Touchless Hand Gesture-Based Digit Recognition

using Light-Sensors, Convolutional Neural Networks and Microcontroller

Winstijn Smit - winstijn@gmail.com
Supervisors: Qing Wang, Mingkun Yang, Ran Zhu

Background

Touching the same surfaces as many other people is a potential source of infection and plays an import role in the spread of a virus (Zhang et al., 2018).

The proposed digit recognition system of this paper enables touch-less interaction with electronic devices at a low cost which can enable new applications.

Other approaches

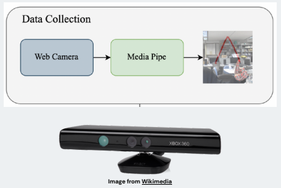


Figure 1: Digit recognition with Microsoft Kinect (Watanabe et al., 2023) is an example of another solution that is too costly.

Previous works

Previous iteration of research project developed the foundation used for this digit recognition system.

- Stijn van Water (2022) developed the custom PCB used for this research
- Dimitar Barantiev (2022) created software to use the PCB-board for development.
- Femi Akadiri (2022) constructed the dataset for gesture-recognition (swipe left, swipe right, clock-wise circle)
- William Narchi (2022) worked on a CNN architecture for gesture recognition (86% accuracy)
- Femi Akadiri (2022) worked on a RNN architecture for gesture recognition (43% accuracy)

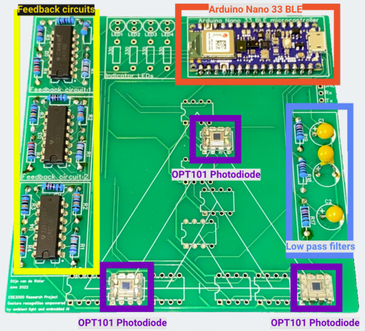
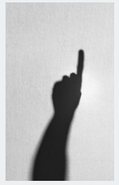


Figure 2: PCB with Arduino 33 BLE Nano with three OPT101 Photodiodes

Goal

A proof-of-concept of a cheap and real time solution to recognise air-written digits using thee light-sensors.



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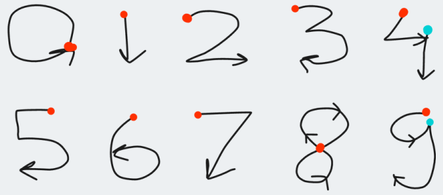

Figure 3: fixed set of air-written digits used for this research.

Contributions to work from last year:

- Recognition of digits instead of gestures (requires higher precision)
- Collection of dataset for digits made by gestures in fixed environment.
- Data augmentation techniques
- Experiments with the data sampling rate

Research Questions

- What is the feasibility of using the proposed system to recogize air-written digits?
- How to collect a dataset of gesture-based digits?
- How to create a convolutional neural network capable of running on a microcontroller that recognises digits made by hand-gestures?
- What is the performance of the proof-of-concept system?

Results

Dataset

- ± 3300 samples from 17 participants
- ± 3100 samples by author
- Fixed lighting environment
- Sampled at 1000 Hz for 2 seconds.

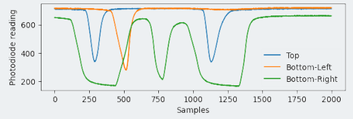

Figure 4: raw sensor-values of the digit #0 performed.

Model performance

58.779% (± 2.647%)
5-fold quantized between candidate performance

93.448% (± 0.444%)
5-fold quantized within candidate performance

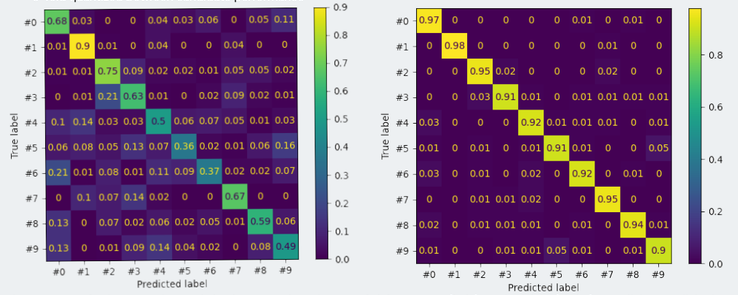

Figure 5: confusion matrices of the best performing model: between (left) and within (right) candidate validation.

Architecture of "2-CNN D2 A" model

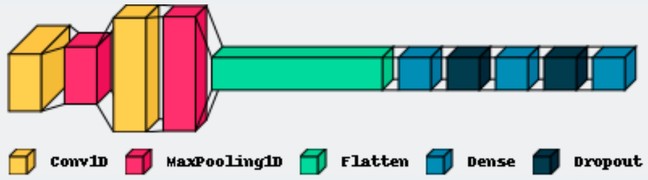

Figure 6: visual representation of the best performing model - created with "visualkeras" (Gavrikov, 2020)

Conclusion: the system now only works reliably in a fixed lighting scenario and for people it has seen during training. Further research is needed to make it work for unseen users and a variable lighting scenario.

References

Zhang, N., Li, Y., & Huang, H. (2018). Surface touch and its network growth in a graduate student office. Indoor Air, 28(6), 963–972. https://doi.org/https://doi.org/ 10.1111/ina.12505
Watanabe, T., Manirruzzaman, M., Hasan, M. a. M., Lee, H., Jang, S., & Shin, J. (2023). 2D Camera-Based Air-Writing Recognition Using Hand Pose Estimation and Hybrid Deep Learning Model. Electronics, 12(4), 995. https://doi.org/10.3390/electronics12040995
Akadiri, F. (2022). Constructing a dataset for gesture recognition using ambient light. Delft University of Technology.
Barantiev, D. (2022). Designing a software receiver for gesture recognition with ambient light. Delft University of Technology.
Lipski, M. (2022). Hand gesture recognition on arduino using recurrent neural networks and ambient light. Delft University of Technology.
Narchi, W. (2022). Recognising gestures using ambient light and convolutional neural networks: Adapting convolutional neural networks for gesture recognition on resource-constrained microcontrollers. Delft University of Technology.
van de Water, S. (2022). Designing an adaptable and low-cost system for gesture recognition using visible light. Delft University of Technology.
Gavrikov, P. (2020). Visualkeras Python Library