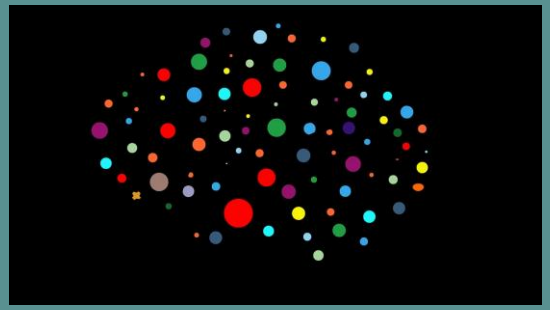
Convolutional Neural Network

December 9, 2020

ECE 4900 Final Project



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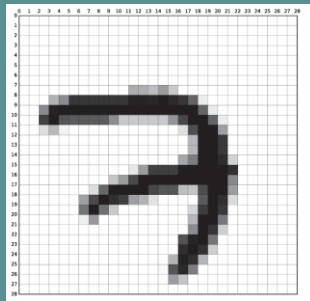
Project Description



(a) MNIST sample belonging to the digit '7'.

(b) 100 samples from the MNIST training set.

Motivation for Project

- We have worked on simple FCN in hardware before (VHDL)
- Plenty of simple FCN prototypes online for aid
- Wanted to add convolutional layers to further improve digit recognition
- Convolutions offer a great opportunity to implement multithreading and parallelization of software to improve efficiency
- CNNs are the approach of choice for addressing complex image recognition tasks.
- TBB vs Sequential time comparison benefits

Specifications

- MNIST handwritten database used for training/testing
  - 60,000 training samples
  - 10,000 testing samples
  - 28x28 image
- 784 inputs -> 10 outputs (0-9)
- CNN: 2 Layers
  - Conv1: 6@24x24, Pool1 6@12x12
  - Conv2: 24@8x8, Pool 2 24@4x4
  - Uses 5x5 kernel for each convolution
- FCN: 3 Layers (Input, 1 Hidden, Output)
  - Input layer: 384 neurons
  - Hidden Layer: 128 neurons
  - Output: 10 neurons (Represents 0-9 digit options)

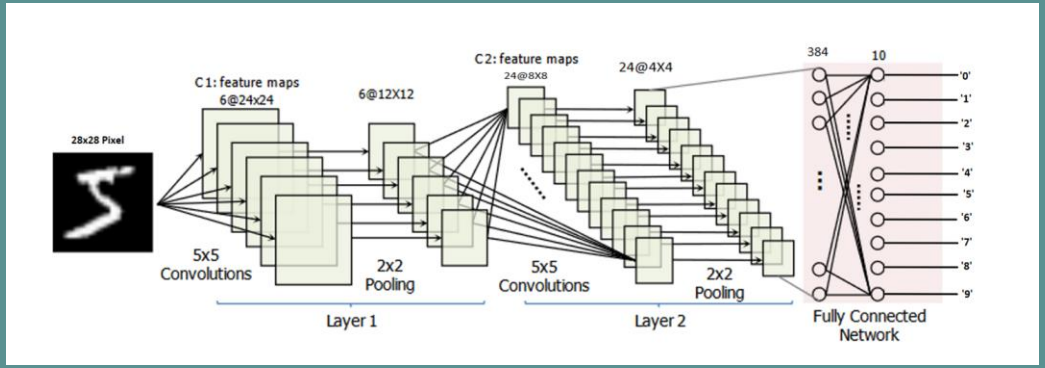
Overview of Implementation (Sequential vs Parallelization)

Sequential

- Straightforward approach with layers of convolution, activation, and pooling with the result being fed into a FCN.

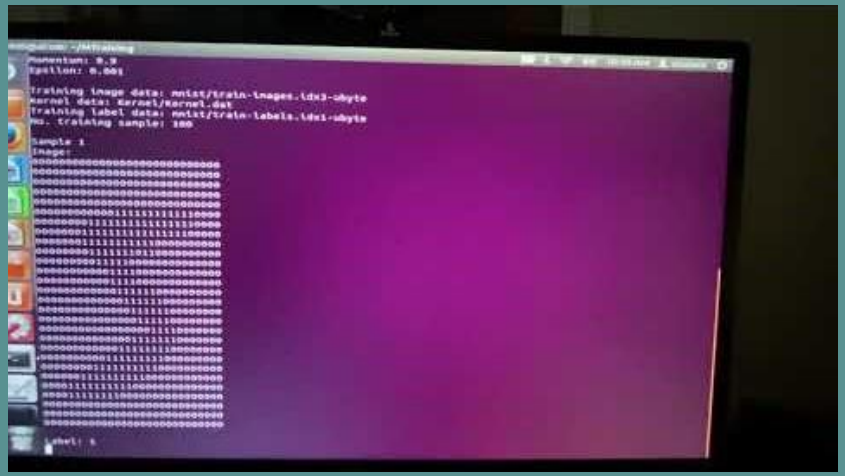
Parallelization

- Implements parallel_for for each set of convolutions
  - 1 for the C1 x 6
    - Additional parallel_for implemented on each epoch for training
  - 1 for the C2 x 24



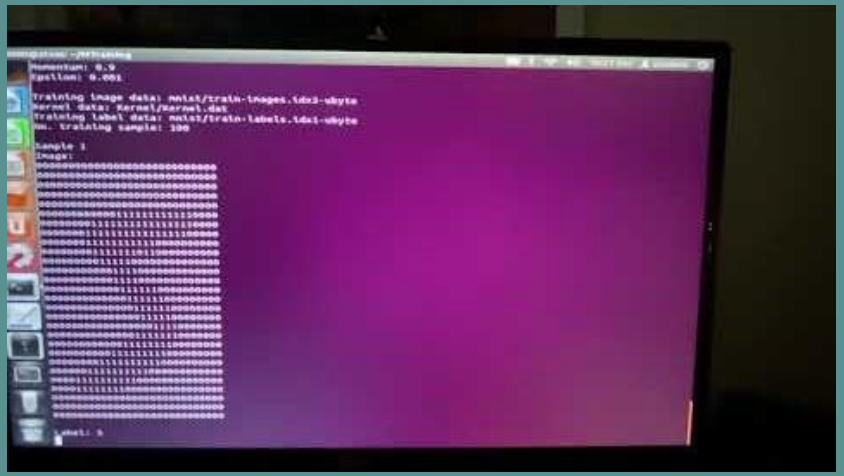
Training Sequential vs TBB

Sequential



https://youtu.be/L1DCfD82Y0I

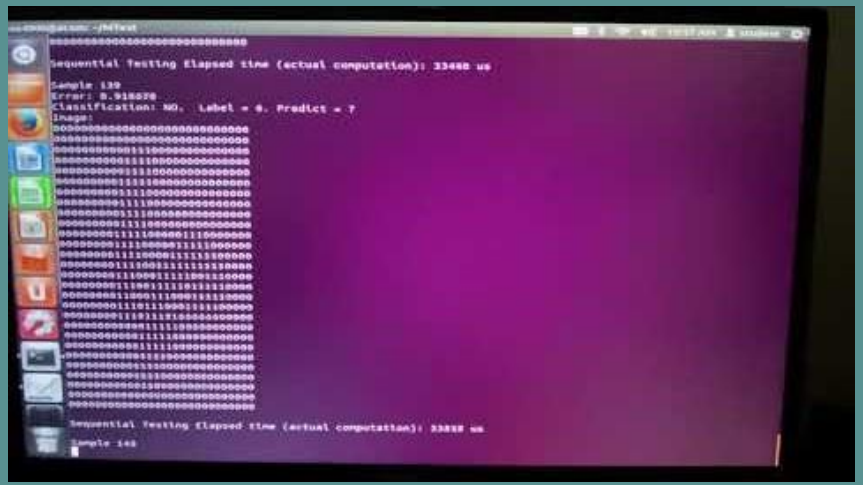
TBB



https://youtu.be/yYyX8eImCl8

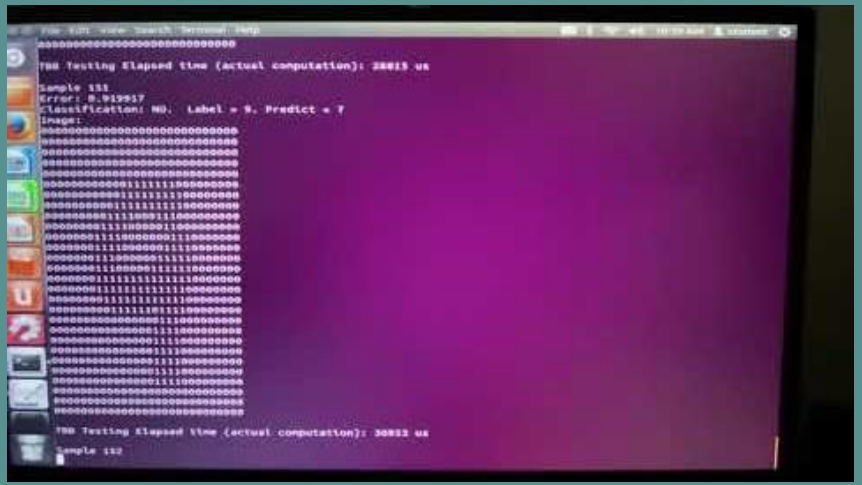
Testing Sequential vs TBB

Sequential



https://youtu.be/i2h7w4CZJuw

TBB



https://youtu.be/QnPNsxg0nwM

Results

Sequential

- Trained 100 Images at 512 Epochs
  - CNN Time: ~ 2.86 s/epoch
  - Total Time: ~ 3.42 s/epoch
  - Total Time: ~ 17.53 s/image
- Testing 1000 Images
  - CNN Time: ~ 3.12 s
  - Total Time: ~ 3.306 s

```
Sequential Training Timings
Average CNN Time: 28668 us
Average FCN Time: 1824 us
Average Back Propagation Time: 3739 us
Average Time for each computation (Per Epoch): 34250 us
Average Time for each computation (Per Training Image): 17536053 us
```

```
Sequential Testing Timings
Average CNN Time: 31202 us(C1: 6753, C2:24433)
Average FCN Time: 1860 us
Average Time for each computation: 33067 us
Number of correct samples: 99 / 1000
Accuracy: 9.90
```

TBB

- Trained 100 Images at 512 Epochs
  - CNN Time: ~ 0.98 s/epoch
  - Total Time: ~ 1.80 s/epoch
  - Total Time: ~ 9.24 s/image
- Testing 1000 Images
  - CNN Time: ~2.80 s
  - Total Time: ~2.97 s

```
TBB Training Timings
Average CNN Time: 9892 us
Average FCN Time: 2411 us
Average Back Propagation Time: 5882 us
Average Time for each computation (Per Epoch): 18049 us
Average Time for each computation (Per Training Image): 9241524 us
```

```
TBB Testing Timings
Average CNN Time: 28010 us(C1: 8003, C2:19992)
Average FCN Time: 1771 us
Average Time for each computation: 29785 us
Number of correct samples: 99 / 1000
Accuracy: 9.90
```

Notes

The CNN time improvement seen on the training is not the same for the testing. Why?

When training only only 1 epoch, the CNN improvement falls off to almost zero.

```
tbb::parallel_for (int(0), int(epochs), [&] (int z) {
    tbb::parallel_for (int(0), int(6), [&] (int i) {
            conv1(i);} );
```

```
TBB Training Timings
Average CNN Time: 24717 us
Average FCN Time: 1794 us
Average Back Propagation Time: 3749 us
Average Time for each computation (Per Epoch): 31031 us
Average Time for each computation (Per Training Image): 31031 us
```

Conclusion

Improvements

- Parallel_pipeline and parallel_reduce for both the testing and training of the data
  - Optimize Parallel_for loops
  - Deeper embedding of parallelization
- Add in back propagation for kernel values
  - Currently trains only the weight values for the FCN
  - Randomized kernel values were used for the training, then brought over for use in the testing
- An increase in accuracy through longer training iterations
  - Trained single batch of 15k
  - Increase average training size from 500