## 2.2 Artificial Intelligence

So far, the factory is controlled by a PLC software. This software allows the developer to set clear instructions what the factory and each machine does. Instructions are worked through precisely. It furthermore needs to be controlled by workmen. The production process is started, viewed and stopped by humans. Furthermore, the quality of products needs to be screened. For a company this always means to pay wages. But how avoid these costs?

With “[the] branch of computer science that is concerned with the automation of intelligent behavior” (Luger and Stubblefield, 1993), which is called artificial intelligence (AI). This could help to take over the task of the mentioned steps of work.

The factory is supposed to be monitored and controlled by artificial intelligence. While AI comprehend many ways of implementations, this project is supposed to use neuronal networks. This chapter will review neuronal networks.

### 2.2.1 Neuronal Network in general

When talking about neuronal network it is meant to have an artificial neuronal network. The idea is to create software that works similar like a human brain, a natural neuronal network. This network gives us our intelligence. It helps us to train our abilities, physically and more important mentally. We can adopt to situations and changes.

But how to build such a system? A computer has an architecture not matching with the brain. It is basically a calculator that can execute software which is based on mathematics. The attempt is to analyze human brain and to create models that reflect the brain. The network consists of many small entities, that are similar like the neurons. They are working like single information storages, powered by electric voltage. As messages reach a neuron, also electrical energy is sent. The voltage level is rising. At some point there is too much energy in a neuron and it will reach out and sends its information. But where to?

**“What fires together, wires together”** (Hebb, 2002) is a quote describing that neurons often reach out to each other will connect. The more often they communicate the stronger their connection will be. For an artificial neuronal network it should work similar. When raw data is put in a new system, there is no connection between the entities. The computer then need to find connections. Hebb is describing the idea of how it’s done: Data often colliding, will have some kind of link. This is how the computer can derive clusters. Once this clusters are established it can be used to solve tasks. The more tasks it solves, the more information the system can collect. This information can also lead to an evolvement of the clusters.

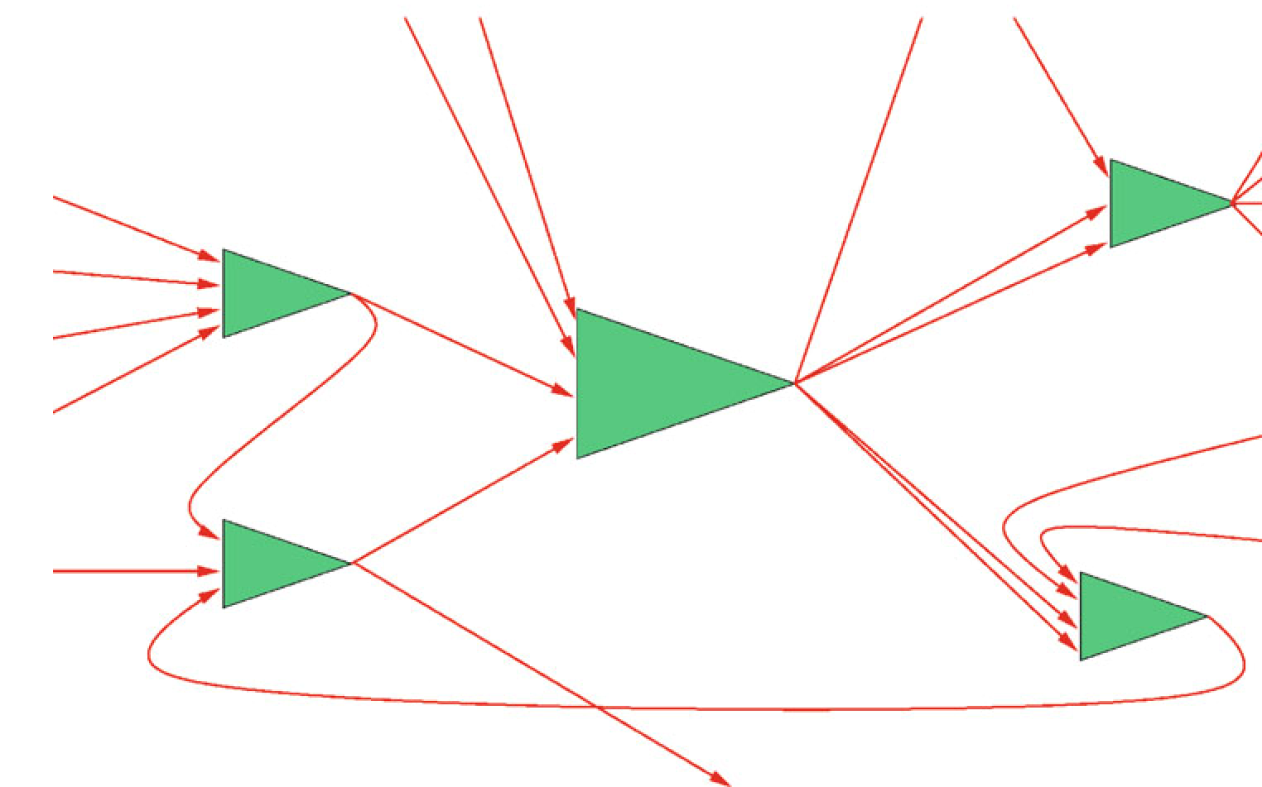


Figure 2.x: Model of network (Ertel, 2021)

The above figure above represents the network. The green triangles are the neurons connected by wires. The following picture shows how this is implemented.

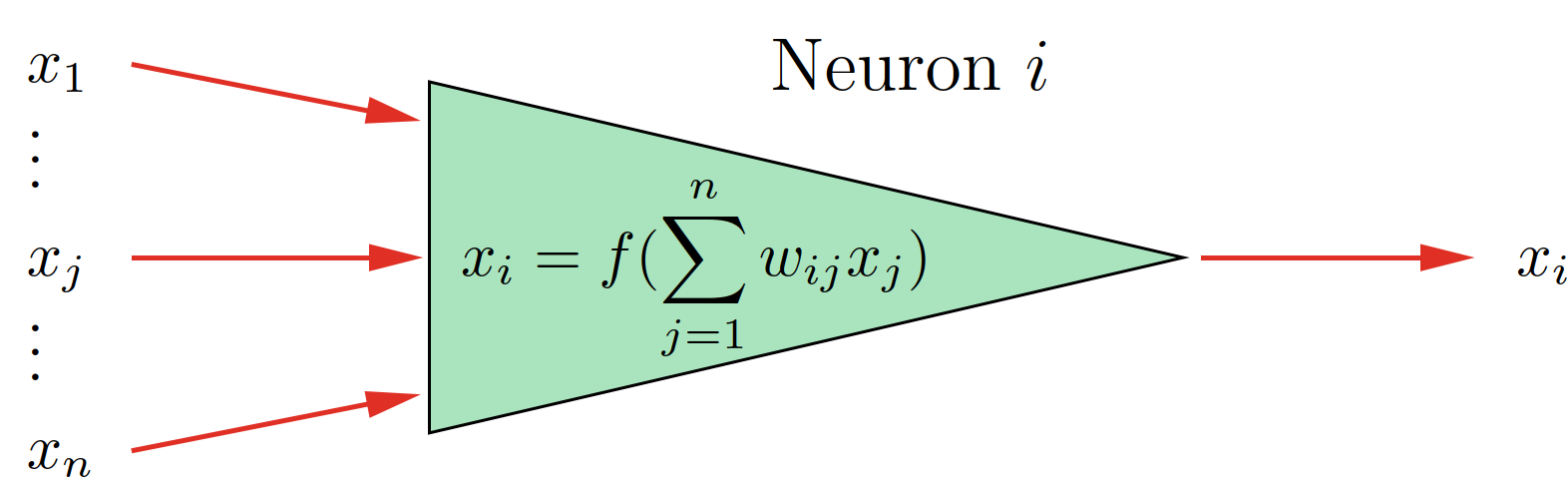
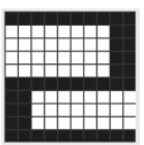


Figure 2.x: Mathematical Neuron (Ertel, 2021)

The input voltage of each wire is represented by variables named in the picture. The higher the voltage value of the human brain is, the higher the value of is in the mathematical model. The factor is fixed to each and represents how strong the connection to the respective previous neuron is. The better the connection, the more electrical power will go through. Despite this being a factor, its value can change, if the connection is changing as result of an adapting process. The product of each input and its factor will then be summed up. This is the output value .

Despite its called learning network in most networks the input data is processed through fixed calculations. In most cases it is a kind of matrix multiplication or applying filters and mask. It is also possible to several steps of calculation. That’s why an expert is required, who knows what the network is used for. The expert can then create the processing formulas.

What is it the network is learning then? It is the adjustment of the factors . When saying the network is being trained, it means that the artificial network does the calculation of the factors based on the received input data. With that the network is then able to detect patterns.

Ein Bild, das Quadrat, Rechteck, Text, Kreuzworträtsel enthält.

Automatisch generierte Beschreibung

Figure 2.x: Pattern of number 2 (Ertel, 2021)

In the above picture an example of pattern image recognition is shown. The network is trained to detect numbers. It is trained as an example with the number 2 on the left side of the figure. The network should then be able to recognize the 2. What makes a neuronal network special, that it is not just able to recognize the same image of the number, but also an image with changes. That is necessary in the real world as there are for example disturbances. This is shown on the right side of the figure. Some pixels of the 2 are not in place. If there was a standard recognition, it would fail to find the 2, but we want to recognize it as a 2. That is where the neuronal network comes in to play. What the network does is applying filters and masks to the picture. This will be done until the pattern of the 2 is recognized.

Another example is face recognition. If you take a picture of a person. The next day you want to recognize the face, it will be hardly possible. Because every day a person looks a bit different. And over the years a person’s face can change immensely. The network still needs to be able to recognize the pattern of a human face. For that a series of pictures is required to enable the network to learn. It then can find similarities and use them to recognize a change face.

The examples just considered image processing. But neuronal networks can be used in different areas. In the human brain, different parts are responsible for different tasks. So every part is structured differently to match its requirements. For artificial networks it is similar. Different networks suit different tasks. That’s why there are many different models that try to attempt to rebuild a part of the brain. Each model has its benefits an application its suits. For our project it will be the convolutional neuronal network and the recurrent neuronal network.

### 2.2.2 Convolutional Neuronal Network

The issue of most networks is that they have a vast amount of data as input. Processing all of it in just one step would take very long. This is addressed by having several steps of processing. In most networks the first step is to extract attributes. These are often referred as preprocessing layers. They often consist of filters, similar like described above capable of learning. With every layer different things can be extracted. If you take image processing as an example, there is one layer to recognize edges of the picture and a layer to extract a face. In most cases the more layers you have the more attributes you can extract. In a second step attributes will be interpreted.

In a convolutional neuronal network (CNN) most of the filters are based on the mathematical convolution. The advantage of the convolution is that it reduces the number of the factors. This helps fasten up the calculation operation.

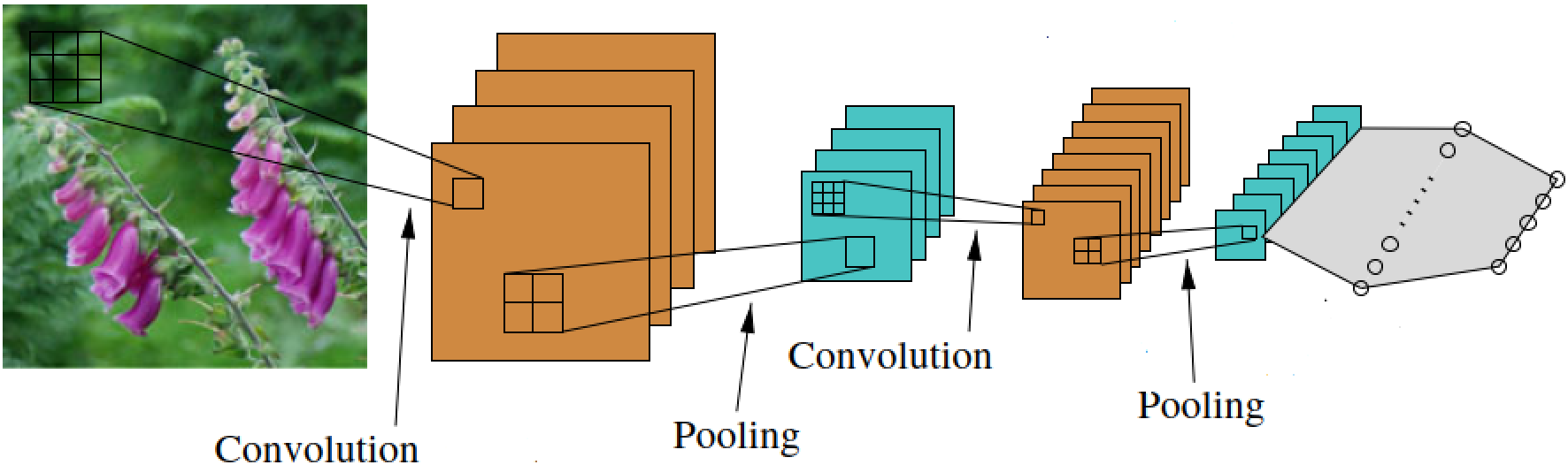


Figure 2.x: CNN working principle (Ertel, 2021)

The figure above visualizes the working principle of the filters for image processing. The input is a picture of flowers. The picture then will be filtered by using the convolution. The result is a smaller picture with highlighted attributes. The next step is pooling. Information that are similar get bundled here. This data reduction helps to safe storage space and ultimately processing time. The two steps will be repeated. The goal is to have a smaller set of extracted data. This get inserted into the neurons of the network.

The whole process is complex. Several mathematical functions need to be used the right way. Additionally, as there are less factors, they need to be more precise. This is leading to long training times. It also requires more validation, to check if the learned factors are precise enough. Otherwise, a to big error in factor value can lead to misinterpretation.

Nowadays, scientist and engineers need to have a huge knowledge about every aspect of the network to make it work correctly. It often requires a lot of experience to know which filters to use and how to order them. Also, on the mathematical side expertise is required. The filters can consist of many different mathematical operations. This can also lead to long development times.

The results of working convolutional neuronal networks are satisfactory though. For example, face recognition has not been possible with classical computation. Despite it is easier to imaging this kind of network is used for image processing it is also possible to use it in other branches. It just gets more abstract, as the constructor of the network needs to be able to create filters that work for data sets that come as example form a factory.

### 2.2.3 Recurrent Neuronal Network

The second network that this chapter covers is a recurrent neuronal network. Compared to the human brain this is working like the short-term memory. It is capable of remembering data input for a while and even take it in consideration for new learning processes.

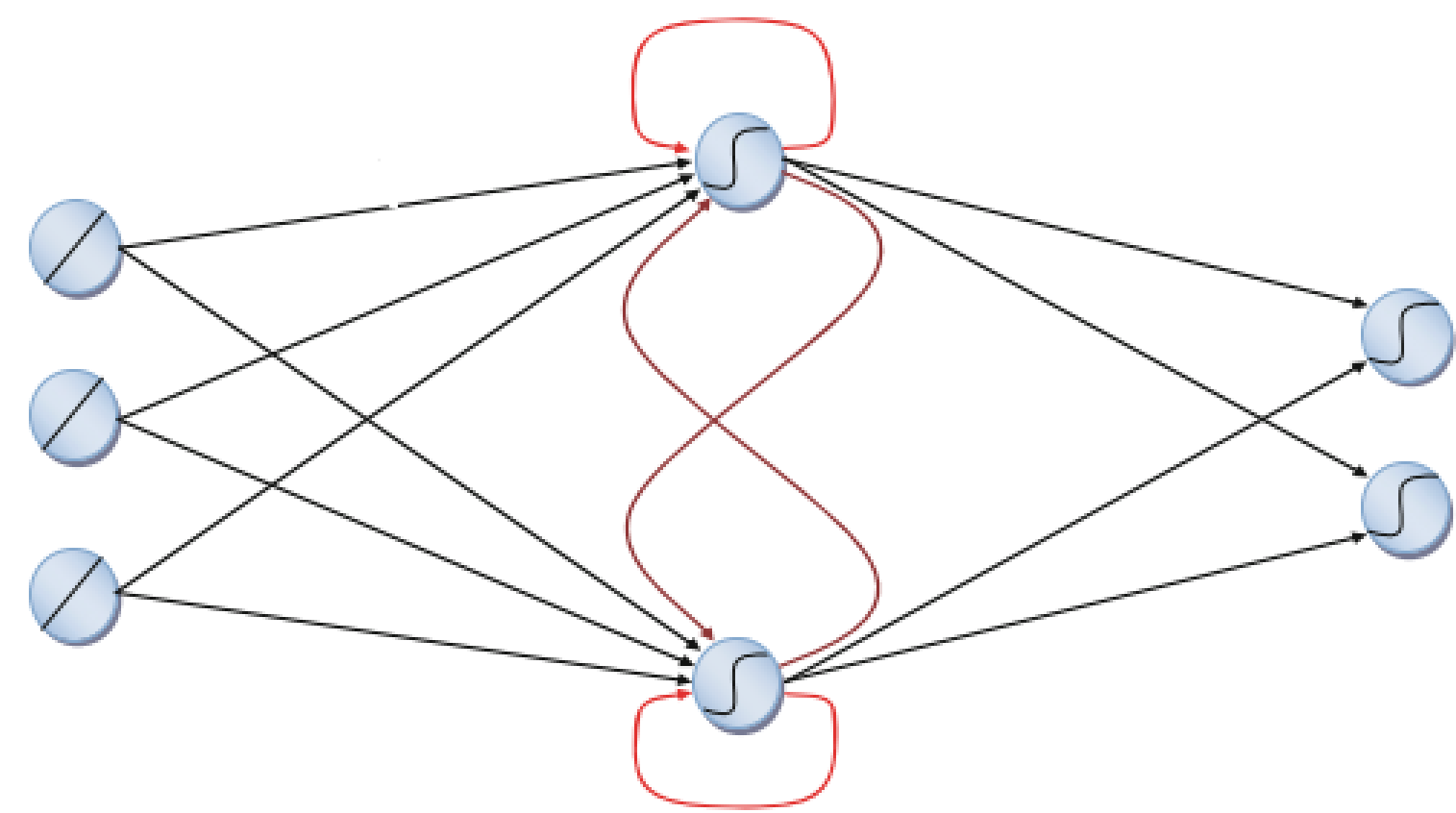


Figure 2.x: Recurrent Neuronal Network (Grum, 2022)

The figure above is a simplified visualization how the working principle. The blue points represent the neurons with connections between them. The processing order is from left to right. What makes this kind of network special are the red connections. The dark red connections are between the same layer level, the brighter red connections are to a neuron itself. This can lead to processing of a specific information for several times. It can even be transferred between different neurons a layer for several times, which makes an information available a longer time. This is what equals the network to the short-term memory.

### 2.2.4 Summary Neuronal Networks

For Human it is often easy to acquire a series of data. The challenge of artificial neuronal networks is to provide the computer with the information. It is also required to process as much raw data as possible, without giving many rule bases. The result should be software that is capable of learning from data, extract patterns and recognize them on new data.

Neuronal networks still have a lot of potential to be unlocked in future. Scientists researching on the matter for a while and still will. The main issues are that the inspiring model, the human brain, has a huge size with approximately 1011 neurons and that its hardly possible to access the human brain. But with ongoing research artificial neuronal networks will grow in power.