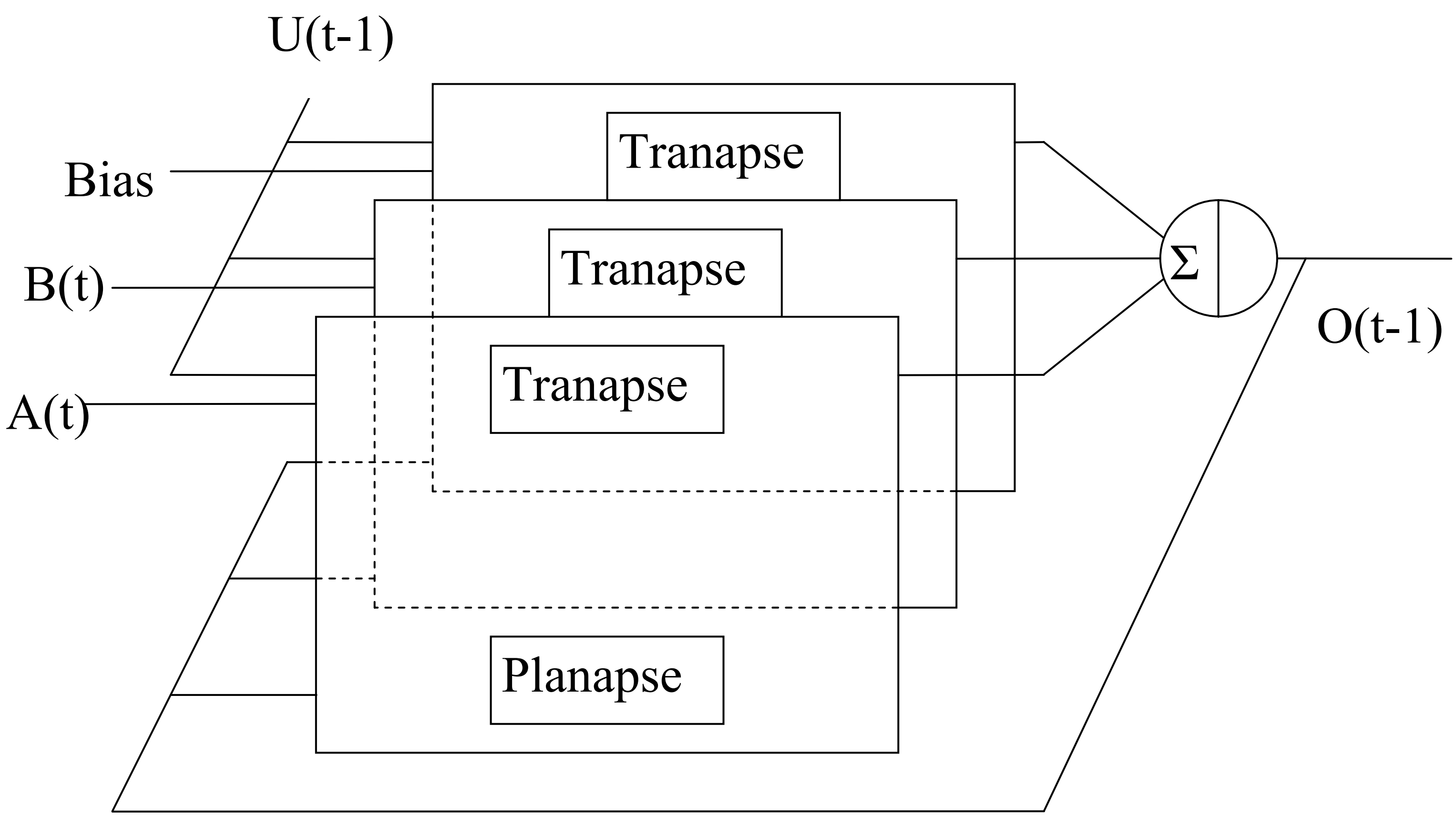


TI | Developer Conference

Definitions

- **Fixed-Weight Learning Neural Network (FWL-NN) – A recurrent network that learns without changing synaptic weights**
- **Potency – A weight signal**
- **Tranapse – A Potency modulated synapse**
- **Planapse – Supplies Potency error signal**
- **Recurron – A recurrent neuron**
- **Recurral Network – A network of Recurrons**

Page Representation of a Recurron



Optical Neural Network Constraints

- Finite Range Unipolar Signals [0,+1]
- Finite Range Bipolar Attenuation[-1,+1]
- Excitatory/Inhibitory handled separately
- Limited Resolution Signal
- Limited Resolution Synaptic Weights
- Alignment and Calibration Issues

Proposed Design

- Digital Micromirror Device
- 35 mm slide Synaptic Media
- CCD Camera
- Synaptic Weights - Positionally Encoded
  - Digital Attenuation
- Planapse, Tranapse trained using Standard Backpropagation
- Allows flexibility for evaluation.

Generation, Acquisition, Processing

- **Demonstration**
  - Left Images (time order)
    - Gray-scale Source Neuron Signal
    - Equivalent Pulse Modulated Source Neuron Signal
    - Gray-scale Source Neuron Signal – Reprise
    - Blank during Target Summation and Squashing
  - Middle Image – Fixed Weights on Attenuator Slide (static)
  - Right Images (time order)
    - Blank during First Source Gray-scale
    - Accumulating (Integrating Pulses) Target Neuron Input
    - Gray-scale during Summation and Squashing
  - Phases and Layers
    - Synapses Connect Two Layers (N and N+1)
    - Only Source Neurons (layer N) Illuminate
    - Only Target Neurons (layer N+1) Accumulate

Hard and Soft Optical Alignment

- **Hardware Alignment**
  - Best for Gross Alignment
  - Precision Stages Required for Precise Alignment
  - Hard to Correct for Distortions in Optics
- **Software Alignment**
  - Fine Image Displacements
  - Image Rotation
  - Integrating Regions of Arbitrary Shape and Size
  - Diffraction Effects Filtered and Ignored
  - Correct for Optical Path Changes

Photonic Circuit Elements

- **NEAR**
  - Optical Fiber
  - Fiber Amplifiers
  - Splitters
- **MEDIUM**
  - Cylindrical Lenses before and after Synaptic Media (1-D systems, sparse media)
  - Non-Linear Crystals for Squashing
- **FAR**
  - Integrated Emitters, Attenuator, Detectors/Limiters
  - Holographic Attenuators (destructive interference)
  - Stackable

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