DATA LOGGING DURING PATTERN RECOGNITION CALIBRATION AS A REMOTE DIAGNOSTIC TOOL

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ABSTRACT

Pattern recognition control uses EMG from the entire residual limb to more intuitively control prosthetic devices. However, this requires a more intimate socket fit to maintain contact with these additional sensors. When users complain of issues with control, it can be difficult to diagnose if the issue is a need for additional practice and training or if there are issues related to the prosthetic fit that need to be addressed. Since pattern recognition allows the recalibration of the system by the user in any location, there is the opportunity to use this feature to assist in troubleshooting issues remotely. By analysing the data logging of calibration data in a pattern recognition system, it is possible to better identify the cause and potential solution in a remote setting.

INTRODUCTION

With pattern recognition (PR), multiple EMG channels can be used as input with all of the information used to calculate which "pattern" is being recreated. Since muscle signals do not need to be targeted and isolated, more information can be extracted from the user, potentially increasing the ability to control a multi-degree-of-freedom system [1]. The user needs to show the system each movement (calibrate the controller), which can be done by following prompts on a computer interface or following along with the prosthesis while it is moved through the different available movements. EMG is recorded by the controller and the classifier is then calculated.

For PR to be successful, the EMG channels must maintain good contact with the residual limb. When fitting a user in the office or a therapy environment, the EMG quality can be monitored as the user begins to perform functional tasks in different planes of movement and adjustment to fit made as needed. However, different environments temperatures and weight gain/loss can all affect signal quality.

When the user lives nearby it can be easy to have them come in for regular rechecks and adjustments; however, when a user lives far away, it can be difficult to troubleshoot the issue and identify if the issue with control is related to EMG quality or if the issue might be related to the need for additional training and/or a review of the patterns of movement associated with each degree-of-freedom.

As part of a study related to pattern recognition control of a transradial prosthetic system, users from across the country were recruited for home trials. During the home trial subjects were instructed to send home logs each week. However, there were instances of poor control noted and it was not logistically possible to bring in subjects for return rechecks. Since, during pattern recognition calibration EMG data are recorded and used to create the classifier, this property of the controller was used to collect data that could be used in a diagnostic manner for evaluation of fit and function. A protocol was developed to record information in various positions to allow repairs and adjustment to take place without an in person visit. This technique was also used to verify fit prior to beginning home trials.

METHODS

Eight individuals with a unilateral transradial amputation were fit with a Coapt pattern recognition system [2] passive wrist, and i-limb TMR revolution [3]. The study (including the ability to collect and record EMG data) was approved by the Northwestern University IRB. During the calibration process of pattern recognition control, data were recorded to be used to generate a classifier as the prosthesis moved through the various movements. The system would first collect EMG of the users' arm at rest (to align with "no movement" of the prosthesis). The prosthesis would then cycle through all of the enabled grasp patterns, opening and closing of each grasp 2 times. For this study, all calibration data was recorded and stored on the embedded controller for later post-processing.

Users were provided OT prior to participating in an 8-week home trial to evaluate their pattern recognition control of the multiarticulating hand. They were trained to calibrate their prosthesis whenever they felt their control had degraded. They checked in weekly using a home log system. Logged issues or calls to the prosthetist/OT over this 8-week window often needed to be followed up and these issues were often difficult to diagnose. In a clinical setting, users would be brought in for a recheck to evaluate fit and function. Since this was not always possible due to distance, alternative options were explored.

Since EMG was recorded for later evaluation during the calibration, a fitting evaluation protocol was designed to use this recording for diagnostics. All subjects had a minimum of 3 grasp patterns enabled. During regular calibration, muscle contractions are recorded for 2 repetitions of hand open and hand close for each grasp (i.e., 4 cycles per grasp). For our users and at least 3 grasp patterns enabled, this allowed for the collection of 13 (no movement plus 4 cycles * 3 grasp patterns) 3-second data blocks. Users were prompted to perform specific movements in various positions during the data recording phases of calibration. The order of movements requested was recorded so that the data collected could be mapped to arm position/contraction type. Table 1 shows the protocol developed and used in most cases. For these diagnostic trials, when collecting movement and maximum voluntary contraction (MVC) data, subjects were instructed to move the arm around in space when the device was moving. When conducted remotely, this prompting occurred via phone call/skype to assist with timing. Six participants used the evaluation protocol developed to diagnose fit and training issues. Some subjects also performed the protocol in lab as a “check out” of fit prior to starting the home trials.

Table 1: List of prompted movements for each calibration for evaluation of EMG quality

Arm supported: Regular calibration with the arm supported (resting on a table)
***Arm down at side**: R*egular calibration with the arm relaxed down at the side (hanging)
Arm in front of body: Regular calibration with the arm in front (as if shaking hands)
***Arm sweeps and MVC** (Maximum Voluntary Contractions)* During the data collection blocks for this calibration, the subject was prompted as follows: 1. Arm down at side and contract all forearm muscles at MVC 2. Arm in front and contract all forearm muscles at MVC 3. Arm out to side and contract all forearm muscles at MVC 4. Forearm relaxed and sweep arm from down at side to up to cabinet level and back down, diagonally 5. Forearm relaxed and sweep arm side to side at cabinet level 6. Forearm relaxed and push in on socket and wiggle 7. Forearm relaxed and pull slightly on socket
Subject prompted to doff and re-don system and repeat the following:
Arm in front of body
Arm down at side

Data were downloaded from the embedded controller for further processing. In most cases this occurred when the arm was sent back by mail (cheaper than flying the user back for an in-person visit) or by downloading to a study computer sent to them. A custom Matlab script was written to import the files and create graphs of the 8 channels of EMG. Data were plotted with each movement plotted in sequential order (i.e., no movement followed by open/close/open/close of each configured grip) with the channels shown 1-8 from top to bottom. The date/timestamp of the data was included in the title for reference and custom titles could be applied. Some of the issues (mechanical and therapy related) that were possible to diagnose:

- No issues with EMG (i.e., clean) during normal use but intermittent EMG saturation either in different positions or during MVCs: Electrode lift off from contraction or position. Or an intermittent loose wire
- Constant EMG saturation or noise: Broken/loose wire or consistent lack of skin/electrode contact
- EMG saturation during muscle contractions: User contracting too hard
- No EMG noted at all (flatline): broken wire or electrode shorted
- High baseline noise on one or multiple channels: 60 Hz interference or potential skin/electrode contact issue with ground electrode
- Clean EMG collected but hand did not move properly during calibration: hand requires repairs
- EMG improperly timed contractions of regular training (contraction only in small part of each window): subject needs more training
- EMG barely detectible for all movements: EMG location not ideal or contractions too light

- Clean EMG but user has poor control after recalibration: user needs more training/alternative imaging for different grasp patterns
- EMG after redonning very different than first 2 trials: user needs more practice with repeating proper donning or recreating grasp patterns

RESULTS

The protocol was used throughout the study to confirm socket fit and EMG quality when subjects were in the lab for testing/fitting and also when subjects experienced control issues at home. Figure 1 shows an example of early fitting with the pattern recognition system. EMG muscle contractions are noticeable on every EMG channel but there is higher baseline noise on multiple channels. This signal noise can occur when electrodes pick up on 60 Hz interference or because of poor skin/electrode impedance matching, or intermittent electrode contact of one or more electrodes (either domes not fully contacting the skin or loose wired connection).

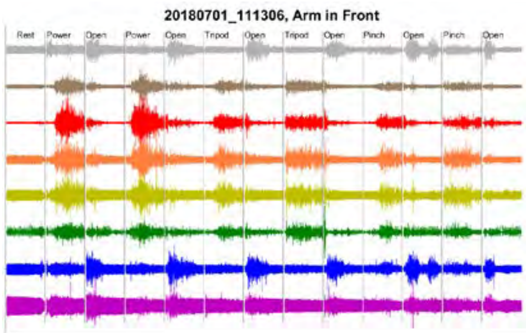

Figure 1: High baseline noise on multiple channels likely due to poor skin/electrode impedance matching or ground electrode not fully contacting the skin.

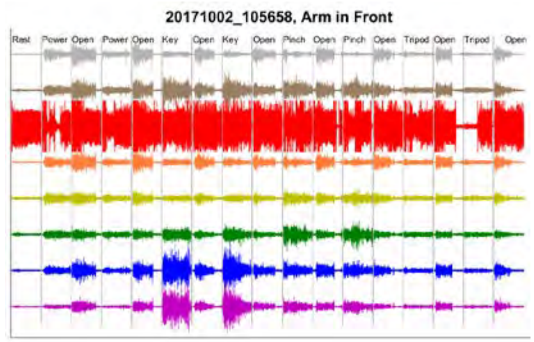

Figure 2: EMG analysis after arm sent in for adjustment. Noise seen on Channel 3 and loose wire located inside socket

Figure 2 shows a second example of the evaluation protocol used for remote troubleshooting. The subject had complained of poor control and was prompted through the diagnostic protocol prior to sending his arm in for review. Upon inspection of the data, channel 3 showed consistent noise across all movements and positions. This EMG contact was assessed and it was found that the wire connection inside the socket at the ring terminal to the EMG dome had broken during use. Though this failure would likely have been found with a thorough inspection of the device, the evaluation protocol made diagnosis and repair much quicker.

A more complex example can be found in Figure 3. This subject had previously undergone a revision surgery and was experiencing continued volume loss during the home trial. It was identified during planned follow up that he was having issues with control in some positions. The EMG from the evaluation protocol was compared to the locations of the electrode channels within the socket. The 4 images show the data collection for a) arm resting, b) arm at side, c) arm in front, and d) channel locations in the socket. When the arm was resting, it appeared that the soft-tissue was pulling away from the anterior channel (channel 4) and then pulling away from the posterior channels when the arm was extended (channels 3, 7, 8). Spacers were added to increase the depth of compression of the electrode domes on these 4 channels and the prosthesis was returned to the user. He reported improved control after return of the device and the EMG quality was verified at his next scheduled in person visit.

Other cases were noted where, upon completion of the evaluation protocol, the EMG quality was good. In these cases, the subjects would continue to work with the Occupational Therapist either in person or remotely to identify phantom movements that would create EMG unique to each grasp pattern.

DISCUSSION

Pattern recognition control has become more common in upper limb prosthetic fittings; however, the increase number of EMG channels associated with these systems can make troubleshooting fit and function difficult. It is

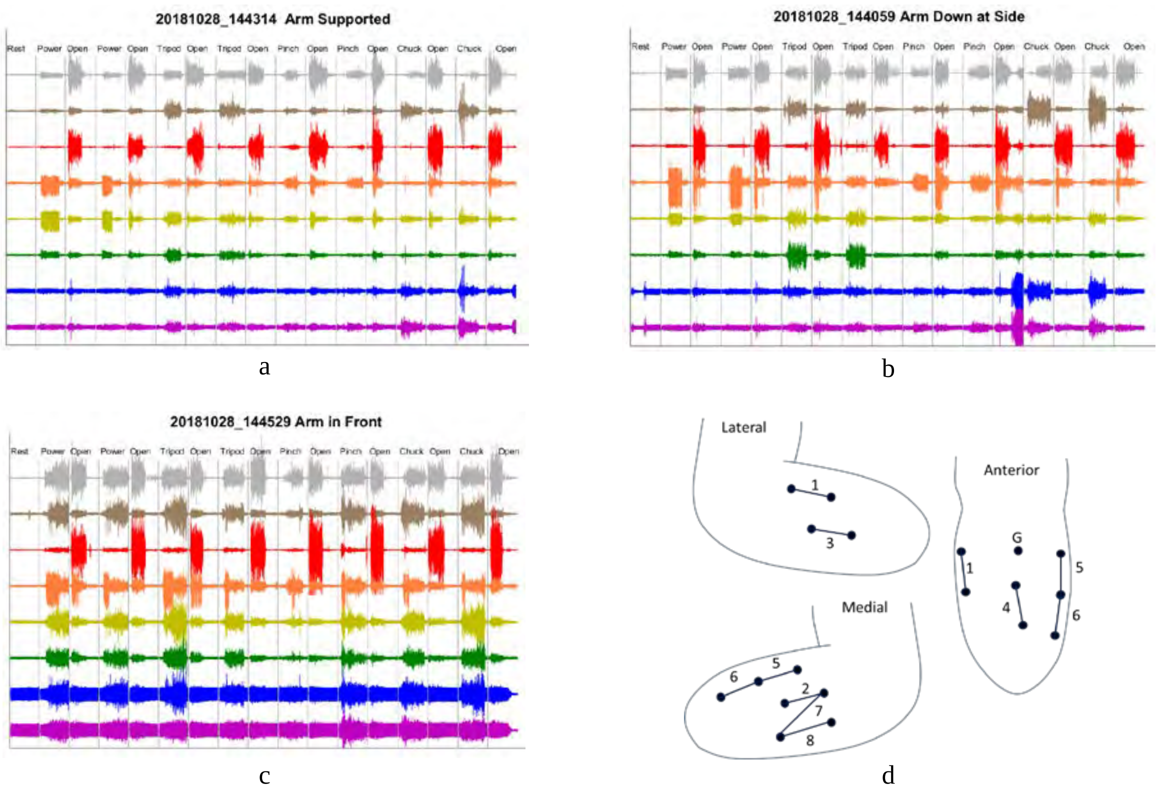

Figure 3: Remote troubleshooting with one subject. The 4 images show the data collection for a) arm resting, b) arm at side, c) arm in front, and d) channel locations in the socket. The 8 EMG channels are shown 1-8 from top to bottom in a-c. The thin vertical lines delineate where the EMG from the various movements (4 different hand grasp patterns) have been concatenated. Each vertical grey band represents 3seconds of data.

possible to visually review the EMG when the user is present but if issues arise a way of assessing the issue remotely is useful.

When EMG calibration data is recorded onto the prosthesis, this feature can be used to collect data to assess EMG and fit. This protocol was used on six individuals participating in home trials and was useful to diagnose loss of contact and broken wires, which were repairable without an in-person visit. In this study we needed to ship the prosthesis back to physically collect the data from the arm (or ship a laptop to the user), but if the data were downloaded remotely to a secure server it would be possible to identify problems with training or other issues that don't require repair to be completely resolved remotely. Additionally, the ability to remotely download the data would have allowed subjects to repeat the series of diagnostic training sessions to confirm that the repairs/socket modifications resolved the issue.

This evaluation protocol was also useful for confirming fit prior to the home trial by prompting the user to control the device in various planes of movement and as a baseline before home trial in case issues would arise later. This paper presents work done for a research study, but a similar evaluation protocol would be useful in the clinical environment to assist the prosthetist and occupational therapist to determine when it is necessary for a user to schedule follow up care.

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