On-chip Training of Deep Neural Networks Using Unsupervised and Supervised Learning Methods
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Abstract
This poster presents on-chip training circuits for memristor based deep neural networks utilizing unsupervised and supervised learning methods. Memristor crossbars are prone to device variations and faults. On-chip training circuits would allow the training algorithm to account for device variability and faults in these circuits. We utilize autoencoders for layer-wise pre-training of the deep networks and utilize the back-propagation algorithm for supervised fine tunning. We demonstrate successful training of memristor based deep networks for the MNIST digit classification and the KDD intrusion detection datasets.

Objectives
- Memristor based deep network training.
- Autoencoders for layer-wise pre-training.
- Circuit for unsupervised and supervised training.

Deep Neural Network

\[ D_P = \sum_{i=1}^{n} x_i w_{ij} y_j = f(D_P) \]

Fig. 1. Deep network.

Memristor Crossbar Neural Network

\[ y_j = R_f [A(\sigma_{s_k} - \sigma_{s_-}) + \ldots + \beta(\sigma_{p_k} - \sigma_{p_-})] \]

Fig. 2. Memristor crossbar.

Fig. 3. Memristor based neuron circuit performing parallel analog operation.

Fig. 4. Memristor based 2 layer neural network.

Fig. 5. Training memristor based deep network.

Experimental Evaluations

Table I: Neural network configurations.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNIST</td>
<td>784→200→100→10</td>
</tr>
<tr>
<td>KDD</td>
<td>41→100→50→20→1</td>
</tr>
</tbody>
</table>

Fig. 6. Training graph for KDD (left) and MNIST (right) datasets.

Table II: Recognition error on test data.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Recognition error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDD (5000 test data)</td>
<td>3.36</td>
</tr>
<tr>
<td>MNIST (5000 test data)</td>
<td>8.06</td>
</tr>
</tbody>
</table>

Conclusion
In this work we have designed on-chip training system for memristor based deep neural networks utilizing two memristors per synapse. We have utilized autoencoders for layer-wise pre-training of the networks and utilized the back-propagation algorithm for supervised fine tunning.