Natural Language Processing
CSCI 4152/6509 — Lecture 16
Neural Networks and NLP

Instructors: Vlado Keselj
Time and date: 14:35 – 15:55, 25-Nov-2025
Location: Studley LSC-Psychology P5260

Previous Lecture

- P0 discussion (3): P-05
- Message calculation: 4 cases
- Inference tasks using message passing
  1. Marginalization with one variable
  2. Marginalization with multiple variables
  3. Conditioning with one variable
  4. Conditioning with multiple variables
  5. Completion in general
- Product-sum algorithm example 1
  - Conditioning with one variable in the "burglar-earthquake" example
- Product-sum algorithm example 2
  - Completion in the HMM example with POS Tagging

Neural Networks and Deep Learning

- Neural Network and Deep Learning models attracted a lot of attention lately, especially in the NLP area
- Great or promising results in the areas such as:
  - word embedding (semantic word embedding in vector space)
  - language modelling
  - machine translation
  - speech recognition
  - other: classification, sequence tagging, question answering, etc.
- Revolutionalized large parts of NLP

History of Neural Networks and Deep Learning Models for NLP

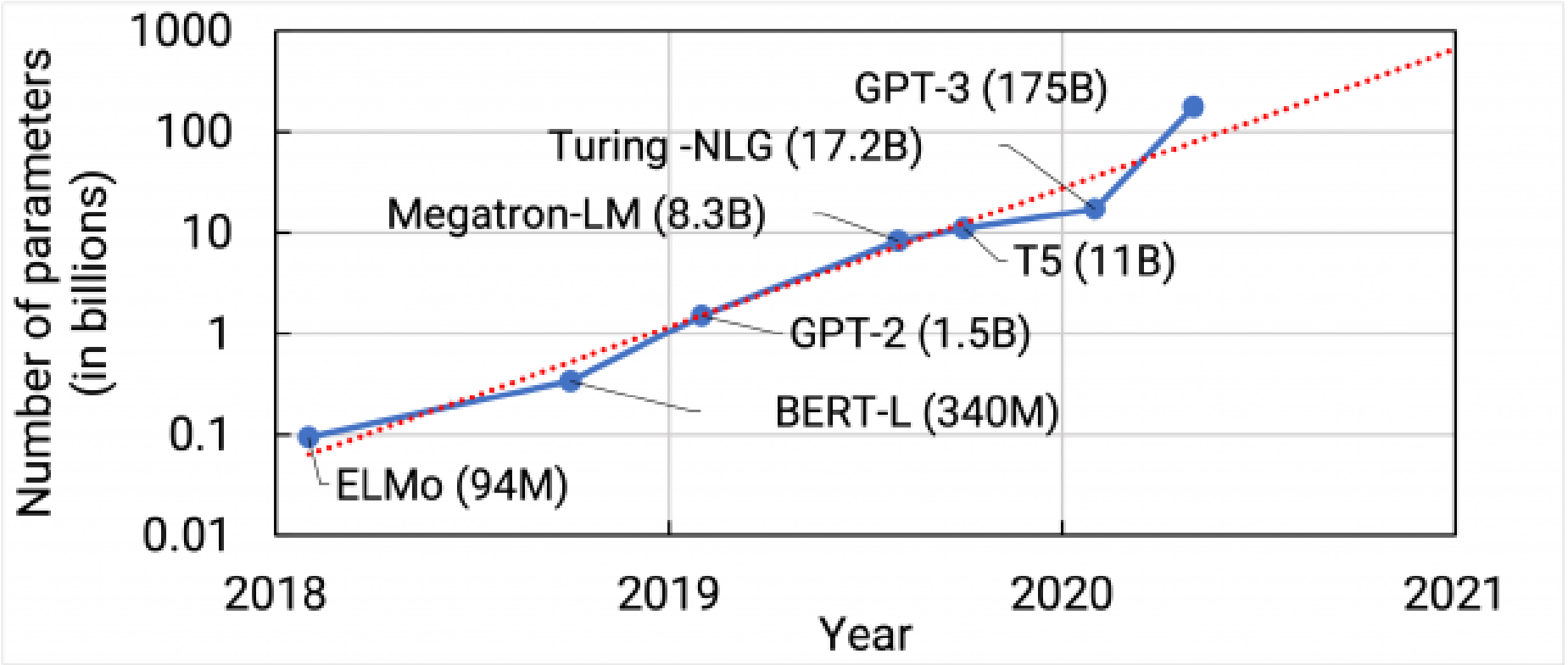
- Artificial Neural Networks research, 1958 perceptron
- Backpropagation training 1986
- Neural Networks used since then but no significant success in NLP
- Important milestone: AlexNet winning ImageNet competition on Sep 30, 2012
- word2vec 2013, Mikolov et al. at Google
- Development of larger models since then

Large Deep Learning Models

- ELMo (Embedding from Language Model) 2018 by Allen Institute for Artificial Intelligence and University of Washington, 94mil parameters
- BERT (Bidirectional Encoder Representations from Transformers) 2018 by Google, 340mil par.
- GPT-2 by OpenAI in 2019, 1.5bil. param.
- Megatron-LM bu NVIDIA, 8.3bil. param.
- Turing-NLG by Microsoft, 17.2bil. param.
- GPT-3 in 2020 by OpenAI, 175bil. param.
- Exponential growth in number of parameters

Deep Learning Language Model Sizes

- Exponential growth:



Deep Learning Language Models

- These are pre-trained language models
- Used to generate text given a start
- With additional training, have potential to solve a range of NLP tasks
- Models are trained on very large text collected from Internet typically
  - E.g., GPT-3 is trained on 499 billion tokens
  - Wikipedia included with only 3 billion tokens
- Models train to simply predict next word, given previous words

Foundations of Deep Learning

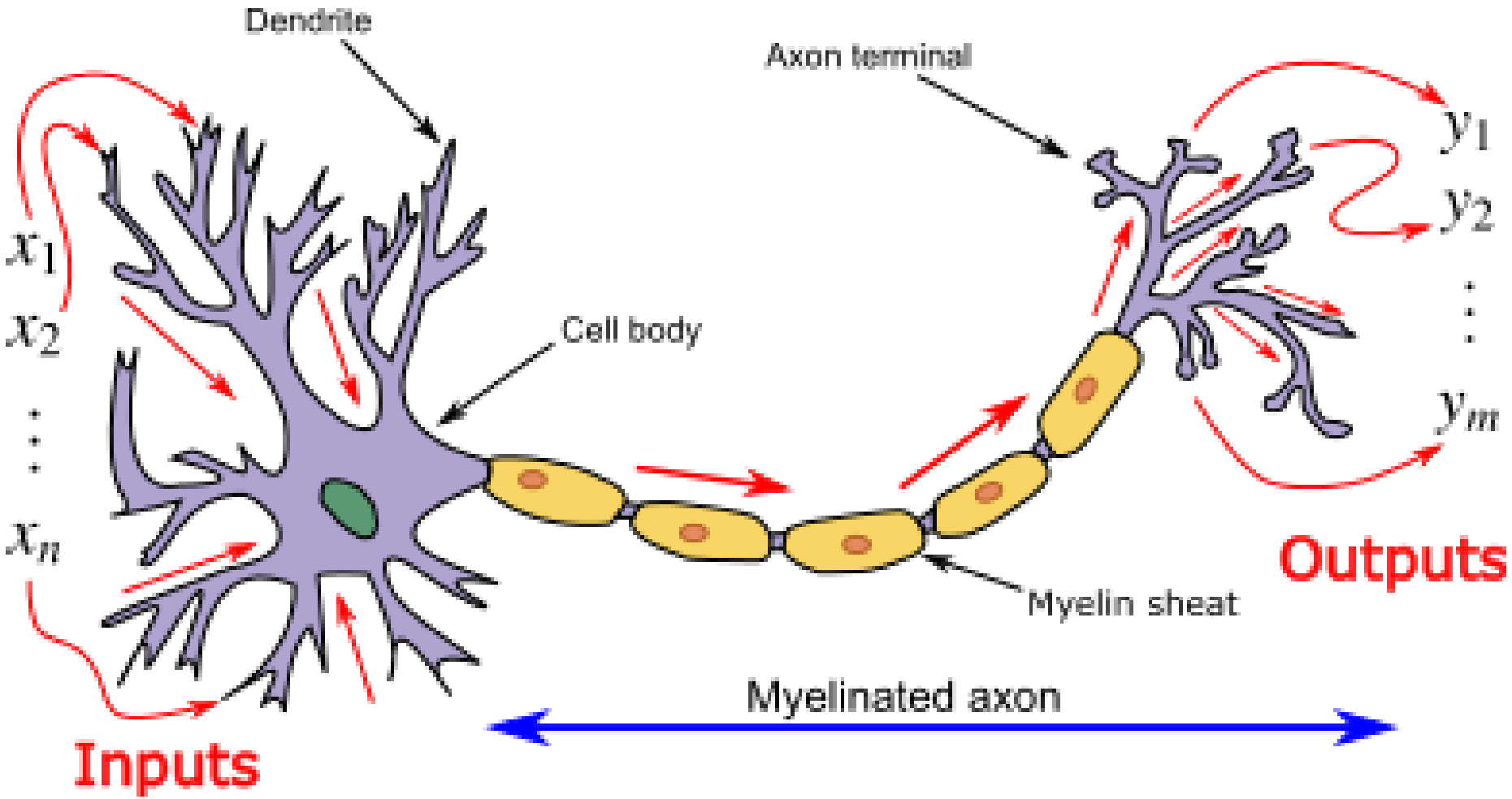
- Classification as a starting concept
- Perceptron and Neural Networks
- Deep Neural Networks

Classification as a Starting Concept

- Another look at the Naïve Bayes classifier
- Linear classifier
- Logistic regression

Perceptron and Neural Networks

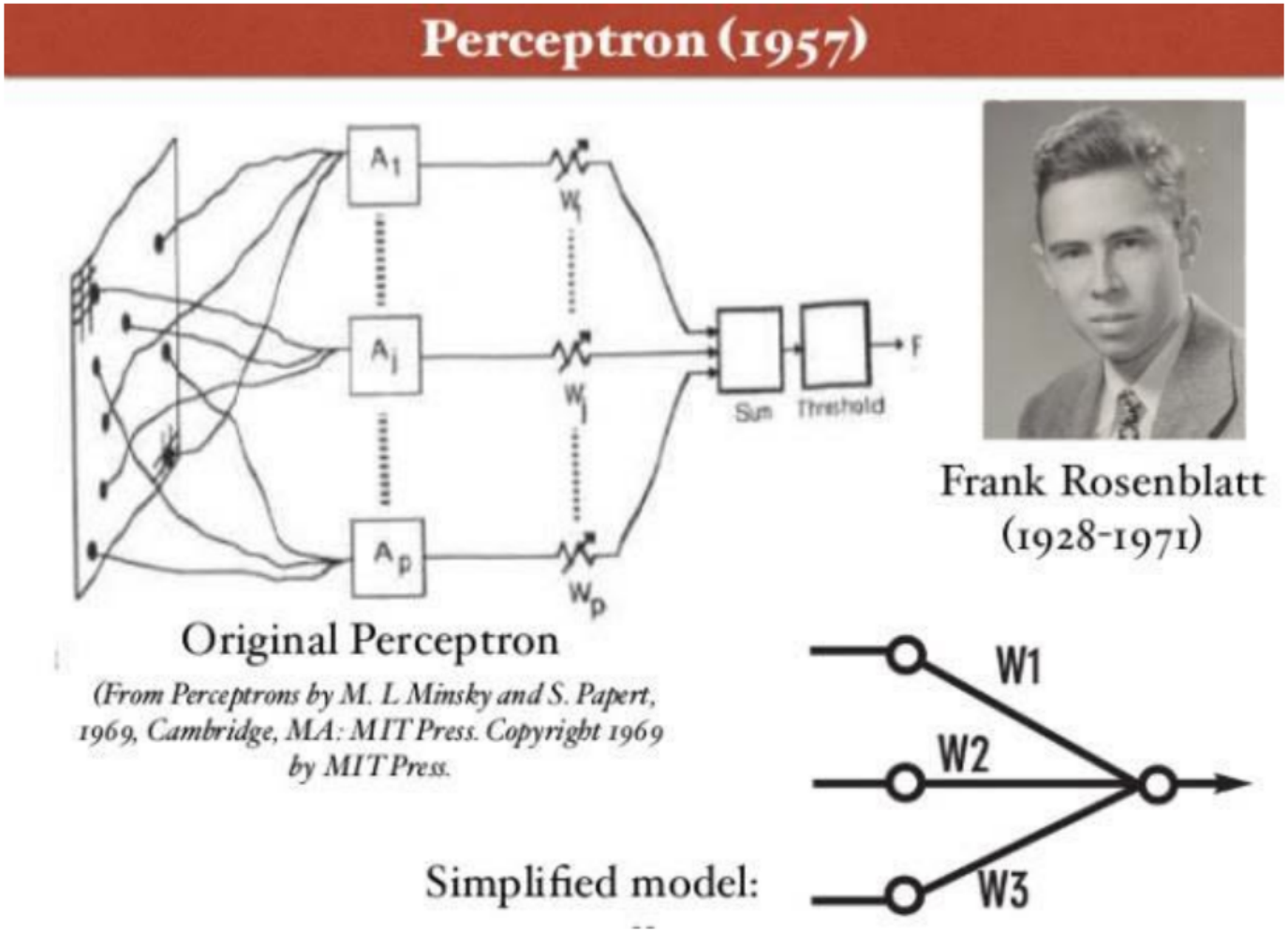
Biological Neuron



By Egm4313.s12 (Prof. Loc Vu-Quoc) - Own work, CC BY-SA 4.0,

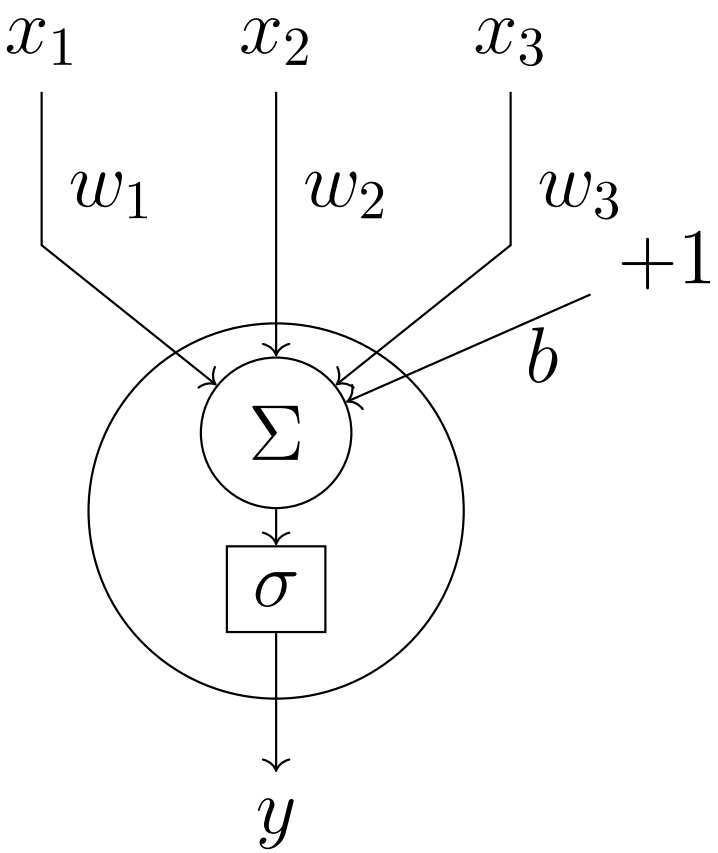
`https://commons.wikimedia.org/w/index.php?curid=72816083`

Traditional Perceptron (Artificial Neuron)



https://www.simplilearn.com/what-is-perceptron-tutorial

Computation in Artificial Neuron (Perceptron)



— input layer

— weights

— (b) bias

— weighted sum

— activation function

— output value

$$y = \sigma(b + \sum_i x_i w_i) = \sigma(b + x_1 w_1 + x_2 w_2 + x_3 w_3)$$

Perceptron Properties

- Biological neurons would imply activation function (non-linear transform) to be step function, or at least monotonically non-decreasing
- Could use identity function or linear function, but not a good idea
- If used as classifier ($y \geq 0$ or $y < 0$), similar to Naïve Bayes, SVM (Support Vector Machines), and logistic regression
  - linear separability
- Connected to make Neural Networks (brain analogy)

Feedforward Neural Network

also called *multi-layer perceptron*