Vector Similarity in Recommender Systems

- Recommendation – assign relevance score to an item w.r.t. a user model (system‘s representation of the user).
  - Core idea in recommender systems: Represent complex entities – users and arbitrary items – as vectors!
- Different approaches: Collaborative filtering, content-based, knowledge-based. In practice: hybrid systems.
- Collaborative filtering: Assign relevance score
  - Based on similarities between users (user-based collaborative filtering)
  - Based on similarities between items (item-based collaborative filtering).
  - „relevant to user A“ ~ user A has rated well, has viewed, clicked on, bought, recommended to someone else, edited, etc.

Learning Goals

Understand

- The machine learning task “classification”
- What is machine learning; unsupervised, reinforcement and supervised learning.
- The principle of the human brain neurons, their components (nucleus, cell body, dendrite, axon, synapse) and the basic function of the components
- The simplest artificial neuron (McCulloch-Pitts Neuron)
- The perceptron

Be able to

- Give examples for a classification task
- Express a boolean formula as McCulloch-Pitts Net
- Express McCulloch-Pitts Net as boolean formula
- Express mathematically (as linear equation) a single-layer Perceptron Network
- Formally define a perceptron

So now we can represent natural language text, users, and any entity
as vector …
and can ask for similar entities

Can we also differentiate between different TYPES of text/user/entity? Automatically add metadata?

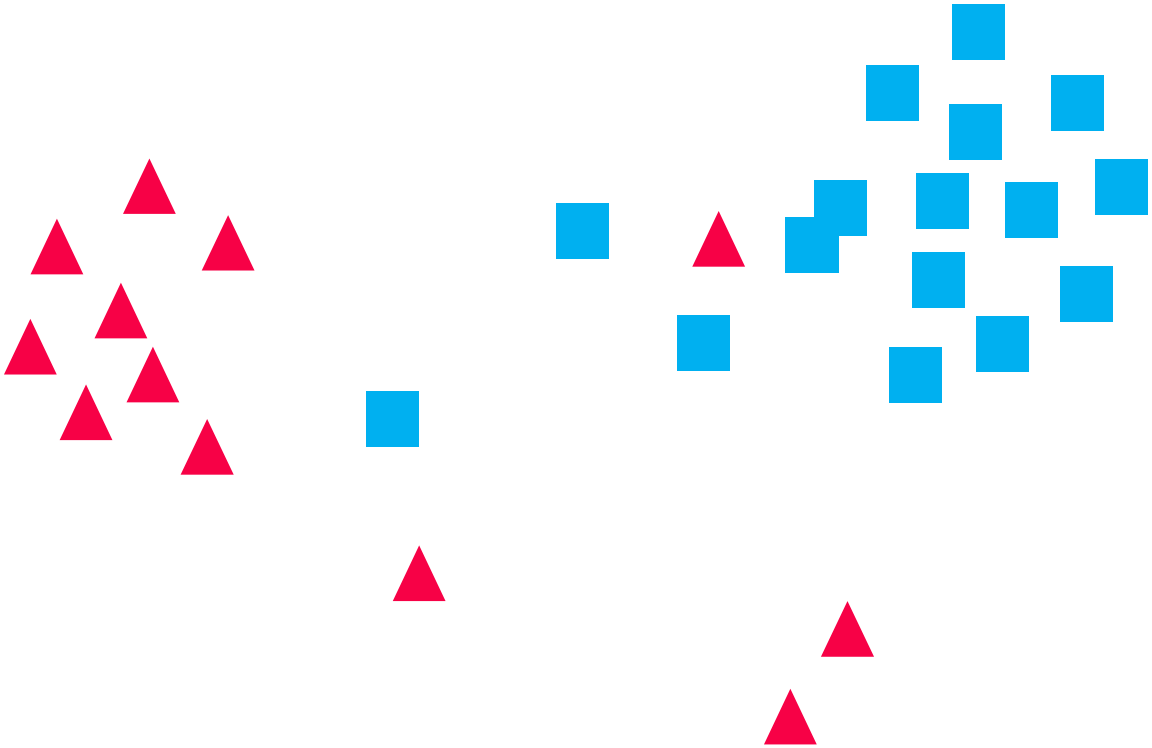
-> Different computational task: Classification

Classification

Is it sunny or raining?

Es nieselt gerade.

Artificial Neural Networks



Classification – Definition

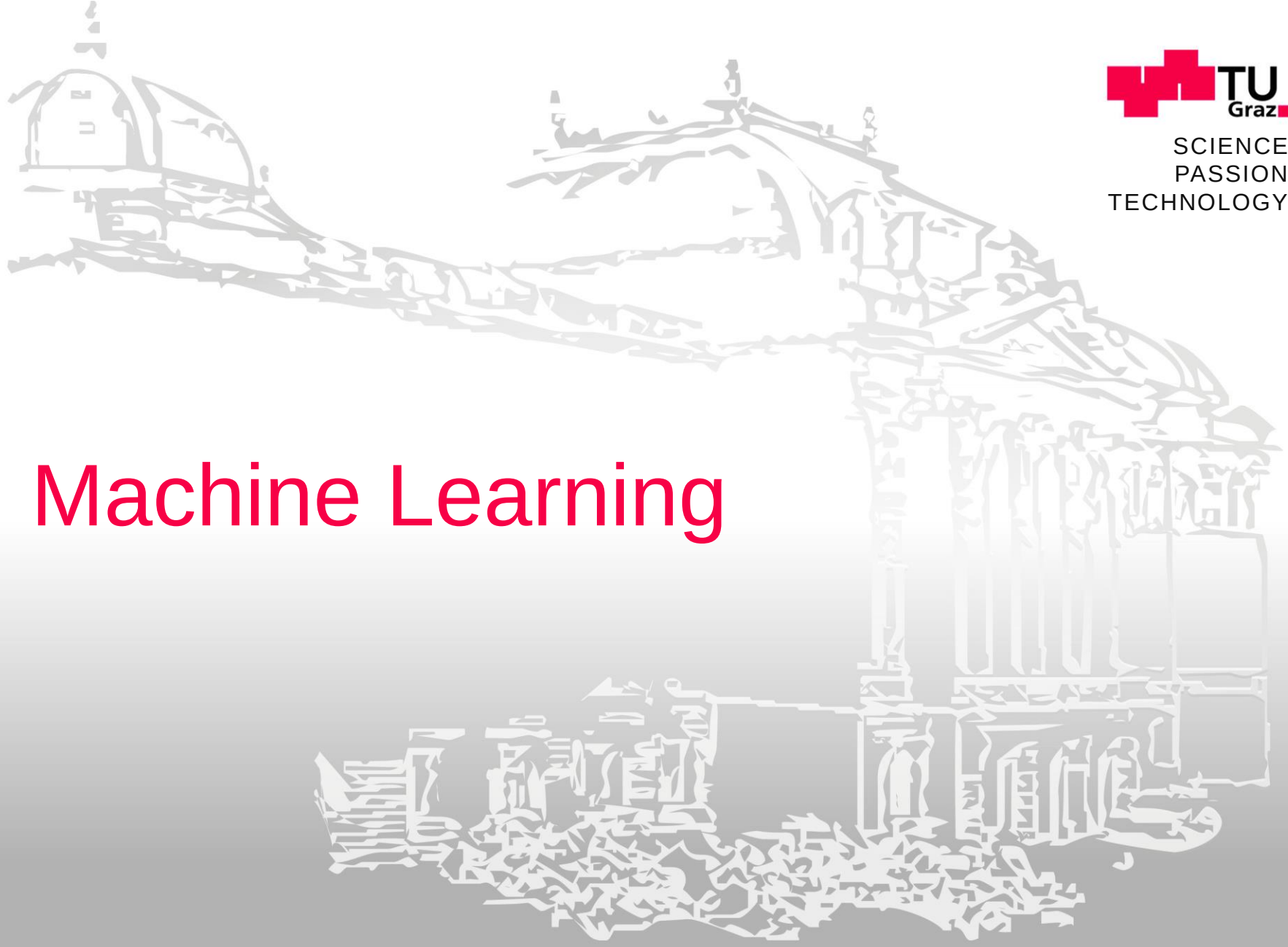
Classification is the activity of deciding for a given input x, to which class/category the input belongs.

Given an input x

Determine $y = f(x)$

$y \in \{y_1 ... y_n\}$ – is one of a finite number of classes

Typical machine learning task, when rules of classification become too complex



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Machine Learning

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What is Learning?

Learning = Long-term changes in knowledge, behaviour, perception due to experience

For humans: change in brain structure

For machines this translates to: change in parameters of represented knowledge / potentially: in knowledge representation formalism / in reasoning method

What Feedback to Use for Learning?

Unsupervised Learning – No explicit feedback is provide, e.g., clustering

Reinforcement Learning – Rewards or punishments

Supervised Learning – Example input-output pairs are given, e.g., classification

- *Reason why supervised learning isn't only a great technique, it's also great human-computer interaction: Humans are much better at giving examples, than at specifying the underlying rules…*

Classification as supervised learning problem

Given a **training set** of example pairs (x_1,y_1), (x_2,y_2) … (x_n,y_n)

Where each y_i was generated by an unknown function $y=f_{TRUE}(x)$

Discover a function f (**hypothesis**) that approximates the true function f_{TRUE}

Measure the quality of f using a **different test set** (example pairs not within the training set)

Example – Simple Happiness Detector based on Short Text Messages (Skype status, FB status, …)

Example 1: (“I’m now working on Analysis”, neutral)

Example 2: (“I got a 1 in Analysis! (dance)”, happy)

Example 3: (“Aaarghh!!! I will never understand Analysis (headbang)”, unhappy)

What machine learning task are we talking about?

Is this supervised, unsupervised, or reinforcement learning?

What could be a hypothesis h on how to detect whether the writer is emotionally neutral, happy or unhappy?

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Artificial Neural Networks

Viktoria Pammer-Schindler

Introduction to Data Science and Artificial Intelligence

www.staff.tugraz.at/viktoria.pammer-schindler

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The Inspiration: The Human Brain

Human Neuron

Dendrites ~ Input

Cell body ~ Processing

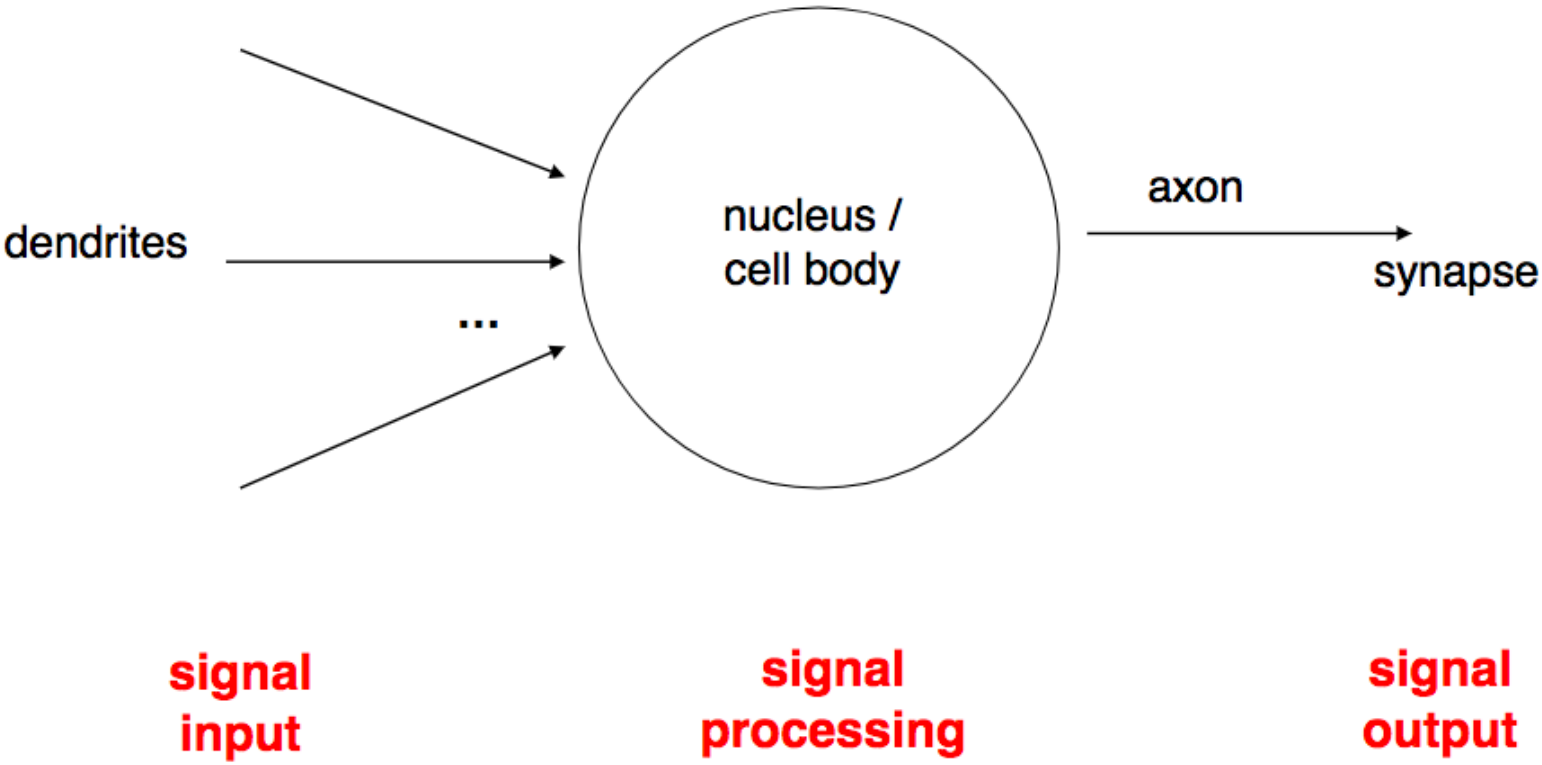
Axon/Synapse ~ Output

Human brain ~ 10^{12} neurons

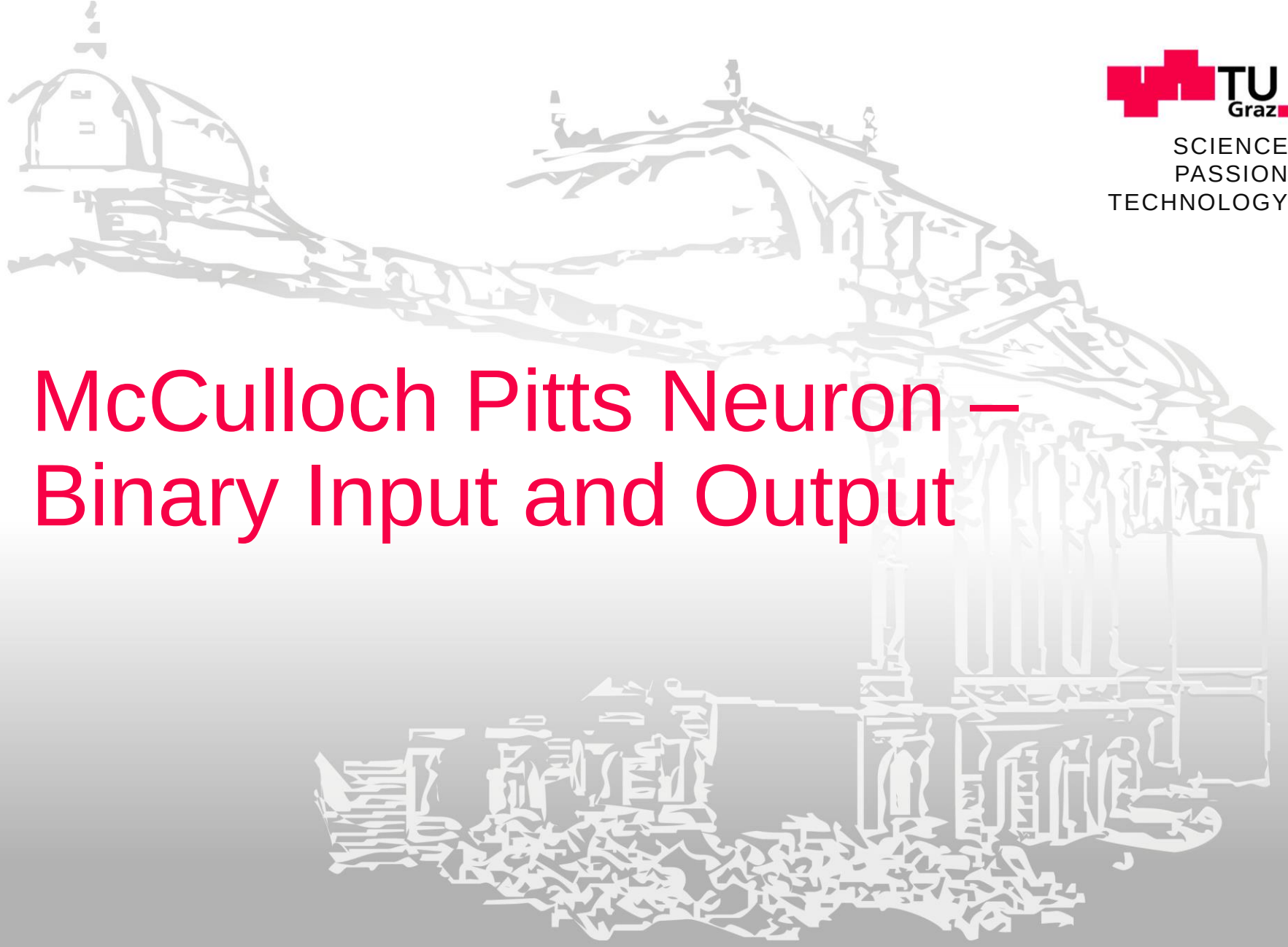
From: https://commons.wikimedia.org/wiki/File:Generic_Neurotransmitter_System.jpg

From: http://maxpixel.freegreatpicture.com/Dendrites-Neuron-Brain-Soma-Axon-Nerve-Cell-1294021

Abstraction



From: https://ls11-www.cs.tu-dortmund.de/people/rudolph/teaching/lectures/CI/WS2017-18/lec01.pdf



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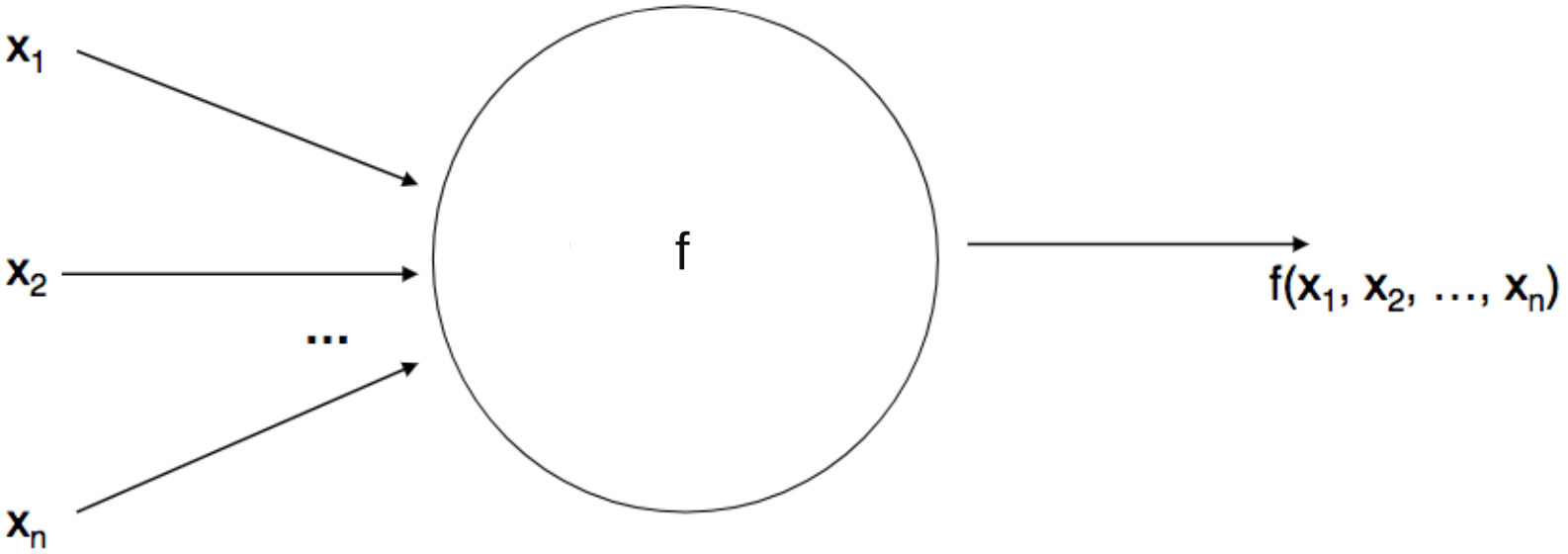
McCulloch Pitts Neuron – Binary Input and Output

McCulloch-Pitts Neuron

$x_1 \ldots x_n \in \{0,1\} = B$

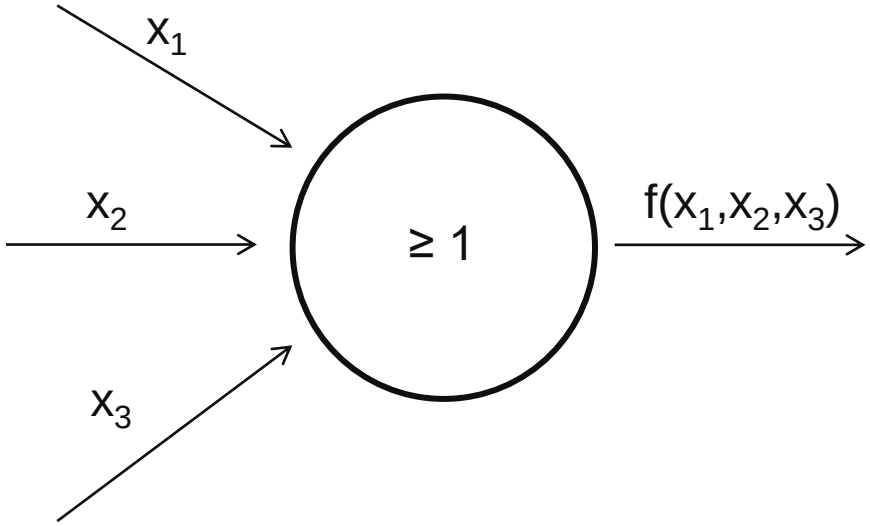
$f: B^n \rightarrow B$

f is a threshold function: if $sum(x_1 \ldots x_n) > T$ then 1, else 0



Example 1

Boolean OR: $f(x_1,x_2,x_3) = x_1$ OR x_2 OR x_3



x_1	x_2	x_3	$f(x_1,x_2,x_3)$
1	1	1	
1	1	0	
1	0	1	
1	0	0	
0	1	1	
0	1	0	
0	0	1	
0	0	0	

McCulloch-Pitts Neuron with Inhibitory Inputs

Normal inputs $x_1 \ldots x_n$

Inhibitory inputs $y_1 \ldots y_m$

Threshold T

if (at least one $y_i = 1$)

then 0

else if (sum($x_1 \ldots x_n$) > threshold T)

then 1

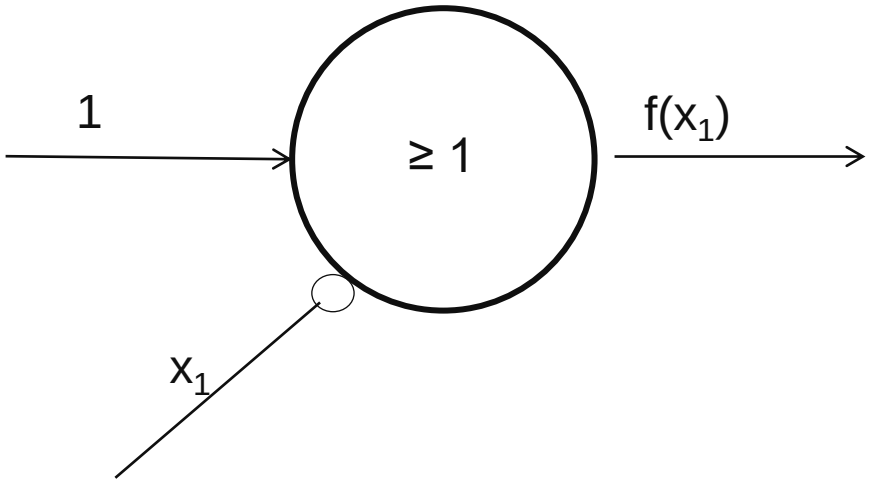
else

0

$$\mathbf{f(x_1 \ldots x_n, y_1 \ldots y_m) = f(x_1 \ldots x_n) * \pi(1-y_i)}$$

Usefulness of inhibitory inputs for neuron‘s expressive power

Boolean NOT: $f(x_1)$ = NOT x_1



x_1	$f(x_1)$
1	0
0	1

With inhibitory inputs, McCulloch Pitts Neurons can express all Boolean functions

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Perceptron

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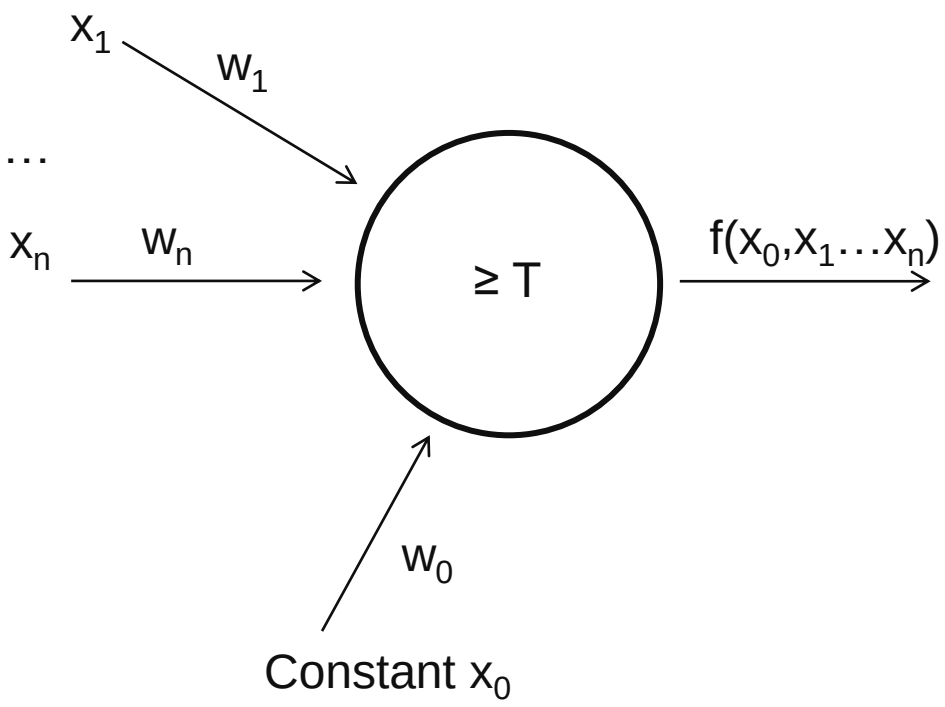
Generalisation: Perceptron

$$f(x_0 \ldots x_n): w_0x_0 + w_1x_1 + \ldots w_nx_n \geq T$$



Generalisation: Perceptron

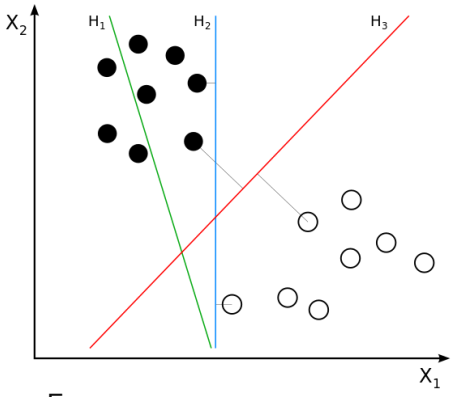
$f(x_0 \ldots x_n)$: $w_0x_0 + w_1x_1 + \ldots w_nx_n \geq T$

$w_1x_1 + w_2x_2 \geq (T - w_0x_0)$

$\rightarrow x_2 \geq (T - w_0x_0)/w2 - (w_1/w_2)x_1$

$x_0 = 0$

$\rightarrow x_2 \geq T/w2 - (w_1/w_2)x_1$



From: https://commons.wikimedia.org/wiki/File:Svm_separating_hyperplanes_(SVG).svg

Separates R^n in 2 classes (with a line/n-dimensional plane)

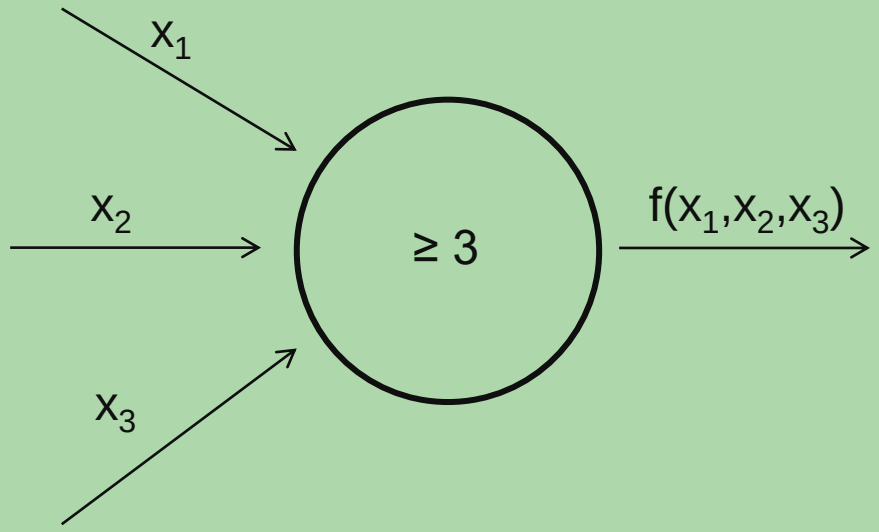
Perceptron: Beyond linear separation

With the following extensions, perceptron networks can also non-linearly separate data:

- Multilayer Perceptron Networks
- Nonlinear activation functions (e.g.: $f(x_1,x_2)$: $2x_1 + 2x_2 - 4\ x_1x_2 > 0$)

Exercise 14

What are the truth values? Which Boolean function is represented by the McCullochPittsNeuron?



x_1	x_2	x_3	$f(x_1,x_2,x_3)$
1	1	1	
1	1	0	
1	0	1	
1	0	0	
0	1	1	
0	1	0	
0	0	1	
0	0	0	

Exercise 15

Draw a McCulloch Pitts Neural Network that expresses the following Boolean formula

$(x_1 \text{ AND } x_2) \text{ OR } x_3$

Recommended Reading

- https://ecee.colorado.edu/~ecen4831/lectures/NNet2.html - Short reading, highly recommended!
- I have found slides by Günther Rudolph very useful (https://ls11-www.cs.tu-dortmund.de/people/rudolph/teaching/lectures/CI/WS2017-18/lec01.pdf) but they contain an error in the picture of the NOT gate

And two classic books:

- the AI classic book by Stuart Russell & Peter Norvig (http://myweb.sabanciuniv.edu/rdehkharghani/files/2016/02/Prentice-Hall-Series-in-Artificial-Intelligence-Stuart-Russell-Peter-Norvig-Artificial-Intelligence_-A-Modern-Approach-Prentice-Hall-2010.pdf)
- Another classic machine learning book by Tom Mitchell (here I took especially the Perceptron figure from): http://myweb.sabanciuniv.edu/rdehkharghani/files/2016/02/Prentice-Hall-Series-in-Artificial-Intelligence-Stuart-Russell-Peter-Norvig-Artificial-Intelligence_-A-Modern-Approach-Prentice-Hall-2010.pdf