Robotics in Medicine

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***Abstract*—In many countries robots are already used for solving everyday problems. Another specific field of application where robots can be used is medicine. This document includes suggestions of how robots can help us to become healthier or deal better with difficult situations.**

Keywords—prostheses; neurobionics; medical robot; artificial intelligence;

I. Introduction

The big problem in today's society is that people are getting older and older. This means research costs in the medicine sector of caring for seniors will keep growing. So, it is clear that the possibility of helping sick people with robots is also increasing. But what is a robot exactly? Robots are stationary and mobile devices or machines, which can be controlled by computer programs for doing certain work for humans. They are therefore "subjects" of humanity and do the work for which we have no desire or we cannot accomplish. However, there is no difference if you build a robot like a myoelectric prothesis for an ex-veteran who lost a part of his body in war (e.g. a hand) or a robot with an AI (Artificial Intelligence) that can take care of a 90-year old person. Furthermore, it is clear that the future is dominated of using robots for medicine. Due to this we would like to take a closer look at today's situation to inform people how to get rid of health problems by using robots.

II. Prosthetics

A. Definition

In general, a prosthesis is an artificial replacement of a part of the body such as a tooth, eye, palate, knee, arm or leg. For that biomechanic is used. This is a science that allows us to produce detailed replicas just as they are created by mother nature. You can design a prosthesis in two different ways, for a cosmetic reason to avoid being stared by people or for functional reasons. Typical prosthesis for joints are hips, knees, elbows, ankles and finger joints. Prosthetic implants can be parts of a joint but also a whole joint. It would be ideal if both methods could be combined and the prosthesis was indistinguishable from the original. The procedure for joint replacement is called arthroplasty. [1]

B. Today's Situation

Previously, prosthetic functions did not resemble a normal limb, today microprocessor-controlled arm or leg prosthesis allow more complex movements and exercises. This is made possible by the years of research that has given us new plastics and other materials such as carbon fiber. The result is a lighter and stronger prosthesis, which requires less kinetic energy to operate the limb due to its lower weight. In addition to new materials, so called myoelectronics are being used now. It is inherent. This means that you have the feeling that the prosthesis belongs to the body and you only notice the difference in difficult maneuvers. On the other hand, there is still the normal wired prosthesis which reacts immediately and physically. This causes a direct feedback. There are two basic principles of operation.

1. Body-operating prosthesis:

   The body-powered prostheses use cables and cable harnesses that are strapped to the patient to mechanically maneuver the prosthesis by moving muscles and shoulder. Despite the direct control and mechanical feedback as mentioned above, this process can fatigue. Therefore, we attempt to operate these artificial limbs outwardly by engines and a battery. Currently these prostheses are commonly used.

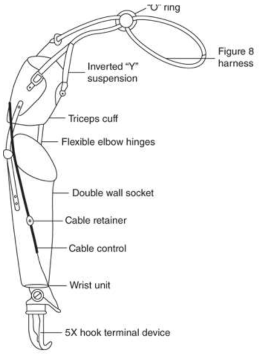

Fig. 1. cable-activated prosthesis

[1] Biomechanics and Motor Control of Human Movement, p. 1

2. Externally-powered prosthesis:

   This type of prosthesis is also called myoelectric prosthesis. It has some advantages over the body-operating prosthesis. Since the artificial limb works by electric motors with batteries, no bulky straps or harnesses are required. For this, the prosthesis is attached to the stump with a suction technique. The prosthesis has electronic sensors that detect nerve, muscle and EMG (electromyography) activity. This is used to measure electrical muscle activity. Since a whole muscle is measured for the prosthesis, the somewhat imprecise surface electrodes can be used. In general, the relationships between the frequencies of the electrical signals in the resting muscle are measured. This is also called spontaneous activity. This technology has been adopted by sports physiology. The two surface electrodes on the top and bottom of the stump detect the time of onset of muscle contraction. This result is then evaluated by a microchip, which minimizes the noise of the signal by rectification and filters it with a low-pass filter. Then the movement is carried out by electric motors. With that process an artificial hand can be opened and closed. [2]

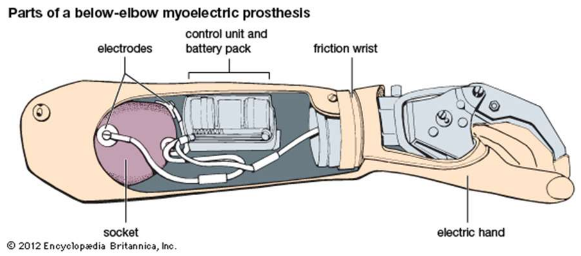

Fig. 2. myoelectric prosthesis

C. Future

The problem with myoelectric protheses is, if an activity requires a movement around several axes, it is only possible with a step by step system. An alternative method is Targeted Muscle Reinnervation. This method (also called TMR) is a surgical procedure for improving control of upper limb prostheses. Basically, the same procedure is used here as in a simple myoelectric prosthesis. In addition, residual nerves of the amputated limbs are transmitted, because otherwise they would have lost their function. These so-called "reinnervated muscles" then serve as biological enhancers of the nerve motor signals, which allow a more extensive and better control of the prosthesis, as there are several nerve signals that can detect the EMG electrodes. This also facilitates operability because the muscles used for this procedure are easy to control.
Another important goal of the TMR is to reduce the pain that a patient suffers. This chronic pain is usually caused by a normal amputation, after which symptomatic neuromas show up. Such neuromas are the result of uncoordinated attempts of the open nerve fibers to regenerate. The problem is that there is no good treatment for neuromas. In the case of TMR, after excision of the neuroma, the remaining nerve stumps are glued to create motor nerves which should innervate the target muscles. Thus, the TMR provides a stimulation for controlled nerve regeneration, thereby the chaotic nerve gets prevented from growing, which leads to neuroma formation.
Targeted Muscle Reinnervation has been used on many patients since 2011, yet it is still in an early stage of development. It is estimated that it will soon be possible to use the TMR to control a multi-joint prosthesis. [3]

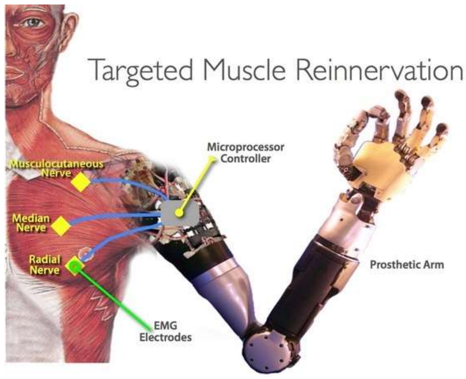

Fig. 3. TMR

III. Neurobionics

A. Definition

Neurobionics is a branch of bionics. It combines neuroscience, biology and applied medical technology to develop new medical procedures to restore damaged nerves or nerve contact after illness or accident.

B. Today's situation

In neurobionics, attempts are made to restore destroyed nerve tracts or contacts which have been ruined by an illness or an accident. An example are implants that can communicate with the wearer via the nerves. This allows someone to feel with the prosthesis if something is hard or soft. It is also possible with a cochlear implant to give deaf people back their sense of hearing, but more on that later. In the following, some important implants and systems are explained in more detail. To control the implants several approaches are available. Probably the most brutal approach is that, in which the data is taken directly from the brain, more specifically from the cerebral cortex. This control option has already been tested on monkeys - with success. Using this implant, the animals could control a robotic arm in real time by moving their own hands. After a while, they were even able to control the mechanical arm only through their thoughts. A huge step forward in this industry. To this day, intensive research and development in this field is being conducted to enable people with physical disabilities to live a normal life. In the following a few major implants are mentioned.

1. Cochlea implant:

   Patients suffering from inner ear deafness cannot get help with traditional hearing aids, because their cochlea is damaged. In this case of severe or even very severe hearing loss, a cochlear implant can help. It is currently still an advantage, if the auditory nerves are not damaged in order to achieve an optimal sound volume.

[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4992705/

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4317279/

The sound waves hit a microphone, which converts them into a binary signal. The signal is transmitted to a receiver by a transmitter which is located on the outside of the cranial bone. The receiver sits on the inner wall of the skull. The binary signal gets converted into an electrical signal, which is sent to the auditory nerves. This allows the pulses in the brain to be evaluated. In order to achieve an optimal hearing result, hearing with such an implant must also be trained. Thus, the wearer can concentrate better on conversations in a noisy environment. The use of such an implant becomes more difficult if the auditory nerves are not functional. In this case, the electrical signal must be transmitted directly to the cochlear nucleus in the brain. This type of transmission is very difficult, because the neural processing of the pulses is very complex. Due this complexity the auditory impression is distorted. [4]

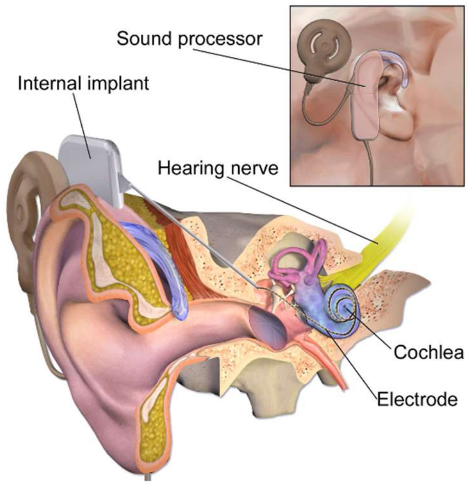

Fig. 4. cochlea implant

2. Retina implant:

   This implant makes it possible to give sight to a blind person. There are basically two different ways of working. On the one hand there is the subretinal implant. In this case, the retina processes the signals from the microchip and sends them to the optic nerves. The prerequisite for this implant, however, is that only the light receptors are damaged and not the retina. A microphotodiode chip is implanted under the retina. When a light beam hits the diode, it sends a signal to the retina, which processes the data and sends it to the optic nerve. But you can also process the data of a video camera and send it to the retina. The power supply of the microchip is wireless. Since the signals from the microchip are processed through the retina, the result of this implant is of course much better than with an epiretinal implant. In this case, the microchip is applied directly to the retina. The images are taken by a camera and then processed so that the optic nerves get directly stimulated by the signal. However, this process is extremely complex, making it currently not possible to construct a microchip where the wearer can see clearly. The current standard sharpness that can be achieved with such an implant is 6%. In addition, with the camera, the rolling motion of the eye cannot be realized.[5]

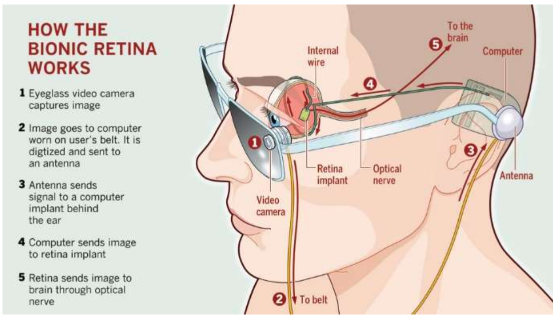

Fig. 5. retina implant

3. Electrical Stimulation of Centers in the Central Nervous System:

   The direct stimulation of these centers is very difficult, but nowadays its already realizable. It is mainly used to help people with Parkinson disease. This affliction causes motor blockages in the brain. Among other things, patients suffer from constant tremors. In addition, they can only perform movements very slowly over time. By stimulating adjacent areas in the brain where this disease occurs, it is possible to alleviate these blockages. The function of this implant is similar to that of the pacemaker. By means of a control device, the wearer can change the intensity of the stimulation depending on the situation. For this type of treatment are no side-effects known. [6]

C. Future

As already mentioned the retina implant is still in the development phase, under the condition that the retina fulfills its function. Otherwise, when the retina is damaged, the complexitivity of the calculation is too high. However, in the next few years scientists will find possibilities to perform these calculations.

IV. Medical Robot

A. Definition

A medical robot is a robot used in the medical sciences. They are classified in three different types: Biorobotics, Telepresence Robots and UV Disinfection Robots. Furthermore, we want to mention the artificial intelligence (AI) later in this document, because this is a very important concept for future robots.

B. Today's situation

As mentioned above there are three different kinds of robots:

1. Biorobotics:

   The prosthetics and neurobionics chapters, on which we had a close look previously belong to this section of robots.

[4] Bionics - Current research results in natural sciences and engineering, p. 83

[5] Bionics - Current research results in natural sciences and engineering, p. 83

[6] Bionics - Current research results in natural sciences and engineering, p. 84

2. UV Disinfection Robots:

These kinds of robots are automatically operating machines, which support the life of elderly people to improve their movement with disinfection of body parts. However, with the help of pulses of intense UV-C radiation they decontaminated surfaces or whole rooms can get disinfected within few minutes. By disinfecting rooms in a hospital, it is more difficult to sicken by hospital germs, which can cause infections. That means the sicknessrate in hospitals dropped heavily. They are divided into two different robots. [7]

- Assistive robots: They should act as a substitute of lost limb movement.
- Therapy robots: Is also known as a rehabilitator, which could help people to regenerate their further body condition after a disease or an accident.

3. Telepresence robots:

These robots enable doctors to scan the surrounding, communicate, participate and moving from remote locations to provide quality care to the patients. On this occasion we do not want to take a closer look on the caretaking robots, because this would go beyond the scope of our paper. The second, more important telepresence robots are the surgery robots. With the help of high-end technology these robots are changing the face of healthcare, due to the greater precision which a robot boasts compared to a human surgeon. That means the doctors can perform many types of complex procedures with more flexibility, control and previously mentioned precision than is possible with conventional techniques. When the robot is connected to a stable internet connection a surgeon, which is not physically present with the patient, is allowed to remote a surgery. The benefits of robot supported surgeries for the patients include: [8]

- fewer complications
- less pain and blood loss
- quicker recovery
- smaller, less noticeable scars

But to our regret there are also some risks. First of all, there is a small risk of infection through the surgery and other common complications.

C. *Future*

The best solution for surgery is a surgery robot which works without any human help. In order to make this possible, the control must be able to make decisions on its own. For this, the use of artificial intelligence must be considered. The problem is that artificial intelligence cannot be realized with today's technology. However, it is still visionary until artificial intelligence surpasses human intellect, because in summer of 2017 scientists conducted an IQ test for an AI which only achieved a score of 47, whereby the average score is 100. The moment when AI is smarter than a human, developments in each industry will be created primarily by artificial intelligence. That means fully automated surgeries will be possible. [9]

Fig. 6. surgery robot

V. SUMMARY

As mentioned in the introduction, the purpose of this work was to identify disadvantaged people in ways to make their lives easier. It does not matter whether the robot is supportive in an operation or directly contributes to human movement. Of course, it is still future imagination, when speaking of self-operating robots, since the artificial intelligence is still in its infancy.

VI. REFERENCES

As some of us have already studied this matter intensively, the external sources needed for certain sections of the paper are limited. Sections that have no source reference were described by using our own knowledge.

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