Drugs and Cell Therapies in Hematology (ISSN: 2281-4876)
Volume 10 Issue 1 (2021)

PROSTHETIC DEVICES AND MACHINE LEARNING

Aman Saini[a], Dr. Divya Jain[b] and Dr. Arpita Nagpal[c]

[a]UG Student, Computer Science & Engineering, The NorthCap University,Gurugram
[b]Assistant Professor, Computer Science & Engineering, The NorthCap University, Gurugram
[c]Assistant Professor,Computer Science & Engineering,G.D. Goenka University,Gurugram

Article History

Article Received: 9/04/2021
Article Revised 10/05/2021
Article Accepted: 15/06/2021

Abstract

Machine Learning now a days is being used in lot of technologies. Prosthetics devices have been exponentially developed over a small period of time. This paper presents a survey done in the field of prosthetics. Prosthetic devices play a pivotal role in healthcare sectors. Prosthetic devices help people to recreate their lost power of sensations, touch, light, feel etc.It helps to repair, replace, or correct any missing part of the body, and keep functioning as before by using artificial substitute. Machine learning not only makes the works easier but is also helps to reduce the algorithm complexities, make the machine or model learn by itself from the past experience and feedback. Using machine learning for prosthetics is the new era of development. This work presents the knowledge about machine learning, prosthetics, history of prosthetics, types of prosthetics, advancement done and future scope, how machine learning is used to develop prosthetics.

Keywords: *Prosthetic Devices, Amputation, Myoelectric Prosthesis, Machine Learning, Future Scope and Advancement*

1 Introduction:-

Prosthetic devicesare artificial made devices used in place of any missing body part. These help people to recreate the lost power of sensation, touch, feel, etc. These devices can be electricity driven or just the replacement to fill the missing part without any advance movement.

According to a survey more than 30 million people in the entire world losses their body part due to some accident or any disease and are need for a prosthetic replacement.The most common loss is the limb loss faced by the majority of people. And more than 75 percent of the developing countries are unable to treat the problem or have the lack of correct technology[1].

There are n number of reasons due to which people lose their limb.Sometimes it is by birth itself i.e., congenital limb deficiency. In such case it is quite difficult to treat the person with prosthetics because the person does not have any experience of sensation in his lost part [2]. The prosthetic device might not be able to recognize the signals from the part it is attached. Some other reasons are due to cancer, infections, trauma, compilations in blood vessels any accident etc. Such cases can be treated quite easily and around 88 percent of devices work quite well in synchronized manner [1].

Treating chronic disease on time is an important step to avoid circumstances which led to use of prosthetics. In [3,4] the author has done various surveys on several feature selection and classification technique which are very helpful, and they help in finding the disease very early and more accurately. This paper contributed to parallel and adaptive classification systems to make the models perform more better.

Technologies with consolidation of Artificial Intelligence and Machine Learning has become a privilege for physically disabled. The engineers, doctors, scientists have significantly exceled in the field of neural networks withsurface electromyography (sEMG) and successfully rehabilitated various biomechanical functions of lost parts of the body [5]. Human is the most advance animal when it comes to the thinking

power of brain and neural networks. On an average brainconsists of more than 86 billion neurons along with trillion of bonds with each other [6].

Every prosthetic is designed according to its user appearance and functional need. A prosthetic device must be fully synchronized with the patient body and should totally be controllable by him. Every patient has a particular need for instance if atransradial prosthesis is required then,he might choose between a body powered device, an aesthetic functional device an myoelectric device or any activity specific device etc [7,8].

This paper will help you to get an in-depth knowledge about prosthetic devices. It will help to get the knowledge about how various technologies like, artificial intelligence,machine learning deep learning,electrocardiography, neural networks, and lot more together help to build new devices [9]. How does a prosthetic device is made, how it works, how it functions, how it coordinates, its types, history, advancement, and further scope of advancement in the field.

This paper is marshalled as following. Firstly, a short note on machine learning. What is machine learning, how it works. Secondly comes the history of prosthetics, how it slowly evolved. Thirdly we proceed to the types of prosthetics devices. Then comes the advantage and disadvantages of prosthetics. At sixth comes the current advance prosthetics i.e., myoelectric prosthetics. Then literature review done on few papers and work done in past. Last comes the future scope and advancement in field of prosthetics.

2 Machine Learning:-

Machine learning - "the science of getting computers to act without being explicitly programmed." It is a subset of Artificial Intelligence. Machine learning is used to train our computers in such a way that they tend to learn themselves. They learn from the data that we provide and also improves its accuracy over a period of time without actually programming to do so. Machine learning is growing at a great pace and are used in various sectors and technologies specially to automate them and make the functioning more advance but simple. Few current uses of machine learning are in image recognition, speech recognition, self-driving cars, virtual personal assistant, medical diagnosis, prosthetics, safety equipment's, stock market trading and a lot more.

Machine learning growth was not an overnight success, it took many years to get so advance. In late 1970s and early 1980s artificial intelligence and machine learning took different tracks. Until then ML was used as a training program in Artificial intelligence. In 1990 a paper titled "The Strength of Weak Learnability", by Robert Schapire introduced and explained the concepts of Boosting which bought evolution in field of machine learning. Supervise learning was improved due to reduction in bias in run time and this was possible due to introduction of boosting algorithms [10]. The working is briefly explained in [11].

In 1997Sepp HochreiterJurgen Schmidhuberdescribed a neural network model named LSTM i.e., Long Short-Term Memory. Most of the current speech recognition training is done via this deep learning technique. But in around 2007 this technique started outperforming in traditional speech programs. And back in 2015 Google introduced its speech recognition program using CTC-trained LSTM which help to increase the performance by 49 percent [12].

In 1995 face recognition algorithms were introduced but they were not that accurate. In 2006 National Institute of Standard and Technology conducted a Face Recognition Grand Challengewhich helped to develop great algorithms and the findings said that the algorithms were 100 times accurate that in 1995 and 10 time accurate that in 2002 [13]. Google in 2012 developed algorithms and program that can

autonomously search for videos containing cats. In 2014 Facebook evolved Deep Face algorithms which was able to recognize individual face as accurately as a human can.

3 Working of Machine Learning :-

Mainly there are four major steps that include in any machine learning model or application. These are as following [14]:

Step1) Selecting and Preparing a Training Data Set – Every machine learning model requires a data set related to the problem it is designed to solve. A training data set can be of two types unlabeled data set and labeled data set. The labeled data set comes withtags like name, colour, weight etc. but unlabeled data set has no such tag [15]. In both cases the data set is divided in two subsets evaluation subset for refining and testing purpose and training subset used for training of model. The data dets must be check for imbalances, de-duped, randomized to avoid any kind of biasness which may affect the model performance.

Step 2) Selecting Algorithm to Run on The Training Data Set – Every model runs on a dedicated algorithm which we need to choose on the basis of amount, type of data (labeled or unlabeled) and on the type of problem. Common algorithms for labeled data dets are Decision tree, Regression algorithm, Instance bases algorithm. And common algorithms for unlabeled data sets are Association algorithms, Neural Networks, Clustering Algorithms.

Step 3) Training Algorithm to Create Model – This is an iterative process. It includes adjusting weights and biases, comparing output with the expected result, running variables through algorithms until it returns correct results. These all process are repeatedly done to maximize the accuracy of the model.

Step 4) Using and Upgrading the Model – This is the final step, and it includes using the model with new and updated sets of data. This helps to improve the usefulness and accuracy over time. For example, a room cleaner robot continuously updates the data in respect to real world changes like change in room, adding things in room, removing any stuff. And in case of fraud mail detections, it takes the data of the messages and mail id. So, every data set need to be updated according to the required results.

4 Histories of Prosthetics:-

Long way back in around 950-710 B.C.E was the first ever prosthetic found. It was not any arm or a leg but a big toe which belonged to a noblewoman in Egypt as shown in figure 1 [16]. The toe does not seem to be such important prosthetic but 3000 years back it was very important for the Egyptians as it was necessary for wearing of traditional Egyptian sandals[17]. In ancient roman the most famous documented prosthetic wearer is General Marcus Sergius. Second Punic War led to loss of his right hand and then he was given a fully ironed prosthetic limb.

Figure 1:First Prosthetic - A Toe [16]

In 1500s -1800s not much advancement was made in the department of prosthetics. Same old fashioned iron limbs with no function were made for the sufferers. But doctorAmbroise Pare made remarkable proceed in both prosthetic limbs and amputation surgery[17-21]. He made great advancement such as locking knee joint leg and hinged prosthetic hand. He was the first one to do so. Amputation surgery development helped the doctors to design more receptive residual limb to the attachment portion.

From 1861 - 1865 American Civil War took place which led to substantial growth in the count of amputees. Which steer the demand in the field of prosthetics. A confederate soldier James Hanger was the earliest sufferer, and he innovated a prosthetic leg made of metal and barrel staves and named it as "Hanger Limb" as seen in figure 2[22]. This was the most advanced leg of that time imposed with a hinge joint at ankle and at the knee [17-21]. The company he founded is leader in industry today.

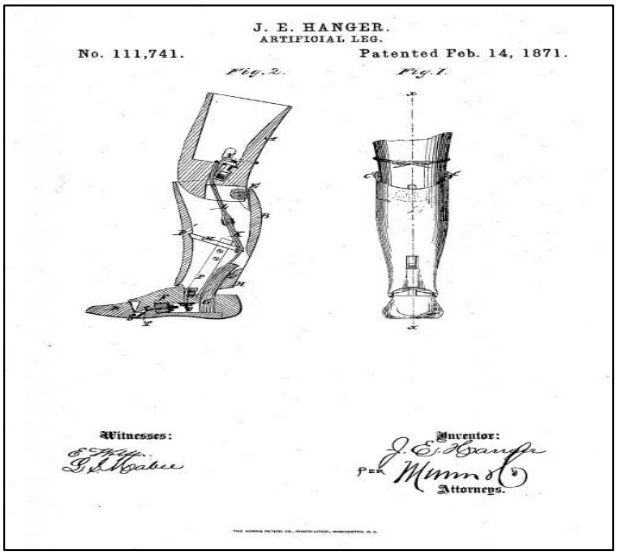

Figure 2: J.E Hanger Artificial Leg Design [22]

Ysidro M. Martinez came up with great inventions in 1970's with a great impact in the history of prosthetics. He succeeds in creating a lower limb prosthetics which was better at gait and minimizing friction instead of duplicating the motion of natural limb. This made the walking smoother, relived the pressure, and upgraded the lives of many future users[17-21].

Today the advancement in technology has led the world of prosthetics to another level. Technologies like 3D printing, Biometrics, X-ray, ECG, EEG, EMG, Myoelectric technology, Machine Learning and A.I. The unique 3D technology is used to design beautiful, light weight, tough, and perfectly fitting prosthetics after scanning and doing various x-rays of the limb structure of the person. The prosthetics uses the electric signals as our other body parts do to various tasks. Myoelectric technology takes place here. It catches the electric signal from the tip of the residual limb with the help of electrodes to further control the movement of prosthetic parts like fingers, wrist etc. Machine learning algorithms plays the next part. With the help of self-learning algorithms, the electric signals are identified based on their frequencies and location and then the signals are further transferred to the prosthetics. These algorithms keep the record of past movements and can be improved by making the Machine Learning model learn.

5 Different Types of Prosthetics:-

There are mainly four various types of prosthetics divided on different factors and uses:

5.1 Joint Prosthetics

In human body there are various joints, and each joint is covered by a padding provided by the cartilage. Over the time due to intense movement and pressure the cartilage gets wear down due which the bones start rubbing against each other. This can cause severe movement problem and pain. To cure such problem prosthetics are used to replace damaged joints.As we can see in figure 3[23]. Shoulder, knee, and hip are the major areas where such conditions occur. The shoulder and knee have ball and socket joint. A plastic lined prosthetic is used to replace and functions as an artificial ligament [24,25].

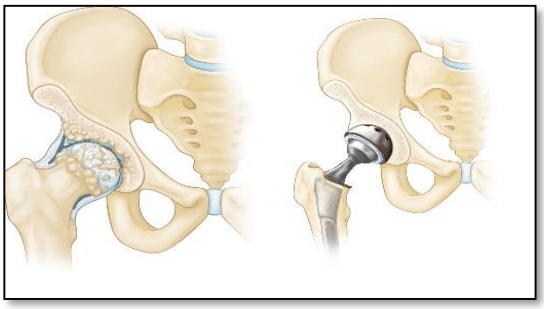

Figure 3: Joint Prosthetic in Hip Joint [23]

5.2 Leg Prosthesis

A missing leg case comes under the leg prosthesis. They are further divided into two parts i.e., transfemoral and transtibial. A transtibial is the case when the missing parts of the leg are below the knee. Transfemoral is used when the whole leg is missing, and the prosthetics are attached to the thigh or the hip joint. Transfemoral prosthesis are more complex compared to transtibial as it includes knee joint as well as in figure 4[26]. A leg prosthesis contains several componentssuch as sockets, foot ankle, shank, suspensions, knee joint etc[24,25]. Foot ankles help to get dynamic response, shank gives the support to the lower portion of the leg, socket evenly distributes the pressure to every portion of the leg. The category of prosthetics to be used depends upon the persons use, occupation, financial resources, leg structure, functionality etc.

Figure 4: Leg Prosthetics Sample [26]

Table 1: List of Knee Joint Technologies Based on The Literature Review [27]

Name of technology (Country of origin)	Brief Description	Highest level of evidence
Not known (New Zealand)	Rotomoulded singleaxis	Field
SATHI friction knee (India)	Weight-activated friction	Limited data available
POF/OTRC knee (USA)	Single axis with ext. assist	Field
Friction knee (USA)	Weight-activated friction	Technical development
LIMBS international M1 knee (USA)	Four-bar	Field
Jaipur Knee (INDIA)	Fourbar	Field
ICRC knee (Switzerland)	Single axis with manual lock	Independent field
DAV/Seattle knee (USA)	Compliant polycentric	Field
ATLAS knee (UK)	Weight-activated friction	Independent field
None provided (Nepal)	Single axis	Field
Wedge lock knee (Australia)	Weight-activated friction	Technical development
Not known (INDIA)	Sixbar with squatting	Technical development
LCKnee (Canada)	Single axis with automatic lock	Field

5.3 Arm Prosthesis

Arm Prosthesis deals with the situation when any part of the arm is missing either big or small. Like leg prosthesis they are also divided into two parts i.e., transhumeral and transradial. Transradial prosthetics are for the damaged part below the elbow. And if the elbowitself is missing then we use transhumeral prosthesis [24,25].Missing elbow makes transhumeral more complex for operating. These are attached to the shoulder of the amputee or the remaining part of the arm above elbow.Design of arm prosthetic is in figure 5 [28].

Figure 5: Arm Prosthetics Design [28]

5.4 Cosmetic Prosthesis

Many a times prosthetics are used just for the sake of better appearance instead of using their functionality. For such cases cosmetic prosthesis are developed. They are almost indistinguishable from the real body parts. They do not help to enhance any function but enhances looks. For example, plastic or silicon hand, feet, toes, fingers, breasts, artificial eye etc[25].

6 Advantages of Using Prosthetics:-

Prosthetics has always been a boon for the amputees. It helped millions of amputees to regain the sense of functioning, gain their confidence and gave the hope of living. According to a survey in 2011 the number of hours of using the prosthetics escalated from 56 to 101 hours/week. Even the walking speed escalated by 32% and the energy consumption for walking decreased by 18%[29].

Lot more advantages come with the use of prosthetics. Like improved quality life, longer walking distances, full range of joint movements, safer and stable standing and sitting. Prosthetics also helps to do the everyday chaos like grasping item, running, holding, pulling, pushing, sitting etc[29,31]. Prosthetic legs help to make moves without the wheelchair.

7 Limitations of Prosthetics:-

Everything has some positives as well as some negatives. Same is the case with prosthetics. Prosthetics are not made for everybody. In spite of high-tech equipment's, we fail to remove low tech problems. Abundant problems like heat rash, increased skin temperature, blisters, abrasions, contact dermatitis, and painful ingrowth hairs.The weight of the prosthesis tied along with the remaining part of limb may cause severe issues[31,32,33]. Skin issues can easily grow into dangerous fungal infections if not treated properly and on time. These can even lead to death scenarios in some cases.

Bulbous at end of limb, neoplasia, chronic swelling are the problems caused due to hanging of the prosthetics. In upper limb amputees the prosthetics is always in a hanging position and in lower limb amputees the prosthetics hang when the movement is to be made like walking with one leg and the other. Due to this movement and hanging of prosthetics a slight vacuum gets created at the tip of the limb mostly with pin and shutter lock liners which causes all these complicationsas shown in figure 6 [30,31,33].

There are lot more disadvantages of using prosthetics as of full time use like Poor Balance, Fear of Falling, General Fatigue, Skin issues and Irritations, Back Pain, Instability, Prosthetics not meeting the needs, Discomfort, Socket Issues, Sensor Issues, Intact Limb Pain but with advancement in technology these issues are slowly being resolved[31-33].

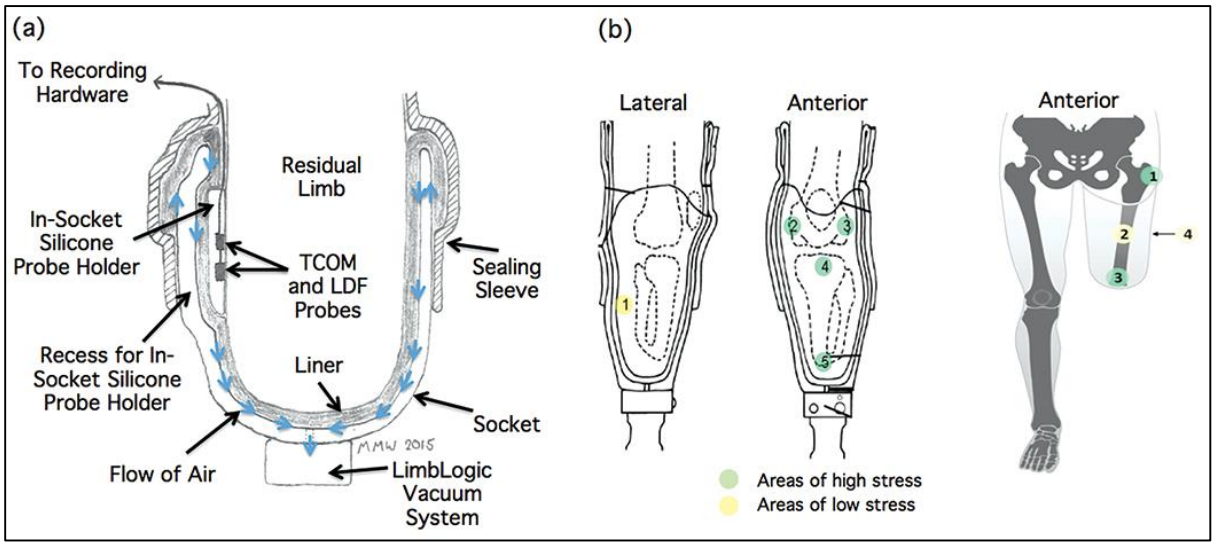

Figure 6: Leg Prosthetics Design and Area of High Stress [30]

8 Current Growing Technology of Prosthetics – Myoelectric Technology:-

Myoelectric technology is the latest on-going advancement in field of prosthetics especially for upper limb amputees. In Greek Myo means muscle. The technology is totally electricity driven full of electrodes, circuits, motors, and algorithms. Myoelectric-controlled prosthetics are the best mimic and best alternative to a real human hand. It contains everything and every movement a human hand can make. It has elbow that can bend, wrist that can twist, fingers that can open or close. It is basically an external powered man-made limb that works with the signals received form the brain for the movements [34-36].

EMG i.e., electromyographic is used in working of myoelectric. A myoelectric prosthetics uses EMG signals. Surface electrodes places on the edge of limb uses EMG signals produced due to muscle movement. Each prosthetic joint comes in motion due to a dedicated electromechanical actuator which receives signals from an electrode placed over each muscle site. Due to this combination every pair of hostile muscle independently control single motion of prosthetics [34-36]. Basic diagram shown in figure 7 [37].

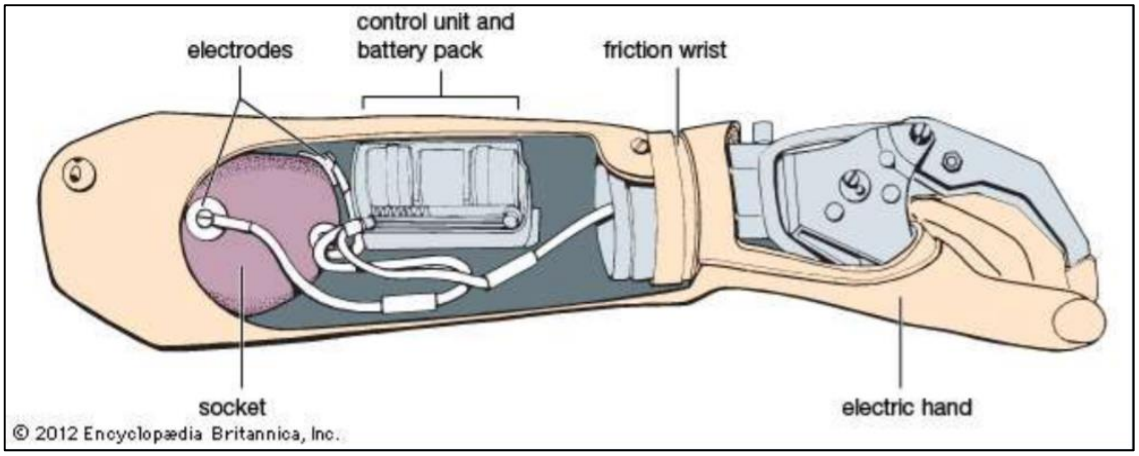

Figure 7: Basic Model of Myoelectric Limb [37]

Myoelectric prosthetics are not easily adaptable by everyone. It requires a period of time to comfortably synchronize with the motions and to control the griping and moving power. An occupational therapist or a prosthetist is required to get the training. It involves mainly three stages of training later discussed in the paper [34-36].

8.1 Working of Myoelectric Prosthetics

The main component of the myoelectric prosthetic are electrodes that are placed at the end of the residual limb and this point is referred as "control site". In a simple myoelectric a single site control is available, and this prosthetic is known as "cookie crusher" and this is for small children. When the child grows and is ready to handle more complex prosthetic the cookie crusher is replaced with two control site prosthetics. In this one control site is responsible for opening hand and the other is responsible for closing hand.

The prosthetics also comes with a feature of "proportional control". This feature helps to decide how fast or how slow amputee wants to open or close the hand. It also helps with the gripping part. Suppose the person wants to hold a book then he/she requires a tight and tough grip to counter the weight but if he/she wants to hold an egg then the grip must be gentle that it keeps a balance between not breaking the egg and even not letting it fall down.

To understand the working we need to know how the natural hand move. If we want to move any finger than our brain sends an electric signal till the tip of the finger, but when a hand gets cut suppose from above the elbow, the signal will still travel but to the tip of the limb left. After this comes the action of myoelectric arm.

The prosthetics socket is attached with the electrodes that receives the electric signal from the limb. The electric signals vary according to the movement desired to make. E.g., electric signal to move all 5 fingers might be high as compared to a single finger movement. These all-signals frequency and strength decides the speed, force, and strength of the overall movement of the hand. Figure 8 shows the basic working[38].

Once the signals are received via electrodes they are further transmitted to the controller. The controller is programmed to command the motors to rotate at a specific angle with specific speed. This is further supported with machine learning algorithms which help to improve the movement on the feedback of past movements. The whole arm is powered with an external battery source which is rechargeable and removable. The motors are attached with the prosthetic parts of the arm like fingers and wrist which we are able to see. This how the overall movement of the hand prosthetics takes place.

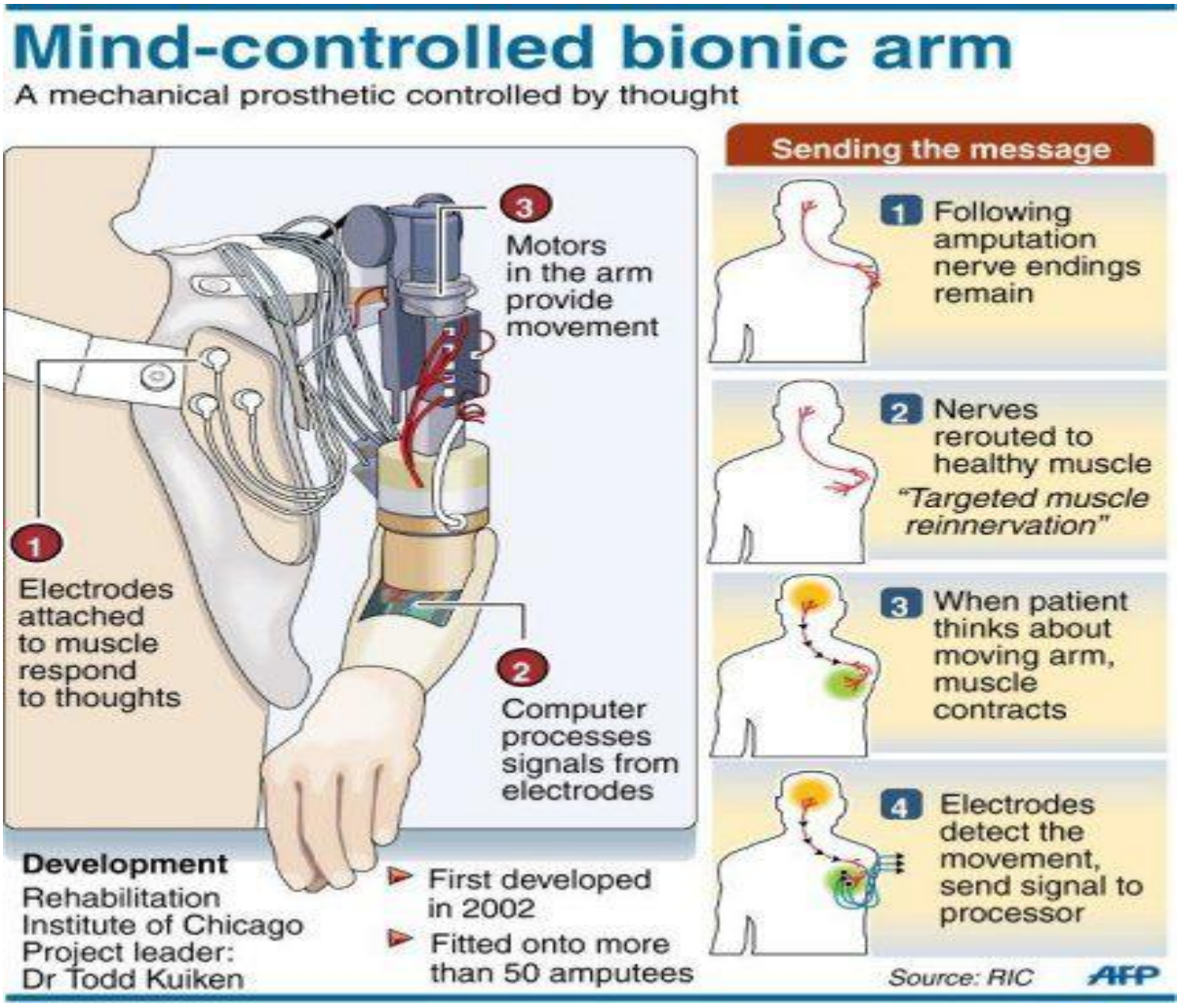

Figure 8: Stepwise working of Myoelectric [38]

8.2 Three Phases of Training

Training becomes important when an amputee is fitted with a myoelectric limb for the first time. This helps the amputee to gain control and increase confidence [34].

8.2.1 Signal Training

In this the amputee is made to learn to have control over the signals made by the movement of the muscles. In this they learn to send and activate muscles on their will and hold back the unwanted movements. The position of the electrodes is changed multiple times to let it fit on the perfect muscle and make the right movement.

8.2.2 Control Training

This training mainly focuses on muscle movement and on the force exerted. This can be done via various methods like for children a toy train may move forward when a particular muscle is moved and move

backward with other muscle. Objects with different size, weight, textures, and shapes are used to train the amputee.

8.2.3 Functional Training

This is the last and most intense phase of training. This might take two weeks to two months depending upon the amputees. This training helps to make an amputee a professional prosthetic user which can do any task as a normal human hand can. It makes the amputee adaptable to the prosthetics. This training includes more complex activities like solving puzzles, placing objects at place and a lot more.

9 Related Work of Machine Learning and Prosthetics:-

Different models are used for the design and working of prosthetic devices. In [39] the author has proposed set of evolving TSK fuzzy models of nonlinear dynamic mechanism which take place in Myoelectric prosthetics. The author has described about fuzzy models and fuzzy decision tree in paper [40,41].

In [42], authors have done various experiments with a goal to compare two switching techniques i.e., adaptive control and non-adaptive control for controlling Myoelectric. The results indicated that the adaptive control method decreased the number of switches and cognitive load by amputee as compared to the other method. They concluded that control interface of myoelectric arm was successful via real time prediction learning.

In[43] the authors have used machine learning for classifying prosthetic types via using conventional giant analysis. The conclusion says that support vector machine learning provides substantial potential with combined usage incorporation such as force plates. It also concludes the magnitude to smoothen the acuity for the reestablishment process for an amputee with amputation in a highly self-operational context. It says the ability to advance the devices is high with the help of machine learning.

In[44] the authors have enhanced the performance of Independent Component Analysis in myoelectric signals. The results shows that fusion of network weights and mixing matrixto classify the sEMG recordings in almost real-time. Recognizing multiple subtle gestures from a single muscle may be possible with little advancement in signal processing.

Breast cancer is growing on an exponential rate which led to removal of breasts. In [45] the author has done a study on diagnosis on diabetes and breast cancer using hybrid feature selection. In [46] the author has done a survey on breast prosthetics and the reaction of women on using them on regular basis.

10. Conclusion and Future Scope:-

Engineers, Scientists, and doctors have already done a lot in the field of prosthetics. But as we know there is nothing like perfect device. Every device, machine needs an upgrade over a period to make itself best in the era. “THE MAGIC TOUCH”. It is the new advancement in the field of prosthetics.

Till now we can make prosthetics which can be controlled by our brain instructions. Our brain sends millions of signals to the end of missing part and from them with the help of electrodes we catch the signals and further decode the actions of prosthetics with the help of algorithms running behind.

A team of researchers at University of Chicago is directing a project to establish a sense of touch to the latest prosthetics. The feeling of touch and sensation has always been very necessary for human body. Adding sensory feedback is not an easy task in already a very complex working neuroprosthetic system.

But adding a touch not just only metamorphose the lives of amputees but also help the people with paralysis.

On an average 30 million plus people require prosthetics and the number increases by 3,700,000 per year. The prosthetics have developed exponentially over a short period of time. The major reason to increasing number of amputees is due to diabetes and cancer related amputation. The growth of limb prosthetic market is due to third party insurances reimbursement.

New and advance technologies like myoelectric, neuroprosthetic have turned dream of many into reality and took the whole world of prosthetics on another level. The use of machine learning has significantly increased in development of prosthetics. With the help of various advance machine learning models, the prosthetics are made more exact to the real limb and can easily copy the similar movement of a real arm.

REFERENCES:-

1) Facts about limb loss. https://www.sralab.org/research/labs/bionic-medicine/news/facts-about-limb-loss (Accessed 28th May 2021)
2)Amputation.https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/amputation (Accessed 28th May 2021)
3)Jain, D., & Singh, V. (2018). Feature selection and classification systems for chronic disease prediction: A review. Egyptian Informatics Journal, 19(3), 179-189.
4) Jain, D., & Singh, V. (2019). A two-phase hybrid approach using feature selection and adaptive SVM for chronic disease classification. International Journal of Computers and Applications, 1-13.
5) Atzori, M., Cognolato, M., & Müller, H. (2016). Deep learning with convolutional neural networks applied to electromyography data: A resource for the classification of movements for prosthetic hands. *Frontiers in neurorobotics*, *10*, 9.
6) How many neurons are in brain? https://www.verywellmind.com/how-many-neurons-are-in-the-brain-2794889 (Accessed 30th May 2021)
7) Geethanjali, P. (2016). Myoelectric control of prosthetic hands: state-of-the-art review. *Medical Devices (Auckland, NZ)*, *9*, 247.
8) Pillet, J., &Didierjean-Pillet, A. (2001). Aesthetic hand prosthesis: gadget or therapy? Presentation of a new classification. *The Journal of Hand Surgery: British & European Volume*, *26*(6), 523-528.
9) Electrocardiography. https://en.wikipedia.org/wiki/Electrocardiography (Accessed 30th May 2021)
10) Ray, S. (2015). Quick Introduction to Boosting Algorithms in Machine Learning. *Quick Guide to Boosting Algorithms in Machine Learning, https://www. analyticavidhya. com/blog/2015/11/quick-introduction-boosting-algorithms-machine-learning/(Sep. 25, 2019)*.
11) A brief history of Machine Learning. https://www.dataversity.net/a-brief-history-of-machine-learning/ (Accessed 2nd June 2021)
12) Apple details how the HomePod uses machine learning to ignore noisy surroundings for Siri requests.https://9to5mac.com/2018/12/03/homepod-machine-learning-siri-speech-recognition/ (Accessed 3rd June 2021)
13) Face recognition grand challenge. https://www.nist.gov/programs-projects/face-recognition-grand-challenge-frgc (Accessed 3rd June 2021)
14) Machine Learning. https://www.ibm.com/in-en/cloud/learn/machine-learning (Accessed 3rd June 2021)
15) Types of Machine Learning. https://livebook.manning.com/book/grokking-machine-learning/2-1-what-is-the-difference-between-labelled-and-unlabelled-data-/v-4/1 (Accessed 4th June 2021)

16)The History of Prostheticshttps://unyq.com/wp-content/uploads/2015/09/cairo-toe.jpg(Accessed 4th June 2021)
17) The History of Prosthetics. https://unyq.com/the-history-of-prosthetics/ (Accessed 4th June 2021)
18) Prosthetics. https://en.wikipedia.org/wiki/Prosthesis (Accessed 4th June 2021)
19) The Future of Prosthetics depends on A.I. https://medicalfuturist.com/the-future-of-prosthetics-depends-on-a-i/ (Accessed 5th June 2021)
20)Zuo, K. J., & Olson, J. L. (2014). The evolution of functional hand replacement: From iron prostheses to hand transplantation. *Plastic Surgery*, *22*(1), 44-51.
21) Finch, J. (2011). The ancient origins of prosthetic medicine. *The Lancet*, *377*(9765), 548-549.
22) The History of Prostheticshttps://unyq.com/wp-content/uploads/2015/09/Hanger-Patent-Diagram-653x1024.jpg
23) Joint Prosthetics https://www.google.com/search?q=joint+prosthesis&sxsrf=ALeKk03btqDSyofhBCjfEkv6Ohyq82XZ2w:1625314701536&source=lnms&tbm=isch&sa=X&ved=2ahUKEwizibuL8cbxAhWdzTgGHXmcBIkQ_AUoAXoECAEQAw&biw=1280&bih=577&dpr=1.5#imgrc=i1kz_2Sr63U2eM
24)Whatare the four types of prosthetics? https://www.touchstonerehabilitation.com/blog/what-are-the-four-types-of-prosthetics (Accessed 7th June 2021)
25) What are the different types of prosthetics? https://livehealthy.chron.com/different-types-prosthetics-1244.html (Accessed 7th June 2021)
26) Leg Prosthetics https://www.google.com/search?q=leg+prosthesis&tbm=isch&ved=2ahUKEwizt6qM8cbxAhUEFnIKHe0wDYgQ2-cCegQIABAA&oq=leg+prosthesis&gs_lcp=CgNpbWcQAzIECCMQJzIECCMQJzIECAAQQzIECAAQQzICCAAyAggAMgIIADIGCAAQBxAeMgYIABAHEB4yCAgAEAcQBRAeUMaoBFjirQRg_K4EaABwAHgAgAHfAogBuQWSAQcwLjEuMS4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=j1XgYPOzFYSsyAPt4bTACA&bih=577&biw=1280#imgrc=j2zCLQ4NtN_2kM
27)Andrysek, J. (2010). Lower-limb prosthetic technologies in the developing world: A review of literature from 1994–2010. *Prosthetics and orthotics international*, *34*(4), 378-398.
28) The Guy who Invented the Segway Made a Mind-controlled Prosthetics arm that really workshttps://www.businessinsider.in/science/health/the-guy-who-invented-the-segway-made-a-mind-controlled-prosthetic-arm-that-really-works/articleshow/35028100.cms
29) Prosthetics. https://advantagepo.com/prosthetics/ (Accessed 8th June 2021)
30) Roy, S., Mathew-Steiner, S. S., & Sen, C. K. (2019). Residual Limb Health and Prosthetics. In *Prosthesis*. IntechOpen.
31) Advantage and Disadvantages Osseointegration. https://www.radboudumc.nl/en/patientenzorg/behandelingen/osseointegration/advantages-and-disadvantages (Accessed 9th June 2021)
32) Common Prosthetic Issues. https://mcopro.com/amputee-resources/common-prosthetic-issues/ (Accessed 10th June 2021)
33) What are some of the long-term effects of not using prosthetics? https://www.amputee-coalition.org/resources/long-term-physical-effects/ (Accessed 11th June 2021)
34) Myoelectric Arm. https://www.waramps.ca/pdf/english-site/ways-we-help/artificial-limbs-and-devices/upper-limb/myoelectric-arms.pdf (Accessed 12th June 2021)

35) Myoelectric Prosthetics 101. https://www.ottobockus.com/prosthetics/info-for-new-amputees/prosthetics-101/myoelectric-prosthetics-101/ (Accessed 16th June 2021)
36) Myoelectric Prosthetics. https://www.slideshare.net/SreetamaDas2/myoelectric-prosthesis?from_action=save (Accessed 20th June 2021)
37) Myoelectric Prosthetics https://www.slideshare.net/SreetamaDas2/myoelectric-prosthesis
38) Wonders of Scientific Research: Mind-controlled Bionic Arm Now a Reality https://steemit.com/steemstem/@eurogee/wonders-of-scientific-research-mind-controlled-bionic-arm-now-a-reality
39)R. Precup, T. Teban, T. E. A. d. Oliveira and E. M. Petriu, "Evolving fuzzy models for myoelectric-based control of a prosthetic hand," 2016 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 2016, pp. 72-77, doi: 10.1109/FUZZ-IEEE.2016.7737670.40) Anuradha, D., & Gupta, G. (2015). Fuzzy decision tree construction in crisp scenario through fuzzified trapezoidal membership function. Internetw. Indones. J, 7(2), 21-28.
41)Dhull, A., & Gupta, G. (2018). An Intelligent Two-Phase Fuzzy Decision Tree Based Clustering Model for Design of Computer Aided Detection/Diagnosis (CADe/CADx) System. MAPAN, 33(1), 63-75.
42)Edwards, A. L., Dawson, M. R., Hebert, J. S., Sherstan, C., Sutton, R. S., Chan, K. M., &Pilarski, P. M. (2016). Application of real-time machine learning to myoelectric prosthesis control: A case series in adaptive switching. *Prosthetics and orthotics international*, *40*(5), 573-581.
43)LeMoyne, R., Mastroianni, T., Hessel, A., & Nishikawa, K. (2015, August). Implementation of machine learning for classifying prosthesis type through conventional gait analysis. In *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 202-205). IEEE.
44)Naik, G. R., & Kumar, D. K. (2010). Hybrid feature selection for myoelectric signal classification using MICA. *Journal of Electrical Engineering*, 93-99.
45)Jain, D., & Singh, V. (2018, December). Diagnosis of Breast Cancer and Diabetes using Hybrid Feature Selection Method. In 2018 Fifth International Conference on Parallel, Distributed and Grid Computing (PDGC) (pp. 64-69). IEEE.
46) Roberts, S., Livingston, P., White, V., & Gibbs, A. (2003). External breast prosthesis use: Experiences and views of women with breast cancer, breast care nurses, and prosthesis fitters. *Cancer nursing*, *26*(3), 179-186.
47) The magic touch: bringing sensory feedback to brain-controlled prosthetics. https://www.medicaldevice-network.com/features/future-prosthetics/ (Accessed 23rd June 2021)