

# On-line recognition of handwritten mathematical symbols

Bachelor's Thesis of

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I declare that I have developed and written the enclosed thesis completely by myself, and have not used sources or means without declaration in the text.

**Pittsburgh, DD. MM. 2014**

.....  
(Martin Thoma)



# Acknowledgement

TODO





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# 1. Introduction

Handwriting recognition is the problem of finding a proper textual representation given a handwritten symbol or sequence of symbols.

In off-line handwriting recognition, all algorithms have to work on pixel image information of the handwriting. On-line handwriting recognition on the other hand can use the information how symbols were written.



## 2. Baseline system

A system for symbol recognition was already written and is described in [Kir10].



## 3. Preprocessing

TODO



## 4. Artificial Neural Nets

Artificial neural networks (ANNs) are models for classification that were inspired by the brain. They consist of artificial neurons and have a lot of different subtypes like Feed Forward Neural Nets.

### 4.1. Artificial neurons

Artificial neurons are inspired by biological neurons.

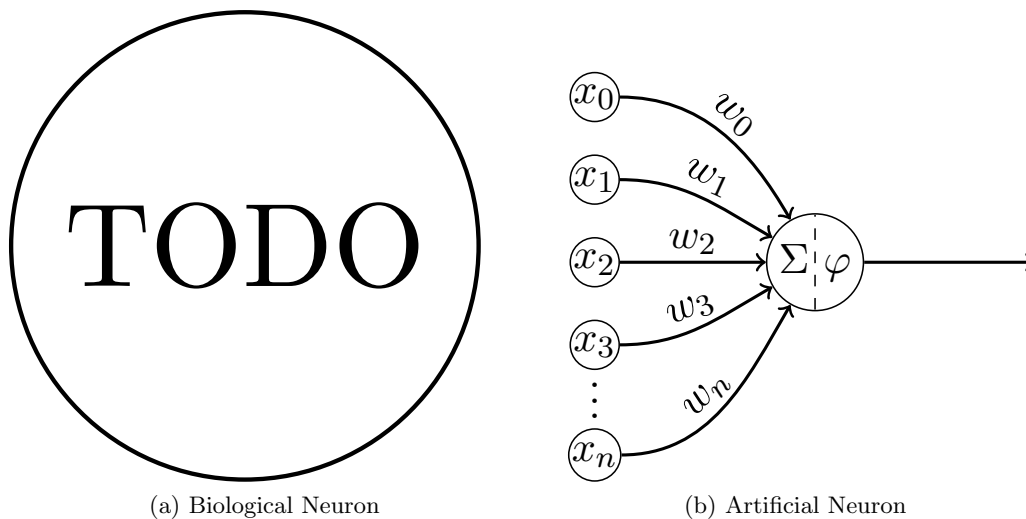


Figure 4.1.: Both neurons receive weighted input, apply a function to that and give output

They receive at least one input and at least one output. Those inputs might get weighted as well as the output.

The neurons apply a function to the sum of all weighted inputs. This function is called *activation function*.

An artificial neuron using the unit step function (see section 4.3.1) is called a *perceptron*.

The artificial neuron sums all weighted inputs  $x_i \cdot w_i$  up and applies its activation function  $f$  to it.

## 4.2. Feedforward Neural Nets

Feedforward neural nets don't have loops.

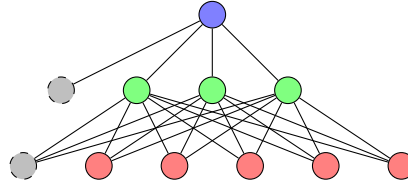


Figure 4.2.: Feedforward artificial neural network

## 4.3. Activation functions

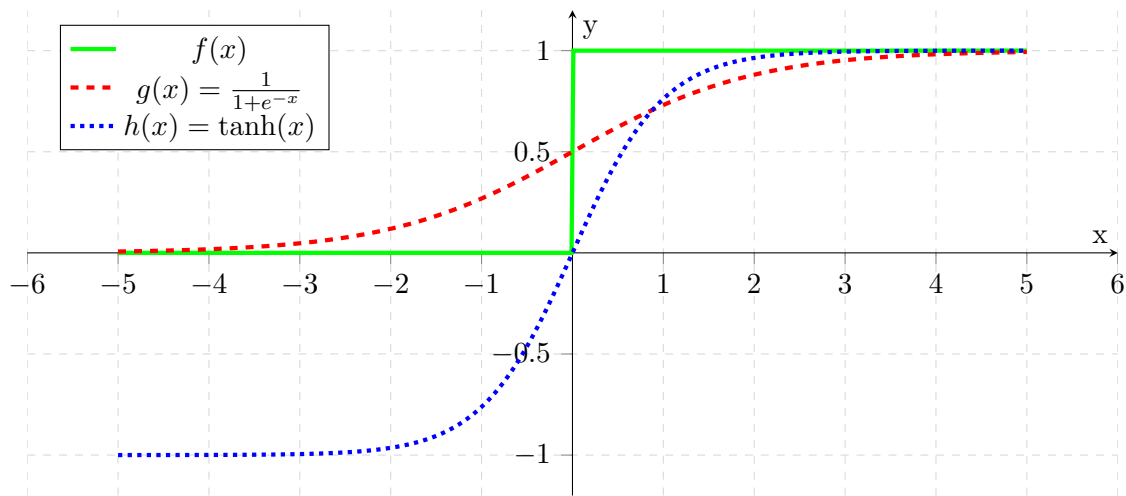


Figure 4.3.: The unit step function  $f$ , the sigmoid function  $g$  and the hyperbolic tangent  $h$ .

### 4.3.1. Unit step function

Not so good, because it's not differentiable. Therefore, the backpropagation algorithm cannot be used.

### 4.3.2. Sigmoid function

Is great because it is infinitely often differentiable.

### 4.3.3. Hyperbolic tangent

Also differentiable, but gradient descent converges faster (sometimes?)



## 5. Evaluation

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### 5.1. Section 1

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### 5.2. Section 2

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### 5.3. Section 3

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## 6. Conclusion

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# Bibliography

- [Kir10] D. Kirsch, “Detexify: Erkennung handgemalter latex-symbole,” Diploma thesis, Westfälische Wilhelms-Universität Münster, 10 2010. [Online]. Available: <http://danielkirs.ch/thesis.pdf>



# Glossary

**ANN** artificial neural network. 7





# Appendix

## A. First Appendix Section

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Figure A.1.: A figure

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