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Towards the Development of a Neuroprosthetic Hand

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Abstract: Prosthetic hand functions as a tool that enables the amputees to perform daily tasks. Instead of just a passive device with acosmetic look current devices come with improved functionality utilizing robotics technology. There are various ways to actuate a prosthetic hand including deploying DC motors, servo, hydraulics, pneumatics, SMA wire and many more. This research presents the conceptual design of a UiTM Neuroprosthetic Hand controlled by Electroencephalography (EEG). EEG signals were recorded from the Motor Cortex through brain wave rhythm at specific locations on the scalp. It involves the development of a graphical user interface to control the robotic hand using the imaginative hand movements of the patient. Analysis will be done until clear rhythmic waves are obtained for the control of the neuroprosthetic hand.

Key words: Brain computer interface, neuroprosthetic, electroencephalography, patient, brain wave

INTRODUCTION

Brain computer interface: The amputee has defined as those who with long-term physical, mental, intellectual or sensory impairments that make it difficult for interact with the community. The lives of the amputees are very challenging in struggling with the disabilities and the self-esteem. The disabilities divided into several groups such as: hearing impairment, lack of vision, physical disabilities, speech Disabilities, learning disabilities, mental disabilities and cerebral palsy. Amputees in Malaysia registered with the Ministry of National Unity and Social Development under the Ministry of Women and Family Development. According to year 2004, about 150,617 people live with amputations and the number has increased in the recent years 2005 about 170,455 people. Out of the number in year 2005, 56,738 are people with the upper limb problem.

Based on the development of modern technology now, various tools can help amputee to improve and increase the ability of human cognitive or sensory-motor functions (Wolpaw *et al*., 2000). This technology is known as Brain Computer Interface (BCI). BCI technology is based on the sense, transmit analyze and apply the language of neurons. BCI is one of the most exciting technologies to explore; it has a bright future for open communication for people who mainly have lost control over their limbs and have difficulty using their muscle to move the armor hand. However, many brain wave rhythm using non-invasive technology as an option for having a great advantage of not exposing the patient to the risks of brain surgery.

Brain Computer Interface (BCI) also known as Brain Machine Interface (BMI) or sometimes called a Direct Neural Interface. A BCI is a direct communication pathway between a brain and an external device. Research and development focused on the use of BCI not only prosthetic hand also opens applications such as controlling a wheelchair (Rebsamen *et al*., 2010; Wang *et al*., 2007), Humanoid Robot (Bryan *et al*., 2011) and Mobile Robot (Millan *et al*., 2004). Neuroposthetic related to the field of neuroscience using neurosignal obtained through the human brain to control the prosthetic device. Between brain wave rhythm of non-Invasive categories such as Electroencephalography (EEG) (Connor, 2013; Shedeed *et al*., 2013), Magnetoencephalogramsm (MEG) (Oishi *et al*., 2003) and functional Magnetic Resonance Imaging (fMRI) (Matthys *et al*., 2009; Schaechter *et al*., 2006).

A complex mechanical BCI system would allow a user to control an external system possibly a prosthetic device by creating an output of specific EEG frequency. The Electroencephalogram (EEG) records a signal by placing electrodes on the scalp with a conductive gel. Electrodes measures voltage differences at the skin in the microvolt (μV) range. The first electrical activity recorded by Hans Berger in 1924. By analyzing the EEG signal, Berger can identify brain waves as a wave began to be called Berger which is known as Alpha waves (8-12Hz). It is found as the first wave of very low signal (Anupama *et al*., 2012). Based on the results of the BCI, researchers began exploring the human brain to get better quality waves to be recorded until using the neurosurgery. Among the famous researcher is Jose

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Delgado in 1950, using implanting into animals and stimulating electrode-using radioreceiver. Followed in 1970, the Defence Advanced Research Projects Agency (DARPA), the US embarked on a program to explore the use of EEG brain communication. In 1999, the First International Conference on BCI was organized in NewYork followed in 2010 in CA, USA and Austriain 2011 (Arafat, 2013).

Prosthetic hand: Human hand plays an important role in every aspect of their daily routine like interacting with the environment and manipulating objects. Hands have unique and complex arrangement of joints, ligaments and muscles. Hand accounts for 26% of the human body's movement potential (Brown, 2008). The human hand considered as a complex system to been replicated, copied or replaced even with the advanced technology available today. However, the fate of losing the hand especially, due to the accident or injury is beyond anyone's expectation. Thus for the amputees to live a normal life, the use of a prosthetic device technology can overcome this problem. The importance of prosthetic devices has triggered researchers all over the world, since 100 years ago until now to upgrade the prosthetic technologies. Besides having the same features, size and consistency, today is prosthetic hand must have a capability to mimic the biology of human hand movements and dexterity in handling multiple tasks.

Advances and progresses in prosthetics technology has produced several well-known prosthetic hands like Stanford/JPL Hand (Boissiere *et al*., 1987), NTU Hand (Lin and Huang, 1998), Utah/MIT Hand (Jacobsen *et al*., 1986), DLR Hand II (Butterfass *et al*., 2001) and Robonaut Hand (Lovchik and Diftler, 1999) produced by NASA. These prosthetic hands driven by a DC motor enables the fingers to move individually and have the ability to grasp certain objects smoothly and firmly. The hand driven by a number of DC motors, it is capable of moving the individual finger and has the ability to grasp objects more firmly. However, the lack of anthropomorphic characteristics, bulky in size and excessive weight limit the human-robot interaction because most of the hands produced are only suitable for industrial purposes. Therefore, this research aims to focus more on the establishment of a small hand finger design as achieved by UB Hand (Ficuciello *et al*., 2011) and Vanderbilt Hand (Dalley *et al*., 2009). These hands also demonstrate to have good grasping skills with a satisfactory speed. However, the driving mechanism of these robots situated at the outer position of the hand and arm and thus no longer suitable fitted for humans. The competition had brought in advanced prosthetic hand like Smart Hand by Dr. Fredrik from Lund University (Cipriani *et al*., 2009) and I-Limb™ Hand by Scottish Company Touch Bionics. In year 2007, i-Limb a first commercial prosthetic hand a release with adaptive control. A recent study from the RSL Steeper also succeeded in producing the third generation Bebionic Hand grip strength with the ability of 140.1N.

Neuroprosthetic hand: A decadeago, theideaof control the machine using brain introduced in fiction movie but now has become a reality and has been explored by scientists seriously. Thus, several studies have explored through brain signals derived from the skin and from the head of the human brain. This technology opens up new alternative without the use of muscle control (Wolpaw *et al*., 2002). It also supported by a few researchers that successfully implant the monkey. The histories of this technological break through encourage other researchers to make human implantation to see its effectiveness. For example is a project of BrainGate.

BrainGate project was introduced in 2003 using a brain implant system produced by the bio-tech company Cyberkinetics cooperation by the Department of Neurosciences at Brown University. Tetraplegic MattNagle became the first person to control artificial hand using a BCI in 2005. The BrainGate is connected directly to the human motor cortex, a stretch of cerebral real estate that runs in a strip from the top of the head toward the cheek bone. A tiny array of 96 electrodes is attached to the part of the motorcortex that controls the arm. Those electrodes send signals through a cable to a computer (Arafat, 2013). This project was carried out with in stances of BrainGate 2 project collaboration between the Department of Veterans Affairs, Brown University, Massachusetts General Hospital, Harvard Medical School and the German Aerospace Center (DLR). As a result in April 2011, a paralyzed woman named Cathy Hutchinson lifted a cup for the first time in nearly 15 years, using a robotic arm controlled by her thoughts.

Newest 2014, US government through its defenses agent DARPA will develop the wireless device Neuroprosthetic Hand a call as Restoring Active Memory (RAM) program which aim their develop and test wireless, implantable neroprosthetic to assist for merveteran soldiers who lost their hands because of the war that passed a few decades. Project RAM is also acting to restore Traumatic Brain Injury (TBI) >270,000 military service members since 2000 (DARPA, 2014). US government also gives full provision to the Defense Advanced Research Projects Agency (DARPA) for the realization of this project for four years. This project is also supported by the University of California, LosAngeles (UCLA) and the University of Pennsylvania (Penn) to develop and test electronic interface that can sense the brain memory. DARPA also collaborated with Lawrence Liver more National Laboratory to develop an implantable neural device (DARPA, 2014).

MATERIALS AND METHODS

The Centre of Excellence of Humanoid Robot and Bio-Sensing (HuRoBs) has developed improved actuation mechanism for hand prostheses (Aqilah *et al*., 2012; Jaffar *et al*., 2011; Kasim *et al*., 2013; Low *et al*., 2013). This project was started in early 2014 with the introduction of full mechanism controlled prosthetic hand with individually actuator. It allows hands with individually controlled and can mimic the movement of the human hand. Coupled with tactile sensors in each fingertip is easier to make hands grasping objects with greater accuracy and perfect.

Figure 1 shows the process flow that occurs when the subject imagines moving their hand. The use of EEG Capisan effective technique because it is easier to use and only requires 30 min or less for each set-up. Brain waves rhythm recorded from the Motor Cortex C3, Cz, C4 (Dokare, 2014) and motor rhythms recorded based on International System Electrode position 10-20. The signal illustrating human motor activity such as moving arms and legs to the left and right movement is driven muscle of the body. The hardware cap will be used is EEG Emotiv EPOC 14 Channel with two reference channels which to monitor for thought, emotions, facial expressions and more. Emotiv cap will send a signal to the receiver signal via Bluetooth. Then, the receiver will send a signal in the Workstation for processing the data by the Graphical User Interface (GUI) developed. GUI goal is to process the data and identify the pattern approval contained in the data. If the pattern is detected together with the recorded pattern, GUI system will send a signal to act in EEG Box to move the actuators in neuroprosthetic hand as required.

This algorithm consists of three modules that communicate with each other. The first layout is software development that involved data processing, data storage, data training and a graphical user interface. Second layout is hardware development that involved BCI tools such as EEG device, system integration that used motor driver and tactile sensor. The third layout is application involves the development of neuroprosthetic hand and phase of training subject. The subject will move his or her hands and the result data will be recorded using the Emotiv test bench Software. Anyway, the raw data obtained is unusable because there area lot of useless artifact signal. Therefore, every data obtained should go through preprocessing process to eliminate the noise in the data. It is important to get the clean signal data without any artifacts. There are several distraction that usually occurs during EEG recording, the first is noise environment and second is physiological noise, several noise is easily to eliminate using Automatic Artifact Removal (AAR) using EEG Lab and a few noise is very difficult to remove (Repovs, 2010).

The clean signal data will be converted into a matrix formand saved as a pattern approval in EEG box data base system. This EEG Box data controlled by using the Graphical User Interface (GUI) generated from Matlab Software. In the GUI interface EEG Box have a training data to be used by the amputee as a supporting training before using the actual prosthetic hand. EEG Box GUI acts as a decision-maker to make every movement neuroprosthetic hand depending on the pattern that has been in the program approval inside the database. EEG box also acts as a real time interface between the GUI

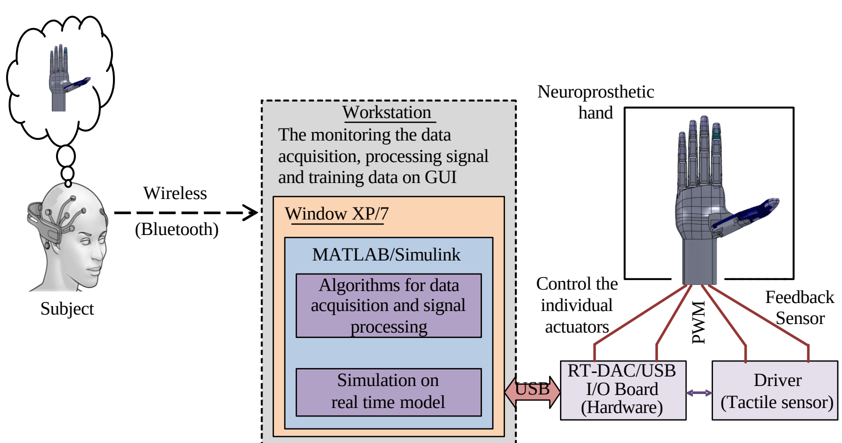

Fig. 1: Controlling a neuroprosthetic hand using imaginative hand movements

software developed by the hardware output as the actuator motor and tactile sensors are used. A strategy used in this project is the neuroprosthetic hand develops with a simple mechanism but effective to perform daily activities for amputee. Among the activities for amputee simple as pick the object, touch the object, hold the object including the holder door grip, grip the bottle and lift the cup. Neuroprosthetic hand is completed with five fingers full with 7° of freedom. Individually, driven by the actuator motor makes more mimic the human hands movement. Using tactile sensor from Robo Touch placed in some important point at fingertip to minimize sensor that used.

CONCLUSION

This research helps the amputees to carry out daily tasks in order to live more comfortably. Prior to the usage of the neuroprosthetic hand, the amputees will undergo several phases of training via interactive graphical video until they succeed in using imaginative hand movements to control the hand prostheses.

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REFERENCES

Anupama, H.S., N.K. Cauvery and G.M. Lingaraju, 2012. Brain computer interface and its types: A study. Intl. J. Adv. Eng. Technol., 3 (2): 739-745.

Aqilah, A., A. Jaffar, S. Bahari, C.Y. Low and T. Koch, 2012. Resistivity characteristics of single miniature tactile sensing element based on pressure sensitive conductive rubber sheet. In Signal Processing and its Applications (CSPA), IEEE 8th International Colloquium, pp: 223-227.

Arafat, I., 2013. Brain Computer Interface?: Past, Present and Future, pp: 1-6.

Boissiere, P.T., G.P. Starr and J.P.H. Steele, 1987. Modelinrr And Control Of The Stanford. JPL Hand, pp: 2-7.

Brown, A.S., 2008. Why hands matter. Mechanical Eng., 130 (7): 24-29.

Bryan, M., J. Green, M. Chung, L. Chang, R. Scherer, J. Smith and R.P.N. Rao, 2011. An adaptive brain-computer interface for humanoid robot control. 11th IEEE-RAS International Conference on Humanoid Robots, pp: 199-204. DOI: 10.1109/ Humanoids.2011.6100901.

Butterfass, J., M. Grebenstein, H. Liu and G. Hirzinger, 2001. DLR-Hand II: next generation of a dextrous robot hand. Proceedings ICRA. IEEE International Conference on Robotics and Automation (Cat. No.01CH37164), 1: 109-114. DOI: 10.1109/ROBOT. 2001.932538.

Cipriani, C., M. Controzzi and M.C. Carrozza, 2009. Progress towards the development of the SmartHand transradial prosthesis. IEEE International Conference on Rehabilitation Robotics, ICORR, pp: 682-687. DOI: 10.1109/ICORR.2009.5209620.

Connor, J.O., 2013. Real-time Control of a Robot Arm Using an Inexpensive System for Electroencephalography Aided by Artificial Intelligence Real-time Control of a Robot Arm Using an Inexpensive System for Electroencephalography Aided by Artificial Intelligence.

Dalley, S.A., T.E. Wiste, T.J. Withrow and M. Goldfarb, 2009. Design of a multifunctional anthropomorphic prosthetic hand with extrinsic actuation. IEEE/ASME Transactions on Mechatronics, 14: 699-706. DOI: 10. 1109/TMECH.2009.2033113.

DARPA, 2014. Restoring Active Memory Program Poised To Launch. http://www.darpa.mil/NewsEvents/ Releases/2014/07/09.aspx.

Dokare, I., 2014. Classification of EEG Signal for Imagined Left and Right Hand Movement for Brain Computer Interface Applications, pp: 291-294.

Ficuciello, F., G. Palli, C. Melchiorri and B. Siciliano, 2011. Experimental evaluation of postural synergies during reach to grasp with the UB hand IV. IEEE International Conference on Intelligent Robots and Systems, pp: 1775-1780. DOI: 10.1109/IROS.2011. 6048621.

Jacobsen, S.C., E.K. Iversen, D.F. Knutti, R.T. Johnson and K.B. Biggers, 1986. THE UTAHh4.I.T. DEXTROUS HAND, S.C. Jacobsen, E.K. Iversen, D.F. Knutti, R.T. Johnson, K.B. Biggers (Eds.). Center for Engineering Design, University of Utah.

Jaffar, A., M.S. Bahari, C.Y. Low and R. Jaafar, 2011. Design and control of a multifingered anthropomorphic robotic hand. Int. J. Mechanical and Mechatronics Eng., 11 (4): 26-33.

Kasim, M.A.A., A. Aqilah, A. Jaffar, C.Y. Low, R. Jaafar and M.S. Bahari, 2013. Development of UiTM Robotic Prosthetic Hand, 7 (1): 1054-1059.

Lin, L.R., and H.P. Huang, 1998. NTU Hand: A New Design of Dexterous Hands. J. Mechanical Design, 120 (107115): 282. DOI: 10.1115/1.2826970.

Lovchik, C.S. and M.A. Diftler, 1999. The Robonaut hand: a dexterous robot hand for space. Proceedings 1999 IEEE International Conference on Robotics and Automation (Cat. No.99CH36288C), 2 (May). DOI: 10. 1109/ROBOT.1999.772420.

Low, C.Y., M.A.A. Kasim, T. Koch, R . Dumitrescu, H. Yussof, R. Jaafar and K.M. Ng, 2013. Hybrid-actuated finger prosthesis with tactile sensing. Intl. J. Adv. Robotic Syst., 10: 1-10. DOI: 10.5772/56802.

Matthys, K., M. Smits, J.N. Van der Geest, A. Van der Lugt, R. Seurinck, H.J. Stam and R.W. Selles, 2009. Mirror-induced visual illusion of hand movements: A functional magnetic resonance imaging study. Archives of Physical Medicine and Rehabilitation, 90 (4): 675-681.

Millan, J., R. Protectdel, J. Millan, R. Protectdel, F. Renkens, F. Renkens, J. Mourino, J. Mourino and W. Gerstner, 2004. Non-invasive Brain actuated control of a mobile robot by Human EEG. IEEE Trans. Biomedical Eng., 51: 1026-1033.

Oishi, M., M. Fukuda, S. Kameyama, T. Kawaguchi, H. Masuda and R. Tanaka, 2003. Magnetoencephalographic representation of the sensorimotor hand area in cases of intracerebral tumour. J. Neurol. Neurosurg. Psychiat., 74: 1649-1654. DOI: 10.1136/jnnp.74.12.1649.

Rebsamen, B., C. Guan, H. Zhang, C. Wang, C. Teo, M.H. Ang and E. Burdet, 2010. A brain controlled wheelchair to navigate in familiar environments. IEEE Trans. Neural Syst. Rehabilitat. Eng., 18 (6): 590-598. DOI: 10.1109/TNSRE.2010.2049862.

Repovs, G., 2010. Dealing with Noise in EEG Recording and Data Analysis. Informatica Medica Slovenica, 15: 18-25.

Schaechter, J.D., C. Stokes, B.D. Connell, K. Perdue and G. Bonmassar, 2006. Finger motion sensors for fMRI motor studies. Neuroimage, 31 (4): 1549-1559.

Shedeed, H.A., M.F. Issa and S.M. El-Sayed, 2013. Brain EEG signal processing for controlling a robotic arm. Proceedings 8th International Conference on Computer Engineering and Systems (ICCES), pp: 152-157. DOI: 10.1109/ICCES.2013.6707191.

Wang, Y., B. Hong, X. Gao and S. Gao, 2007. Implementation of a brain-computer interface based on three states of motor imagery. Annual International Conference of the IEEE Engineering in Medicine and Biology-Proceedings, pp: 5059-5062. DOI: 10.1109/IEMBS.2007, 4353477.

Wolpaw, J.R., N. Birbaumer, W.J. Heetderks, D.J. McFarland, P.H. Peckham, G. Schalk, T.M. Vaughan, 2000. Brain-computer interface technology: a review of the first international meeting. IEEE Transactions on Rehabilitation Engineering?: A Publication of the IEEE Engineering in Medicine and Biology Society, 8 (2): 164-173. DOI: 10.1109/TRE.2000.847807.

Wolpaw, J.R., J.R. Wolpaw, N. Birbaumer, N. Birbaumer, D.J. McFarland, D.J. McFarland and T.M. Vaughan, 2002. Brain-computer interfaces for communication and control. Clinical Neurophysiology?: Official J. Intl. Federation of Clinical Neurophysiol., 113: 767-791. DOI: 10.1016/S1388-2457(02)00057-3.