An FPGA Implementation of Convolutional Spiking Neural Networks for Radioisotope Identification

Xiaoyu Huang, Student Member, IEEE, Edward Jones, Siru Zhang, Shouyu Xie, Steve Furber, Fellow, IEEE, Yannis Goulermas, Edward Marsden, Ian Baistow, Srinjoy Mitra, Senior Member, IEEE, Alister Hamilton

University of Edinburgh, UK, University of Manchester, UK, University of Liverpool, UK, Kromek Group plc, UK

2021 IEEE International Symposium on Circuits and Systems
May 22-28, 2021 Virtual & Hybrid Conference
Why Convolutional Spiking Neural Networks?

Radioisotope Identification:

1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID


Why Convolutional Spiking Neural Networks?

Radioisotope Identification:

1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID


Why Convolutional Spiking Neural Networks?

Radioisotope Identification:

1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID


Why Convolutional Spiking Neural Networks?

Radioisotope Identification:

1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID

Why Convolutional Spiking Neural Networks?

Radioisotope Identification:
1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID

Frame-based Method


Why Convolutional Spiking Neural Networks?

Radioisotope Identification:
1. Scintillation
2. Photon Detection
3. ADC & Integration
4. Histogram Generation
5. Radioisotope ID

Problems:
It continuously consume power, even when the event arrival rates are very low or zero

Why Convolutional Spiking Neural Networks?

Problems: Scalability and data resolution limitations


Why Convolutional Spiking Neural Networks?

<table>
<thead>
<tr>
<th>Structure</th>
<th>ICECS 2020</th>
<th>This work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input neuron No.</td>
<td>100</td>
<td>1,024</td>
</tr>
<tr>
<td>Total neuron No.</td>
<td>148</td>
<td>5,368</td>
</tr>
<tr>
<td>Weight No.</td>
<td>4,320</td>
<td>2,036</td>
</tr>
<tr>
<td>Operations/event</td>
<td>Max. 360</td>
<td>Max. 160</td>
</tr>
</tbody>
</table>

Kernel size: 5
Stride: 1
Output: fully-connected

Kernel size: 16
Stride: 16

Input: 1024

Conv: 1020 4 1 1 2

Pool: 256

Output: 8


FPGA Implementation

Microarchitecture of convolutional layer

<table>
<thead>
<tr>
<th>Logic Utilisation</th>
<th>Used</th>
<th>Available</th>
<th>Utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice Registers</td>
<td>1,470</td>
<td>41,600</td>
<td>3.53%</td>
</tr>
<tr>
<td>Slice LUTs</td>
<td>1,044</td>
<td>20,800</td>
<td>5.02%</td>
</tr>
<tr>
<td>BUFGCTRL</td>
<td>1</td>
<td>32</td>
<td>3.13%</td>
</tr>
<tr>
<td>Block RAM</td>
<td>1</td>
<td>50</td>
<td>2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dynamic Power (mW)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Clocks</td>
<td>Signals</td>
<td>Logic</td>
<td>BRAM</td>
</tr>
<tr>
<td>4</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

Static Power (mW)
FPGA Performance Results

3 second accuracy results

- Am241: 100%
- Ba133: 99%
- Co57: 100%
- Co60: 92%
- Cs137: 99%
- Eu152: 82%
- Ra226: 7%
- Th232: 4%

60 second accuracy results

- Overall: 90.62%
- 10cm: 100.00%
- 25cm: 96.13%
- 50cm: 89.03%
- 1m: 81.94%
- 1.5m: 84.52%

Histograms for Ba133 and Ra226.
Conclusion

- A convolutional SNN has been implemented on FPGA for low-power and high resolution radioisotope identification

- More than 90% accuracy and less than 76 mW has been achieved in 60 second inference time

- Future work involves early-stopping inference and advanced verification techniques for accuracy drop debugging