Comparing Handwritten Number Recognition Networks

Keras versus Nengo

Simon Tröster, Dominik Weidner

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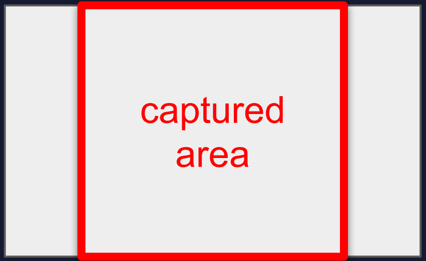
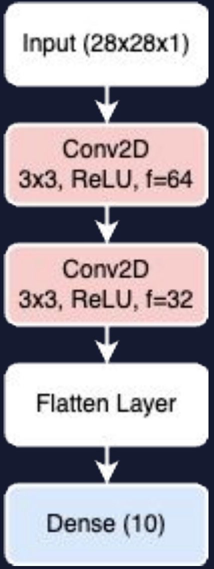
Project Overview

- Create 2 versions of a handwritten number recognizer
- Utilizing the MNIST dataset for training
- Provide model input via webcam
- Compare the 2 approaches regarding performance, programmability, usability and other metrics

Traditional Approach: CNN with Keras

- Straight forward implementation
  - Well documented resources and examples
- This approach was used to test and implement the webcam functionality
  - More sophisticated approach by finding contours in the full webcam image didn't prove viable
  - → Solution: Using the biggest square image frame possible



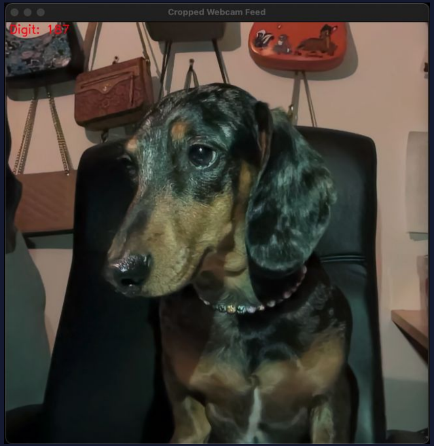


← Topology

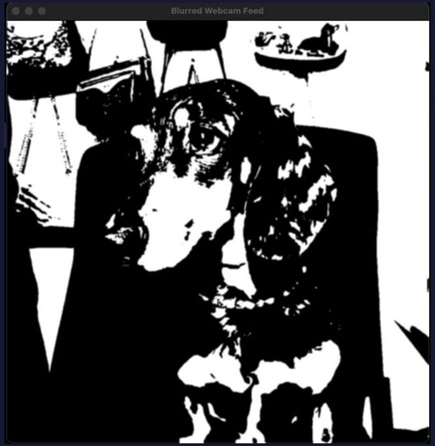
Optimizer: RMSProp(0.001)

Loss: sparse categorical cross entropy

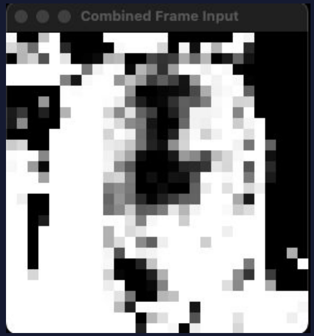
Model Input Preprocessing with Webcam



1080p raw capture



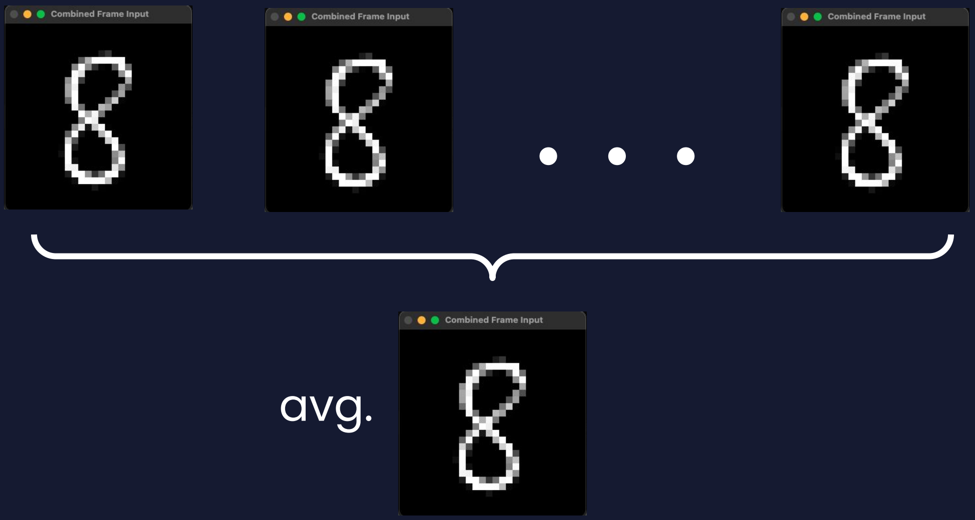
Transformations:
greyscale
gaussian blur



Inverted model input
28x28p (280x280)

Model Input Image Buffering

- Running the model/sim every frame is expensive
- Instead: A 30 frame buffer is implemented

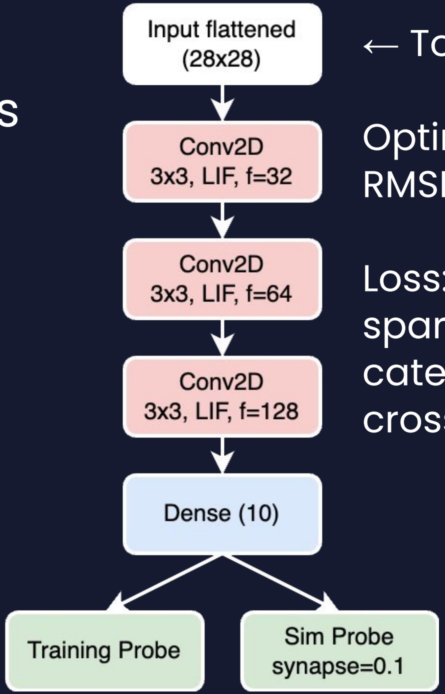


This reduces camera shake and increases general image quality

In Nengo, this is needed as the simulation can not yield "real-time" results

The Nengo Approach

- Goal: Mirroring the Keras CNN as closely as possible but utilizing spiking neurons (LIF)
- Additional goal: Incorporating the "real-time" webcam functionality
- Additional Conv2D layer added as it improves result quality



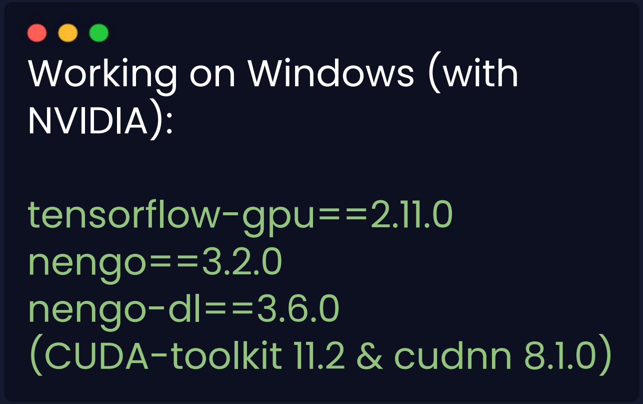
← Topology

Optimizer: RMSProp(0.001)

Loss: sparse categorical cross entropy

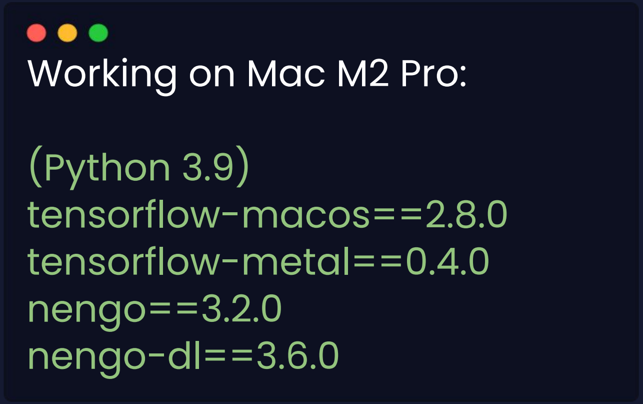
The Nengo Approach - Requirement Conflicts

- nengo, nengo-dl and tensorflow library are needed
- Conflicts: Version and system compatibility are problematic on mac & windows w/o nvidia gpu



```
Working on Windows (with
NVIDIA):

tensorflow-gpu==2.11.0
nengo==3.2.0
nengo-dl==3.6.0
(CUDA-toolkit 11.2 & cudnn 8.1.0)
```

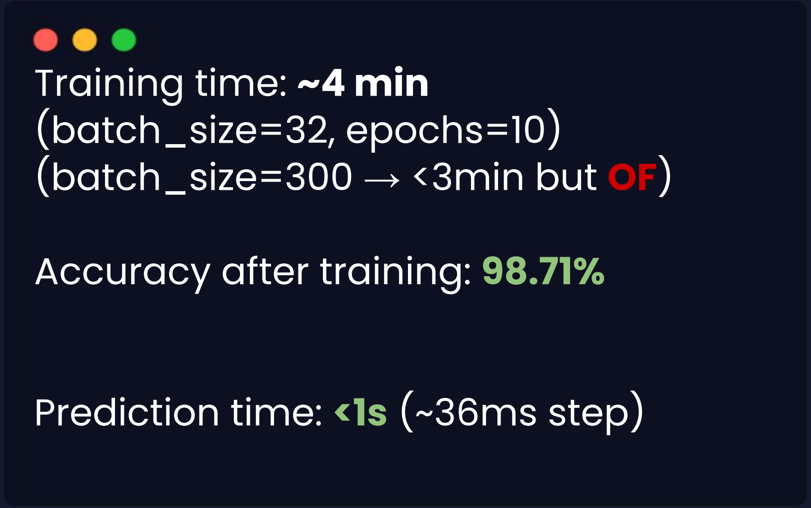


```
Working on Mac M2 Pro:

(Python 3.9)
tensorflow-macos==2.8.0
tensorflow-metal==0.4.0
nengo==3.2.0
nengo-dl==3.6.0
```

Results - Both Models in Numbers

Keras CNN

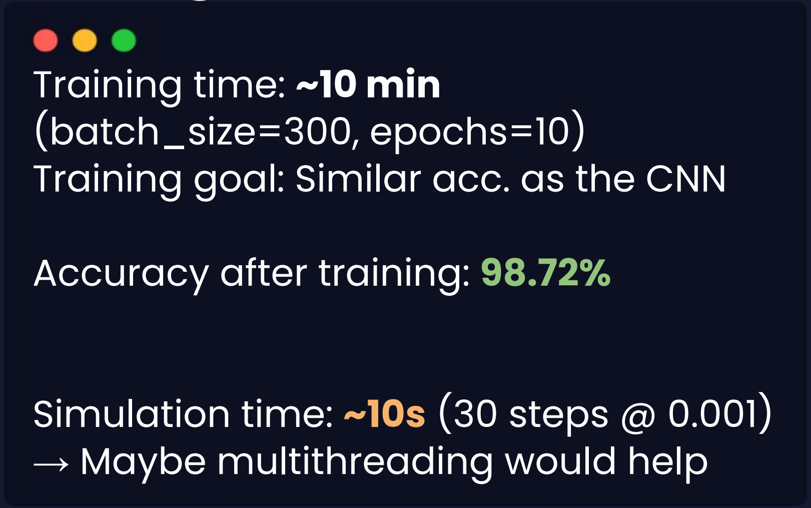


Training time: **~4 min**
(batch_size=32, epochs=10)
(batch_size=300 → <3min but **OF**)

Accuracy after training: **98.71%**

Prediction time: **<1s** (~36ms step)

Nengo SNN



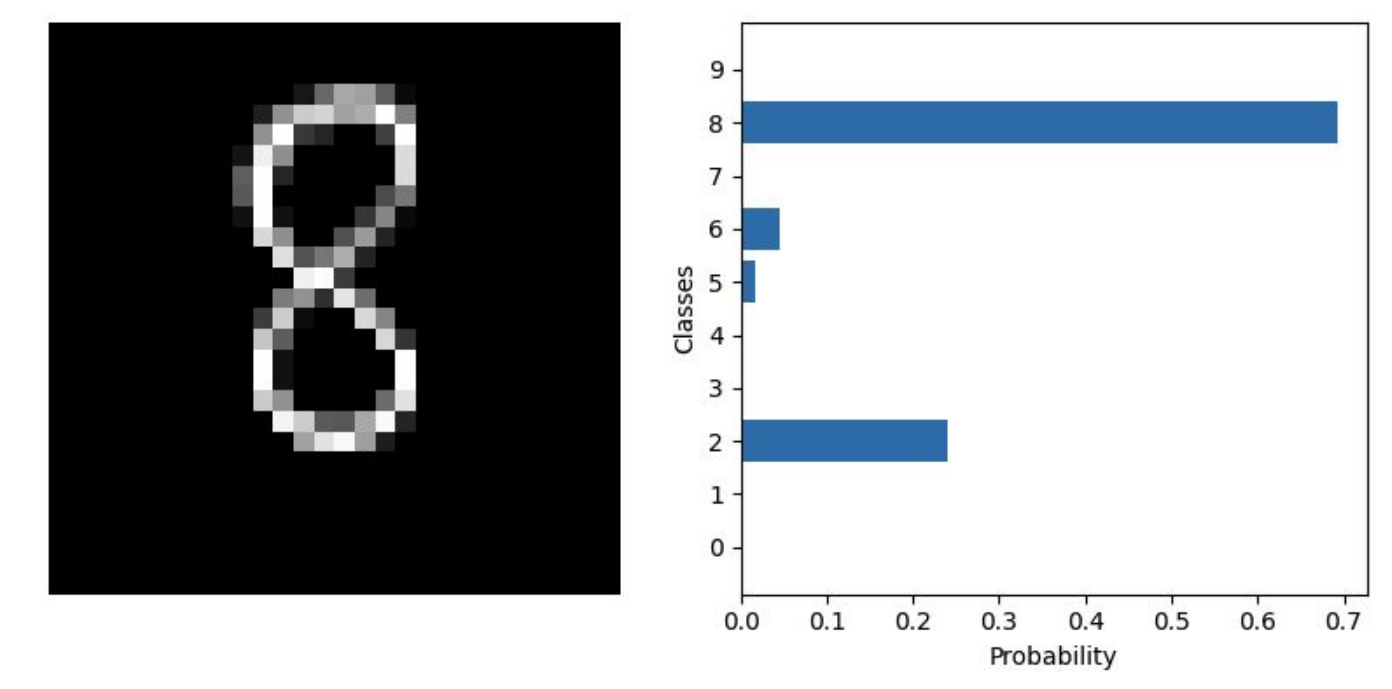
Training time: **~10 min**
(batch_size=300, epochs=10)
Training goal: Similar acc. as the CNN

Accuracy after training: **98.72%**

Simulation time: **~10s** (30 steps @ 0.001)
→ Maybe multithreading would help

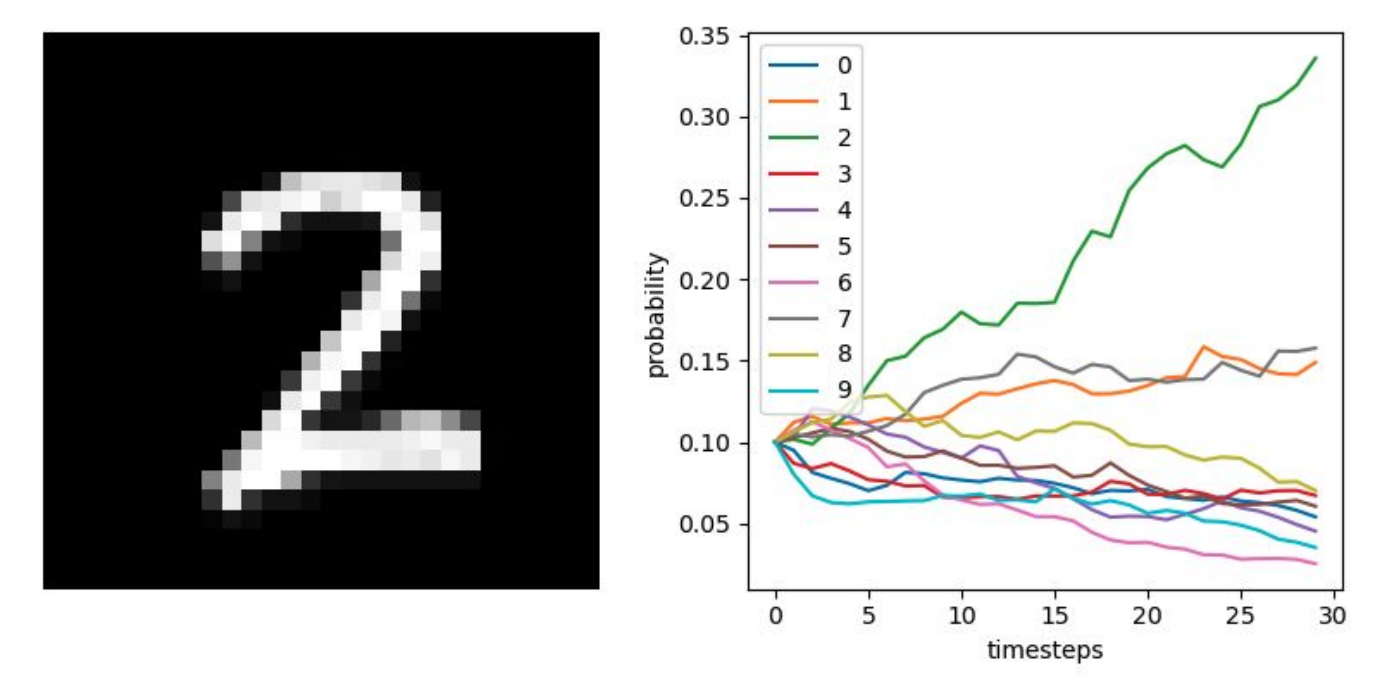
Visualized Results - CNN

Visualized Results – CNN Plotted



Visualized Results – SNN

Visualized Results – SNN Plotted



Conclusion

- It is possible to create a well-functioning handwritten digit recognizing SNN with webcam functionality
- Obvious drawbacks include longer training times and the simulation time
- In the right circumstances (low power environments) the SNN can provide a viable alternative to traditional models

Outlook

- It would be interesting to see the SNNs performance compared with an implementation on neuromorphic hardware (Intel Loihi)

Thank you for your attention!