Experiment protocol for test subjects

Title of the project
Using confidence levels of movement recognition in user training to improve prosthesis control

Details on investigators
All investigators are 2nd semester biomedical engineering master students at Aalborg University.

Background and purpose
Electromyography (EMG) is widely used for controlling functional lower arm prosthetics for transradial amputees. The ideal purpose of a functional prosthesis is to behave as functional as possible compared to a biological arm. Functional prosthetics that rely on pattern recognition-based control are becoming exceedingly good in performance in a clinical environment, due to highly optimized system control. However, still only one commercially available pattern recognition-based prosthesis exist. Users reject these functional prosthetics usually due to functionality issues when utilizing them in daily life tasks outside the clinical environment. Many improvements have been made in the area of system control, but another approach of improving the prosthetic control is by training the user. User training has only been explored scarcely in the research literature, thus, new techniques to improve the user's ability to control a prosthesis are yet untouched. This experiment will focus on training the user to improve prosthetic control on a fixed pattern recognition-based control system. The novel approach in this study is to provide the user with information on how well the system recognizes the performed movement during user training.

Research hypothesis
Exposing subjects to user training, in which confidence levels of movement recognition is used as feedback, will show improvement in performance in a classification-based myoelectric prosthetic control scheme, when compared to subjects who have not had the same feedback during user training.

Ethical considerations
The investigators do not foresee any obstacles of ethical nature during the proceedings of this experiment. No test subjects will be exposed to any physical interventions besides being asked to wear the Myo armband. No part of this experiment puts the subject in any danger.

Session time
The experiment consist of three sessions, which are spread over three consecutive days; one session per day. Each session is estimated to have a total duration of 30-60 minutes.

Inclusion criteria
The subject needs to be:

- able bodied.
- between 18 and 60 years of age.
- able to read, understand and speak Danish and/or English.
- assessed by the investigators to understand and perform the instructions given during the experiment.

Exclusion criteria
The subject must not have:

- diseases that might influence subject performance.

Experiment procedure

The experiment consists of three sessions containing different steps as illustrated on figure 1. The concept and chronology of each step is described below the illustration. it is important that during the experiment the subject will be placed sitting on a chair, with the arm, wearing the Myo armband (MYB), hanging relaxed down by the side of the body.

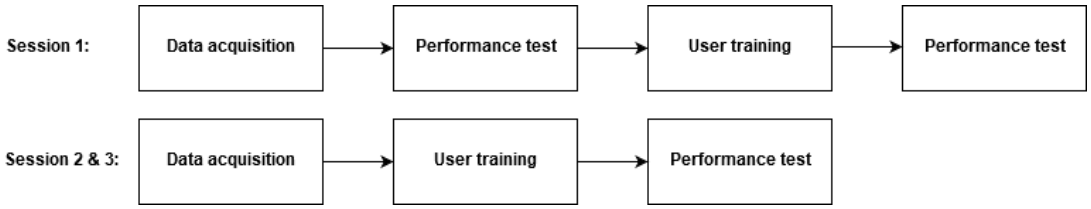

Figure 1: Pipeline for the three sessions in the experiment and what steps each session contains.

Data acquisition
For the myoelectric control system to be able to identify a performed movement as the movement that is actually performed, it needs information about how the movement looks when represented as a EMG signal. Thus, EMG data needs to be acquired from the forearm of the subject while the subject performs the movements that is used in the experiment, see figure 6 on the last page. This data is fed to the control system to train the system to recognize each movement. In this experiment EMG data will be acquired from the subject with an EMG-electrode armband: MYB from Thalmic Labs. The chronology of this step is as follows:

1. Apply MYB on dominant forearm at the thickest part.
2. Synchronize MYB by performing wrist extension until three distinct vibrations are felt from the MYB.
3. Perform 15 seconds of maximum voluntary contraction (MVC) of instructed movement. Following the MVC the subject will be given a 15 seconds resting period to avoid muscle fatigue.
4. Perform three 15 seconds contraction trails of respectively 40%, 50% and 60% of MVC. During these contractions the subject will control a green marker representing the EMG signal and try to follow a trapezoidal trajectory as precise as possible. The trapezoidal trajectory consists of two five second transition phases and one five second plateau phase. Between each trial the subject will be given a 10 seconds resting period to avoid muscle fatigue.
5. Repeat step 3-4 until training data from all four wrist movements has been recorded.

An illustration of the interface used for data acquisition is shown in figure 2.

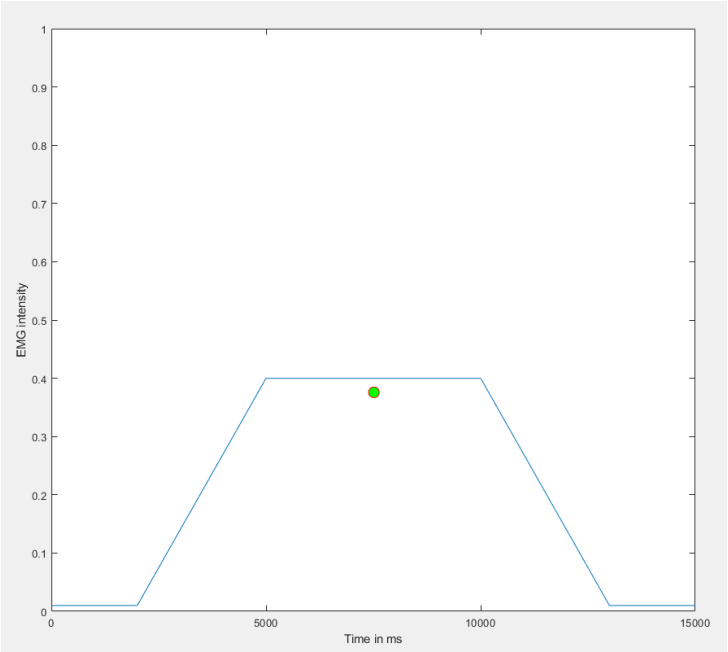

Figure 2: Illustration of the data acquisition interface showing the trapezoidal trajectory and the green marker representing the EMG signal.

User training

The purpose of user training is for the subject to train the movements used in the performance test. During the user training the subject will train one movement at a time at different contraction levels. When training a movement, visual feedback in form of confidence levels on how well the control system recognizes movements, is shown in percentage in a bar plot. In addition, the level of contraction is shown in a text box above the bar plot. When performing the instructed movement at the instructed level of contraction the background colour of the text box will appear green; if it is outside the instructed level it appears red. The aim for the subject is to reach and withhold the instructed contraction level with 100 % recognition certainty for each movement. The chronology of this step is as follows:

1. Perform extension at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
2. Perform flexion at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
3. Perform radial deviation at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
4. Perform ulnar deviation at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
5. Perform closed hand movement at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
6. Perform opened hand movement at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
7. Repeat step 1-6 at 35-45 % contraction level.
8. Repeat step 1-6 at 55-65 % contraction level.
9. Repeat step 1-6 at 75-85 % contraction level.

An illustration of the interface used for user training is shown in figure 3.

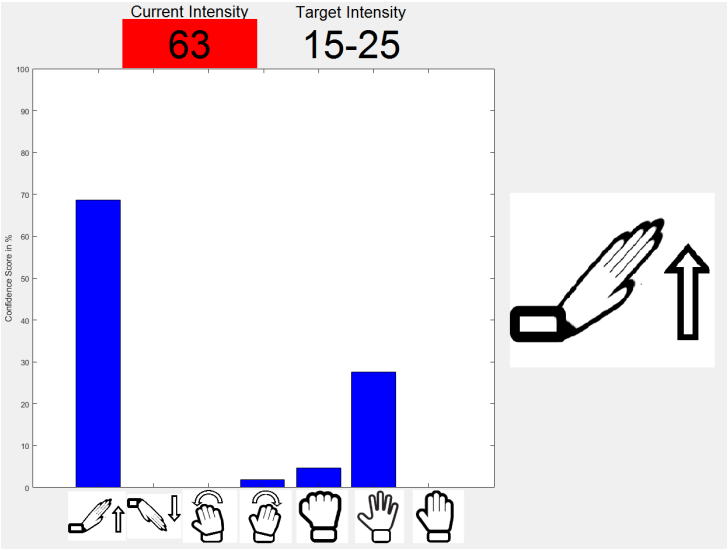

Figure 3: Illustration of the user training interface showing the bar plot indicating the confidence level of movement recognition and the text box indicating contraction level. The picture on the right side of the bar plot indicates which movement needs to be performed.

User Training

The purpose of user training is for the subject to train the movements used in the performance test. During the user training the subject will train one movement at a time in different contraction levels. When training a movement, visual feedback on which movement the control system recognizes, is shown in percentage in a bar plot. In addition, the level of contraction is shown in a text box above the bar plot. When performing the instructed movement at the instructed level of contraction the background colour of the text box will appear green; if it is outside the instructed level it appears red. The aim for the subject is to reach and withhold the instructed contraction level with 100 % recognition certainty for each movement. The chronology of this step is as follows:

1. Perform extension at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
2. Perform flexion at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
3. Perform radial deviation at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
4. Perform ulnar deviation at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
5. Perform closed hand movement at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
6. Perform opened hand movement at 15-25 % contraction level for 30 seconds followed by 10 seconds rest.
7. Repeat step 1-6 at 35-45 % contraction level.
8. Repeat step 1-6 at 55-65 % contraction level.
9. Repeat step 1-6 at 75-85 % contraction level.

An illustration of the interface used for user training is shown in figure 4.

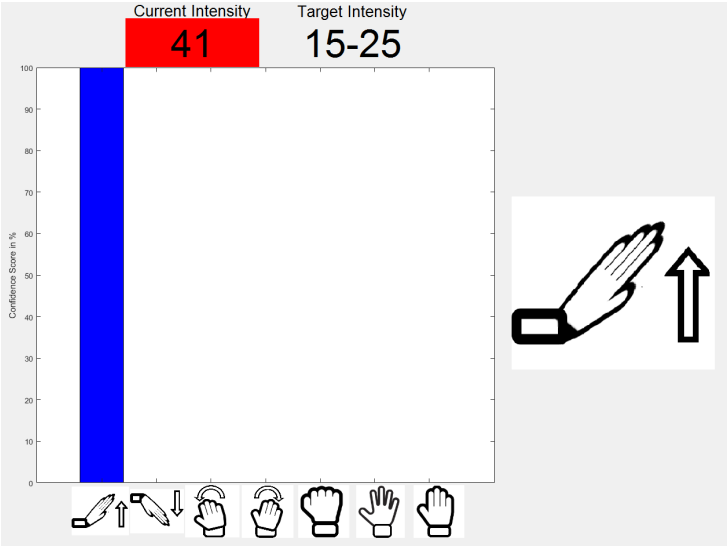

Figure 4: Illustration of the user training interface showing the bar plot indicating which movement is being recognized and the text box indicating contraction level. The picture on the right side of the bar plot indicates which movement needs to be performed.

Performance test

The purpose of the performance test is to assess the subject's ability to control a prosthesis. Instead of doing a test with a real prosthesis a virtual alternative has been developed for this experiment. The prosthesis is represented as a red circular cursor with a black dot inside in a Cartesian coordinate system, which the subject can move as well as expand and shrink in size by performing the trained movements. The following bullets describe which movement corresponds to which action in the coordinate system:

- Extension moves the cursor right.
- Flexion moves the cursor left.
- Radial deviation moves the cursor up.
- Ulnar deviation moves the cursor down.
- Closed hand shrinks the cursor.
- Opened hand expands the cursor.
- Rest keeps the cursor still.

The performance test consists of a target reaching test, where the subject must reach 16 targets of different sizes and locations. A target consists of a circle with a smaller circle inside. Only one target will be visible at a time. For the subject to reach a target and make a new appear, the subject must center the black dot of the cursor in the small circle of the target and expand/shrink the cursor to fit the size of the outer circle of the target. The cursor will appear green, when located at the correct position. The subject must dwell the cursor in a target for 1 seconds for it to be reached. When the cursor has dwelled for 1 second, it will appear blue for 1 second to indicate that the target has been reached. If a target is not reached within 15 seconds a new target will appear. The aim for the subject is to reach as many

target as possible as quickly as possible. The subject is only able to perform one movement at a time, as trained in the user training. Thus, no simultaneously performed movements will be recognized by the control system. The chronology of this step is as follows:

1. Reach the visible target.
2. Repeat step 1 until all targets have been shown.

An illustration of the interface used for the performance test is shown in figure 5.

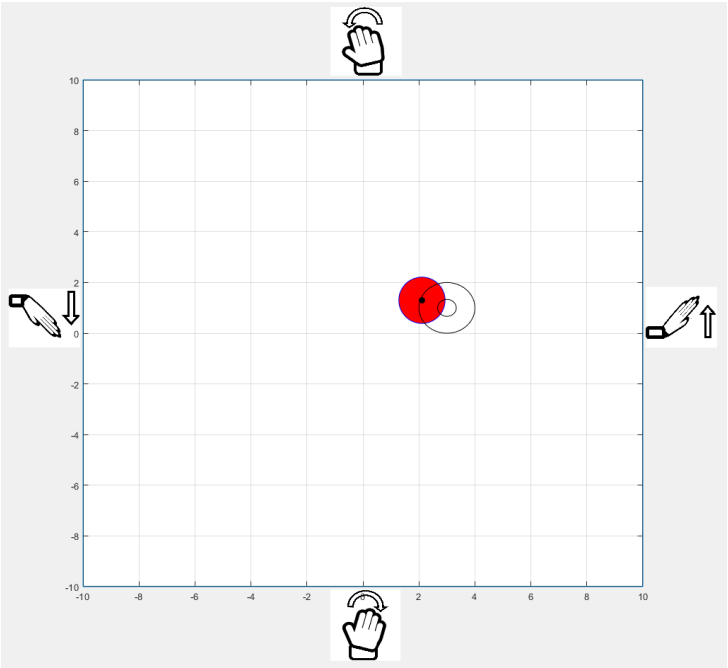

Figure 5: Illustration of the performance test interface showing a target and the cursor representing the prosthesis output. The pictures on the axes indicate which movement must be performed to move the cursor in a certain direction.

Movements used in the experiment

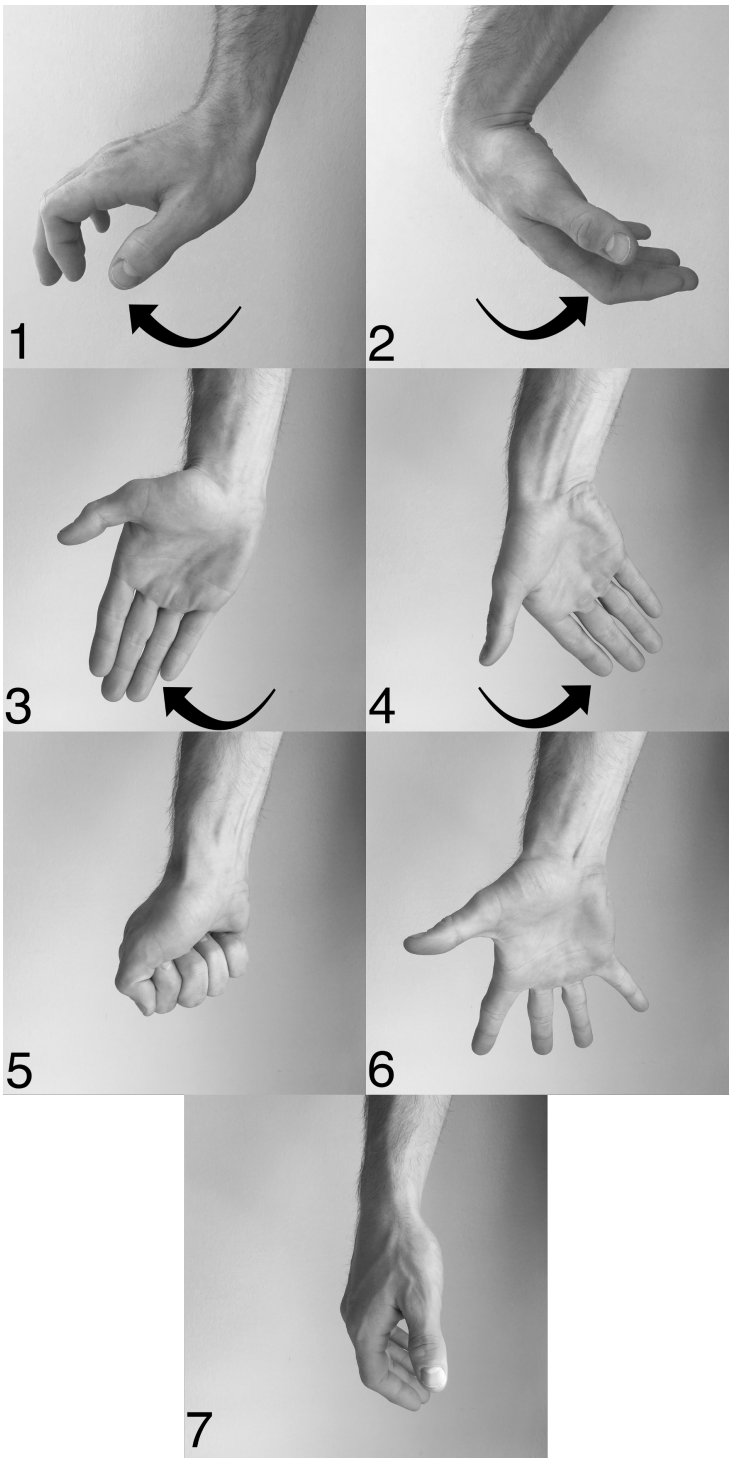

Figure 6: Illustration of the movements used in the experiment. 1: extension, 2: flexion, 3: radial deviation, 4: ulnar deviation, 5: closed hand, 6: opened hand and 7: rest.

Experiment protocol for investigators

This protocol functions as a checklist for the investigators in the experiment "Using confidence levels of movement recognition in user training to improve prosthesis control". The checklist is used to ensure all steps in the experiment is performed correctly and that no steps will be neglected. The experiment consists of 3 session of 3-4 procedures in each session, as shown in figure 7. The same procedures (data acquisition, user training and performance test) occur in all sessions and needs to be performed similarly each session. A checklist for each procedure is described in the sections below figure 7.

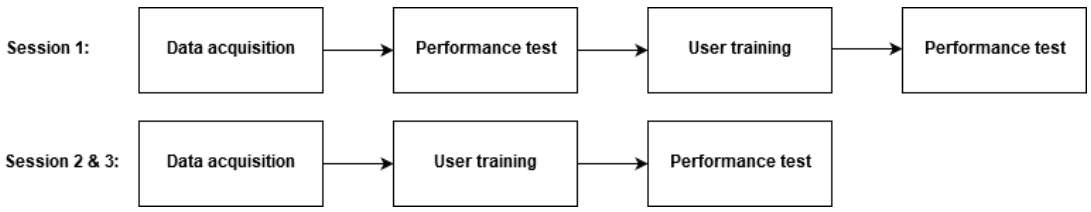

Figure 7: Pipeline for the three sessions in the experiment and what procedures each session contains.

The instruction of the of aim the respective procedures and content and functions in the interfaces is based on the information written in the experiment protocol for test subjects. It is expected that the subject has read the experiment protocol handed out prior the experiment, but the information regarding the respective procedures is retold to verify that the subject has understood the following procedure.

Data acquisition

- ☐ Disinfect MYB with alco-swabs.
- ☐ Disinfect MYB application area of subject's dominant forearm with alco-swabs.
- ☐ Instruct subject to stand in anatomical standard position.
- ☐ Mark with a permanent marker the size of the main channel (channel with LED) of the MYB on the most lateral position of the thickest circumference of the subject's dominant forearm.
- ☐ Instruct subject in applying MYB with the main channel (channel with LED) located on the marked position. The MYB must be worn so that the LED is located as distally as possible. Add clips to tighten the MYB if necessary.
- ☐ Ensure that the main electrode-channel is placed correctly.
- ☐ Instruct subject to sit on a chair facing the screen showing the interface, with the arm wearing the MYB hanging relaxed lateral to the torso.
- ☐ Connect MYB in armband manager.
- ☐ Instruct subject in synchronizing MYB by performing extension until three distinct vibrations are felt from the MYB.
- ☐ Instruct subject in the movements about to be performed in the data acquisition.
- ☐ Instruct subject in performing an MVC; that the contraction must be steady during the 15 seconds.
- ☐ Record MVC for one movement. Observe spider plot meanwhile. If the activation pattern for the channels alters too much during the recording is to be discarded and a new must be acquired.

- ☐ Extension
- ☐ Flexion
- ☐ Radial deviation
- ☐ Ulnar deviation
- ☐ Closed hand
- ☐ Opened hand

☐ Instruct the subject in tracing the trapezoidal trajectory with the green cursor in different contraction levels of the MVC.

☐ Record contraction levels of MVC for one movement. Observe spider plot meanwhile. If the activation pattern for the channels alters too much during the recording is to be discarded a new must be acquired.

- ☐ Extension: ☐ 40 %, ☐ 50 %, ☐ 60 %
- ☐ Flexion: ☐ 40 %, ☐ 50 %, ☐ 60 %
- ☐ Radial deviation: ☐ 40 %, ☐ 50 %, ☐ 60 %
- ☐ Ulnar deviation: ☐ 40 %, ☐ 50 %, ☐ 60 %
- ☐ Closed hand: ☐ 40 %, ☐ 50 %, ☐ 60 %
- ☐ Opened hand: ☐ 40 %, ☐ 50 %, ☐ 60 %

☐ Build regressors for each movement and build classifier trained with all movements.

User training

☐ Instruct subject in aim of the user training, and explain the content and functions of the interface.

☐ Initiate user training.

Performance test

☐ Instruct subject in aim of the performance test, and explain the content and functions of the interface.

☐ Initiate performance test.

☐ Save all training data and performance measures in folder named after name of subject, session number and which experiment group the subject belongs to.