

# How does artificial intelligence accomplish the feat of learning?

Ingo Blechschmidt  
with thanks to Tim Baumann and Philipp Wacker

University of Augsburg  
34th Chaos Communication Congress

- 1 Successes of AI
- 2 How artificial neural networks work
  - Structure
  - Learning by gradient descent
  - A look into the hidden layer
- 3 Why not sooner?
- 4 Challenges for the future
- 5 Recommendations

# Part I

## Recent successes of artificial intelligence



Speech  
synthesis



AlphaGo



Style transfer



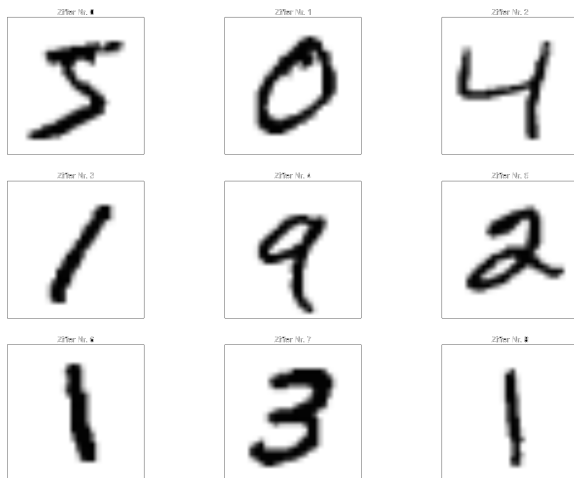
Jam with Magenta

# Part II

## How artificial neural networks work

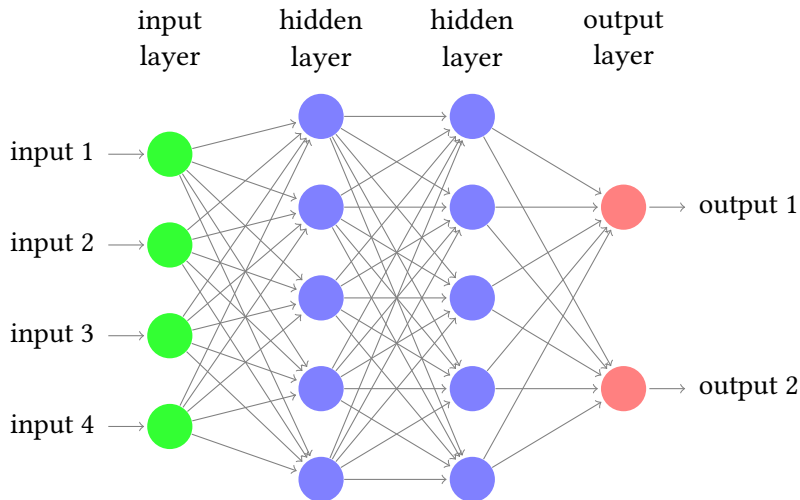
- 1 Structure of a simple net
- 2 Valuation by a cost function
- 3 Error minimization using gradient descent

## The MNIST database

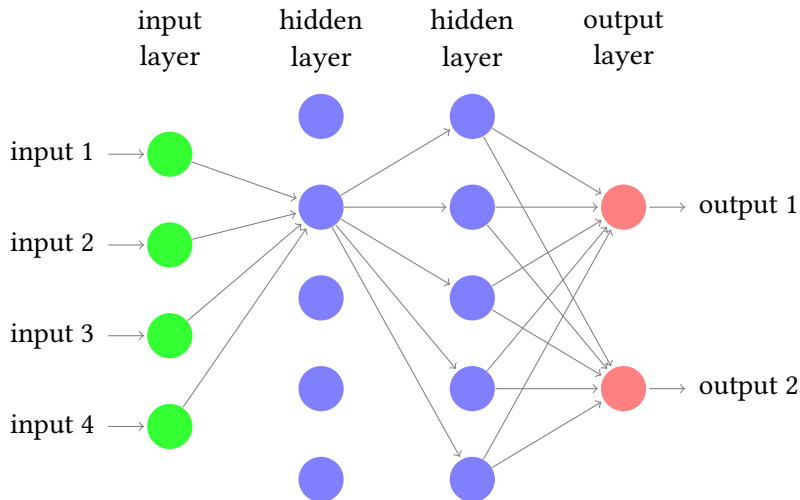


70 000 images consisting of  $28 \times 28$  pixels

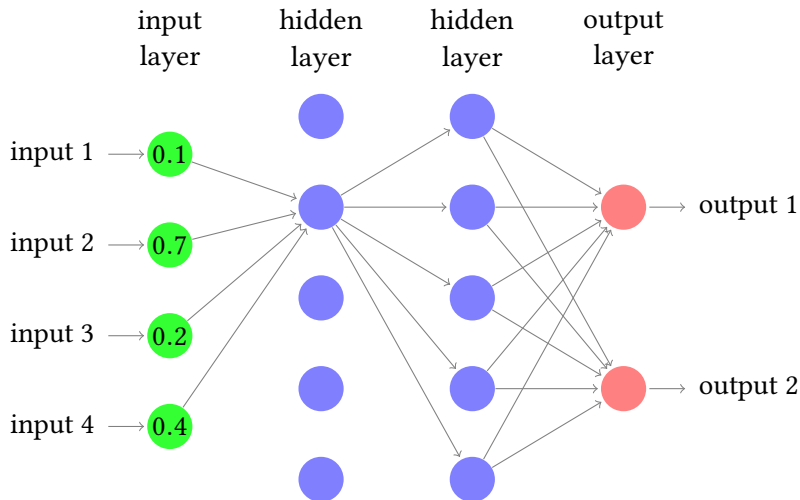
# Structure of a simple net



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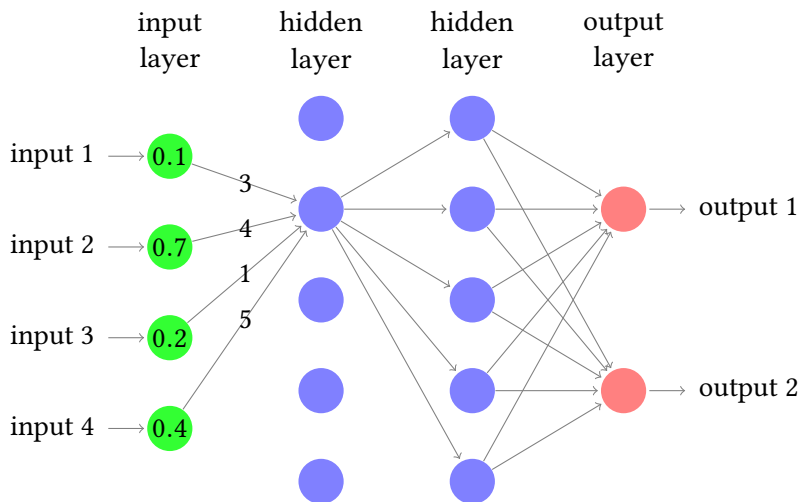


# Structure of a simple net

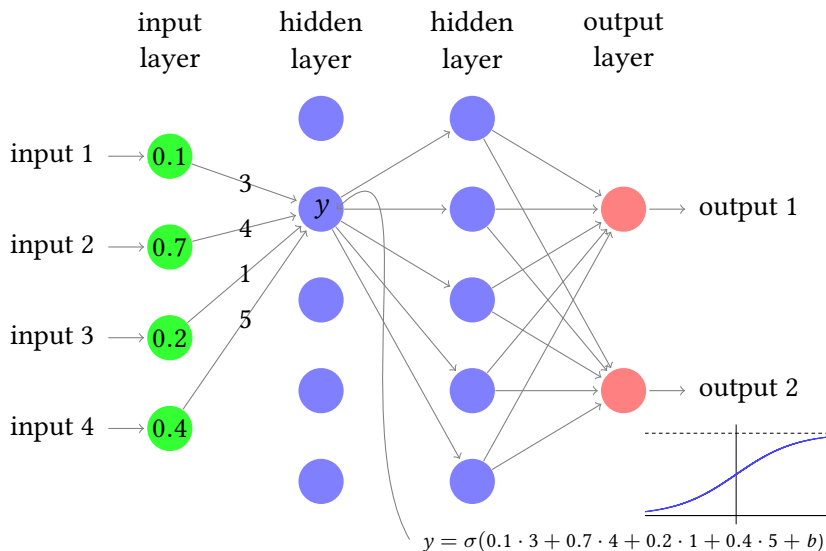




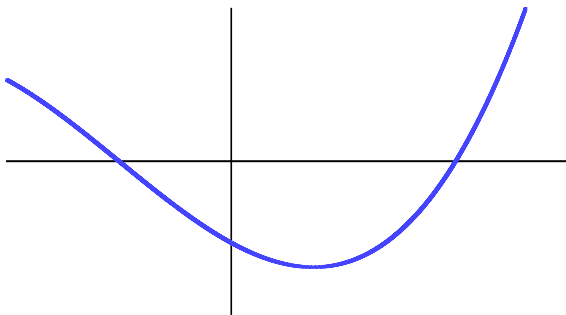
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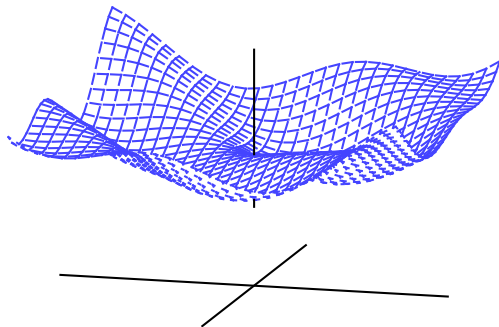


# The curious importance of minimization



one unknown:  $x$

# The curious importance of minimization

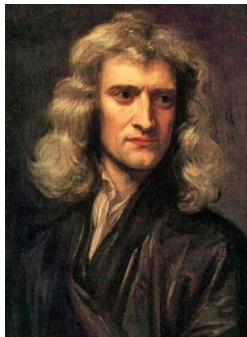


two unknowns:  $x, y$

# The curious importance of minimization



Leibniz (\* 1646, † 1716)



Newton (\* 1643, † 1727)

arbitrarily many unknowns

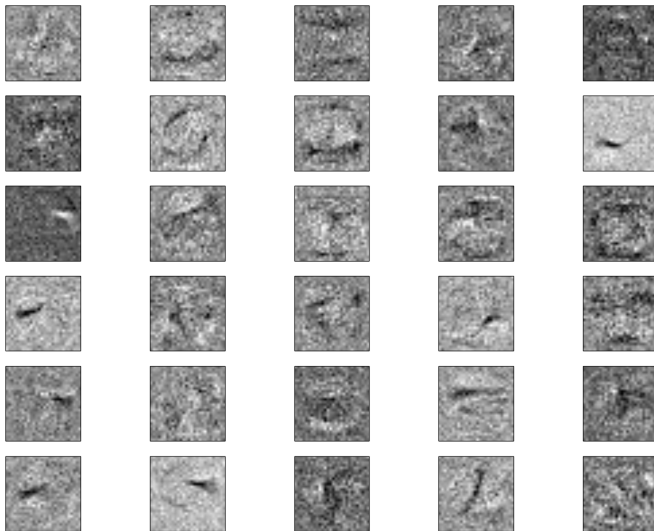
# The feat of learning

- 1 Calculate for all of the 60 000 training cases the activations of the ten output neurons.
- 2 Sum for all of the resulting 600 000 activations the individual **quadratic errors** to obtain the **total costs**:

$$\begin{aligned}
 & \underbrace{(0.1 - 0)^2 + (0.7 - \mathbf{1})^2 + (0.1 - 0)^2 + \dots + (0.2 - 0)^2}_{\text{first test case (should be a one)}} \\
 & + \underbrace{(0.3 - \mathbf{1})^2 + (0.2 - 0)^2 + (0.2 - 0)^2 + \dots + (0.1 - 0)^2}_{\text{second test case (should be a zero)}} \\
 & + \dots
 \end{aligned}$$

- 3 Change the weights and biases slightly in the direction of the **steepest descent** to very slightly improve performance.
- 4 Go to step 1.

# A look into the hidden layer



# Part III

## Why not sooner?

- 1 More computational power



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- 2 Availability of large data sets for training

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- 1 More computational power
- 2 Availability of large data sets for training
- 3 Mathematical breakthrough: Convolutional Neural Networks

# Part IV

## Challenges for the future

- Extend neural nets to further tasks
- Understand the inner workings of a net
- Develop resistance against adversarial examples
- Solve ethical challenges with self-driving cars
- Answer existential questions regarding strong AI

# Part V

## Recommendations

- HBO series *Westworld* about androids who pass the Turing test and develop consciousness
- Talks by Joscha Bach
- The Unreasonable Effectiveness of Recurrent Neural Networks by Andrej Karpathy
- TensorFlow – enabling AI development without prerequisites in maths or programming
- Neural Networks and Deep Learning von Michael Nielsen