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End-effector wheeled robotic arm gaming prototype for upper limb coordination control in home-based therapy

Ahmad Hoirul Basori
Faculty of Computing and Information Technology Rabigh, King Abdulaziz University, Saudi Arabia

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ABSTRACT

The stroke patient will be having difficulty to control their upper limb, which causes their handling to become weak and unorganized. Conventional therapy designed to retrain the subject ability when it's losses due to stroke. As previous study concern that a subject with strong motivation and concentration of treatment tends to recover better than people who don't follow the program. This research focused on intensifying the training by providing user with wheel robotic arm to train their upper limb. User will be asked to do exercising on moving particular objects to another position repetitively during a specific period. The robot will help the user to assist and relearn their motoric skill and improve muscle strength and coordination. The result of training is quite convincing when the user gives a positive response toward the practice. Around 86 percent of subject likely prefer the proposed system as their home-based rehabilitation system. The Anova testing with alpha 0.05 shows that there is no significant difference between trained subject and untrained subject on operating the wheeled robotic arm. It's mean the proposed system is reliable and user friendly to be used without an assistant so user can have more flexibility and improve their accomplishment on regaining their motoric skills. The future work will focus on stroke patient testing with more challenge and obstacle in enhancing the effectiveness of the stroke rehabilitation system.

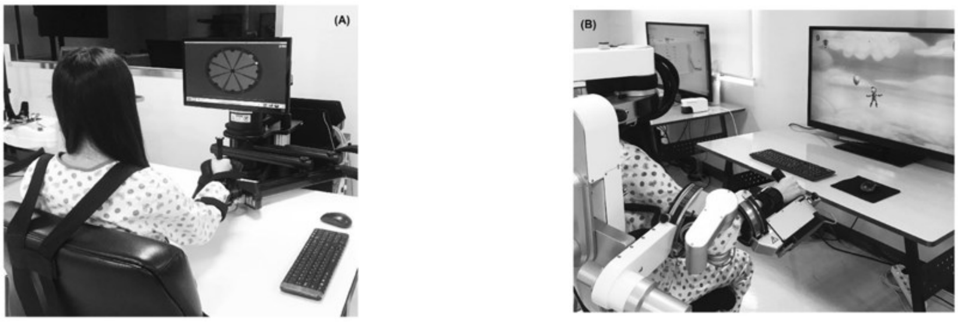
Corresponding Author:

Ahmad Hoirul Basori,
Faculty of Computing and Information Technology Rabigh,
King Abdulaziz University,
Rabigh, Makkah, Saudi Arabia.
Email: abasori@kau.edu.sa

1. INTRODUCTION

The utilization of robot for neuro-rehabilitation has been accepted widely, and previous researcher used this method to do treatment of Cerebral Palsy student. It's proven as an effective method for their therapy [1]. The rehabilitation processes a game that can help them to re-coordinate their motoric, memory and even cognition skills. As we know, that upper limb holds a vital role for people to perform their daily activities [2, 3]. Therefore, the researcher keep innovates, and they also used Kinect camera as assistive technology to help stroke patient gain their motoric skills again [4]. They offered levelled tasks with various of the challenge of interaction. The role required motoric and coordination upper limbs control. Kinect technology has been effectively used for multiple control in stroke rehabilitation. Some of them by combining the virtual reality (VR) technology to create virtual boat and bootle, then ask the user to perform a particular task. The game designed to monitor movement of subject and keep track of their progress based on accomplishment of each task [5-11]. The robot for therapy has been increased for the past several years and keep growing in term of number and method how to produce more intensive and quantifiable training [12-14]. It argued that robotic treatment successfully increases the efficiency of therapy to be more interactive, efficient, adaptive and intense. The other researcher focused on studying the mechanical design of the robot used for treatment and how significant the impact of the robot toward rehabilitation process. It covers the model of interaction between man and robot, how the control is ignited, and how the training model is performed [15-20]. Rehabilitation using robotic generally divided into cluster end-effector (EE) and exoskeleton (Exo) robot according to mechanical construction of the robot [8]. EE robot uses a connector to link with one focused point of the human body, for example, hand, or finger so the joint not synchronized. While Exo robot makes synchronization between human joint and robot fully, therefore coordination of motion and its torque is more under control [21, 22]. Besides, to choose a suitable robot for rehabilitation, several comparisons have been made between end-effector (EE) and exoskeleton (Exo) rehabilitation robot [23]. Their experiment focused on two different clusters: EE and Exo cluster. Their assessment based on the score of the fugl-meyer assessment (FMA) and wolf motor function test (WMFT). Its claimed that the differences between both groups are minimum or nothing significant, refer to Figure 1 for both testing comparison.

The other researcher provides argued that training concerning upper limb motoric nerve with EE able to boost up the recovery process, compared to conventional therapy with subacute stroke patients [24]. They claimed that the intensity of training would produce a better result for rehabilitation. The upper extremity training is one of the methods used by researcher to return the functional task of the upper limb during daily activities [25]. It can influence the motoric skills of a stroke patient. They used the end-effector robot along with virtual reality game for a variety of training, refer to Figure 2. Previous researcher has worked intensively by combining various methods, hardware and technology. The contribution of our research focused on the low-cost solution yet work efficiently for home-based therapy. It's used Kinect camera as robot controller and Arduino based board as end-effector moile robotic arm motherboard.



(a) (b)

Figure 1. (a) Represent the experiment of the EE group, while
(b) experiment by exos group. image courtesy of Lee, S.H et al. [23]

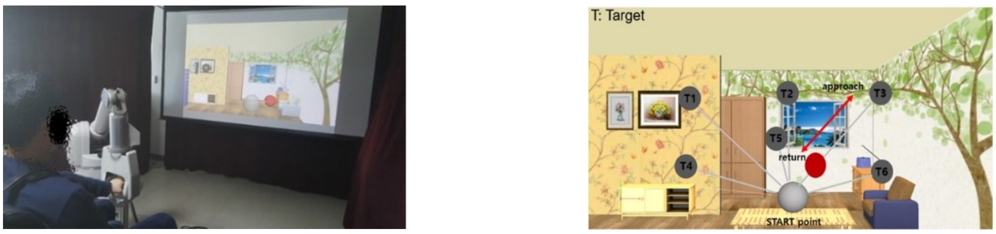


Figure 2. The EE Robot device combined with VR games,
image courtesy of Cho K. H., and Song W. K. [25]

2. RESEARCH METHOD

The subject will use the Kinect camera as the control of the wheel robotic arm, which is synchronized with a human arm. They will be asked to perform several tasks repetitively in different period.

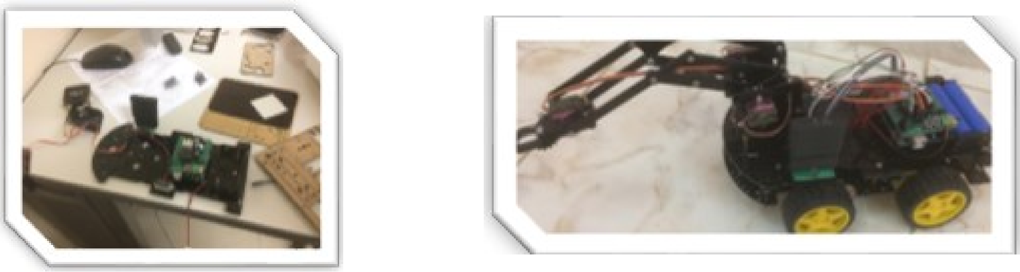
Materials:

There is three leading hardware used for the experiment:

– Arduino based wheel robot that has four motor servos for arm gripper, and four motor servo for the wheel, refer to Figure 3.
– Kinect camera for human body tracking.
– PC/laptop for software processing.

The robot has four motor servo that handling arm, one motor for hand gripping, the other two motors supporting the arm for lifting or holding the object. The last motor servo is handling based on the arm, which serves rotation purpose. These four motor servos work together synchronously based on the given control. The other component is the Bluetooth sensor(HC-05) that responsible for receiving the command or control from a Kinect camera. Since we used Kinect, then we map the human arm toward robotic arm component as shown in Figure 4.

The proses are started by adjusting the position of the Kinect, then Kinect will begin to recognize the location of the user. Kinect will grab the depth image of the user then convert into a sequence of motion to be sent to the wheeled robotic arm via Bluetooth connection. Once its fully synchronized, the user can control the wheeled robot, make it move to another location and control the gripper, the methodology is illustrated in Figure 5.



(a) (b)

Figure 3. Arduino based wheel robotic arm, (a) assembly in progress, (b) assembly complete

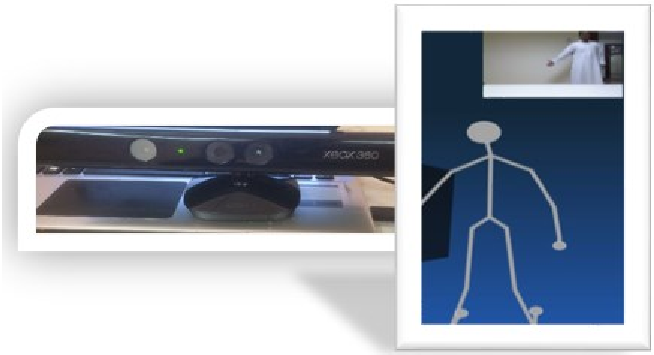


Figure 4. Subject arm synchronization with Kinect camera

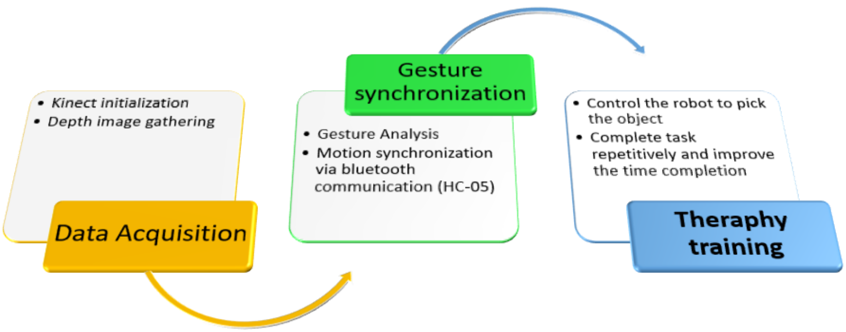


Figure 5. Methodology of the proposed system

Figure 6 describes various SDK involves on building the prototype, visual studio and Kinect SDK come as a bundle for handling gesture tracking of the human skeleton. While Arduino library is responsible for communication between Kinect camera and motor servo of the robot, the hand gesture of user will be captured by Kinect camera then passed over Bluetooth sensor. This sensor will send the command wirelessly via Peer to Peer communication with Arduino board.

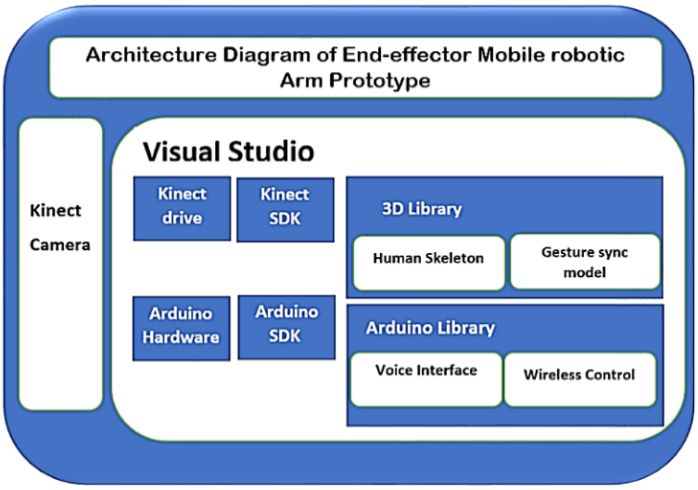


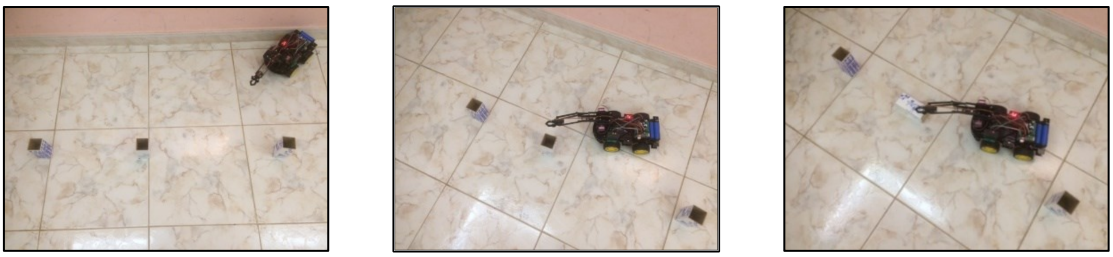
Figure 6. Architecture diagram of the end-effector wheel robotic arm prototype

3. RESULTS AND DISCUSSION

The proposed research aims to help subject regain their motoric coordination and balancing their movement toward practice with the robot. To relearn the subject upper extremity, a repetitive task yet challenging need to be stimulated continuously toward through consistent training. During the training, the user needs to accomplish a few jobs by moving the whiteboard marker from one holder to another holder:

3.1. General challenge of stroke therapy

This challenge focused on controlling the robot to freely move from one location toward another location by using the subject gesture. User needs to move the wheeled robotic arm through three obstacles. The speed of the robot can be set up independently or automatically. User need to provide gesture such as moving hand left and right to manoeuvre and avoid an obstacle. This training is reflected in Figure 7, and user will initiate the wheel robot movement then try to evade three boxes. At first, subject able to avoid the obstacle, when the second trial its failed and crashed the box. User will repetitively use their hand gesture to move the wheeled robot with more obstruction according to the level of training as shown in Figure 7.



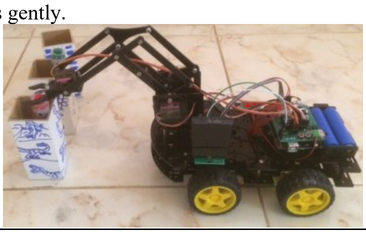
(a) (b) (c)

Figure 7. General challenge of StrokeTheraphy: (a) wheel robot initialization, (b) subject try to evade the obstacle, (c) user not able to avoid obstacle (crash)

3.2. Upper extremity challenge for upper limb motoric nerve

This challenge is designed to help user for relearning their upper limb motoric skills and coordination that might lose due to stroke. In the first level, three pen holders consist of two board markers. User needs to move the board markers from one holder into other holders repetitively. The second level: pen holders are raised, and the subject will do a similar task by moving the board marker from one holder to another holder. However, in this second level, user will struggle on their upper extremity due to the wheel robotic arm barely catch up to the height of the box. The whole process is described in Table 1.

Table 1. Upper extremity challenge for upper limb motoric nerve

Challenge	Scenario	Score
1	The subject requires to control the wheeled robot and make it close to the objects.	1 point if user closed enough for arm to reach the board marker and didn't crash the box
2	The Subject asked to approach a pen holder and hold the marker. 	1 point if the pen holder not falling down
3	The Subject raise the board marker out of the pen holder and moved backwards. 	1 point if the box and board marker not dropping
4	The Subject put the board marker on the pen the third pen holders gently. 	1 point if the box and board marker successfully inside the pen holders and its not falling down

The initial evaluation was tested with 16 healthy subjects to proof the user acceptance toward our prototype, two hypotheses derived from the experiment:
H1: The state of a subject that has intensive training with wheeled robotic arm for stroke therapy.
H2: The state of subject used the wheeled robotic arm for stroke therapy without any training.
To prove our hypothesis, we run the ANOVA test as shown in Table 2, and we obtain the F value 0.128449 < 4.170877 (F crit). So, we cannot reject the null hypothesis that means, there is no significant difference between training before the therapy with direct use of wheeled robotic arm. Its also proven that our proposed system is generally accepted by the user and its easy to use as home-based therapy, where user can have more flexibility to do self-therapy independently and intensely, refer to Figure 8.

Table 2. Anova analysis for the proposed wheel robotic arm

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Without Training	16	1329.7	83.10625	41.63929		
With Training	16	1342.8	83.925	41.862		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.362813	1	5.362813	0.128449	0.722556	4.170877
Within Groups	1252.519	30	41.75065			
Total	1257.882	31				

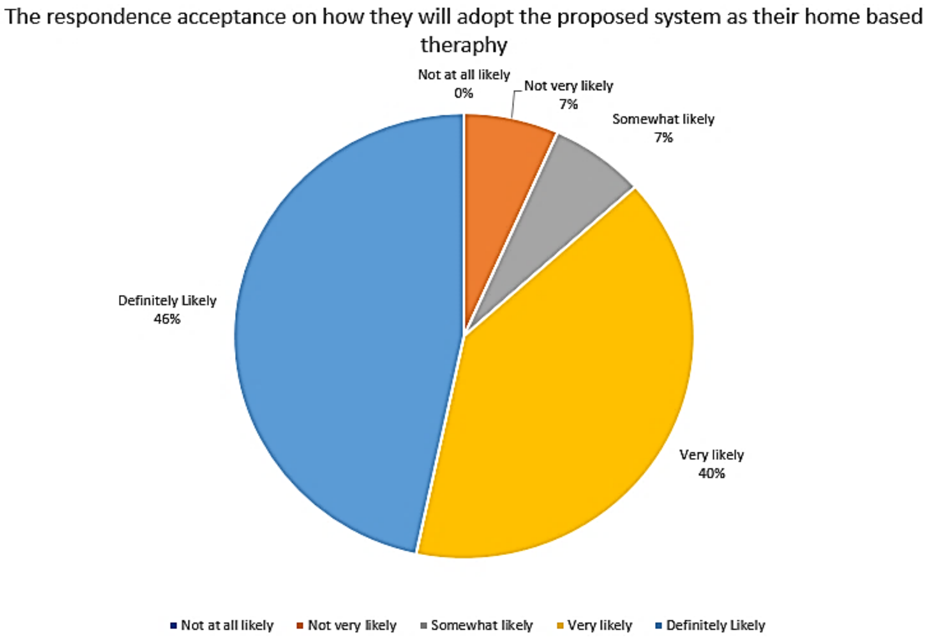


Figure 8. User acceptance toward the proposed system

4. CONCLUSION

The stroke has caused a lot of issue in daily human life. Human obstructs to their daily activities due to limited movement on their upper limb, and they cannot lift the object quickly. Therefore, an intense training called stroke rehabilitation is designed to relearn their motoric skills and coordination between muscle and brain. However, due to of complexity of therapy system in the hospital that mainly used very expensive exoskeleton robot, user stuck with the very tight schedule and limited number of training. This paper proposes an innovative and low-cost solution with an end-effector wheel robotic arm that built based on the Arduino board and its component. The controller uses a Kinect camera that has capability on tracking the human gesture. The subject asked to perform an intense training with two main challenge: general and upper extremity challenge. They are very excited about the training and mostly happy with this home-based therapy system. The evaluation result shows that the user didn’t meet any difficulty to use the system with a 95% confidence rate and around 86% of them likely will adopt this proposed system as their home-based rehabilitation system. We believe this system can be enhanced further with more challenge toward stroke patients to gain efficiency of the proposed system toward society.

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BIOGRAPHIES OF AUTHOR

Ahmad Hoirul Basori, received B.Sc (Software Engineering) degree from Institut Teknologi Sepuluh Nopember Surabaya in 2004 and the Ph.D (Computer Graphics) from Universiti Teknologi Malaysia, Johor Bahru, Johor, in 2011. In 2011, he has appointed as Assistant Professor with the Department of Computer Graphics and Multimedia, Universiti Teknologi Malaysia. In 2016, he is promoted to Associate Professor rank in Faculty of Computing and Information Technology Rabigh, King Abdulaziz University. He is the member of Editorial board of some international journal, and published more than 80 articles. He is also a member of professional membership IEEE, ACM SIGGRAPH, IAENG and Senior Member of IACSIT. His research interests include Computer Graphics, Facial Animation, Cloth Simulation, Medical Visualization, Haptic Interaction, Man Machine Interaction and Robotics.