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A REVIEW ON DEVELOPMENTS AND TRENDS IN BIONIC ARM DESIGN

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***Abstract*— Prosthetic arms have been long used in order to replace an amputated hand. From ancient times, people were using wooden arms as prosthetic devices in order to replace them for a lost arm. These devices only provided body balance and never truly worked as an actual substitute. After the advancement of electronic and software technology, prosthetic arms have been developed in order to provide a bio – feedback. These modern bionic arms could do some operations using electromechanical devices which imitated the actual actions of a hand. These bionic arms have become very popular and is easily available now due to their mass production. But due to the present-day design, the cost of the bionic arm is very high due to the large number of electronic components used in them which also increases the delay of the feedback system. In this paper an exhaustive survey is done in order to bring on some design tweaks in the design of the prosthetic arm which reduces the number of components used thereby decreasing the delay in the feedback system. Also, decreasing the number of components in the device reduces the complexity of the system thereby significantly reducing the cost of the bionic arm. The designs surveyed in this paper can be easily manufactured using simple lab equipment and components present in a normal workshop or laboratory.**

Keywords*— EMG (Electromyography), EEG (Electroencephalography), Upper Limb Prosthesis, 3D Printing, Body Controlled Prosthesis, EMG Sensor, Bio – feedback system.

I. INTRODUCTION

It can be argued that the most important possession of a human being is his body. Losing a body part can be very painful and traumatizing. Often people who lose their motor organs like their hands and legs face difficulty in performing even the simplest of daily tasks in each and every moment of their life. This often leads to depression and them losing hope thereby making them to resort to adverse actions like suicide. From times immemorial, people have been trying to find a substitute for the lost body part by replacing them with various artificial objects. People in Egyptian civilization and Indus Valley Civilization often used a wooden substitute which was carved in the shape of their arms or legs. Though this was one of the best solutions at that time, it only helped in maintaining the body balance and served no other purpose. This method was used for almost the next two millenniums until the advancement of electronic technology which helped in creating bionic arms which could perform basic actions like a normal human hand. Development of sensors and electromechanical components helped the researchers to predict the actions to be performed by sensing various signals sent by the brain and then developing a program which actuated certain electromechanical components embedded in the prosthetic device thus mimicking the actual action a normal hand would have performed. This has proven to be a huge leap in the prosthetic arms development though contemporary designs often use too much components in their system thus increasing the cost of the device and the delay in the feedback. Many people often give up on the idea of using these bionic arms due to their high cost and complexity of usage. This paper provides the simple design tweaks that can be used to reduce the number of components used to design and develop a prosthetic arm which in turn reduces the cost of the device and complexity of usage.

II. LITERATURE SURVEY

Deng *et al* [1] (2016) proposes in his work that proper holding power is exceptionally hard to get for a prosthetic arm because of the absence of a definite feedback data. At the point when the power applied was excessively little, a heavy item would slip, while an excessively huge power would distort delicate articles. A framework has proposed a bionic reflex control framework intended to recreate the humanoid reflex control work for a prosthetic hand. A unique model of an underactuated ligament – driven prosthetic hand was gotten utilizing Lagrange's equation technique. Next, a force sensing resistor was received in the control system to identify slippage dependent on exact model deterioration. At that point a polyvinylidene fluoride sensor was acquainted with the control framework to appraise the firmness of an article, which was utilized for adjusting the underlying wanted getting a handle on force to maintain a strategic distance from twisting. The exhibition of the proposed bionic reflex control framework was explored through a progression of trials, the consequences of which effectively show its adequacy, and check that the getting a handle on ability of a prosthetic hand was accordingly improved.

Gauthaam *et al* [2] (2011) describes in his research a novel way to deal with the control of a multifunctional prosthesis dependent on the order of myoelectric designs. It was indicated that the myoelectric signal displays a deterministic structure during the underlying period of a muscle constriction. Highlights were extricated from a few time sections of the myoelectric sign to protect design structure. These highlights were then grouped utilizing a fake neural system. The control signals were gotten from normal compression designs which could be delivered dependably with minimal subject preparing. The new control plot expanded the quantity of capacities which could be constrained by a solitary channel of myoelectric signal yet did as such in a manner which didn't build the exertion required by the amputee. The information which was introduced, recommended there was extensive structure in the myoelectric signal during the beginning of a withdrawal. Moreover, accordingly structure was particular for constrictions which delivered diverse appendage capacities. Thus, the genuine structure of the myoelectric signal after some time could be utilized to separate appendage work. The aftereffect of this segregation could be utilized to control the determination of a prosthetic appendage work. A further advantage was that corresponding control of chosen work was effortlessly consolidated into the new state determination plot.

Ebrahimi *et al* [3] (2017) proposes an impelling instrument of joints on the exoskeleton which was link driven, pressure driven, pneumatic and electrically activated. Profoundly proficient electrical engines were utilized as the drive instrument in the field of Prosthetics and Orthotics (P&O). The force densities of current electrical engines were improved utilizing new materials with incredibly attractive qualities. High thickness changeless magnets, new composites of iron with higher immersion limits and new geographies of winding and the acknowledgment of entangled get together procedures had come about in exceptionally productive electrical engines. Yet at the same time both of these frameworks were not tantamount with the force thickness of human muscles. A normal individual could without much of a stretch produce up to 70 Nm force at the elbow. Subsequently, the force thickness of the drive framework was upgraded by utilizing a rigging framework with relative high proportions. The determination of the rigging influences the development of the absolute framework. A blend of an epicyclical and slope outfitting was utilized to deliver a force up to 13 Nm at the elbow pivot. A fast, low force engine was connected opposite to the pivot hub of elbow. Accordingly, two unique riggings were expected to decipher the force appropriately at the elbow. Utilizing multi-stage outfitting framework caused a few disservices, for example, a decline in proficiency and precision of situating and an expansion of mechanical backfire and weight.

Alejandro *et al* [4] (2017) investigates the practicality of utilizing three Dimension (3D) printable technology towards the advancement of minimal cost automated prosthetics. As an underlying approval, two models were manufactured: a hand with 5 fingers constrained by a wearable instrumented glove and a hand-arm that could be constrained by flexing any muscle in the client's arm through a sensor that gathers EMG signals from the muscle. Finger movements were constrained by servomotors which function as actuators while the turn of every servo engine was controlled utilizing microcontrollers. The point was to show the possibility of utilizing 3D printing innovation for building a model of a controlled hand as a first step towards the improvement to stream cost prosthesis as a potential guide for low salary individuals with inabilities. It was demonstrated that it was conceivable to create an automated arm utilizing 3D printing innovation which imitated an arm prosthesis with moderately little exertion, minimal effort, and with a truly satisfactory activity. EMG corresponding control worked appropriately and it was sufficient for essential control of the hand. The mechanical structures of both hand models were effective and met desires.

Muhammad *et al* [5] (2019) presents that bio signals gave data which gives us significant understanding into the regular procedures happening inside the human body. This made it basic for the sign to be liberated from noise with the goal that it gave a commendable gauge of the data by the bio signals. The proposition of a versatile channel-based sign handling plan progressively to expel commotion from the EMG signal considering the erratic nature and changing elements of clamor got from the general condition while utilizing dry EMG terminals. Moreover, an instrumentation conspires which not just dropped external interference utilizing simple channels and Driven Right Leg circuit, yet additionally gave a sign balance without the utilization of snake circuits to empower an Analog to Digital Convertor (ADC) to procure the sign. To approve the presentation of the proposed signal handling and instrumentation plot, an investigation of the separated EMG signal in time and frequency domains in terms of signal to noise ratio, discrete Fourier transform, and cross spectral density. At long last, it was reasoned that the sign procurement conspires proposed gives an EMG signal which adequately diminished noise and could be valuable for different EMG applications.

Ciarán *et al* [6] (2014) presents a propelled, minimal cost prosthetic arm created for trans-radial amputee's dependent on the requirement for access to further developed appendages for those of restricted monetary means. The structure of the arm was greatly helped by the current blast in open source innovation and leisure activity level quick prototyping. The mechanical structure of the arm was completely 3D printed while the gadgets are approximately founded on the Arduino Mega. The EMG sensors were reproductions of the open source Advancer Technologies EMG pack. The general assembling process was finished utilizing promptly accessible hand instruments and a RepRap 3D printer. The all-out expense of materials for one complete arm was roughly €460 ($640). Right now, the arm was controlled through the constriction of either the wrist extensor or flexor. Different grasp examples could be picked to manage different circumstances, giving the hand the best adaptability. Current criticism from each finger considered power restricting and gave a contribution to essential mechano-material haptic input.

Said *et al* [7] (2018) proposes a plan for an adjustable wearable powerful 3D printed bionic arm been designed and actualized for a right hand. A trial test was directed for an individual who had been born without a correct arm. A control of a 9 Degree of Freedom (DOF) hand was developed effectively utilizing EMG signals procured by myo - armband. Various motions were perceived and planned to control various developments of the hand. Essential day by day exercises were cultivated in the wake of preparing the individual. The arm was lightweight for every day and long-lasting utilization. The expense of the arm was modest contrasted with accessible arrangements accessible available.

Zhang *et al* [8] (2018) mentions about a bionic movement arranging approach for the getting development of robot arm based which was drawn closer from examining the movement example of science by psychological researchers. As indicated by the guidelines of human getting development, the bionic movement strategy guaranteeing the progression of the quickening will be zero toward the beginning and end of the development. This methodology had been executed on a 3-DOF three Radial (3R) planar robot arm. The outcome indicated that, inside a characterized time, the position hole and the disposition hole could be shut simultaneously, and the bends of joint speed, quickening and driving force was ceaseless and smooth. From the consequences of recreation, the speed and increasing speed of each joint were zero toward the start and end of the development, which implied the robot arm could easily arrive at the objective. The underlying and last forces of three joints were zero also, and the change patterns of force were smooth.

Tejas *et al* [9] (2017) shows a study that 1.8% of India's all out populace were arm amputees. This included right around 24 lakhs of the all-out Indian occupants. Out of which, 60% held their source from rustic foundation. The Bionic arms were expensive to these individuals as it was costly because of the innovation in question. Consequently, these individuals decided to stay an amputee forever, instead of contributing on a counterfeit prosthetic appendage. The thought was to build up a prosthetic arm which impersonated all the activities of the human arm. It was worked on a remote stage, accordingly disposing of wires running on the body. The two Flex Sensors were appropriately modified and when twisted back or forward, the comparing servo engine would react. The top most servo engine at the shoulder would lift the whole arm. When lifted, this servo engine additionally encouraged turning developments of the shoulder of about ±30° as for the shoulder line. After the activity, the automated arm came back to its rest position. The subsequent servo, put at the shoulder moved the arm to and fro sideways of about ±80° as for the shoulder. In any case, the to and fro developments was not be conceivable when the main servo engine was in activity. In conclusion, the third servo motor, put at the elbow level, offered the lifting and withdrawing of the automated arm.

Takahashi *et al* [10] (1988) presents a technique for estimating the movement of the shoulder. The framework made out of five segments, i.e., a component part which comprised of a gimbal and a sliding free arm with four optical turning encoders, a counter circuit which decoded the yields of the rotating encoders, EMG speakers, a PC framework and two holding gears for the subject's trunk and elbow. To consider the shoulder complex movement, the microcomputer-based mechanical assembly with synchronous EMG recording capacity was created. Framework had capacity to quantify not just traditional Range of Motion (R.O.M) of the shoulder complex but circumduction of the shoulder complex quantitatively. This list was the new idea to assess three - dimensional movement of it. Improvement of a small-scale PC based mechanical assembly for estimation of the shoulder complex movement with EMG by generally basic framework. By presenting PC, not just ordinary ROM. yet in addition, 3D ROM were estimated productively. Also, viewpoint show from subjective view point was accessible for study and determination of the shoulder complex.

Seo *et al* [11] (2017) proposes a strategy on mechanical lower arm component to expand the Pronation and Supination (P/S) development of the trans-outspread amputee when he/she had the option to lead the P/S movement mostly with his/her residual lower arm. The P/S movements of the current prostheses and mechanical arms created till now were totally not quite the same as those of the human. At the point when it was to build up the mechanical prostheses for the amputees, two significant issues were viewed as, for example, restorative issue to look like ordinary arm and movement agreement issue between automated prosthesis and the cut off living arm. Most prostheses don't understand the human-like P/S movement, yet the basic rotational movement at the wrist by utilizing the electric engine. The spatial four-bar component was embraced to impersonate human P/S movement as though the individual does, in light of the fact that it was perhaps the best contender to depict real human lower arm development. To acquire the structure boundaries of the component first, 3D information of the cut off arm just as the contrary side non-excised arm were caught by utilizing Magnetic Resonance Imaging (MRI) and 3D scanner. The plan boundaries, for example, interface lengths, joint areas, and volumetric shape were resolved from the deliberate information.

Scarcia *et al* [12] (2015) presents a plan for improving, prototyping and the gathering of a wrist system with 2 DOF for human ligament driven mechanical hands. The structure idea permitted a significant decrease of both the quantity of parts and their assembling intricacy, ensuring simultaneously the decoupling of the fingers and the wrist movement by methods for a selection of ligaments steering. The simplification of the system accomplished with the halfway disadvantage of presenting extra contact powers along the ligaments, which were anyway remunerated by the control and didn't significantly influence the general conduct of the hand. The proposed wrist configuration had been embraced in the advancement of the University of Bologna Hand, form - IV (UB-Hand IV). Likewise, the methodology for the structure and the prototyping of a 2 DOF system reasonable to be coordinated in a human automated hand incited by ligaments. The fundamental preferred position of this arrangement was the extraordinary simplification of the instrument and its assembling and gathering forms. It was made out of just 3 sections which could be acknowledged with a standard 3D printer without trading off its mechanical opposition and without demonstrating any shortcoming in regards to the wear.

Rubenstein *et al* [13] (1984) proposes a paper which guaranteed that prosthetic hands could just endeavor to reestablish the hold movement like manikin developments. Open-close didn't give an individual the office to play the piano or to type. Open-close gave the crude hand activity that permitted an individual to get a few articles and clutch them in a contradicting thumb design. The elbow would join free swing, relative input, and snappier, smoother, calmer activity. The shoulder/elbow/hand framework would consolidate pivoting and flexing wrist and shoulder parts. A replaceable module power packs and would have the option to emulate completely the natural framework as far as criticism and simplicity of control. Chip would be utilized to arrange the data sources and tactile criticism signals, settling on "choices" identifying with the valid/bogus nature of the movement. More broad use would be made of custom half breed and incorporated hardware, with the plan to give standard framework modules to design into a prosthesis. More consideration would be paid to the issues of steadiness and control in the lower furthest points.

Sumit *et al* [14] (2018) presents in his work a novel real - time motion recognition framework for EMG signal obtaining and classification, which could arrange hand presents from multi-channel EMG signals assembled from arbitrarily positioned arm sensors as precisely as current set sensor EMG securing approaches. Its consolidated time-area highlight extraction, Linear Discriminant Analysis (LDA) include projection and Multilayer Perceptron (MLP) classification to permit nine particular stances to be accurately identified over 95% of the time, additionally contrasting the best in class put sensor EMG procurement frameworks. In general, the Processing times took 11.70 ms additionally made this a feasible up-and-comer approach for constant EMG securing and preparing in pragmatic prosthesis applications. To check the viability of the proposed approach, tests were directed for ten ordinary subjects (seven guys and three females, 26 ± 4 years) for EMG information recording. Twenty meetings of EMG recording were directed from each subject. The first ten meetings were utilized for classifier preparing, with the staying ten meetings utilized for testing. In each meeting, each movement was executed once for a term of 5 sec. The length of the moving window was set to 250 ms with a 125 ms window increase, hence, permitting the proposed plan to settle on two choices inside 300 ms. The EMG design acknowledgment approach for various wrist-hand movements gave 95.57% classification precision which was a phenomenal tradeoff between computational execution and exactness when contrasted and complex time-recurrence approach.

Palli *et al* [15] (2012) presents on the advancement of the mechanical hands, called UB Hands, since it was created at the Laboratory of Automation and Robotics of the University of Bologna about over 25 years of exploration in this field. Beginning from the UB Hand I, the first robot hand model created in the labs, the distinctive plan arrangements and methods of reasoning that had been followed toward the imaginative UB Hand IV. Toward the end the Remarkable qualities of the UB Hands were additionally the entire hand control capacities, the capacity of recreating the contact powers over the entire hand surface as on account of the UB Hand II, and the nearness of power/material sensors as in the UB Hand IV. The gadget with two equal fingers, an opposable thumb and a palm was created. The robot hand was called UB

Hand I. The phalanges were constrained by counterfeit muscles, ligaments and a regulator, spoke to individually by DC-engines, steel links and a extremely large arrangement of mini-computers and electronic gear. The aftereffects of the undertaking were an achievement for the exploration in the zone, and various hypothetical and trial issues had been raised, which began a few intriguing coordinated efforts.

Murai *et al* [16] (2015) proposes a strategy for structuring an attachment and mechanized hand as a major aspect of a myoelectric prosthetic hand for fractional hand amputees with fingers staying on the removal stump. This proposed plan technique could adjust to singular removal stumps and remaining finger capacities. The technique fused the influenced rakish and separation boundaries into the hand kinematic model, and structured attachments by shelling the 3D strong model of removal stumps from the extended 3D strong model of removal. The incomplete EMG prosthetic hand was be equipped for utilizing the rest of the fingers and mechanized counterfeit fingers freely. The EMG prosthetic hand controlled EMGs related muscles that regularly associated with finger bones, which didn't exist on an amputee stump. While remaining EMG intruded on disarticulating EMG, it meddled with the order capacity of the prosthetic hand control, bringing about control glitches. A control technique was required to dismiss remaining EMG and to utilize disarticulating EMG to perform characterization of hand movement and control the prosthetic hand. It was practiced by utilizing neural system with a capacity to dismiss the rest of the EMG highlight.

Meattini *et al* [17] (2016) proposes a framework being worked with Raspberry Pi processor. In the framework, the client set the clock by methods for a processor. The enactment and deactivation times were modified with processor. Constant Clock (RTC) chip DS1307 was utilized to set the calendar. Fluid Crystal Display (LCD) show was given to show the current time. DS1307 was interfaced to the Raspberry Pi processor for genuine planning execution. A 3V battery was appended to DS1307 only for precautionary measure for time unsettling influences brought about by power disappointments. Information put away stayed in the memory considerably after force disappointment, as the memory simply ensured for perusing of the most recent spared settings by the processor. The framework utilized controlled 5V, 12A movable force gracefully. Unregulated 12V DC was utilized as transfer and 7805 three terminal voltage controllers for voltage guideline. Notwithstanding, a further developed criticism than visual was expected to let the client control all the more intentionally the muscle co-withdrawal, keeping away from semi-aimlessly regulations that occasionally bring to bomb the grip task. A more prosthetic arranged automated hand must be acknowledged including an immediate variety of the finger's joints solidness and a keen simplification of the ligament incitation framework, that would improve ease of use of the gadget and general exhibitions of the whole HRI.

Lim *et al* [18] (2016) proposes the idea of a biomimetic skin-type tactile sensor gathering practically identical to human skin through the building examination of detecting component in human skin and the advancement of different sensors impersonating mechanoreceptors in the human skin. A material sensor get together was planned with different sorts of sensors having 3D structures course of action inside the diverse Young's modulus multi layered squares. Particularly, the ideal plan of warm detecting was explored to forestall the temperature distinction between the reached outmost layer and temperature sensor situated in profound area because of the awful warm conductivity of skin-like elastic. The structure depended on the totally human skin. The components of physical properties, structures, and morphology of human skin layer were considered absolutely and seven unique sorts of material sensors were under creating by mirroring the essential mechanoreceptors. Besides, the concentrated way for the temperature sensor which was in more profound layer was distinguished as a piece of biomimetic skin-type material sensor 3D get together.

Kalpande *et al* [19] (2018) presents his overview referencing around 5 million handicapped individuals. The impaired individuals were influenced with different neuromuscular issues. To communicate, one must give them augmentative and elective correspondence. Cerebrum PC interface framework (BCI) was created to address. The essential supposition of task reports the plan, development and a testing imitation of the human arm which means to be progressively precise. The gadget attempted to look like the development of natural human hand by perusing the signs created by mind waves. The cerebrum waves were detected by sensors in the Neurosky headset and produced alpha, beta and gamma signal. At that point this sign was prepared by the microcontroller and the development was then created to the counterfeit hand by means of servo engines. Patients who experienced removal underneath the elbow could profit by this bio-mechanical arm. The prosthetic arm through electroencephalographic information arranged client information to three yields given by the Neurosky Mind wave headset framework. A broad preparing time would permit the client to promptly control the arm all the more precisely. Additionally, a few electroencephalography (EEG) sensors would support the exactness and would help in investigating it into more ranges. On the off chance that the precision could be expanded, at that point it is assumed the prosthetic arm could be effectively actualized in genuine circumstance.

Bustamante *et al* [20] (2018) presents that the far reaching of 3D-printing innovation has brought about the presence of many open-source prosthetic hand models, particularly for incomplete hand removals. Be that as it may, the vast majority of these plans are not editable and keeping in mind that some are parametric somewhat, customization for each client is constrained to scaling the size of a base structure. As outcome, most prostheses neglect to intently coordinate the client explicit anthropometry and have helpless feel, which could bring about surrender of the gadget. Besides, accomplishing a serious extent of customization could be a tedious assignment and requires past information on CAD structure. This work presents a prosthetic hand simple to tweak by changing parametric components of the finger phalanges and palm on an Excel sheet. Furthermore, the structure handles basic issues from past 3D-printed body-controlled prosthetic hands by fusing new highlights, for example, the utilization of linkages rather than links as finger flexors and another link changing framework which requires no extra instruments and makes the tensioning of finger ligaments simpler and faster.

III. Conclusion

This paper reviews many researches and designs proposed in various research papers and journals to analyse the modern day design trends and future development of the bionic arms. From many of these works, it can be found that simple design changes and tweaks can reduce the present-day problems faced while using prosthetic arms like cost, feedback delay and complexity of usage.

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