Determine socket shift in trans-radial amputees using ultrasound and 3 D motion capture

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In pattern recognition-based myoelectric control several robustness problems are well known. Different positions of the upper limbs and donning and doffing cause unintended electrode shifts (pistoning) with adverse effects on classification accuracy. To our knowledge the shift of the socket with respect to bony structures has never been assessed. We developed a set up to measure the shift of the socket with ultrasound and 3 D motion capture system in trans-radial amputees. We got obtained accuracy values with .655 mm for our set up. A pilot measurement showed high reliability and a displacement of the socket around 2 mm. We are going to conduct further test measurements and develop parameters to distinguish longitudinal and perpendicular shift of the socket. In future works pistoning parameter should be considered in order improve pattern recognition based myoelectric control.

I. Introduction

Pattern recognition based myoelectric control has the aim to make prosthesis control intuitively and naturally. Several studies have shown classification problems in different limb positions [1]. Further studies have reported classification problems after donning and doffing and weight bearing on the socket as well [2]. The occurring electrode shift (pistoning) of nonstationarities is one of the reasons for the limitation of laboratory performed research. Even a small electrode shift of around 2 cm leads to classification problems[3]. So far electrode shift has quantified only with respect to the skin and with a small number of subjects. To our best knowledge in the literature there are no studies to explore the displacements of the socket and the stump for the upper limbs with respect to underlying bony structures. Several methods are suggested in the literature to measure the movements between the socket and the residual limb, especially for the lower extremities [4], [5]. Most of them were using an x-ray stereography, which is cost-intensive and exposes subjects to radiation. But for clinical outcomes and studies in biomechanics of prosthetic users, the pistoning is an important parameter. Therefore, we developed an accurate setup to evaluate movements between the socket and the stump with respect to underlying bony structures in order to receive quantitative data. In future work these data can be used to improve myoelectric control considering pistoning parameters.

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II. Aim of this Study

The aim of this study was to develop a set up to quantify the shift of the socket with respect to bony landmarks and to determine the shift after donning and doffing, between several quasistatic arm positions and in weight bearing condition.

III. Method

To determine the shift between prosthetic socket and residual limb we developed an accurate measurement set up combining 3 D motion capture system with 14 infrared cameras (Vicon Motion Systems, Oxford, UK) and an ultrasound system (US, Sonosite Titan). Retro reflective markers are attached to the ultrasound probe to receive the position and the orientation of the probe in the global space. With virtual calculated markers we determined the scanning plane of the ultrasound system. In the captured ultrasound picture we detected certain bony landmarks and calculated its global positions. Retro reflective markers were also attached to the prosthetic socket. In order to determine the shift of the socket we calculated the distance between the global coordinate of the bony landmark and the markers attached on the socket.

Fig. 1. Two custom made test sockets. The features of them are the same as the daily used sockets in combination with a prosthetic hand (Michelangelo hand, Otto Bock Healthcare Products GmbH).

To test and improve the accuracy of the developed setup we used an adapted procedure introduced in [6]. A table tennis ball (tt ball) was fixed in a box filled with distilled water and the center of the ball was calculated prior. We determined the global coordinate of the center of the tt ball with our ultrasound system from different scan directions and calculated the rout mean square error (rmse) to the prior calculated center of the tt ball. If the accuracy was at an acceptable level we fixed the probe in a custom made frame with attached markers and saved the positions of the markers attached to on the ultrasound probe and the virtual calculated markers relative to the custom made frame. Due to this saved information we were able to check the correct calibration of the system with the frame in a quick and uncomplicated manner before measuring a new subject. We performed tests of the accuracy of the set up with one observer in three sessions who determined the center of the tt ball 10 times in three different scanning directions per session. Custom made sockets were equipped with fitted holes to scan through with the ultrasound probe and to detect the bony landmark (see Fig. 1). The sockets had approximately the same spatial features and weight as a daily used socket. We included male subjects from 18 till 60 years of age with unilateral amputation on transradial level due to traumatic reasons. We performed three measurements. 1. During four quasistatic arm positions (1. arm hanging besides body; 2.forearm horizontal to the ground; 3.upper arm horizontal to the ground and elbow 90° flexed; 4. arm abduction at approximately 135 °). 2. Weight bearing with different weights (2-5 kg) on the socket during the four mentioned limb positions. 3. After donning and doffing. We scanned well recognizable bony structures like the proximal radius head and tried to retrieve them between different measurements. Each measurement condition was repeated five times. We analyzed the captured 3 D data and ultrasound videos with Matlab R2011b (The MathWorks, Inc., Natick, Massachusetts, United States).

IV. Preliminary Results

In terms of accuracy we got an rmse value over all three sessions with .655 mm (session 1:.635 mm, session 2:.535 mm, session 3: .795 mm). We conducted a pilot measurement with a prostheses user to get preliminary results. Since we measured only one subject up to now and the pilot character of this measurement the results are depicted in a descriptive manner. Since the socket didn't fitted to the subject as it should be we were only able to perform the measurement with inner socket. Therefore the calculated distances were neglected and we concentrated on reliable issues. Two independent observers analyzed the captured pictures and determined two bony landmarks (distal humerus head and proximal radius head) (Fig. 2). The standard deviation (std.) for the radius head appears even lower than for the humerus head. The range of the std. for conditions except 'after' for both raters is: radius: .1-.4 mm, humerus: .5 – 1 mm. For the condition 'after' the std. for the radius are .9 and .96 mm and for the humerus 1.1 and 1.2 mm.

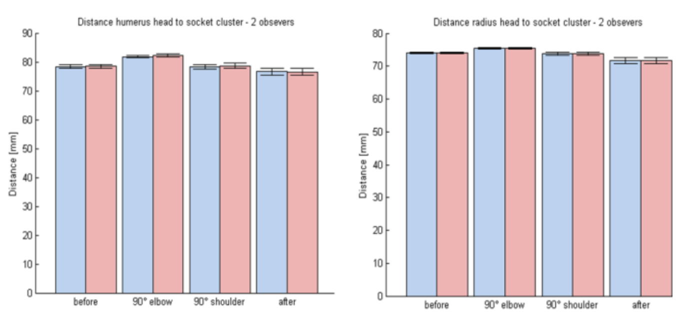

Fig. 2. Distance (mean±standard deviation) between bony landmarks (distal humerus and radius head) and marker attached on the socket determined by two independent observers (blue and red bars).

V. Discussion and conclusion

Due to the fact, that we performed the measurements only with the inner socket the absolute distance values were negligible. The weight of the inner socket is only around 1/10 of the complete system. Therefore we assume that the measured distances are much smaller than with the complete system. But from the results of the two independent observers we assume that the proximal radius head is better detectable in terms of reliability than the distal humerus. In upcoming works we will perform further measurements with the complete test socket. For this we improved our recruitment procedure. Besides we will work on outcome parameters which describe the shift of the socket more precise in longitudinal and perpendicular directions due to the results of [3]. It appears that the electrode shift in perpendicular directions affects the classification accuracy much more than in the longitudinal direction. Up to now we are limited in the way that we only could describe the shift of a point in the local coordinate system of the socket. But other approaches trying to create a local coordinate system to the stump used either radiation [4] or wasn´t applicable to donning and doffing [5]. Recognition of bony landmarks between different limb positions is a considerable issue. We hope that precise knowledge about the shift of the socket in different conditions, limb positions and after donning and doffing will be considered in the future development of pattern recognition algorithms to make those systems more robust.

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