Neuroprosthetics of the Hand: Current Hot Research Topics, Research Trends and Challenges, and Recent Innovations

Andreas Otte

If you want to buy a new car today, you can expect a flood of digital features and assistance systems that initially make the analog human heart beat faster. But are these developments right? Can we use all the built-in functions usefully and appropriately and operate them safely in increasingly hectic and dangerous everyday traffic?

The reconstitution of hand movement for people with amputations, tetraplegia, apoplexy or other neurological disorders has become an important area of research and development. While non-invasive electrode-based systems that utilize electroencephalography/electrooculography (EEG/EOG) or electromyography (EMG) input have proven successful, these systems tend to be expensive and require a great deal of effort on the part of the individual to learn or require the assistance of others. Due to the extracorporeal nature of the systems, they are confronted with the challenge of processing the superposition of a wide variety of signals and deriving control signals from them. This means that learning how to use these control systems is a major hurdle for many patients, which means that the acceptance rate of such systems determined in various studies is sometimes surprisingly low [1]. Electrode-free visual approaches are on the rise. They do not require the acquisition of significantly new skills, as, in most cases, the grasping process is controlled visually anyway. Such non-invasive, robust approaches for supporting amputees or people with tetraplegia outside and independently of a complex laboratory environment are, in addition to the EMG/EEG-operated systems mentioned above, the subject of current research. The contactless visual control of neuroprostheses using augmented-reality (AR) glasses could be a desirable alternative to conventionally controlled concepts [2]. So far, AR glasses have only been included in the concept as an add-on to current EMG or EOG/EEG methods for intention recognition. However, the sole use of AR glasses to control the prosthesis or robotic hand—without further complex signal detection by EMG, EOG or EEG—is new and could simplify the usability of prostheses for patients in the near future. Their simple operation and lack of electrodes (and thus the problem of placement and mechanical irritation) make such systems a promising alternative for the partial reconstitution of basic manual functions.

Invasive methods such as targeted muscle reinnervation, targeted sensory reinnervation, brain arrays and peripheral nerve electrodes for closed-loop neuroprosthetics [3] are promising, but they always remain one thing—their invasiveness. Specific situations, patient groups and age groups are certainly receptive to such approaches but the masses are not.

Apart from clinical studies of new prosthetic concepts (the pandemic has certainly stolen a few years from us here too), what we still lack are detailed surveys of patients to find out what they want. Do they want simple or complicated prostheses, and should these be controlled by invasive sensing, or are non-invasive methods sufficient? To what extent should the prosthesis be personalized? Should it be a technical Terminator-style hand or a perfect replica of the once healthy hand? Moreover, there is a lack of interaction between engineers and physicians [4], but the field of prostheses in particular requires interdisciplinary think tanks and cooperation.
In principle, the spread of 3D polymer printing has led to a large number of research projects in the field of hand prosthetics. Even if these systems do not come close to the performance of industrially manufactured prostheses made from more stable materials, they are often able to deliver (highly) functional, personalized solutions with high cost efficiency rates, which could make them an important contribution to emerging and developing countries in particular.

Let us return to our initial mental scenario of buying a car. Do we really want a high-tech, autonomous car, or will the faithful (analog) automobile suffice? How can AR help us; how may it harm us? Can neuroprosthetics become smarter at any price? [5] This topic is highly complex, and many questions remain unanswered. But it is certainly worthwhile.

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**References**


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