Brain-like Computing: Mixed-mode Circuit Implementations of Neural Networks for Artificial Intelligence Applications

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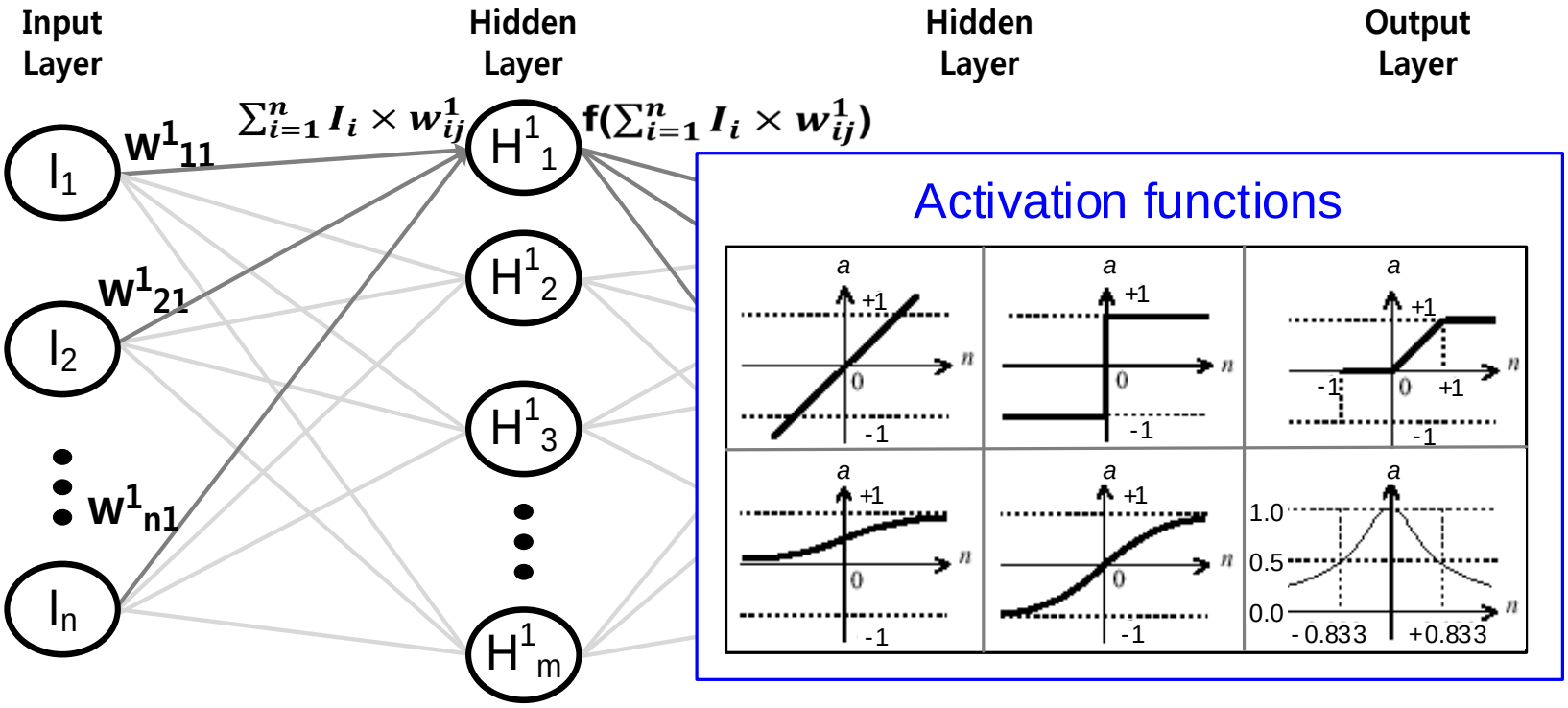
Neural Network Operation

- **Feed-forward operation (*inferencing*)**
  - MULT, ADD, activation function
- **Feed-back operation (*training*)**
  - Back-propagation $\Delta w_i = \frac{\partial}{\partial w_i}(\frac{1}{2}\sum_p (d_p - z_p)^2)$

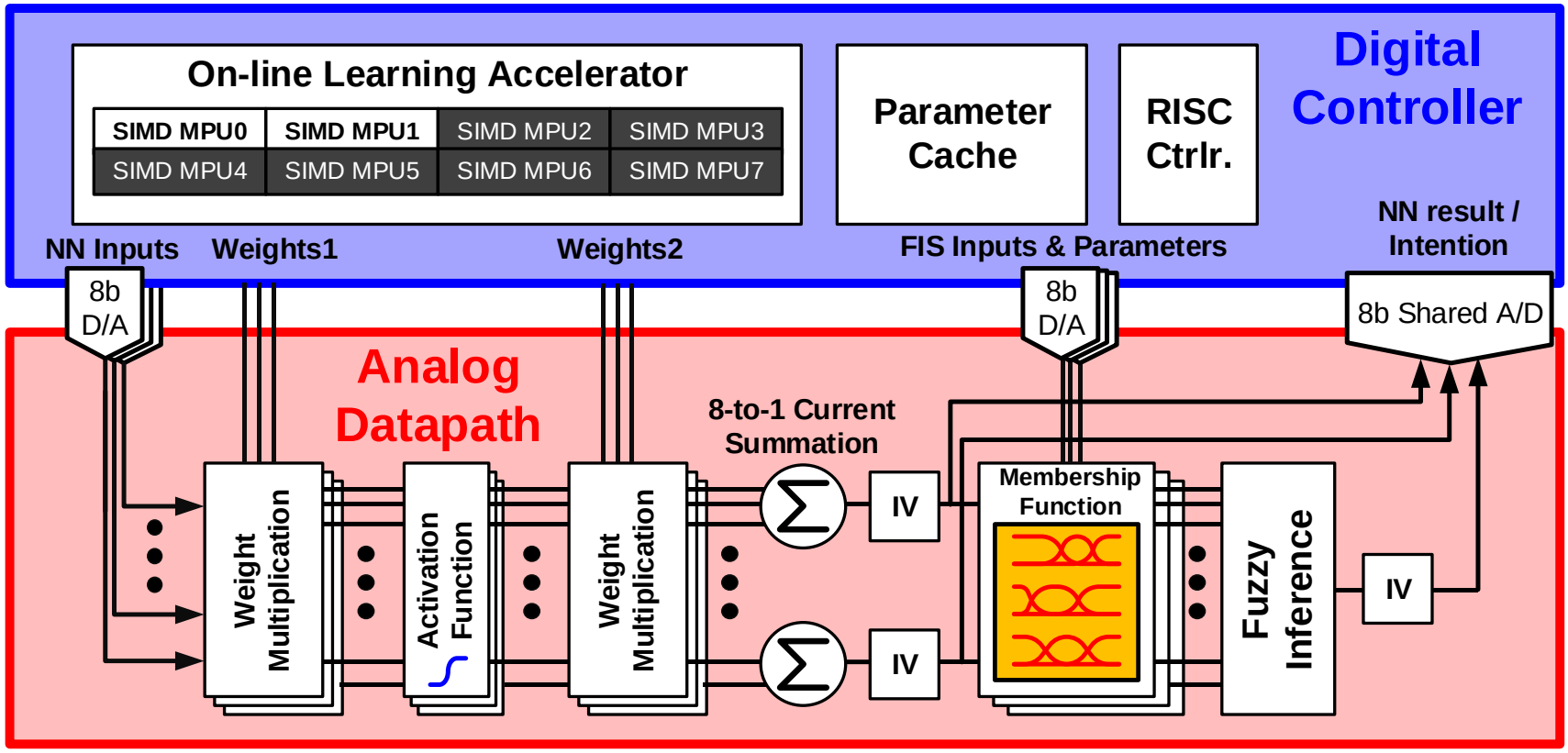


Importance of Hybrid Computing

	Advantages	Disadvantages
Hybrid Computing **Mixed-Mode Implementation**	1. Analog acceleration of basic operations ➔ Small area 2. Accurate digital computation for training 3. Flexible control 4. Static data storage	1. Domain conversion overhead 2. Complicated design

- **Analog : Non-Linear, Parallel Operation → Inference**
- **Digital : Repetitive, Accurate Operation → Training**
- **Data Conversion → Parameter, In-Out Load/Store**

Mixed-Mode Architecture Example



Mixed-mode RNN-FIS Circuit

1. **Current Mode Analog Datapath** for **Ultra-LP**
2. **Digital Controller** for **Flexible On-line Learning**

*DPE: Deep Risk Prediction Engine **RNN: Recurrent Neural Network ***FIS: Fuzzy Inference System

System Demonstration Example