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REVIEWER No. 2 : Comments to Authors

Manuscript No. 15

Title : Towards Adaptive Hand Prosthetics
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Comments to authors: (Please continue on additional sheet if necessary.)

Title: Towards automated multidimensional EMG control of hand prostheses

The manuscript from Castellini et al. primarily addresses the interesting and relevant topic, in how far information from multi-channel surface EMG recordings could be more effectively used for control of advanced hand prosthesis.
The authors experimentally collected surface EMG and force data during a paradigm of 5 different grasp patterns and 3 different training modalities in 3 hand amputees. Based on this information a Support Vector Machine (SVM) was trained for realtime classification of the grasp patterns and for estimation of the grasp force.
Since SVMs have not often experimentally been used in users of prostheses the paper is somehow novel and worth to be published.

However the paper is very poorly structured, it lacks precision, has some methodological weaknesses and therefore needs major revisions.

First, to my opinion the title of manuscript is too general since the work focuses on the classification of myoelectric signals as a basis for prostheses control. However an actual coupling of the myoclassifier to a real prostheses has not been done. Therefore I would recommend a more conservative title like “Towards adaptive hand prosthetics by EMG based grasp pattern classification and force estimation”.

Second, the paper looks like a puzzle, where you find parts of the discussion section and the results section distributed all over the manuscript. Please remember, that in the results section only hard facts should be given, which are then interpreted in the discussion section.

Third, some expressions within the manuscript may be misleading, which seems to result mainly from an incorrect translation. Please replace the verb “imagine” when talking about the gripping process. I would strongly recommend substituting it with “perform” since the patients actually performed the grasp. If they would just think about the movements no or almost no EMG activity could be recorded.
Please substitute “guess” / “guessed” with “estimate” / “estimated”.
Please use the more appropriate words “subject”, “study participant”, “individual” instead of “patient”.
Overall, I would strongly advice to let a native speaker read the final manuscript in order to improve the language of the paper and the herewith enhance its general understanding..

Fourth, the work contains some methodological weaknesses, like the subsampling of the data and the subsequent filtering, which should be done vice versa. Furthermore more technical details have to be given on the training process and the tests experiments since these directly affect the classification results.

Fifth, the discussion should be much more critical about the results that have been obtained. What impact do they really have on all-day life prostheses control ? How robust are the methods in terms of maintaining the classification rate over time ? Does the system has to be retrained after re-placement of the EMG-electrodes ?

In detail the following corrections are recommended:

Abstract:

In the sentence „„while asked to imagine, with“ the word “imagine” has to be substituted by “perform”, because the patients have actually performed the grasps.

Please delete the second part of the last sentence “feedback loop of reciprocal learning, leading to shorter training times and a better quality of life”, because this has not been evaluated in the presented work and is - to my opinion - speculation.

Introduction:

No literature has been cited about other studies and experiments that have been performed (e.g. ….) over the last couple of years in the field of multi degree of freedom control of prostheses.
Therefore a much better overview over recently introduced control methods based on surface EMG recordings have to be given in order to clearly identify the novelty of the work presented in the paper.

Footnote 1 should be included into the introduction.

The paragraph “The machine is able to distinguish …..excellent performance” has to moved to the results section.

The lines “The task seems hard at first …….better quality of life for the patients” have to be moved to the discussion section.

Material and Methods

A. Patients

Please provide some information about the cause for amputation, because this gives some hints on how much muscle tissue has been preserved. Have all amputations done due to trauma ?

Please delete “Moreover, subject 1 ….other subjects”, because this information is already contained in the sentences before.

B. Setup

Delete “See the Discussion .. this issue”.

Please give detailed information on the differences between the two types of EMG sensors that have been used.

What do you mean with “excellent noise rejection ratio ?” Do you mean the integrated notch filter for power line signal rejection ?

“Moreover they perform a run-time root-mean square evaluation of the signal”. As far as I know, the electrodes only do a simple rectification of the raw EMG signal and a low-pass filtering. Please provide experimental data about that.

Were the electrode positions maintained in each of the patients during the whole experiment ? Have the electrodes been re-placed between the training and the test sessions ? If not, please give some information about the influence of re-placement of the electrodes on the classification error in table I.

C. Experimental design

Please give more information about the selection process of the 5 grasp patterns used for the experiment. Have they been chosen because they are provided by some type of multifunctional prostheses ? Or do users ask for these most often ? If they have highest user priority, please provide a literature reference for that.

Why was only subject 3 asked to perform a stretch of his hand ?

Please give references for “, as has been done in literature so far”.

“The idea behind ….. and ease the ghost limb pain”. Substitute “ease the ghost limb plain” with “decrease the phantom pain”.

“We figured out that ……activation patterns.” Give a literature reference on this or - if not available – transfer this sentence into the results section.

“The result is ….. with signals gifted with diverse frequence”. Please delete the word “gifted”.

“The result is that the patients applied a …., which helped test wether out approach would work equally well with signals gifted …” Please delete “gifted”.

Please give more information about the duration of the training experiment (supervised learning) and the test session (free running classification).

Please delete sentence “At the aforementioned sampling ….”, since it contains no additional information.

D. Methods

Please move the paragraph “As already mentioned … or a real value (regression).” into the introduction section.

“SVM [12] are a good machine learning method to solve this problem, so we employed them”. Please be more precise: What means “good” ? What are their advantages over other machine learning methods like Fuzzy classificators, statistical methods etc. ? Which problem in particular has to be solved ? Please specify the technical problems of integrated grasp classification and force estimation in realtime based on surface EMG signals.

“The input space is chosen to be ….”: Please give a more detailed information about the input variables to the SVM. Have you fed the SVM directly with the EMG activity signals of the different electrodes ? If so, you may classify different amplitude combinations. However, then the classification accuracy is depending on the stability of the EMG activity signals, which under real world conditions decline over time. Please comment on this issue. Would it be possible to increase classification rate – also over time – by using more sophisticated input features like

III. Data Pre-Processing and preliminary analysis

“Subject 1 actually needed the no-action data set to be replicated for each modality, ….”: Please compare the applicated base line values with the no-action data between grasp pattern transitions in the other modalities. If there are relevant differences than the analysis of subject 1 has to deleted from the manuscript. If there are no relevant differences this sentence could be deleted.

“Moreover, we could not record ….” Please be more precise, whether no recording or no classification of the “pointing index activity for subject 1 was not possible.

“Spectral analysis of the EMG signals as read from the electrodes …”. Please write “Spectral analysis of the EMG activity signals provided by the electrodes …”

“, shows that the bandwidth lies below 10-12 Hz (see Figure 4), so we could safely subsample the signals at 25 Hz ….. Subsequently we applied a 2.nd order low-pass filter with cutoff frequency.” This is a severe methodological mistake: You should first apply a 5 Hz filter and then do the subsampling. Please make a verification of your data if this has an influence on your results. Also the type of filter has to be given..

Figure 4 gives some frequency spectra of the force signals and “typical electrodes”. I would recommend deleting this figure since it contains no data, that has to be explicitely shown to the readers.

“Principal component analysis (PCA) reveals that the 5 signals …” Which signals ? EMG signals ?

“As is apparent from the Figure …” Which figure do you refer to ?

The paragraph “One last point is that PCA …..We are investigating this issue” has to be shifted to the discussion section”.

Please give more information in the discussion section about the influence of the heavy drifts on two electrodes of subject 3. This is a most important issue, since it gives some hints on the robustness of the whole classification system for the proposed application of prostheses control. One of the reasons, why the state of the art of current control methods for prostheses based on surface EMG-electrodes is so simple, that is has to be highly reliable over many hours in all day use.

IV. Experimental results

The whole paragraph “For classification, the performance ……grid search using the aforementioned performance index” has the shifted to the methods section.

Please give more information on the two hyperparameters, since not all of the readers are familiar with the methods contained in the manuscript. How are the used ? What information do they provide about which part of the classification process ?

Table 1: Please provide more detailed information about the number of training sets and of testing sets that have been used for obtaining the performance values.

Figure 6: Please rename the y-axis of figure (a) in “label 1”, “label 2” etc.

The paragraph “It is unclear why ….. of the 2-dimensional PCA-transformed input space” has to be transferred to the discussion section.

“Really, most mistakes in classification involve label 0, ….”: What happens if a user directly moves from one grasp pattern to another without inserting a relaxing state in between ? Does this have an influence on the classification results ? Please provide some information about this.

The paragraph “In these cases, willing to obtain ……spurious signal” has to moved to the discussion section.

“…. one can think of using a regression system to guess when the required force is above a reasonable threshold ….”: Why not starting the classification only in case a certain EMG activity threshold is reached ?

The paragraph “In practical terms, let us consider …….. to a real online framework” has to shifted to the discussion section.

V. Discussion and Conclusion

“…. Way than before: finer, force-controlling and more dexterous.” Please refine the expression “finer” or otherwise please skip it.

“We have actually found …… point of view”: Since subjects 1 and subjects 2 are well trained users of myoelectric controlled prostheses its no surprise that relevant EMG activities could be recorded even many years after amputation. Please discuss this issue more critical since users of myoelectrically controlled prostheses do not suffer from a disuse of the muscles in the stump. There are many studies that show this.

“The use of three different modalities ….. and mirror-box modalities.”: It is not clear in how far the experiments under the different modalities have been performed multiple times and in randomized order. If they would have been performed several times a statistical analysis also in 3 patients would have been possible and the repetition would then maybe have an influence on the differences that have been observed between the subjects.