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An Imitating Device for Assisting Trans-Radial Amputees using Gestures

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Abstract

A prosthetic arm is an artificial device which mainly focuses on mimicking the functioning and activities of the human forearm for facilitation of their Activities of Daily Living (ADLs). This paper aims to capture the hand gesture or representation actions to actuate the prosthetic limb of trans-radial amputees. The approach mainly focuses on the hand gesture of contralateral arm, instead of physiological signals. The two phases involved in this process include gesture sensing phase and motion phase. Initially, during the gesture sensing phase, images are captured using proximity sensor and orientation sensor of 1SHEELD mobile application. This tracks the motion and gesture of the contralateral arm. Motion phase includes servo motors which are controlled by Arduino UNO using Embedded C codes. Once a particular gesture is captured, the input signals are given to 1SHEELD+ board where template matching and gesture recognition takes place through predefined algorithms. After successful gesture recognition, the servo motors are driven by Arduino UNO Microcontroller. This initiates movement in the prosthetic limb. The major theme of the paper is to provide an affordable and easily operable device for the ease of convenience of the trans-radial amputees. This helps the amputees to carry out their day-to-day activities by themselves in a sustainable manner. Antecedent to this approach, they have used software coding to track the articulations of hand and finger for supporting the motions of robotic arm, which is attached to the exoskeletal structure of the human hand. In our proposed methodology, we use 1SHEELD+ board for inducing movements in trans-radial amputees.

Keywords: *Prosthetic Arm, Trans-Radial Amputees, 1SHEELD+ board, Proximity, Contralateral, Activities of Daily Living.*

1. INTRODUCTION

For the past 5 years, several technical advancements have been introduced in prostheses or prosthetic implants [1]. These devices are used for replacing the missing limb of patients, which is lost by congenital defect (birth), illness, trauma or accident. Prosthetics can be designed either by hand or with software interface that creates a 2D or 3D graphical structure of the arm. The factors which are primarily considered during design of prosthesis are appearance and functional needs of a person. Cosmesis (life-like limb that is made from either Silicone or Poly Vinyl Chloride) is another type of prosthesis, which is purely designed for its use in cosmetic applications, having very little or no functions. Such prosthesis is designed to mimic the functions of the lost limb. They are attached to the body by suction, adhesion or

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skin sleeve, whereas, other prosthesis has high functionality and very low cosmetic effects upon the human body. They are designed to be covered by artificial skin or fabrics. Prosthesis enables the amputated patients to carry out various activities such as climbing stairs, swimming, walking, running, etc. Now-a-days, advancements in the prosthetic arm include individual control to specific fingers. This helps in boosting independence and dramatically improving individual's life through technology.

Hand gesture recognition is a way of interpretation of hand gestures by using computer aided algorithms and technology. The four distinct steps which are used in hand gesture recognition in accordance with the existing proposals are: Image Frame Acquisition, Hand Tracking, Feature Extraction and classification of hand gestures [2]. Several methods are adapted for hand gesture acquisition using various tools for capturing and recording of real-time based images in databases. One such method, for image capturing uses vision-based hand gesture recognition technique. In some cases, along with vision-based gesture recognition technique, they have used data gloves with flex sensors for rendering images. But comparatively vision-based techniques have added advantages of stability and reliability [3]. For increasing the precision grips in prosthetic fingers leap motion controllers have been incorporated along with gyroscopes and flex sensors therefore helping to act effectively in soft touch applications [4]. In order to fetch the static hand gestures from captured images, RGB cameras and depth data are used [5].

A Kinect based direct acquisition techniques are utilized for dynamic hand gesture recognition processes which uses depth cameras for image capturing of real-time gestures [6]. Using a 24 gigahertz Radar sensor, it is possible to record the hand gesture signals for Human Computer Interaction [7]. Hand tracking process is the method by which the computer can differentiate the user's motion and gestures from the surrounding objects. This can be performed with the help of Multi-scale colour feature hierarchies that uses a variety of colour shades that helps in differentiation of user's hand from the surrounding background objects [8]. Feature Extraction is applied using discrete Fourier transform operations. The input data is obtained using from a webcam and then image processing is followed. Principle component Analysis is used in extraction of featured hand images proves to reduce dimensionality [9]. The features extracted are to be tested and trained with the help of appropriate classification algorithms like KNN, SVM, ANN. Deep convolutional neural network is one of the methods adapted for classification of gestures [10]. KNN classifier is far superior compared to SVM classifier in terms of accuracy [11]. Linear Discriminant Analysis is the best classifier out of all others [12].

Limb prosthesis is further divided into two sub categories which include upper as and lower extremity prosthesis [13]. The varied levels of upper extremity prosthesis include forequarter, elbow disarticulation, full hand, shoulder disarticulation, trans-radial prosthesis, partial finger and wrist disarticulation [14]. The different types of upper limb prosthesis include passive devices, body power devices, externally powered or myoelectric devices [15]. Passive devices or passive tools are used for specific activities (vocational or leisure). They are adjustable in nature. They do not have any grasping or orientation operations but are useful in bimanual tasks (fixation or support of objects). Body powered or cable operated limbs have wired connections between the artificial limb and the human body [16]. Myoelectric arms sense the muscle signals via electromyography surface electrodes and replicate the motions of the human arm. Trans-radial amputation, also called below arm amputation occurs at some point along the radial bone [17]. Recovery of such amputations is easy after surgery and these patients will continue to use the artificial arm more likely in their daily life. The main reason behind trans-radial amputation is either accident or trauma. In this case the radius and ulna bones are shattered or broken beyond repair [18]. People around 20 to 40 years are prone to trans-radial amputation. But compared to elderly patients, their recovery is fast.The recovery time depends on the healing capacity of the limb after surgery. In some cases, some patients receive temporary prosthesis two to three weeks after surgery. Permanent prosthetic fitting begins usually six to eight months after surgery [19].

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This paper mainly concentrates upon capturing the hand gesture or representation actions to actuate the prosthetic limb of trans-radial amputees. Initially, gesture sensing is done with the help of proximity sensor and orientation sensor available at the 1SHEELD mobile application [20]. Four servo motors are utilized in this process out of which three servos are used by orientation sensors and the remaining one servo is used by proximity sensor. For the establishment of communication between the Smart phones and the Prosthetic Device, we use a unique board called 1SHEELD+ board [21]. Therefore, through this proposed method, we can control the prosthetic arm easily through single line coding. As there are no physiological signals involved in our proposed method, the prosthetic arm that we design will be of great use for the trans-radial amputees. Also, there is no necessity for making electrode connection in user's body for signal acquisition [22].

2. Related Works

Hand gestures are mainly used for communication purpose to translate the user's intention in the form of hand motions. In Human-Computer Interaction, the users are allowed to communicate with the computer using hand gestures. Interpretation of hand gestures and execution of commands, based upon the understanding got through a specific gesture is an essentialpart of perceptual computing. Earlier methods include hand gesture recognition alone as a part of their work [23]. The significant use of recognized gestures for a particular application is not discussed. Also, they have used vision-based recognition gadgets, web cameras and depth cameras for their role in image frame acquisition of hand gestures. The difficulties in processing of gestures are particularly seen in elimination of background colour from the obtained hand gestures. The hand gesture recognition is noted in many applications, such as robotics, sign language etc. Commonly, gesture recognition is used for controlling robotic arms in virtual based manner and in some other cases; it is used for controlling reality based industrial robots. In our proposed methodology, we use 1SHEELD+ Board for our gesture sensing application and these gestures are used for the manipulation of prosthetic arm in trans-radial amputees.A real- time vision-based hand gesture interaction prototype depends on finger gesture using colour markers. Raspberry Pi is used to identify colour markers on the fingers[3]. The major steps recommended by the authors are: Image acquisition to import hand gestures, extraction of hand gesture area from captured frame, determination of gesture pattern by PCA algorithm and generation of instructions corresponding to matched gesture for specified robotic action. The authors presented a leap motion sensor, which consists of two monochrome cameras with three infrared LEDs generating a 3D dot pattern [24]. The leap motion software detects the movement of the hands and fingers. This software is effectively used to analyse the nature of movement induced in the arm. The authors performed Object recognition by the following steps:

Initially the hand is detected by using skin filtering and palm cropping. The extracted image is then processed using the canny edge detection technique that is used to extract the outline images of the palm. After palm extraction, the hand-features are extracted by KL transform technique and the object is identified [25]. A web camera is used to capture the shoulder arm with in the work volume. Here two reference points are considered and various points are detected in the work area. Depending on the position of finger placed and actuation points, the robot engraves the game path and follows the particular motion in the arm. The construction design and movement are achieved with the help of various controlalgorithms in MATLAB software [26]. A system consisting of three main modules are used which are: Multi-proposal hand region segmentation, hand pose recognition and hand gesture recognition. Prediction of hand poses is done through feature vector computation and the output is given to a multi-class SVM classifier to predict the final hand gesture [27]. Body gestures are recognized using datasets from two different tracking devices. The RGB-depth camera is used to recognize the body posture. These hand gestures are detected, with the help of leap motion sensors [28].

3. PROBLEM STATEMENT

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Amputation drastically changes the functioning and life of the affected person as it proves to be a shortcoming in their life. The change in the aesthetic look undergone by these amputees demotivates them and pulls them back from leading a normal life as before. Moreover, they face a lot of medical problems due to imbalance of their body structure such as instability, fatigue reduced mobility and general patient discomfort. This brings a feeling of hostility and indignation to the amputees thus making them quit their public interactions. A major section of the amputees is troubled by decreased self-esteem, dependency, social isolation and physiological morbidity. It is catastrophic sudden irreversible injury, emotionally affecting the victims. The mental stress and condition of lower limb amputees is harder than upper limbed amputees due to their decreased mobility and locomotory actions. Vascular complication which include diabetes or traumatic accidents serve as one of the cause of amputees. It not only affects the daily activities and performance of the amputees but also their standards of living. Once amputated most patients withdraw from group participation due a feeling of depression and insecurity. This makes them urge for a psychological support. In-order to provide rehabilitation to such amputees and bring them back to normal life prosthetic devices are designed as per their requirements. This not only serves beneficial in providing a moral support but also helps to bring back their normal life without external dependence. Our proposed prosthetic arms allows its beneficiaries in opening and closing their hands and even control their individual finger movements as per their requirement.

4. METHODOLOGY

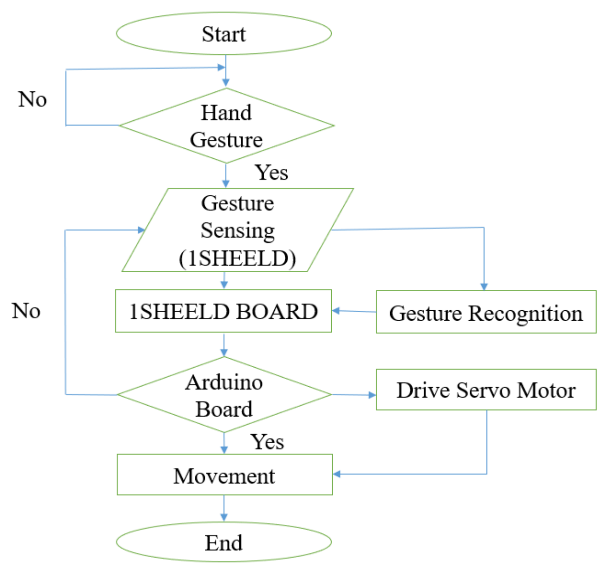

Fig. 1 Flow Diagram

The working principle of the prosthetic arm is demonstrated in the flow chart given below. [**Fig. 1**]By making use of the sensors present in the Android or IOS devices, the 1SHEELD application performs our primary function which is gesture recognition. When a particular gesture is rendered by contralateral arm of the amputees, information pertaining to individual gesture is conveyed to the user accordingly. Likewise, relevant input commands are assigned for the corpus of gestures. This tends to enable a particular movement in the prosthetic arm with reference to the input commands given. To assign these input commands, we use Arduino coding. The 1SHEELD+ board is mounted over the Arduino, which bring forth communication between the 1SHEELD application and Android or IOS devices. The main benefit of using 1SHEELD is that it allows the smartphones to behave as virtual shields for the Arduino Microcontroller. By this approach, we can replace the traditional usage of physiological signals by hand gestures as input. Initially, a peculiar hand gesture is interpreted and this gesture behaves as input to the 1SHEELD board. From this 1SHEELD+ board, these gestures are passed on to the smartphones through

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the 1SHEELD application via Bluetooth 4.0. The 1SHEELD application has numerous shields like proximity sensor, accelerometer, GPS, gyroscope, magnetometer, Toggle Button and so on. For our application, we are concerned with the utility of proximity and orientation sensors respectively. The orientation sensors are used for positioning the objects to specific directions relative to the corresponding points in Cartesian coordinate space. The proximity sensor is mainly used for pick and place applications in our proposed work. Thus, determination of the position of contralateral arm is achieved by orientation sensors and based upon the opening and closing of contralateral human arm, the prosthetic arm is able to perform pick and place operations using proximity sensors. Now the acquired gesture information is fed as input to the Arduino Uno Microcontroller. Predefined Embedded C codes are incorporated to the Arduino Uno Microcontroller for mimicking the hand gestures.

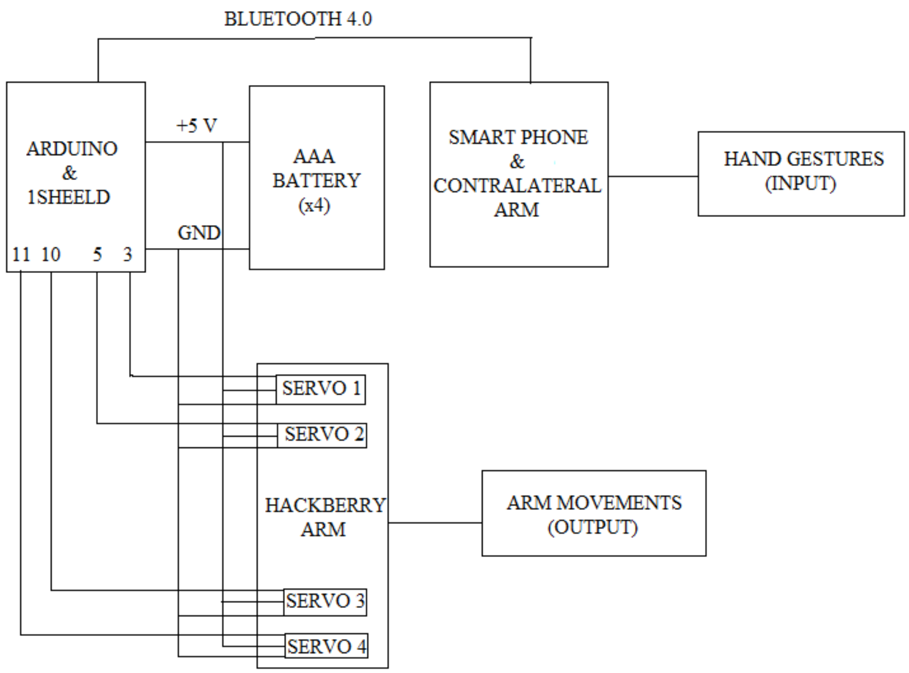

Fig. 2 Circuit Diagram

The microcontroller acts as the central system for movement of attached servo motors in different locations of the prosthetic arm. Four servo motors are used in this case. They are: MG90S micro servos (x2), MG996R servo motor and Futaba S3003 servo motor, among which MG996R servo motor is used for proximity applications while the other servos are used for orientation applications. [**Fig. 2**] Now the Embedded C code comes into action for driving the servos either in clockwise or anticlockwise directions to control the arm movements. In this way, a particular hand gesture is replicated from the contralateral arm of the amputees and is fetched by the prosthetic arm. Moreover, the added advantage of using ISHEELD application is that it uses Bluetooth technology for its application so that the pathway of communication is well-established, secured and free from threatening of hacking. Another benefit is that only one user is allowed to connect with the 1SHEELD application at a time, exclusively, and in case, if many users try to connect simultaneously with the 1SHEELD application, the application acts in accordance with first-in-first-out (FIFO) approach. Thus, the proposed methodology opens the door for a novel means of controlling prosthetic arm through gestures, allowing the trans-radial amputees to get the most benefits out of it.

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The main steps involved in this process are as follows:

1. Power Supply

An external power supply from 4x AAA is required to provide the adequate power supply for the four servos, MG90S micro servos (x2), MG996R servo motor and Futaba S3003 servo motor used in this case.

2. Hackberry Arm Assembly

The 3D Printed Hackberry arm which is used in this case is them assembled with all servos, screws and glue materials, once post processing of the arm using Wetordry polishing paper 1000 is over.

3. Input Gestures

The input gestures from the contralateral hand are captured with the help of the smartphone and 1SHEELD application.

4. Gesture Sensing

These captured gestures are fed to the Arduino Uno microcontroller and 1SHEELD+ board, situated inside the Hackberry Arm, i.e., the opposite arm where we intend to bring the hand motions, in accordance with the gestures introduced from the Contralateral Arm.

5. Motion Deliverance

The motions of the Hackberry Arm rely mainly on the gesture input which is acquired from the Contralateral Arm. The servo motors are connected to the digital pins 3, 5, 10 and 11respectively. These servos are responsible for driving the Hackberry Arm.

6. Precautions to be followed

Before connecting the circuit, disconnect the AAA battery supply connection. Check for the servo functioning prior to the circuit test run. Make sure the 1SHEELD is connected with Arduino Uno and Smartphone in a well-established manner via Bluetooth 4.0 communication. [28]

7. MATLAB simulation - steps to be followed

- Initially we need Robotic System tool box package has to be installed in the MATLAB to do the simulation process.
- This toolbox has to be stored inside the MATLAB drive provided in addition with your MATLAB account.
- Then, the tool has to opened inside the current folder of your MATLAB, where MATLAB files are usually present.
- We have to make sure that every individual file containing the rvc tools of the Robotic System tool box is added to current path or not
- After that, we need to launch these rvc tools, by writing startup_rvc in the command window of the MATLAB.
- After this step, we can write the source code for forward and inverse kinematics actuation of the robotic arm.
- Based on the Theta values (Th_1, Th_2, Th_3), we will be able to get accurate simulation results of the robotic arm.
- Here, the Robotic System tool box is the one that provides the GUI,required for arm simulation.

5. EXPERIMENTAL OUTPUT

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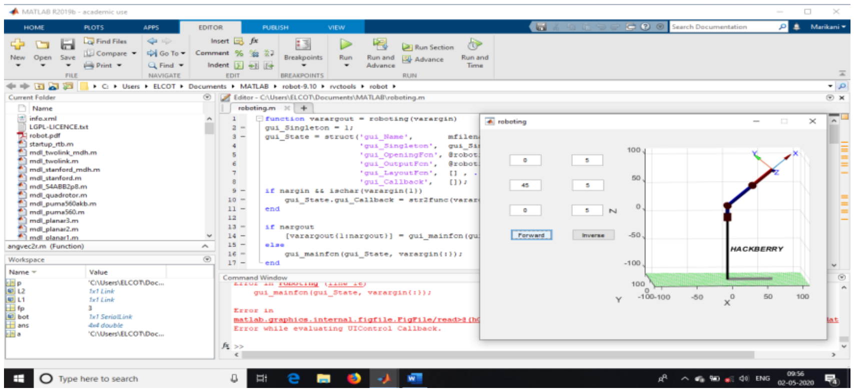

Fig 3 . Forward Kinematics

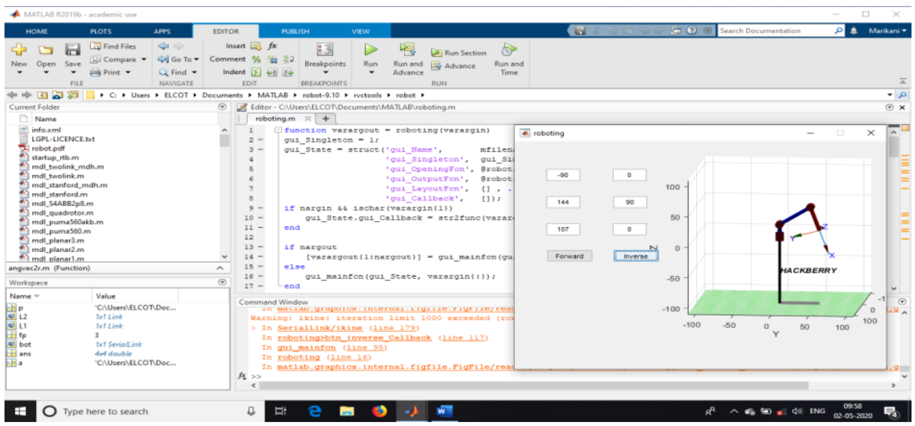

Fig 4. Inverse Kinematics

6. PERFORMANCE ANALYSIS

6.1 ACCURACY

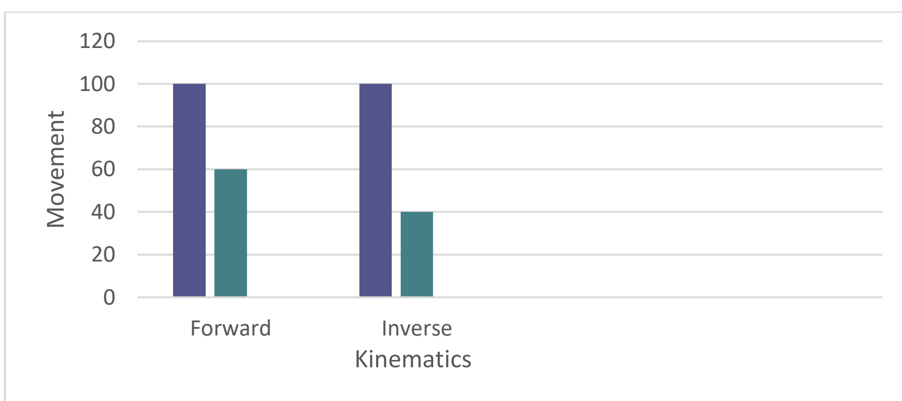

Fig 5. Accuracy Values

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Here, in this case, graph has been plotted in terms of the accuracy of the attached prosthetic device in comparison with the normal arm of the patients. Relation has been plotted between the forward kinematic and inverse kinematics simulation which is carried out in the MATLAB software.

6.2 SENSITIVITY

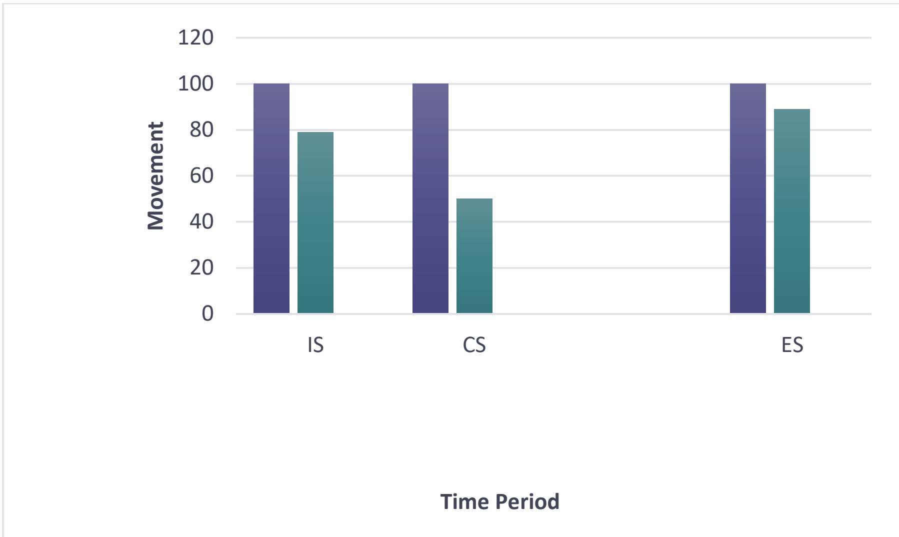

Fig 6. Sensitivity Values

Here, in this case, graph has been plotted between the differences in the sensitivity of initial state changed state which is subjected to change as per the requirement and the final state as the particular motion[27].

7. RESULTS

A simulated form of human arm was successfully designed in MATLAB, bringing out various gestures and motions for the betterment of the amputees, in order to accomplish the basic motions of the body, such as flexion and extension. This project helps in improvisation of quality of life of the amputees in a drastic manner. We used a 3 DOF robot for this case. We typically, studied and analysed the forward and inverse kinematics applied in this process and hence we understood the way how the end effector gets manipulated by the manipulator for different angle values which are in accordance with the orientation sensor values denoted in x, y and z axes respectively. Thus, we were able to design a simulated kind of virtual robotic arm, which would be effectively be useful for the amputees when it comes to existence in its full-fledged prototype format.

8. CONCLUSION

Therefore, through this proposed methodology a particular hand gesture is replicated from the contralateral arm of the amputees which is fetched by the prosthetic arm, through single line coding. As there are no physiological signals involved in our proposed method, the prosthetic arm will prove to be highly effective and efficient for the amputees. Through this method we eliminate the need signal acquisition which is done via electrode connection in user's body. The added advantage is usage of ISHEELD application. It uses Bluetooth technology for its application so that the pathway of communication is well-established, secured and free from hacking. Another benefit is that there is crosstalk between n no of signals if received. The signals are allowed to connect with the 1SHEELD application one at a time, exclusively, and in case, if n users try to connect simultaneously with the 1SHEELD application, the application acts in accordance with first-in-first-out (FIFO) approach. Thus,

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the proposed methodology opens the door for a novel means of controlling prosthetic arm through gestures, allowing the trans-radial amputees to get the utmost benefits out of it and lead a healthy living.

9. FUTURE WORKS

Real time implementation of the project is planned with a biocompatible material such as polylactic acid so that it does not cause any discomfort to the patient. The design of the arm is already developed that has to be printed and assembled as per the requirements of the amputees. A complete device is yet to be developed that's traps the gestures of the contra lateral arm of the amputees and replicates or mimics the particular gesture in the limb attached. We also aim in developing a device which does not contradict with any structural or functional aspects of the human arm, thus providing a enhanced living and better livelihood to the trans radial sections of the amputees. Once successful we would like to extend it towards the trans-humoral sections of the society as well.

REFERENCES

1. J. Ten Kate, G. Smit and P. Breedveld, "3D-printed upper limb prostheses: a review", DisabilRehabil Assist Technol. vol.12 ,no.3 ,(2017),pp. 300-314.
2. C. Ananya, T. Anjan Kumar and S. Kandarpa Kumar, "A Review on vision-based handgesture recognition and applications", IGI Global, vol.11, (2015), pp. 261-286.
3. R.C. Oinam, P. Anushree, S. Spandan and D. Piyanka. "Comparative study for vision-based and data-based hand gesture recognition technique". International Conferenceon Intelligent Communication and Computational Techniques. IEEE. (2017), pp. 26-31.
4. Gunawardane PDSH and Nimali TM. "Comparison of hand gesture inputs of leap motion controller & data glove in to a soft finger". International Symposium on Robotics and Intelligent Sensors (IRIS). IEEE.(2017), pp. 62-68.
5. A .Rytis and L. Arunas,"Robust hand detection using arm segmentation from depth dataand static palm gesture recognition". International Conference on Intelligent DataAcquisition and Advanced Computing Systems: Technology and Applications. IEEE. (2017), pp. 664-667.
6. AK. Atharva and DJ. Apurv, "Dynamic hand gesture recognition using Kinect",Innovations in power and advanced computing technologies (I-PACT). IEEE. (2017), pp. 1-3.
7. S. Alagarsamy, K. Kamatchi, V. Govindaraj, YD. Zhang, A. Thiyagarajan, "Multi-channeled MR brain image segmentation: A new automated approach combining BAT and clustering technique for better identification of heterogeneous tumors" Biocybernetics and Biomedical Engineering,vol.39,no.4,(2019),pp.1005-1035.
8. S.Alagarsamy, K. Kamatchi,V.Govindaraj, A. Thiyagarajan"A fully automated hybrid methodology using Cuckoo-based fuzzy clustering technique for magnetic resonance brain image segmentation", International journal of Imaging systems and technology, vol. 27,no.4, (2017), pp. 317-332.
9. G.Vishnuvarthanan, MP. Rajasekaran, P. Subbaraj, V.Anitha. "An unsupervised learning method with a clustering approach for tumor identification and tissue segmentation in magnetic resonance brain images", Applied Soft Computing, vol. 38,(2016), pp. 190–212.
10. L. Shengchang, H. Zonglong, T. Haoyu, Y. Kai and Y. Wenshuang, " A hand gesturerecognition system based on 24 GHz radars",International symposium on antennasand propagation (ISAP). IEEE.(2017), pp. 1-2.
11. Z. Weiguo, L. Congyi, J. Xin, L. Peng, C. Haoyao andL. Yun-Hui. "Real-time implementation of vision-based unmarked static hand gesture recognition with neural networksbased on FPGAs",International conference on robotics and biomimetics (ROBIO).IEEE. (2017), pp. 1026-1031.
12. TP. Salunke and SD. Bharkad,"Power point control using hand gesture recognitionbased on hog feature extraction and K-NN classification",International conferenceon computing methodologies and communication. IEEE.(2017), pp. 1151-1155.
13. Ibrahim A, Hashim A, Faisal K and Youngwook K. "Hand gesture recognition using input impedance variation of two antennas with transfer learning."Sensors Journal. (2018), pp. 4129-4135.
14. Rania AE, Mohammed SS and Mahmoud IA. "Hand gesture recognition based ondimensionality

ISSN: 2005-4238 IJAST

reduction of histogram of oriented gradients". Japan-Africa conference on electronics, communications and computers JAC-ECC. IEEE.(2017),pp.119-122.
15. Nabeel S, Rosa HM and Chan RHM. "A wearable hand gesture recognition devicebased on acoustic measurements at wrist",International conference of the IEEEengineering in medicine and biology society EMBC. IEEE. (2017), pp. 4443-4446.
16. [16] G. Senthilkumar, K. Gopalakrishnan and V. Sathish Kumar. "Embedded Image capturing system using Raspberry Pi system",International Journal of Emerging Trends & Technology in Computer Science (IJETTCS),vol. 3,no.2,(2014) ,pp. 213-215.
17. [17] JoyeetaSingha and Karen Das. "Hand gesture recognition based on Karhunen-Loeve Transform", Mobile & Embedded Technology International Conference.(2013), pp. 365-371.
18. Jagdish Lal Raheja, RadheyShyam, ArunRajsekhar G and Bhanu Prasad P. " Real-time robotic hand control using hand gestures", Robotic Systems – Applications, Control and Programming. (2012), pp. 413-428.
19. SarmadHameed, Muhammad Ahson Khan, Bhawesh Kumar, ZeeshanArain and MoezulHasan. "Gesture controlled robotic arm using Leap Motion,"Indian Journal of Science and Technology. Vol.10,no45,(2017), pp. 1-7.
20. Jaime Lien, Nicholas Gillian, M. EmreKaragozler, Patrick Amihood, CarstenSchwesig, Erik Olson, Hakim Raja and Ivan Poupyrev. Soli: "Ubiquitous Gesture Sensing with Millimeter Wave Radar " ACM Trans. Graph.Vol.35, no 4, (2015), pp. 1-19.
21. PanagiotaTsarouchi, AthanasiosAthanasatos, Sotiris Makris, XenofonChatzigeorgiou and George Chryssolouris. "High level robot programming using body and hand gestures."Procedia CIRP 55. (2016), pp. 1 – 5.
22. T.G. DandaraA.Andrade, Akari Ishikawa, D. Amparo Munoz and Eric Rohmer. "A Hybrid Approach for the Actuation of Upper Limb Prostheses Based on Computer Vision",Latin American Robotics Symposium (LARS) and Brazilian Symposium on Robotics (SBR). IEEE. (2017), pp. 1-6.
23. SudiptaSaha, AnindaSaha, Zubayr Khalid, Pritam Paul and ShuvamBiswas. "A Machine Learning Framework Using Distinctive Feature Extraction for Hand Gesture Recognition",Advances in Science, Technology and Engineering Systems Journal (ASTESJ).Vol. 3, no,5, (2018),pp. 72-81.
24. M. Neil. J. Bajaj, Adam,P. Spiers, and M.Aaron Dollar. "State of the Art in Artificial Wrists: A Review of Prosthetic and Robotic Wrist Design",IEEE Transactions on Robotics.vol. 35,no1,(2019), pp. 261-277.
25. V. Shiela David, D. Tharun, P. Maheswar Reddy and A.U Mani Vinay, "Hand Gesture Controlling Device",International Journal of Engineering and Advanced Technology (IJEAT). Vol.8, no 4, (2019): 1439-1442.
26. Nilanjan Das, Nikita NagpalandShailee Singh Bankura. A review on the advancements in the field of upper limb prosthesis. Journal of Medical Engineering& Technology. Taylor &Franci, vol.42,no.7,(2018),pp. 532-545.
27. Ghazal Ghazaei, Ali Alameer, Patrick Degenaar, Graham MorganandKianoushNazarpour. "Deep Learning-based Artificial Vision for Grasp Classification in Myoelectric Hands",Journal of Neural Engineering.vol. 14,no.3, (2018),pp. 36025-36043.
28. Rahul GowthamPoola,AniletBala A, Rajesh Peddikuppa and KasireddyMahanth Reddy."Gesture Regulated Animatronic Robotic Hand",International Journal of Pure and Applied Mathematics.vol.120 no.6, (2018), pp. 1335-1346

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