prosthesis

Editorial

Reconstructing the First "Iron Hand" of Knight Götz von Berlichingen and Its Derived Modern Developments: Back to the Future

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"Ad fontes!"
Francesco Petrarca (1301–1374)

In the beginning, there was an idea: the reconstruction of the first "Iron Hand" of the Franconian imperial knight Götz von Berlichingen (1480–1562) (Figure 1). We found that with this historical prosthesis, simple actions for daily use, such as holding a wine glass, a mobile phone, a bicycle handlebar grip, a horse's reins, or some grapes, are possible without effort [1]. Controlling this passive artificial hand, however, is based on the help of a healthy second hand.

Figure 1. First "Iron Hand" of Götz von Berlichingen, a 3D-printed polymer replica. The replica was printed by a 3D multi-material printer, the Stratasys J750, that allows for the production of transparent components, offering insights into the mechanics of the hand. Picture credits: Offenburg University, Germany.

Today's state-of-the-art approaches for controlling hand prostheses are using electromyography (EMG) sensors placed on still existing and functioning muscles, or, if muscles cannot be innervated any more, electroencephalography (EEG) or hybrid electrooculography/electroencephalography (EOG/EEG) to evaluate neuronal patterns and derive commands for the prosthesis [2]. These concepts come with high costs for complex and expensive systems, as well as exhausting calibration and/or learning procedures. The patients´ acceptance of such systems is thereby restricted [3].

Normally, grasping with a prosthetic hand is just as visually controlled as grasping with a healthy hand. Using augmented reality (AR) with optical see-through glasses and

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an accurate tracking method offers the possibility to control the prosthesis with minimal movements of the viewing direction, as has been shown recently (Figure 2) [4,5]. Solely using AR glasses—without any other complex signal detection by EMG, EOG, or EEG—to control the prosthesis or robot hand is new and may simplify the usability of prosthetic devices for the patient in the near future. Low-cost 3D-printed motorized hands, controlled by optical see-through glasses and driven by energy-efficient neural network platforms, could have an impact.

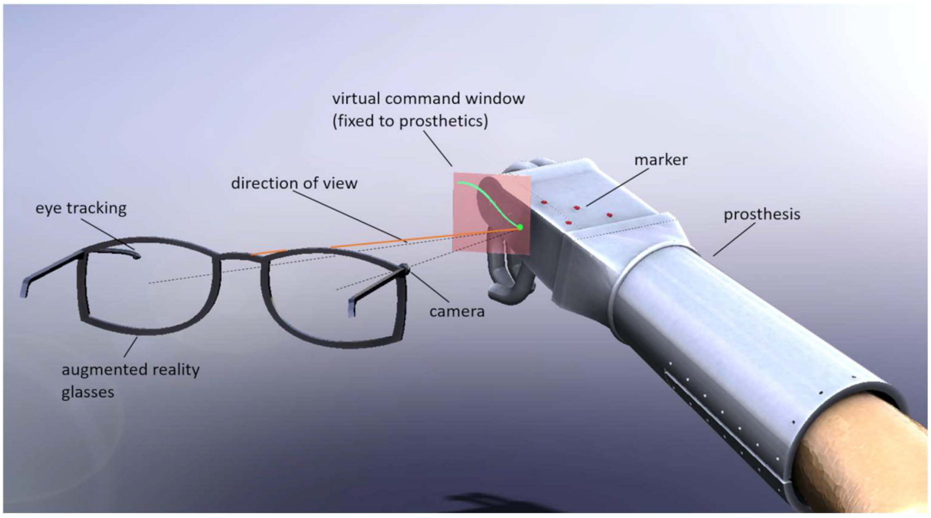

Figure 2. Concept of electrode-free visual prosthesis control using augmented reality (AR) glasses. The prosthesis markers (in red) are tracked with the camera integrated into the AR glasses, enabling the evaluation of relative movements between the AR glasses and the prosthesis. A ray perpendicular to the glasses defines the direction of view and is used as a pointer (in green) in the virtual command window (red) attached to the prosthesis. The user can enter commands by moving the pointer over the command window. From [4], with the permission of the authors under the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4, accessed on 13 March 2024).

Furthermore, personalization has yet to become a topic, and therefore we developed personalized hand prostheses, in which the healthy (real) hand is scanned using a 3D light scanner, the data mirrored to replace the amputated hand, processed in computer-aided design (CAD), and then 3D-printed from flexible material (Figure 3) [6,7] or used to create a personalized, 3D-printed mold for casting. Sensors can also be integrated into the prosthesis so that haptic feedback can be realized. These can be inserted into the molds and further cast with silicone or other material. This would even allow for the texture of the hand's palm to be reproduced realistically. Just as Götz von Berlichingen had his two artificial "Iron Hands" adapted and personalized for everyday life requirements, modern artificial prostheses should also offer the possibility for personalization or adaptation to the patient's needs. With modern manufacturing techniques, this can be achieved significantly faster and cheaper.

We had not yet planned that reconstructing Götz von Berlichingen´s first "Iron Hand" would become a new neuroprosthetic research field of its own at our institution. We are therefore all the more pleased to appreciate the wide range of new ideas that we have so far derived from the "Iron Hand".

It is interesting to observe how technically adept people were at that time and what impressive technical systems they were able to produce with their limited capabilities compared to today's technologies. For the development of modern prostheses, one can certainly derive the insight that prostheses should provide the maximum benefit for the user in everyday life, which does not necessarily have to be a one-to-one replacement hand compared to the original.

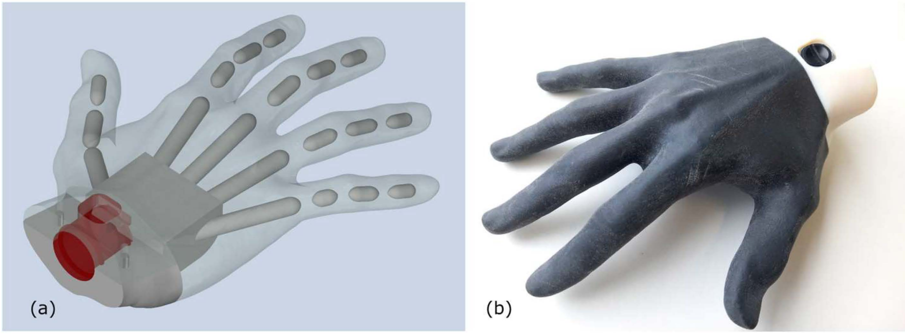

Figure 3. (**a**) Model of a scanned real hand with an integrated skeleton. The closure system with which the hand prosthesis is attached to the prosthetic stump is shown in red. The skeleton gives the hand prosthesis more rigidity and thus enhances its natural appearance. (**b**) Prosthesis printed using a 3D printer and a flexible, rubber-like material. The skeleton is printed directly into the hand from a firmer material using a multi-material printer. Picture credit: Offenburg University, Germany.

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