The future of prosthetics

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Introduction

Prosthetics have come a long way since their inception, with the oldest known being a toe made from wood and leather from almost 3000 years ago discovered in Egypt [1]. Since then prosthetics have advanced at a slow rate, with the metal arm of General Marcus Sergius from the second Punic war (218-201BC) [1], and the non-locking knee joint of 1696 [2], it has taken almost 5,000 years for the field to begin to compare to natural limbs. The fourth industrial revolution has opened the door to new robot prosthetic limbs once relegated to science fiction. For example, in 1980 the film “Star wars: Episode V – The Empire Strikes Back” the main character Luke Skywalker receives a prosthetic hand after losing his own. In a perfect example of life imitating art this hand has been used as an example of what prosthetics could be in the future and has inspired new technology in the field.

Main text

Control

Luke’s hand is fully controllable by Luke with seemingly only his thoughts. The idea of controlling a prosthetic with one’s thoughts is one of the major fields of research in prosthetics. There are several methods that can, and are, used to control prosthetics. Electromyography (EMG) is the recording of electrical signals in a muscle, generated by muscle fibres when they move, and can be acquired by using surface sensors or implanted sensors. EMG signals are acquired by using two electrodes to measure the potential difference over the muscle in question. These signals can still be detected in the surviving muscle after an amputation [3]. EMG is extremely susceptible to interference due to the low signal-to-noise ratio, this can be mitigated but not entirely removed by implanting the sensors into the muscle.

Work by R.F. Weir ; P.R. Troyk ; G. DeMichele ; T. Kuiken proposes using 16 implanted sensors. These sensors record EMG and wirelessly transmit the signal to external coils where they can then be processed using fuzzy logic to control a prosthetic (fig 1) [4].

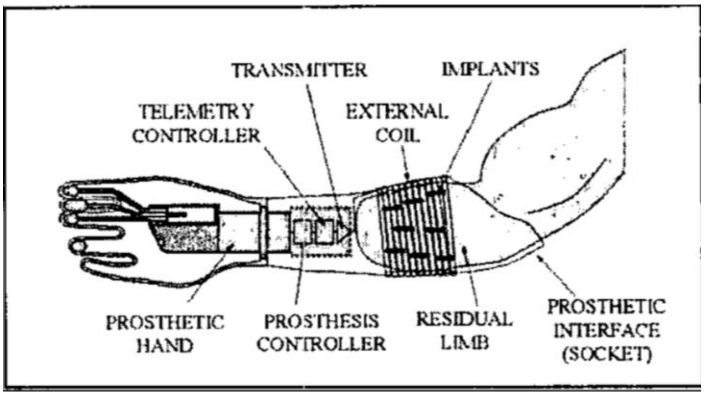

Fig 1: Implanted EMG sensors wirelessly send signals to then control a prosthetic limb [4]

Another, arguably more advanced control method is electroencephalography (EEG). EEG is the use of sensors to detect brain signals, and much like EMG can involve surface and implantable sensors. The use of an array of implanted sensors, using a technique called electrocorticography (ECoG), allowed for a paralysed man to control an exoskeleton and walk [5]. The electrodes were in a titanium casing which was then implanted below the user’s cranium allowing for signals to be wirelessly transmitted to a receiver on the exterior of the users cranium (fig 2).

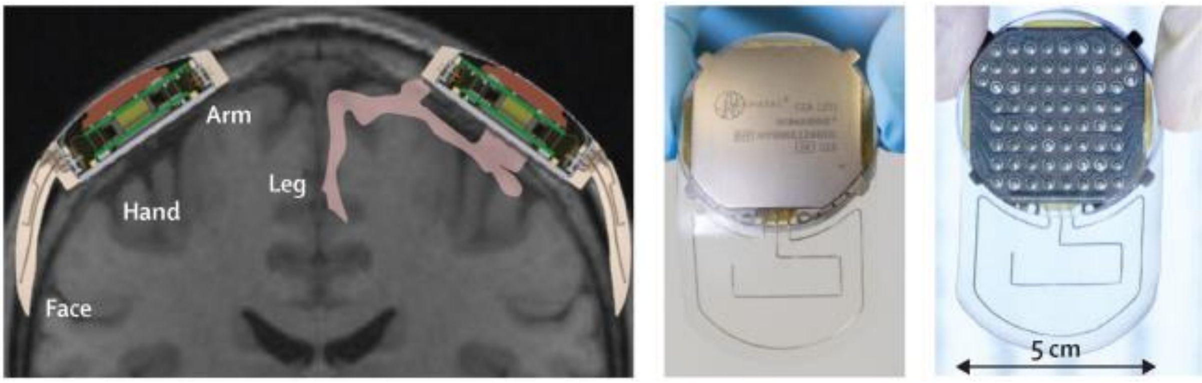

Fig 2: The WIMAGINE wireless controller consisting of 64 electrodes and their placement in a user's skull [5].

Drive

Luke's hand is able to articulate and exert force like a normal hand, something that has only recently been made possible. The small (10mm diameter [6]) but powerful (1.6mNm [6]) Faulhaber DC motor is used in the "Bebionic" hand to allow for movement on the fingers in the device. While the hand doesn't have as strong a grip as a human hand, the model can still carry up to 25KG and allows for the precise articulation required to operate, for example, a keyboard [7].

Treading the line of using appropriate force for a task is a necessity that is being pursued actively by researchers. In 2016 in Switzerland the first cybathlon games were held. Styled to be an Olympics for prosthetic users, the games include several races one of which, the powered arm prosthesis race, encourages precise control over brute force with tasks such as slicing bread and screwing in a light bulb (fig 3).

In the future prosthetic hands will be able to exert appropriate force to a given task much like a human hand.

Fig 3: A pilot of team Bebionic performing in the powered arm prosthetic race [8].

Feedback

Luke's hand is able to feel a robot poke his fingers. This has inspired the idea of giving prosthetic users feedback to touch in the way a human hand would. The university of Utah has been inspired more so than others and have developed the LUKE arm [9]. The LUKE uses the “Utah Slanted Electrode Array”, an array of 100 microelectrodes and wires implanted to a user’s nerves, to send signals up existing nerve tissue to trick the brain into “feeling” what the user is touching. Sending signals the brain will recognise as touch required research into the signals sent in normal human nerves. The research team at Utah hopes to in the future make the limb portable and expand the possible sensations to cover temperature and pain [9].

Fig 4: The LUKE arm being used to pick grapes [9]

Price

Prosthetics are extremely expensive, a leg can cost between $5,000 and $50,000 according to the Hospital for Special Surgery [10]. Prosthetics will need to be made cheaper to allow for more amputees to access the technology.

One method of reducing cost is to recycle old plastic bottles into prosthetic sockets. Developed by De Montfort University, it is estimated this method could reduce the cost of a socket from £5,000 to £10 [11].

3-D printing has allowed for the creation of prosthetics at a lower cost than traditional methods. Open Bionics, a prosthetics company based in Bristol, has developed the ‘Hero arm’, the first medically approved 3-D printed prosthetic arm. This device is largely 3-D printed and costs approximately $3,000 compared to the $95,000 cost of other similar limbs [12]. The greatly reduced cost of the limb makes them much more accessible; Open Bionics is in talks with the NHS to allow them to be given for free across the UK [13]. The device incorporates EMG sensors with haptic feedback to offer high function despite its low relative cost and with the use of 3-D scanning, each limb can be custom built for its user.

Reducing the cost of prosthetics can be considered the most necessary requirement due the expected increase in amputation rates as diabetes becomes more common [14].

Conclusion

Prosthetics technology has a long way to go before robotic limbs are as functional as human limbs, but recent innovations in signal processing, high performance motors and implantable electrodes have allowed for great advances to be made. This combined with the reduction of cost of these technologies could allow for the science fiction robotic limbs to become a reality soon.

These advances will become increasingly necessary to minimise the social and economic impacts of an increased amputation rate, caused by an aging population and increased diabetes rates [14].

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