Experiences in the Creation of an Electromyography Database to Help Hand Amputated Persons

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Abstract. Currently, trans-radial amputees can only perform a few simple movements with prosthetic hands. This is mainly due to low control capabilities and the long training time that is required to learn controlling them with surface electromyography (sEMG). This is in contrast with recent advances in mechatronics, thanks to which mechanical hands have multiple degrees of freedom and in some cases force control. To help improve the situation, we are building the NinaPro (Non-Invasive Adaptive Prosthetics) database, a database of about 50 hand and wrist movements recorded from several healthy and currently very few amputated persons that will help the community to test and improve sEMG-based natural control systems for prosthetic hands. In this paper we describe the experimental experiences and practical aspects related to the data acquisition.

Keywords: Prosthetics, Surface Electromyography, sEMG, signal analysis.

Introduction

Daily life of hand amputees can be difficult compared to the situation before an amputation. Current hand prostheses usually do not offer more than a maximum of 2-3 degrees of freedom and a very coarse control of the force.

Patients most often interface with the prosthesis via surface electromyography (sEMG). Learning how to control the device through an sEMG channel is a long and difficult process for most patients, and usually open/close is the only possible movement. This is in contrast with recent advances in mechatronics, which led to mechanical hands with many degrees of freedom and fine-grained force control. It is also in contrast with the recent advances in sEMG control that can enhance the capability of dexterous hand controls from amputees [1,2]. Moreover, there is currently no large, public sEMG database on hand prosthetics available, nor a widely accepted recording protocol to acquire sEMG data (neither for healthy subjects nor for amputees) and both could help researchers in the field to compare their tools and algorithms to create personalized control for each patient.

The NinaPro (Non-Invasive Adaptive Hand Prosthetics) project started in January 2011 with the aim to help fulfilling the two needs. The main goal of this project is to develop a family of algorithms able to augment the dexterity of EMG controlled prostheses and to reduce the required training time. The first phase of the project consists of the development of a standardized acquisition protocol and the acquisition of a large collection of data from intact and later hand-amputated persons. The successive phases will be based on the analysis and classification of the acquired data. The sEMG database will be made available to the scientific community and research groups will have the opportunity to compare their tools during a challenge workshop. In this paper we describe first experimental experiences related to the data acquisition.

1. Methods

1.1. Acquisition Setup

First, the NinaPro database has to be capable to contain sEMG and hand-movement data useful for research, second to be applicable to industrial products and finally to be portable in order to acquire data in different locations. After analysis of the scientific literature and practical experiences we decided to use the following acquisition setup (see Figure 1): a laptop with a PCMCIA Slot (DELL Latitude E5520); a digital acquisition card (National Instruments DAQCard-6024E, PCMCIA); ten sEMG electrodes (Otto Bock 13E200); a Cyberglove II (CyberGlove Systems LLC) with 22 sensors; a 2-axes inclinometer (Kübler 8.IS40.23411); custom-made acquisition software implemented to acquire the data from all of the peripherals in a synchronized way; a password protected web-based interface to the database to store the data.

The choice of the standard electrode type is particularly important to create a database useful both for the scientific community and for further industrial applications. Our choice was determined by the evaluation of the scientific literature [3], and by the wide use of the chosen electrode type in clinical practice.

1.2. Acquisition Protocol

The data acquisition of each subject lasts about two hours, including placing and removal of the electrodes and the explication of the protocol. First, the subject is asked to fill general and clinical data (such as age, gender, weight, height, laterality, work, hobbies related to the use of hands). If the subject is hand amputated, (s)he is also asked for clinical data regarding the amputation (date of the amputation, type of accident, positioning of the amputation on the forearm, particular clinical notes and previous use of an sEMG prosthesis). Non-amputated subjects have to wear the sEMG electrodes, the dataglove and the inclinometer on the right hand, while amputated subjects wear the sEMG electrodes on the stump and the dataglove and the inclinometer on the contralateral hand.

Two electrodes are placed according to anatomical guidelines on the muscles (one on the finger flexor muscles and the other on the extensors) [3,4]. The remaining eight electrodes are placed uniformly around the forearm according to the pattern matching research trend for sEMG, which proves that precise placement of electrodes on specific muscles is not required [1,5,6]. In order to maintain a constant position in the subjects, the electrodes are placed in a constant distance to the position of the radio humeral joint.

The electrodes are positioned mainly by a computer scientist that had been taught by physiotherapists and physisicans involved in the project on the placement. Two pictures are also taken, one before and one after the positioning of the electrodes, in order to have a precise record of the placement of the electrodes and of the visible features of the amputation. All subjects are shown a movie that describes how the experiment has to be performed. Finally, the subjects are asked for a training sequence and then three exercise sessions, each divided by 5 minutes of rest.

1.3. Hand Movements

A hand prosthesis is considered dexterous if it is capable of assuming several positions and exerting an arbitrary force [1,7,8,9]. These results are accomplished using a classifier predicting the required movement among a finite set, and a regressor predicting the required force. Currently, there is no established protocol that a patient or a healthy subject can follow to train a dexterous prosthesis, even if specific examples appear in single papers [1,7,8]. In the NinaPro acquisition protocol we selected 52 movements from the robotics and the taxonomy literature, and from the DASH (Disabilities of the Arm, Shoulder and Hand) protocol for functional movements [10]. Each movement lasts 5 seconds, followed by 3 seconds of rest, and is repeated 10 times.

These movements are subdivided into four main classes: *1)* finger basic movements (12 movements, 15 minutes); *2)* hand static movements (8 movements, 25 minutes); *3)* wrist basic movements (9 movements, 25 minutes); *4)* hand grasps and functional movements (23 movements, 30 minutes).

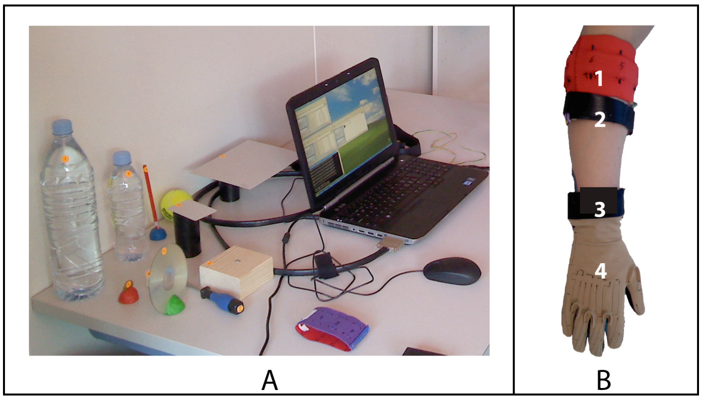

Figure 1. Acquisition setup: A) grasp and functional objects, laptop with the acquisition software; B.1) equally spaced electrodes; B.2) electrodes placed anatomically; B.3) inclinometer; B.4) cyberglove.

2. Results

The current NinaPro database is stored in a database with a web interface: it consists of 27 healthy persons and 1 amputee, 21 males and 7 females, 26 right handed and 2 left handed. The average age is 28.1 years with a standard deviation of 3.4 years. The scientific literature suggests active double–differential electrodes as the best choice for hand prosthetics control, moreover these types of electrodes do not require cleaning/shaving, making the acquisition easier. Our preliminary results confirm the effectiveness of their signal to noise ratio and their comfort. In a few acquisitions the signal from one or two electrodes is missing, probably due to connection problems. In order to avoid this kind of problem, we are implementing an algorithm to check automatically that the electrodes function correctly.

During the preliminary data acquisitions we noticed that the subjects often continued to repeat the same movement once or twice after it changed. In order to avoid this, we programmed the custom acquisition software to play a sound to alert the subject of an upcoming movement change.

The use of both methods for electrode placement (i.e., placing them on the involved muscles and uniformly on the forearm) turned out to be a good choice to compare current trends to the more traditional approach. The 52 hand movements proposed are based on a review of the literature of hand taxonomy and robotics. 12 basic finger movements, 8 static hand postures, 9 basic wrist movement, 23 hand grasps and functional movements are combined in the tests. The first three sets of movements are executed without objects, while the last one require objects. We chose 13 common objects (such as two plastic bottles, a credit card, a compact disc and a pencil), in order to make the data useful for possible applications and to make the acquisitions easily reproducible. In the preliminary acquisitions, we evaluated more functional movements taken mostly from [11], but finally we decided to reduce the number in order to be more consistent with the robotic literature and to give more space in the acquisition to simpler movements.

A first data acquisition with a hand-amputated subject was recorded in order to check the feasibility of the procedure. This acquisition was extremely useful to determine several changes in the protocol (such as the need of longer brakes between the exercises), changes to the instructions (for example to not ask the amputated subjects to move the imaginary limb but to think to repeat the movie with both hands), and to identify critical points (such as the possibility of sweat on the forearms of amputated subjects due to the previous use of a prosthesis).

Finally, we made 27 data acquisitions on non-amputated subjects. The results from these acquisitions enhance the feasibility of the acquisition protocol, but they also showed that it is difficult to place the electrodes exactly in the same position in different subjects. In order to solve this problem we are currently working on pre-processing algorithms to be applied on the sEMG signal to normalize them. These algorithms are based on the comparison of inter-subject data and on the spatial registration of the the signal.

3. Discussion

In this paper we describe the experimental setup and practical experiences related to the acquisition of the NinaPro sEMG data. The NinaPro project aims at developing a new generation of sEMG-based prostheses by giving to the scientific community the opportunity to test optimized machine learning tools and research findings on a large collection of data (100 intact and 50 amputated subjects).

The experiences gained improved the acquisition protocol, the acquisition setup and the hand movements. This helped us to identify and solve many different experimental problems related both to the acquisition of intact and hand-amputated subjects. The preliminary data sets show encouraging results in the feasibility of the protocol and in the analyses of the signals.

The movements included in the acquisition protocol permit to investigate the muscles involved in almost all hand movements as well as several specific functional needs. The sEMG electrodes positioning combines several research trends (electrodes uniform placing and placing on specific muscles). Moreover, the anatomical references should permit to implement pre-processing algorithms to spatially register and normalize the signals from the equally spaced electrodes.

We decided to investigate one amputee in order to evaluate the feasibility of the acquisition protocol. The subsequent phases of the project will include the investigation of more amputated subjects in order to evaluate factors as the level of the amputation and post-amputation anatomy. In the future, we plan to add an acquisition device to detect the fingertip force during the movements to perform a better analysis of the acquired data.

The NinaPro project hopes to aid the development of a new generation of sEMG-based prosthetic control methods, and should have multiple applications, as it will permit to analyze the sEMG signal generated by healthy controls and amputated people.

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