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ARTIFICIAL INTELLIGENCE FOR DIGIT RECOGNITION

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Fraunhofer IMS has developed AlfES (Artificial Intelligence for Embedded Systems), a platform-independent and constantly growing machine learning library in the programming language C, which implies a fully configurable feedforward artificial neural network (ANN). AlfES uses standard libraries based on the GNU Compiler Collection (GCC). The program source code is reduced to a minimum, thus even the integration on a microcontroller including learning algorithms is possible.

To show the new possibilities offered by AlfES, Fraunhofer IMS has equipped a commercially available touchpad with new functionality. Touchpads in modern laptops can detect gestures for zooming or scrolling in addition to the normal use as a mouse replacement. In modern cars a touchpad is also used for the handwritten input of letters or digits to enter the desired destination in the navigation system. But in this application the detection takes place on the high

performance computer unit of the vehicle. But how about the touchpad itself taking over the character recognition and transmitting only the result? Fraunhofer IMS investigated this question and developed an extremely compact ANN with AlfES, which recognizes handwritten digits entered on a touchpad. The developed ANN and the feature extraction are so compact, that they can be easily integrated on a cheap microcontroller. The demonstrator corresponds to the first test phase of the system using only a small amount of training data.

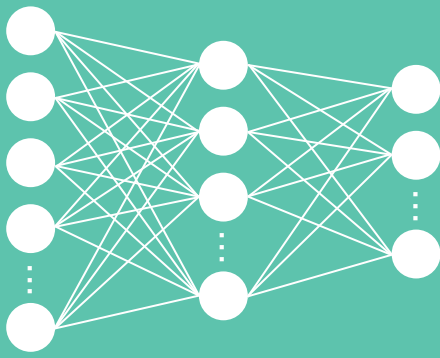
One microcontroller for everything

For the demonstrator the well-known Arduino UNO is used, which not only controls the hardware with its ATmega328P but also performs the digit recognition. Since AlfES can be integrated on almost all microcontrollers, it is also possible to use other hardware.

16 INPUT NEURONS

12 HIDDEN LAYER NEURONS

10 OUTPUT NEURONS



The touchpad

A commercially available external touchpad is used which communicates via the standard PS/2 interface and is directly connected to the Arduino UNO.

Feature extraction

The position data of the touchpad during the character input are buffered and pre-processed. A feature extraction was developed especially for this application which reduces the input parameters for the ANN.

The artificial neural network

With AlfES an extremely small ANN with only 12 neurons in one hidden layer for the digit recognition has been developed. As usual for a classification 10 output neurons were used according to the digits from 0 to 9. For the calculation a total of only 334 weights are needed which can be regarded as constants.

LCD display

The results of the classification are visualized on an LCD display. In addition the output can be customized.

Training data and learning algorithm

As training data a total of 360 digits (36 datasets of 0-9) entered by different people were recorded. A special evolutionary algorithm developed by Fraunhofer IMS, which is integrated into AlfES, was used for the training. The training was carried out using

the PC version of AlfES and could be directly ported to the microcontroller due to the compatibility.

Detection rate

95% of the training data could be recognized successfully and with high probability after the training. A higher number of training data would further optimize the system. Since the demonstrator is an early predevelopment, a more concrete statement about the recognition rate can't be made at this point. Of course, the structure of the ANN can still be changed to achieve a better recognition rate. More neurons and additional hidden layer can improve the recognition rate, but lead to a greater need for resources.

Calculating speed

The Arduino UNO with a CPU frequency of 16 MHz requires approximately 20 to 25 ms for the entire digit recognition including the feature extraction. The calculation speed depends on the number of recorded measurement points or the stroke length of the written digit. The stroke length of a "1", for example, is shorter than that of an "8" and thus less measuring points are recorded. Since the calculation speed depends on the CPU frequency, the measured times are only valid for the used microcontroller.

Memory requirements

- 334 constant weights as floating-point numbers
 - 1.34 kB (4 bytes / float)
- Implementation of the neural network
 - 3.31 kB (program memory)
- Implementation of the feature extraction
 - 3.96 kB (program memory)

Potential applications

- Enhancement of the touchpad function of notebooks and keyboards
- Replacement of numerical entries such as
 - Automated Teller Machines (ATM)
 - Pin entry for security systems
 - Number dialing for telephones
 - Pocket calculators
- Universal floor selection for elevators
- Control element for low-cost electrical appliances
- Control panel for smart home applications

Outlook

In addition to the digit recognition it is also possible to learn complex gestures to control devices for example. The recognition of letters is also conceivable but requires further development work. This demonstrator uses the touchpad as sensor element, which is equipped with a new functionality by AlfES. By the way, AlfES can also be used for many other sensors and sensor systems.

3 Neural network structure

4 Touchpad