A Study on Various Trans-Humeral Prostheses Using Surface EMG

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Abstract: Upper limb amputation arise due to cardiovascular defects, trauma, health problems, or inborn defects. A disabled person needs an assistive mechanism like the prosthetic arm to perpetrate in their day-to-day activities. A Prosthetic Arm is an artificial system for interfacing my generated signals with external physical activities, which is extensively used to communicate and control the interactions between humans and machines. Many bio-generated signals can be utilized to control prosthetic arm like Surface Electromyogram, Electro Encephalogram, etc. But here using Surface Electromyography (s EMG) signal to control Prosthetic arm. s EMG is an inquiry of electrical activity of the striated muscle which is monitored at the surface of the skin. This signal is interfaced with a prosthetic device which helps to improve the quality level of amputees. Maximum movements are the target, which includes movements of fingers, forearm, and trans-humeral areas. The body-generated signal can be extracted using various electronic equipment and can be analyzed actual brain intention on various hand movements. With the support of artificial devices, one can achieve the goal. Neural networks and advanced Embedded System applications are also included in this prostheses implementation. This paper involves the study of various trans-humeral prostheses using electromyogram.

1. Introduction
A Prosthetic Arm is an artificial substitute for an arm. The idea of an artificial body-powered upper-limb prosthesis was invented by German dentist Peter Baliff [1]. A leather strap is used to transmit tension and thereby control the muscle action of the trunk and shoulder. The 1960s were an era of pneumatic prostheses. However, the control was not so satisfactory to attain requirements. Body-generated signal-based control is a suitable remedy for the above issue [2]. Trans-Humeral, Trans radial, Trans carpal, Elbow, Hand, and Shoulder amputation are some of the amputee situations. This paper concentrates on some relevant papers using surface Electromyogram signal technique, but much research comes out based on other bio-generated signals. Reference cited from [9],[10],[11],[12],[13],[14],[15] are the sum of significant works recently. Actuators and motors can be used to execute the real movements in the residual limb, and this paper indicates the scope of prosthetic studies.
2. Existing Prostheses in market

The Luke Arm is the current upper arm prosthesis designed by Defense Advanced Research Projects Agency, introduced by Dean Kamen. This arm provides the maximum movements with dimension 18DoF, and this system is more relevant in the current applications and its reliability and robustness are also noticeable.

Proto 2 is another prosthetic arm commonly used in the current market and it uses a hundred sensors for acquiring myoelectric signals. It was a four-year project of DARPA. Actuated Trans-humeral Prosthesis has 21 DoF, the arm uses hydrogen peroxide as a gas generator to power nine pneumatic type actuators which drive elbow, wrist, and a 17DoF compliant hand.

3. Trans-Humeral prosthesis

A trans-humeral prosthesis is a machine alternate for body parts just below the shoulder [3]. It also covers the elbow and palm. Actually, the analysis of the trans-humeral part is a very tedious job because of its complexity of signal sensing capacity. Prostheses consist of many actuators and motors for realizing efficiently.

4. Classification of prosthetic devices

The selection of prostheses is determined based on the usages of our body parts. If the system utilizes a myoelectric signal, it is body-powered and if there exists an external power for driving these prostheses, it is known externally powered prostheses and if there exists any static body part it is named passive. A hybrid control system consists of both body and external powered mechanisms.

Saravani Chanda et al proposed a new algorithm based on sEMG signals for the classification of various physical movements.[4]. The oscillatory behavior of the signal is used in this algorithm. The classification is based on the Tunable-Q factor Wavelet Transform (TQWT). Q-factor and redundancy can be tuned easily in TQWT. The transform is based on a real-valued scaling factor. A perfect reconstruction over-sampled filter bank with real-valued sampling factors is used in this system. The transform is calculated for discrete-time signal of finite length and infinite length and FFT implementation was performed. The Q-factor and the redundancy are the two significant parameters of the transform.
5. Review of Techniques used for trans-Humeral Prosthesis control

The transfer function of LPF and HPF after $N$ stages is given by
\[
S_0^N(w) = \prod_{i=0}^{N-1} S_0 \left( \frac{w}{\alpha_n} \right) = 0 \quad |w| \leq \alpha^n \pi \\
\alpha^n \pi < |w| \leq \pi 
\]
\[
S_1^N(w)=S_1(w)\prod_{i=0}^{N-2} S_0(w) \left\{ 1 - \beta \right\} \alpha^{n-1} \pi \leq |w| \leq \alpha^{n-1} \pi \\
=0, \quad \alpha^n \pi \leq |w| \leq \pi 
\]

where $\alpha$ and $\beta$ are the scaling factors of the filters.

Nasrul Anuar Abd Razak et al. suggested a work that compared the mathematical model of elbow joint using sEMG, body-powered socket pressure, and air splint socket pressure prosthetics for trans-humeral application which characterizes the required forces to succeed in dealing with the passive prosthetics at the residual limb [5].

In body-powered socket pressure, prostheses are controlled by manual operation using other parts of the body like the shoulder, elbow, or chest. In myoelectric prosthetic technique, prostheses are controlled by the signal generated by the body muscles. The Air splint socket pressure technique is implemented by combining a pressure sensor with an air splint and microcontrollers [6].

The performance of trans-humeral prostheses is based on the biomechanical principle of the elbow joint in three conditions such as normal hand, self-powered myoelectric, and air splint prostheses. It is evaluated through various experiments and proper lab simulations were conducted based on age, weight, trans radial mass of each subject and thus theoretical
values are calculated. Secondly, the pressure force applied for each type of prostheses is evaluated. Another analysis is a comparison of force applied by each type of artificial arm with normal hand force. From these three methods, it is clearly understood that the suitable mechanical force applied to both body-powered and air splint artificial arms are quite the same but the above indicated mechanical force and pressure application will be different in nature. The various movements at the elbow with arm, flexion, and extension of elbow play a major role in the load. Different prostheses applied different biomechanics on the residual limb region. Finally, one can notice that in air split prostheses, the socket size gives correct pressure to the residual limb. If constant pressure is provided, the socket will be more comfortable to the user.

The previous system is a muligrasp for trans radial amputation [7] Nasser A. Alshammary et.al. implemented the capabilities of a person with a trans-humeral amputation to control a multigrasp hand from residual musculature on the upper arm [8]. They conducted various experiments based on EMG signals generated from biceps and triceps corresponding to the virtual prostheses’ movements. The possibility of multigrasp prostheses is increased due to technological advancement. There are two approaches, pattern recognition, and hierarchical approaches. The second approach is utilized in this work. The capacity to control a multigrasp prostheses from the upper arm and same action using native hand is also performed.

Prosthetic related Papers [9],[10],[11] are concentrated on various methods of hand prostheses and many approaches are also described here. [12],[13]. Distributed Control System for Vision-Based Myoelectric Prosthetic Hand [14] [15] are some of the significant works in the present scenario. In this paper, more focus is given to the vision-based analysis. Simulation and experimental results are also included. Actuators and motors can be used to execute the real movements for the residual limb, and all the above studies indicate the scope of the prosthetic area in the coming future. The simulations and experimental results have been included in all the above papers, so Embedded platform-based prototype development will have a significant role in the related industries. Microsensors will have a very significant role in future prostheses developments.

6. Conclusion

A prosthetic is a human-machine interface that is used as an amputated part of a person. This paper reviewed three important techniques for establishing the Trans-Humeral prostheses system. The first paper focuses on human-machine Interface TQWT for classifying the physical movements and can be achieved 97.74% accuracy.

The next approach proposes a mathematical model of elbow joint using three dissimilar types of Trans-Humeral cases and proposed required mechanical force to drive the artificial arm at the existing body part. It also compared the torque, force, and pressure while using a human-machine interface with a normal hand. The F scan sensor is used to measure the pressure.

Finally studied a new method Muligrasp body-generated control approach for use by Trans-Humeral amputee. The same approach was developed for Trans radial amputees earlier. Now the same approach is utilized in Trans-Humeral amputees. The simulations and prototyping were conducted on five cases, comparing their potential to attain one of seven hand postures in virtual prostheses using simulation software. Results clearly show the
ability to control the multigrasp technique using musculature in the upper arm. It is more efficient than the trans radial approach.

Table 1: Summary of Review Papers

| Sl. No | Approaches                                      | Parameters                                      | Findings                                                                 |
|--------|------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------|
| 1      | Physical Action Classification using sEMG       | Tunable Q Factor Wavelet Transform approach for physical classifications | 97.74% Classification accuracy is obtained.                               |
| 2      | Biomechanical principle of elbow joint for Trans-Humeral prostheses | The equation of mechanical force applied torque, weight, and length of different types of artificial arms and the characteristics of prosthetics hand are studied | Results taken from the elbow kinematics of seven amputees using three different artificial arms, the exact pressure required is obtained. |
| 3      | Assessment of a Multigrasp myoelectric control approach for use by Trans-Humeral amputees | Examine the ability of a person to control a multi grasp hand artificial arm from the muscle region in the upper arm | The MMC approach is utilized double extension to change between enmity and reposition conditions. |

7. Acknowledgement

The authors would like to thank the authorities of the Electronics and Communication Engineering Department, Karpagam Academy of Higher Education, Coimbatore. Special thanks to faculty members of the Electronics Department, MES College Marampally, Aluva for their great support.

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