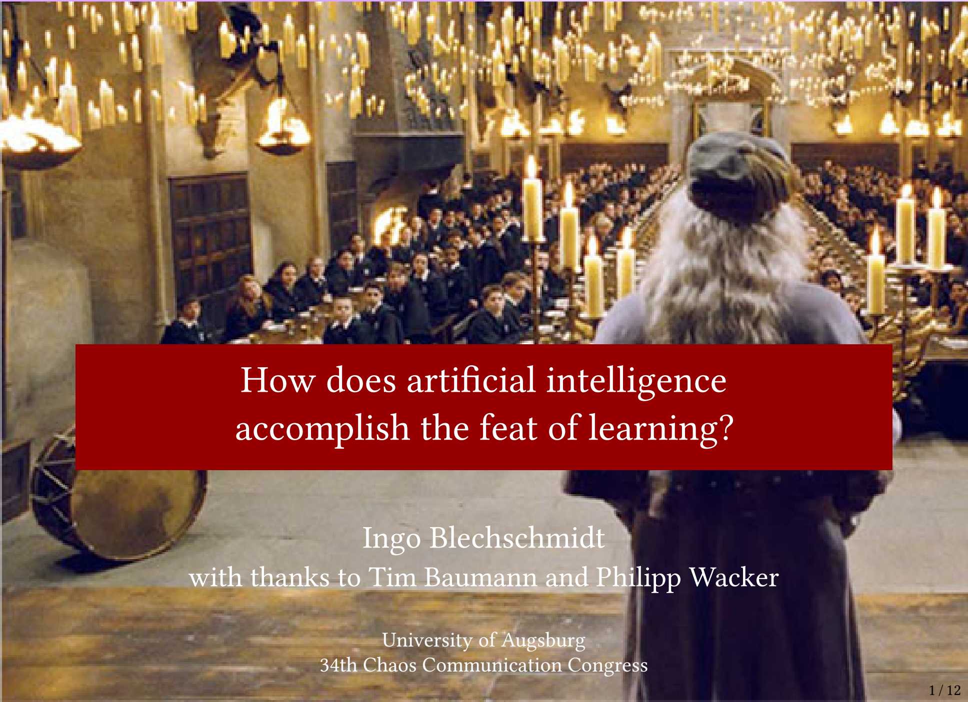


How does artificial intelligence accomplish the feat of learning?

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
- Architecture
- Learning by gradient descent
- A look into the hidden layer

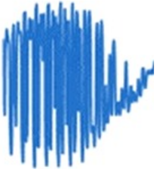
3 Why not sooner?

4 Challenges for the future

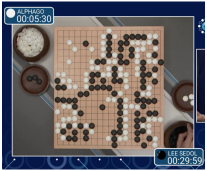
5 Recommendations

Part I

Recent successes of artificial intelligence

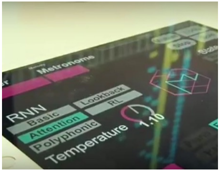


Speech synthesis



AlphaGo

Style transfer



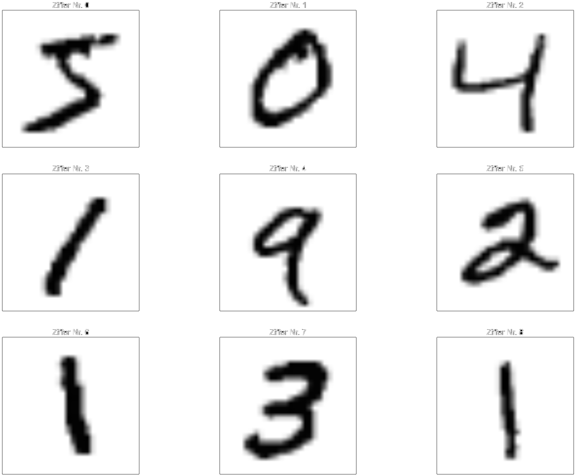
Jam with Magenta

Part II

How artificial neural networks work

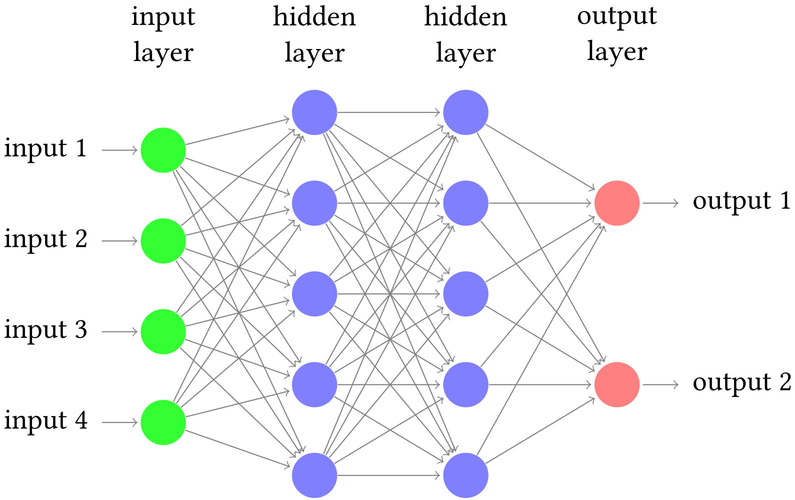
1. Architecture of a simple net
2. Valuation by a cost function
3. Error minimization using gradient descent

The MNIST database

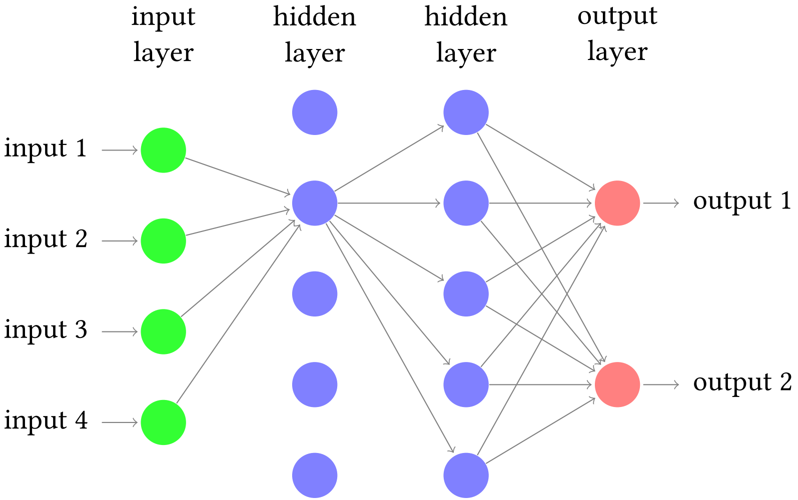


70 000 images consisting of 28×28 pixels

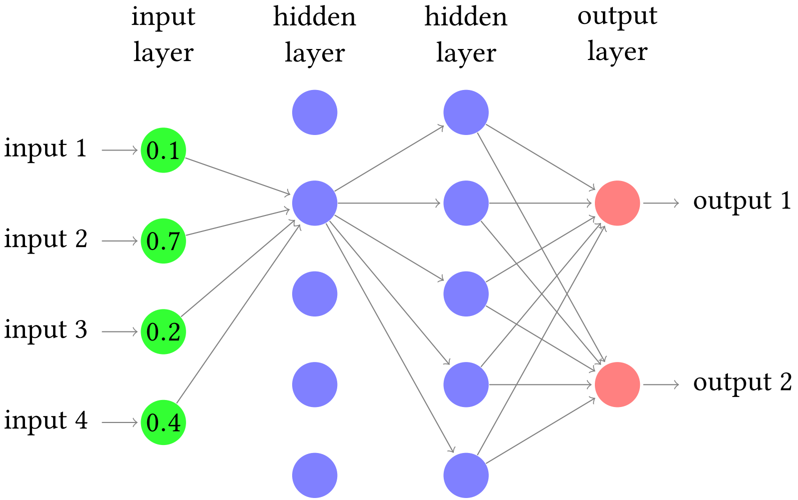
Architecture of a simple net



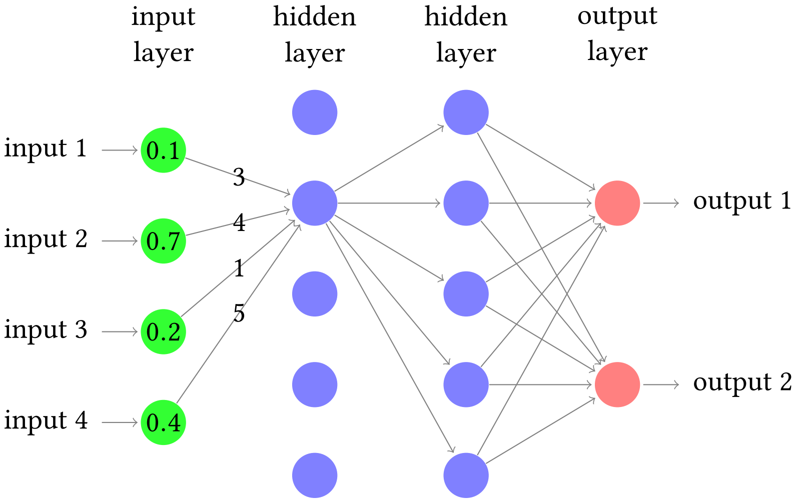
Architecture of a simple net



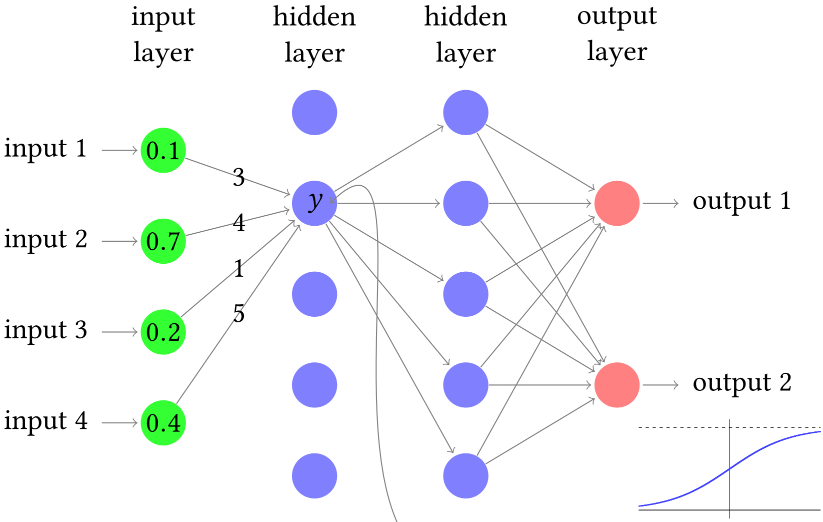
Architecture of a simple net



Architecture of a simple net

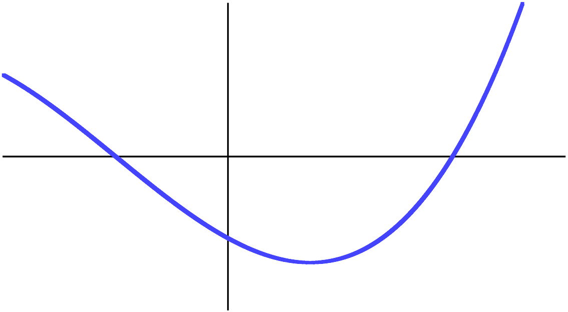


Architecture of a simple net



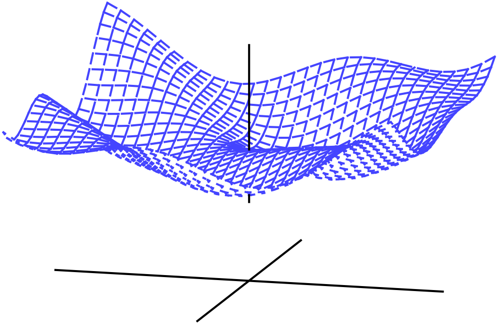
$$y = \sigma(0.1 \cdot 3 + 0.7 \cdot 4 + 0.2 \cdot 1 + 0.4 \cdot 5 + b)$$

The curious importance of minimization



one unknown: x

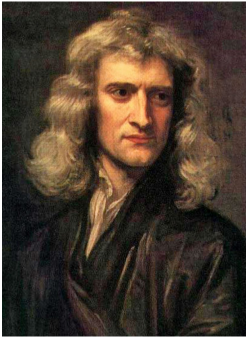
The curious importance of minimization



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**:

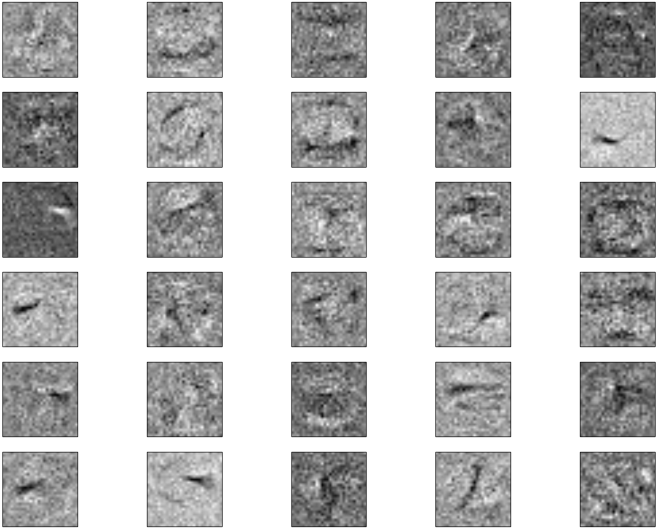
$$\underbrace{(0.1-0)^2+(0.7-\mathbf{1})^2+(0.1-0)^2+\cdots+(0.2-0)^2}_{\text{first test case (should be a one)}}$$

$$+\underbrace{(0.3-\mathbf{1})^2+(0.2-0)^2+(0.2-0)^2+\cdots+(0.1-0)^2}_{\text{second test case (should be a zero)}}$$

$$+\cdots$$

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

Part III

Why not sooner?

1. More computational power
2. Availability of large data sets for training

Part III

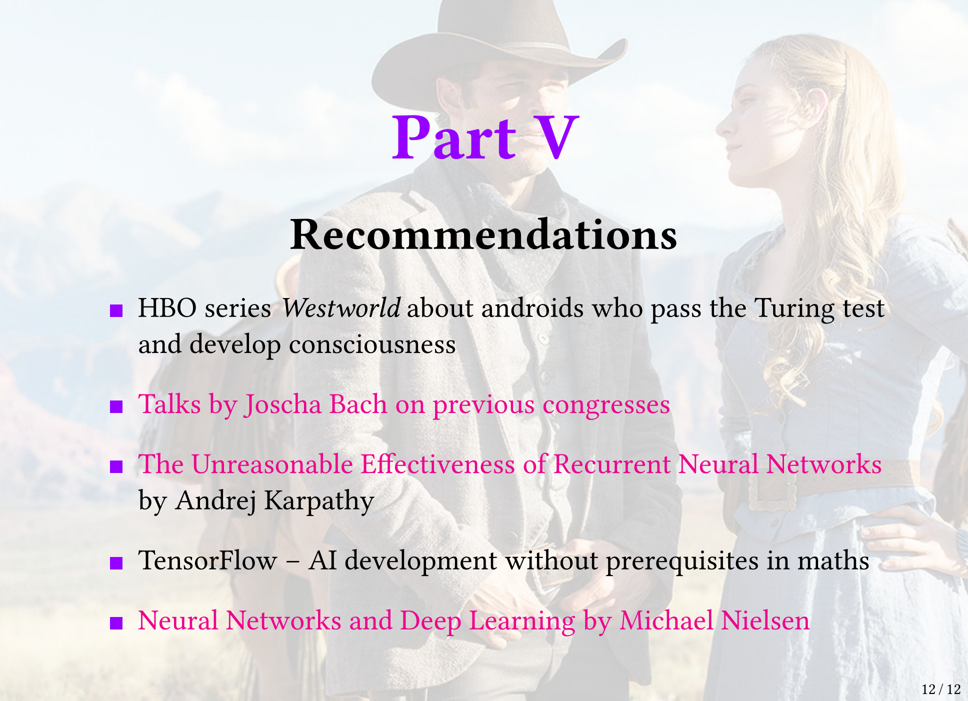
Why not sooner?

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 trained net
- Develop resistence 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 on previous congresses
- The Unreasonable Effectiveness of Recurrent Neural Networks by Andrej Karpathy
- TensorFlow – AI development without prerequisites in maths
- Neural Networks and Deep Learning by Michael Nielsen