Advancements Towards Noninvasive, Naturally Controlled Robotic Hand Prostheses

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Objective
Nowadays prosthetic hands with advanced mechanical features do exist. However, the control systems allow controlling only few movements with unnatural sequential strategies. The application of machine learning techniques to analyze the sEMG signals seems promising, but it is far from practice due to the heterogeneity of the studies and the lack of data.
In this work we describe the results and the clinical applications obtained from the analysis of Ninapro, the largest sEMG database of hand movements. We show that relationships between several clinical parameters and robotic hand control capabilities by sEMG do exist, thus laying the foundations for innovations in neuroscience, phantom limb pain treatment, amputation surgery procedures and, of course, hand prosthetics.

Methods
Eleven transradial amputated subjects participated to this study. All subjects except one were originally right-handed. The amputated arm is the right one in seven cases and the left one in three cases, while one subject underwent a bilateral amputation. All subjects underwent amputation due to traumatic injury, except one who was amputated due to a tumor.
Data were acquired under the final version of the NinaPro acquisition protocol (1,2). For all subjects we recorded age, weight, height, percentage of the remaining forearm, time elapsed since the amputation, intensity of phantom limb sensation (0 to 5 subjective scale), prosthesis use and DASH (disabilities of the arm, shoulder and hand) score (3).
During data acquisition, the subjects were asked to mimic with the missing hand 50 movements shown on the screen of a laptop. Muscle activity was recorded with 12 double differential sEMG electrodes located in order to combine two methods widely diffused in the field (i.e., dense sampling approach and precise anatomical positioning strategy).
The sEMG signals of the movements were classified with machine learning techniques and the results were statistically analyzed to reveal the relationship with clinical parameters.

Results
The accuracy of the classification of 40 movements is in some cases higher than 60% and it is possible to select up to 11 movements that are classified with accuracy higher than 90%.
The capability of the subjects to reproduce the movements is significantly related to several clinical parameters (including for example the intensity of the sensation of phantom limb), introducing new questions about the relationship between these

parameters and amputation. Finally, several subjects reported an increased feeling of muscle control during the acquisition.

Conclusions

The described results could improve the prognosis for the subjects by reducing the discomfort related to the amputation and improving the rehabilitative capabilities offered by modern prostheses. The relationship between classification accuracy and clinical parameters adds new information regarding the nature of phantom limb sensation, introduces questions about the evolution of the nervous system in the amputated arms and suggests that future surgery procedures could improve the natural control of robotic hand prostheses in many different movements.

Bibliography

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