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RAPPORT - report

Sur la thèse présentée par - On the thesis presented by

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Ayant pour sujet – on the subject of: Investigations on upper limb prosthesis control with an active elbow

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Rapport - report:

The thesis describes an original approach to help transhumeral amputees that are amputated above the elbow. The important challenge for these patients is to control not just a prosthetic hand but also the prosthetic elbow. Because controlling then several degrees of freedom are involved this might be a high challenge too high for most patients. The current thesis investigates whether the changes in elbow angle (flexion-extension) can be predicted from the movements in the shoulder. This is a novel approach in the literature and might be very promising. It certainly would help patients a lot if they would not need to control the elbow independently. The strategy of the thesis is robust in that first a technical assessment is made about the possibilities, then the new technology is tested with able-bodied people before it is tested on patients.

The thesis starts with an overview of the literature. This overview is quite thorough, but could be made more complete with including incidence rates and rejection rates. Also check the papers of Biddis and Chau and Ostlie to see how urgent it is to address the issue of an automated elbow.

The thesis then proceeds with providing a detailed explanation of the experimental protocols as well as the choices that were made in this. Moreover, background is provided with regard to the computation of the body angles and the reference frames in which this is done. The next chapter provides the background on the algorithms that are used in the thesis and of which the effectiveness is compared. In the ADL use of the prosthesis the current project aims to use IMUs and the experiment validated the use of IMUs with using an opto-electrical system.

Chapter 4 contains the first experimental implementation of the developed model: a simulator is developed with which the prosthesis and the control algorithms can be tested with healthy participants. Therefore participants had to perform a reaching task to targets in front of them. The targets were placed at a distance such that movement in the shoulder and the elbow is necessary to reach all targets. All participants tried all four control algorithms that were presented in a random order. General movement properties (movement duration and precision at target) as well as postural strategies (angles in trunk, shoulder and elbow) and variations in center of pressure to use the prosthesis were evaluated. It was argued that model 1 and model 2 had a preference above the other two models.

In chapter 5 the algorithm and the prosthesis is tested with six transhumeral amputees. It is uncertain whether in this chapter the question is still about the control algorithm; not the algorithm was varied but the control type of the elbow was varied in this chapter. One group of participants used conventional control of the prosthesis hand whereas the other groups had the prosthesis attached via osseointegration. The main experimental manipulation regarded the control mode of the elbow of the prosthesis; the elbow could be controlled myoelectrically where muscles in the residual limb could be activated to either flex or extend the elbow. The other control mode of the elbow was the automatic algorithm developed in this thesis. It turned out that the socket used in the ME group affected the movements in the shoulder, making the OI group making movements that were more natural.

The thesis is well written and easy to follow. The algorithms and the computations of the joint angles are presented extensively.

General comments

The most important comment on this work is that no statistical tests are performed. Behavior is compared while real participants/patients used different versions of control modes of a prosthetic device. To establish whether the control modes differ, statistical tests should be used on the dependent variables (duration, error at target, joint angles, etc). Note that these tests need to be performed as ANOVAs, in line with the design of the study. I believe that adding statistical analysis would certainly add to the strength of this work. Would analyses be included than there is a logical place for this in the methods, results, and discussion of chapter 3, 4, and 5. One could start with one chapter.

Note that with an ANOVA, interaction effects can be tested. Moreover, it makes it possible to change the figures and presentation and discussion of the results in a way that these can focus more on the important differences. Also, testing the interaction effects makes that more information is obtained about the conditions in which one control mode is better than the others. This makes it not only possible to give a more in depth assessment of which control mode to chose, it also makes it possible to get a deeper understanding of how a control mode affects the performance.

A point related to this point is the issue that the discussion of a chapter should discuss only results that are presented in the results section. In chapter 3, 4, and 5 often new information is added in the discussion that actually is a result and hence, should be presented in the results first.

Be more specific about the experimental instructions. Do the participants make a ballistic movement with their upper arm, and then wait what the algorithm does to see whether the arm ends up in the target? Or are additional modifications possible with which it is possible to end up in the target with the arm using feedback about the performed movements.

What I miss is a general discussion of the work. The introduction presents issues regarding prosthesis use and technological developments. What a reader would like to learn is how the current findings fit into the picture of the situation as it is described in the introduction. Address which problems are solved with this new technology. Moreover explain which problems will/should be addressed in the future based on the knowledge gathered in this thesis.

Chapter 1

When mentioning the cosmetic prosthesis, it should be explained that these prostheses have a relatively high functional value for most of the users.

Chapter 3

On p41-45 the different models that are compared in the current study are presented. Although the structure of each of the models is explained, it is not clear on the basis of which criteria these specific models were selected. What could be explained is whether the selection of these particular models originates from aspects of the data or that there are considerations regarding model building are at the basis of selecting these models.

What also should be addressed in this chapter is why the choice is made for velocity control (i.e., velocity in the shoulder angle joints is related to elbow angle velocity).

On p 46- 47 the angles of the IMUs are compared with the angles of the optoelectrical system. However, given that the control algorithm used in the new prosthesis uses velocities of the angles, wouldn't it be better to validate the angle velocities instead of the angle positions?

P48, fig III.3; there seems to be an anchor point in the data, or an invariant posture in time (i.e., standard deviation is zero, during the movement trajectory). This is present in the traces of both participants. Why is this anchorpoint not further discussed? Is this anchorpoint related to an action in the elbow? Or an other event?

P53 mentions the objective of chapter 4, but is this really the objective? Isn't the objective to compare the control models?

P53, what is meant with randomly driven by one of the models?

Chapter 5

It should be specified which model was implemented in this experiment, as well as the arguments why this particular model was implemented. Also should the results with this model be clearly evaluated with regard to the knowledge obtained in chapter 3 and 4, where all the four models were examined.

Although my assessment is critical I really enjoyed reading the thesis and truly appreciate the work! The work is innovative and the topic needs more attention in the literature. The thesis proposes a technological innovation that aims to improve the life of patients, and that is good.

I do approve the oral defense of this thesis. I complement the candidate and the supervisors with the work presented in this thesis

Sincerely,

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