Perceptron Networks and Applications

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Administrative

- **Grading**
  - Midterm: 35%
  - Homeworks: 25%
  - Final: 40%

- **Textbook**
  - K. Mehrotra, C. Mohan and S. Ranka, Elements of Artificial Neural Networks, The MIT Press, 1996.

- **Other helpful texts**
  - M. Hagan, H. Demuth and M. Beale, Neural Network Design, PWS Publishing Company, 1996.
  - S. Haykin, Neural Networks: A Comprehensive Foundation 2nd edition, Prentice Hall, 1999.
  - L. V. Fausett, Fundamentals of Neural Networks: Architectures, Algorithms and Applications, Prentice Hall, 1993.

Administrative

- **Notes for homeworks & reports:**
  - This is an individual assignment. All the work should be the student‘s and in accordance with the ethical policies.
  - All resources should be cited in the text and the bibliographic information should be given end of the report.
  - All assignments are due one week.
  - Late homeworks will not be accepted.
  - Submit a single pdf file which contains the report and the all attachments.
  - The homework file name should be formatted as: StudentNumber_CourseCode_HomeworkNumber.pdf
  - The midterm report file name should be formatted as: StudentNumber_CourseCode_Midterm.pdf
  - The final report file name should be formatted as: StudentNumber_CourseCode_Final.pdf

Course outline

- Introduction
- Neural network architectures
- Perceptrons
- Single layer neural networks
- Multilayer neural networks
- Learning rules
- Backpropagation
- Recurrent neural networks
- Self organising maps
- Hopfield neural networks

Content

- Introduction
- History of neural networks
- Biological neurons
- Artificial neuron models

Introduction

- A system must have at least three abilities in order to be intelligent:
  - it must be able to **receive information by itself,**
  - it must have **a flexible structure** to represent and integrate information,
  - it must have a mechanism to **adapt itself to the environment** using the acquired information.

Introduction

- **The goal** of neural network research is to **realize an artificial intelligent system** using the human brain as the model.
- There are three basic problems in this area:
  - **What kind of structure** or model should we use?
  - **How to train or design** the neural networks?
  - **How to use neural networks** for **knowledge acquisition?**

Introduction

- This course introduces:
  - the basic models
  - learning algorithms
  - applications of neural networks
- After this course, you should be able to know **how to use neural networks for solving different problems**.

Introduction

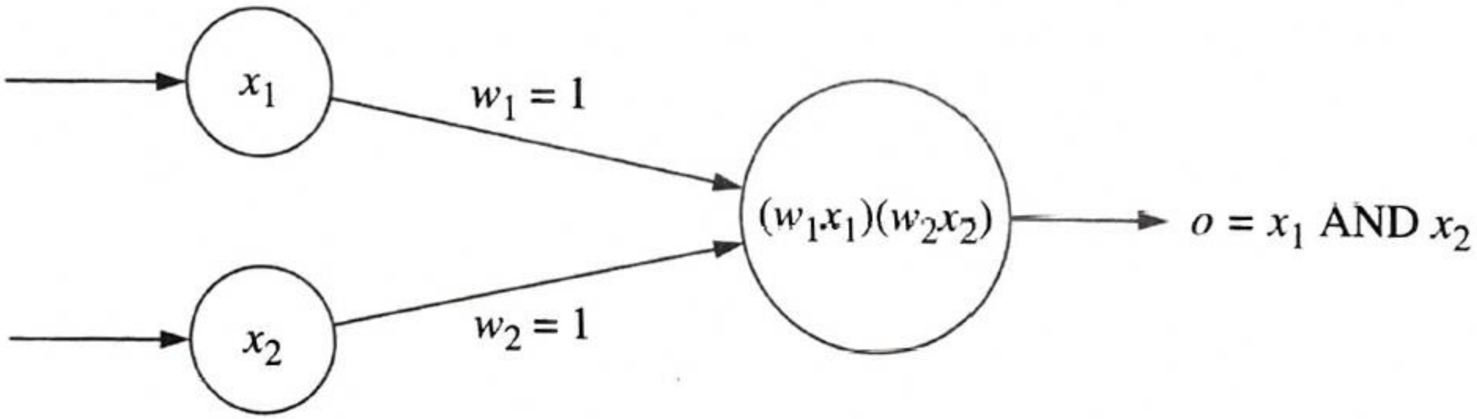
- **The artificial neural networks** are all variations on the **parallel distributed processing idea.**
- Many tasks involving intelligence or pattern recognition are extremely difficult to automate.
- **Animals recognize** various objects and make sense out of the large amount of visual information in **their surroundings**, apparently **requiring very little effort.**
- **The neural network** of a human contains a **large number of interconnected neurons.**
- Artificial neural networks refer to computing systems inspired from the analogy of biological neural networks.

Introduction

- **ANN** as a **directed graph** consists of **a set of nodes** (vertices) and **a set of connections** (edges/links/arcs) connecting pairs of nodes.
- Each node performs some **simple computations**, and each connection **conveys a signal** from one node to another.
- **Connection strength** or **weight** indicates that a signal is **amplified** or **diminished by a connection.**
- **Different weights result in different functions in neural networks.**

Introduction

- **Generally weights are initialized randomly.**
- **A learning algorithm** must be used to determine weights for the desired task.



x_1	x_2	o
0	0	0
0	1	0
1	0	0
1	1	1

Content

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- History of neural networks
- Biological neurons
- Artificial neuron models

History of neural networks

- **The studies** about the neural networks date back to **a century ago.**
- **The roots** of all work on neural networks are **in neurobiological studies.**
- Psychologists tried to understand **how learning, forgetting, recognition are accomplished by humans.**
- **McCulloch and Pitts** developed the first mathematical model of a neuron.
- Neural network **learning rules** mostly use **gradient descent** search procedures.

History of neural networks

- 1949 **Hebb's** learning rule **modifies weights** by examining whether two connected nodes are **simultaneously ON or OFF.**
- 1958 **Rosenblatt's perceptron model** and the learning rule are based on **gradient descent** to change weights **depending on the desired outputs**.
- 1938 **Rashevsky** initiated studies for representing activation and propagation in neural networks using differential equations.
- 1943 **McCulloch and Pitts** invented the first artificial model for biological neurons.
- 1943 **Landahl, McCulloch, and Pitts** noted that many **arithmetic** and **logical operations** could be implemented using McCulloch and Pitts neuron models.

History of neural networks

- 1954 **Gabor** invented the **learning filter using gradient descent** to obtain optimal weights that minimize the **mean squared error.**
- 1956 **Taylor** introduced an **associative memory network** using Hebb's rule.
- 1958 **Rosenblatt** invented a **learning method** for the **McCulloch and Pitts neuron model.**
- 1960 **Widrow and Hoff** introduced the Adaline as a simple network trained by a gradient descent rule.
- 1961 Rosenblatt proposed the **backpropagation** scheme for **training multilayer networks.**
- 1964 Taylor constructed **a winner-take-all** circuit.

History of neural networks

- 1969 **Minsky and Papert** demonstrated the limits of simple perceptions.
- Combinations of many neurons can be more powerful than single neurons.
- 1962 **Dreyfus** formulated learning rules to **large neural networks.**
- **Gradient descent is offently not successful** in obtaining a desired solution to a problem.
- **Random**, **probabilistic**, or **stochastic methods** have been developed.

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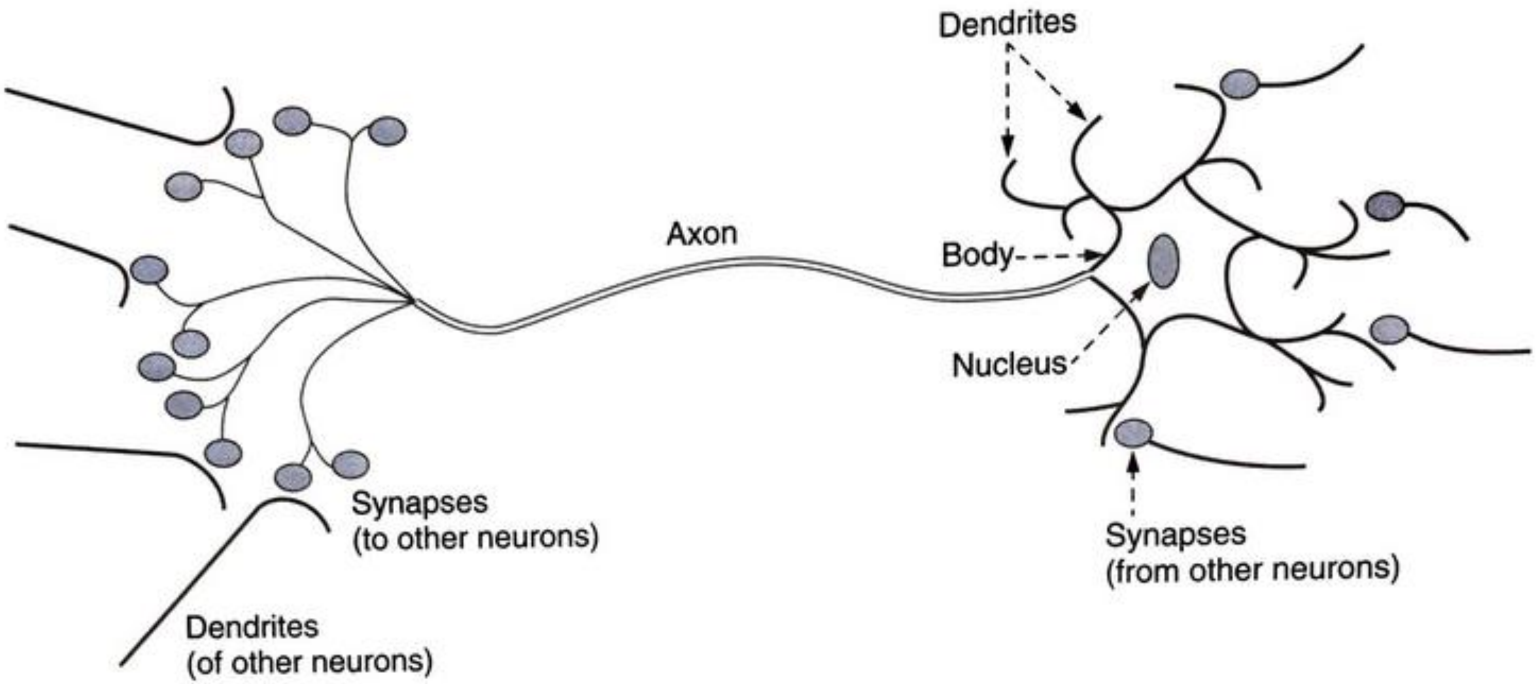
Biological neurons

- A typical biological neuron is composed of **a cell body, an axon** and **dendrites.**



- The **dendrites** surround the body of the neuron.
- The **axon** of a neuron forms synaptic connections with others.

Biological neurons

- The **small gap** between an end point and a dendrite is called a **synapse**.
- **The synapses** decide that **which information is propagated.**
- The **number of synapses** received by each neuron range from **100** to **100,000.**

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Artificial neuron models

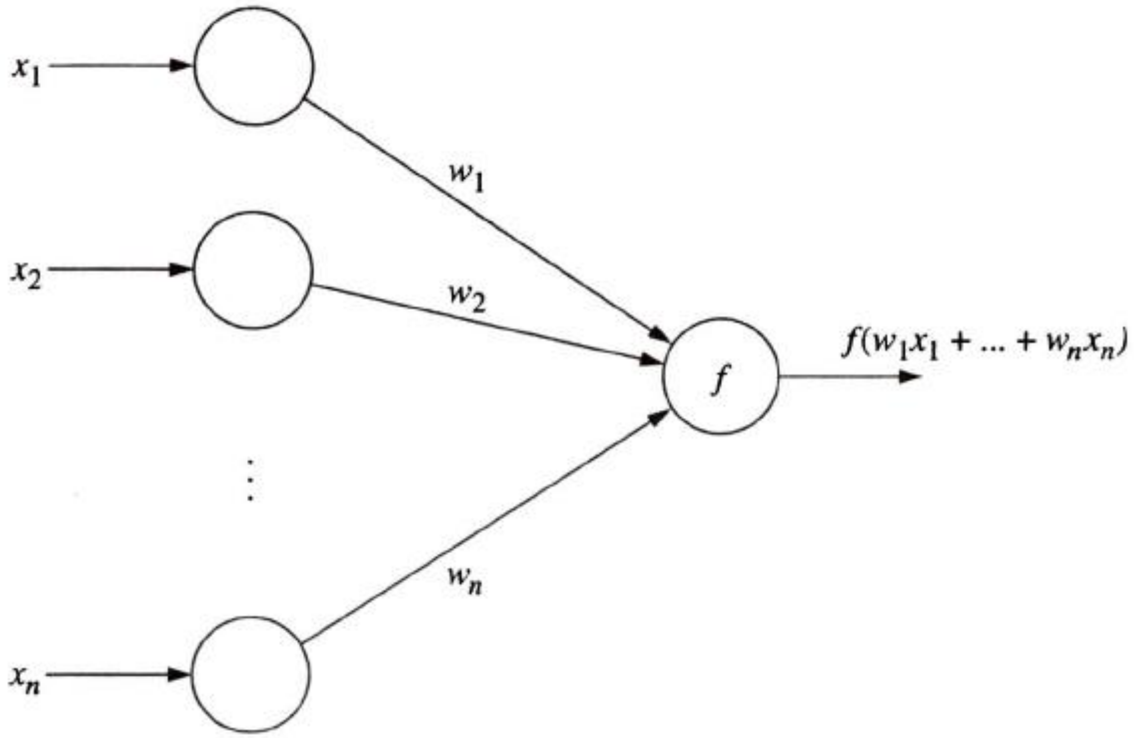
- The **artificial neuron** was created **inspired by the biological neuron.**
- Each part of the **artifical neuron** has an **equivalent part** in the **biological neuron.**

Terminology

Biological Terminology	Artificial Neural Network Terminology
Neuron	Node/Unit/Cell/Neurode
Synapse	Connection/Edge/Link
Synaptic Efficiency	Connection Strength/Weight
Firing Frequency	Node Output

Artificial neuron models

- Many different **weighted inputs** are summed.



- The neuron output is:

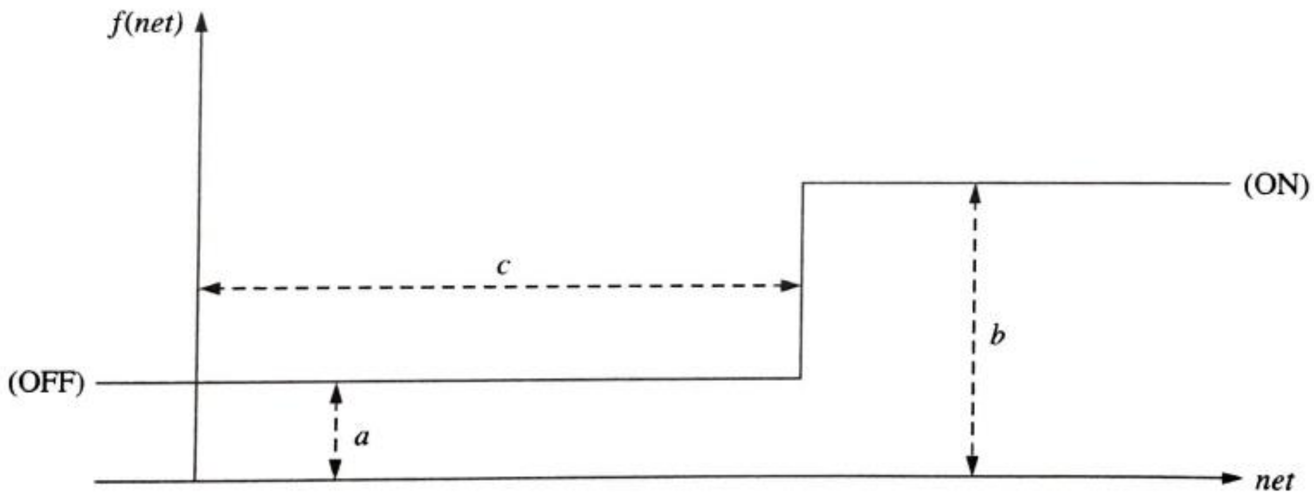
$$f(w_1x_1 + \cdots + w_nx_n)$$

$$f(\sum_{i=1}^{n} w_ix_i) \text{ or } f(net)$$

$$net = \sum_{i=1}^{n} w_ix_i$$

Step function

- Step function is commonly used in single neuron model.



- Common values for a, b, c are

$(a = 0, b = 1, c = 0)$ or $(a = -1, b = 1, c = 0)$

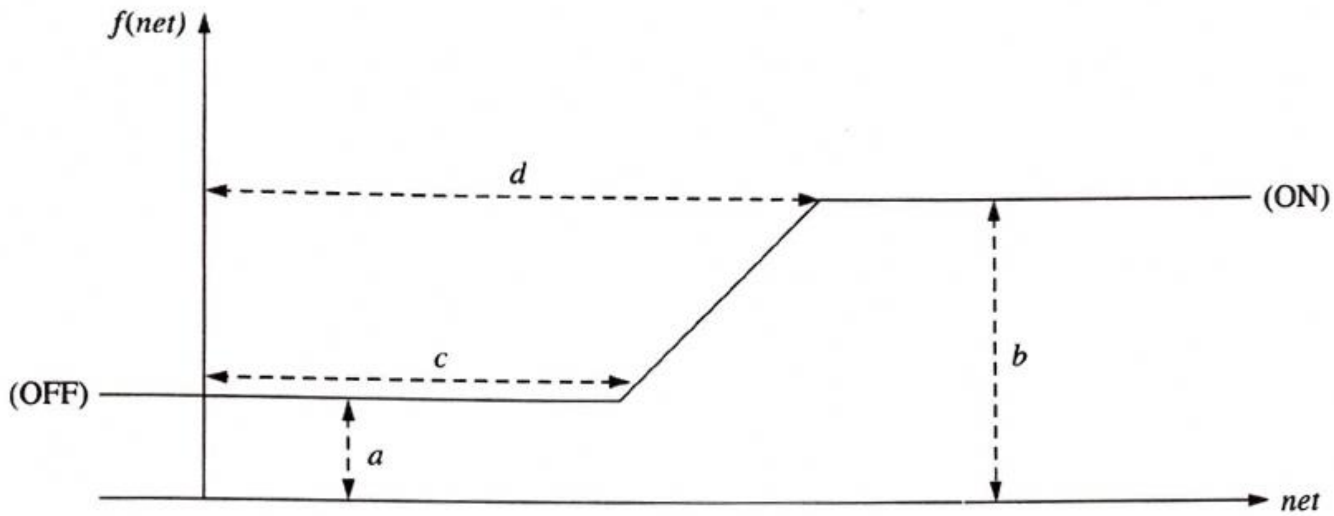
- The function is defined as:

$$f(net) = \begin{cases} a & \text{if} \quad net < c \\ b & \text{if} \quad net > c \end{cases}$$

Artificial neuron models

Ramp function

- Ramp function is commonly used in single neuron model.



- Common values for a, b, c, d are,

  ($a = 0$, $b = 1$, $c = 0$, d = 1) or (a = -b, c = -1, d = 1)

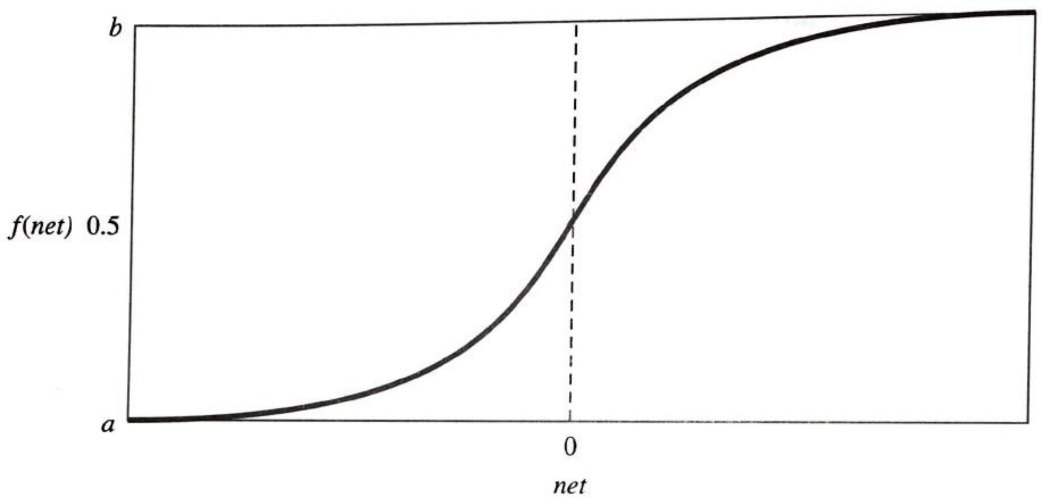
- The function is defined as:

$$f(net) = \begin{cases} a & \text{if } net < c \\ b & \text{if } net > d \\ a + ((net - c)(b - a))/(d - c) & \text{otherwise} \end{cases}$$

Artificial neuron models

Sigmoid function

- The most popular node functions used in neural nets are sigmoid **(S-shaped)** functions.
- These functions are **continuous** and **differentiable** everywhere.



- Common values for a, b, c are

  $(a = 0, b = 1, c = 0)$ or $(a = -1, b = 1, c = 0)$

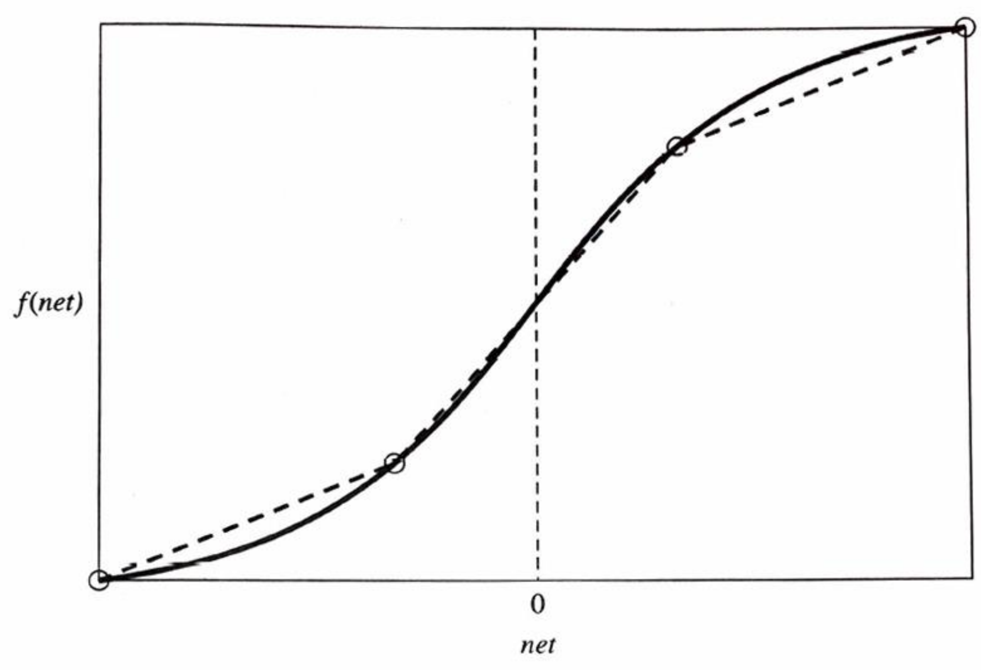
- The function is defined as:

$$f(net) = z + \frac{1}{1 + \exp(-x \cdot net + y)}$$

Artificial neuron models

Piecewise linear function

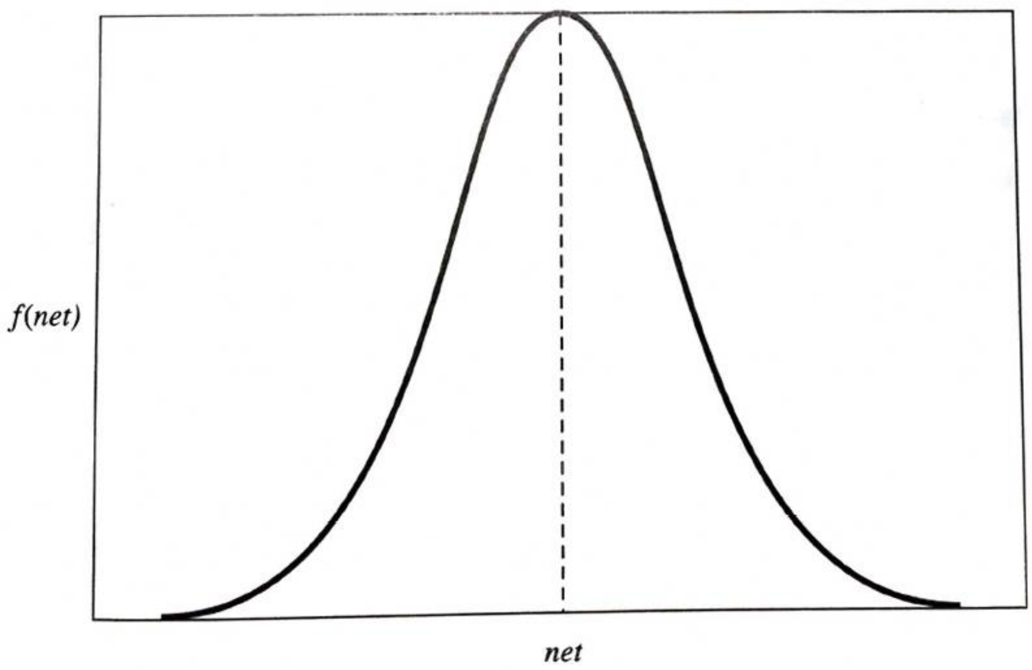
- **Piecewise linear functions are combinations of various linear functions.**
- Piecewise linear functions are **easier to compute than nonlinear function.**
- In the figure, the **dashed line** is the piecewise linear function, and the **straight line** is the sigmoid function.



Artificial neuron models

Gaussian function

- Bell-shaped curves known as **Gaussian** or **radial basis functions.**
- Gaussian node functions are used in **Radial Basis Networks.**

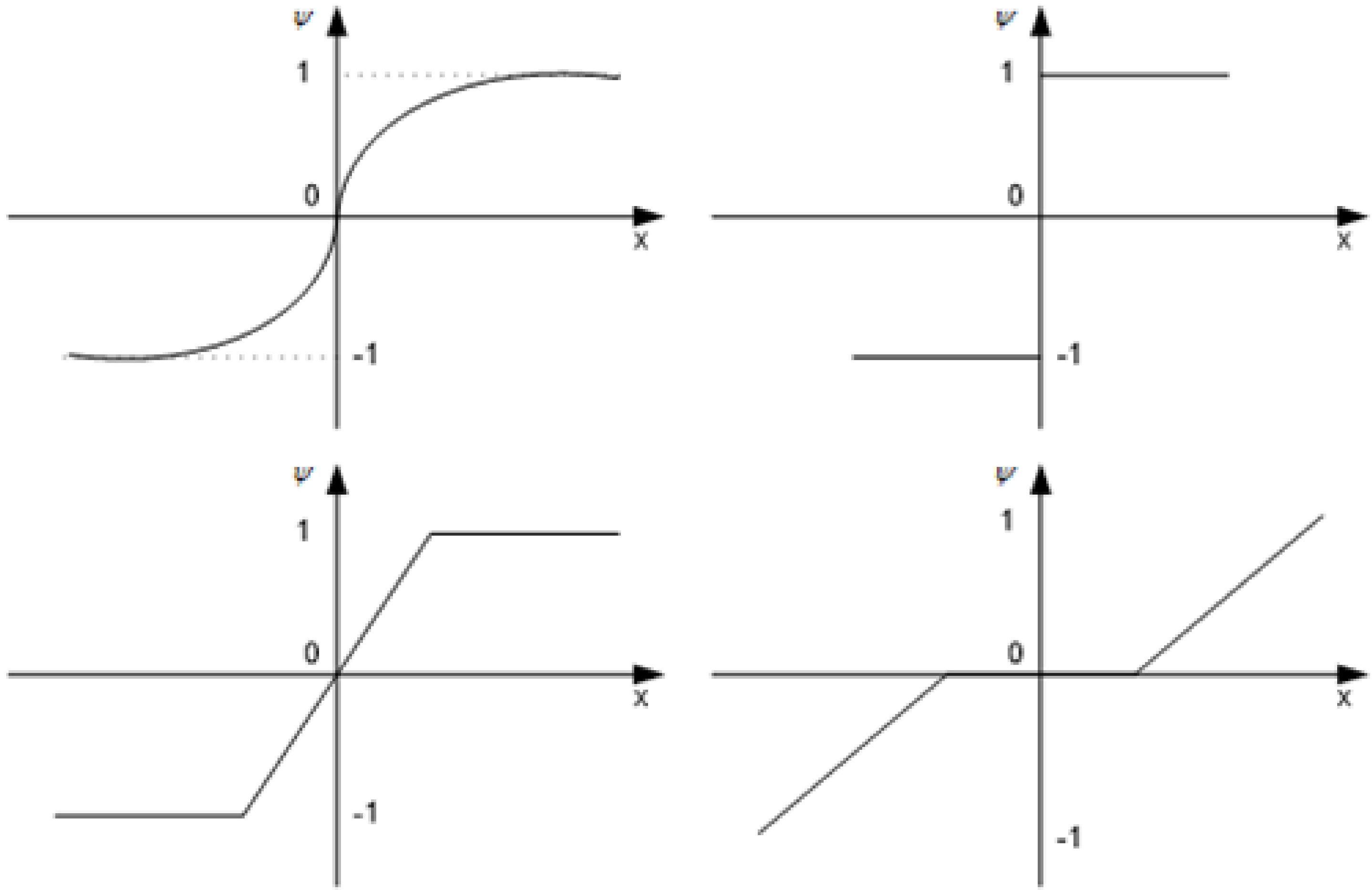


$$f(\text{net}) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{1}{2}\left(\frac{\text{net} - \mu}{\sigma}\right)^2\right]$$

Artificial neuron models

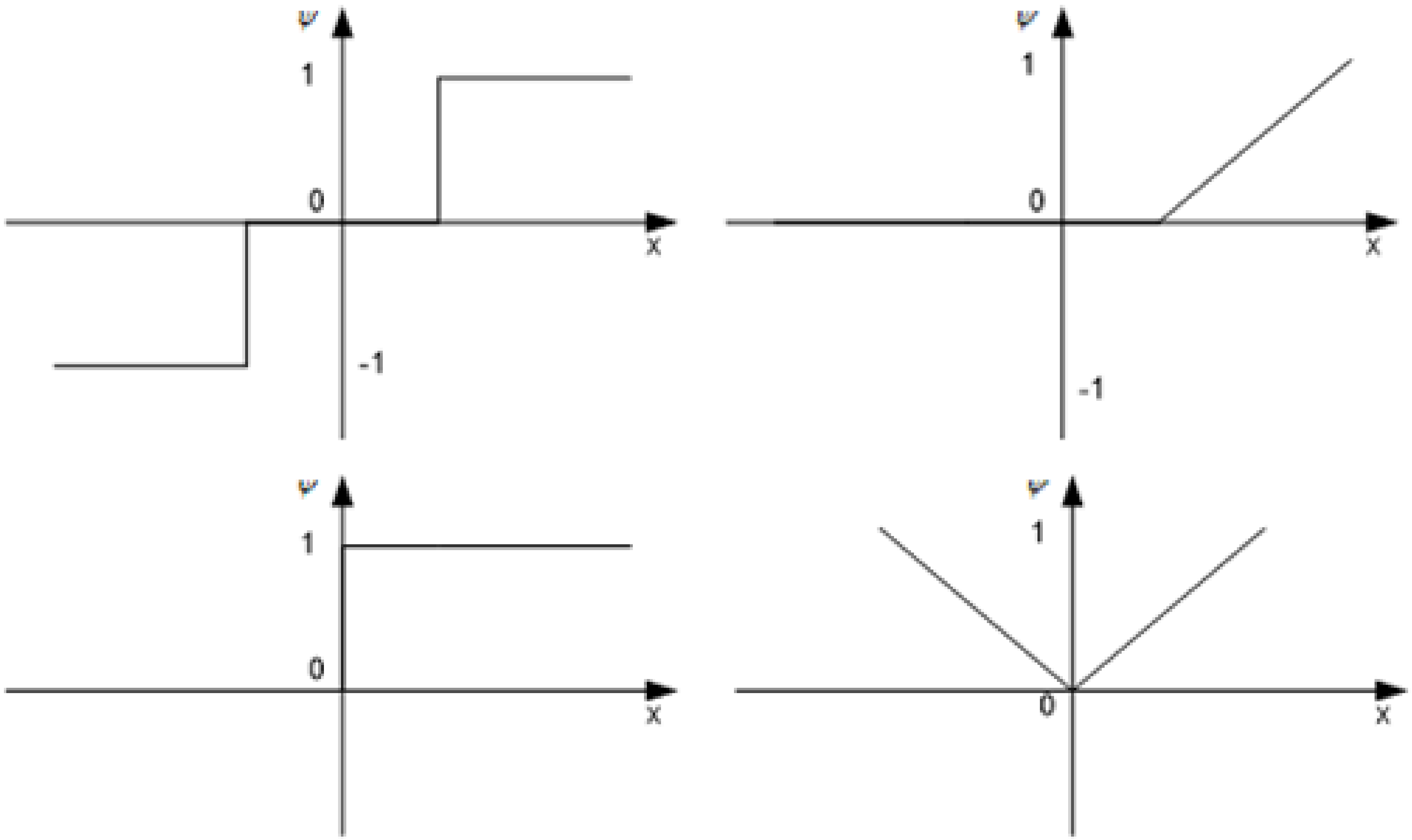
Other functions

- There are many different functions that are used as activation functions.



Artificial neuron models

Other functions



Homework

- Prepare a report on the use of artificial neural networks in the medicine (diagnosis and treatment).