Therbligh Motions as a Basic of Movement Therapy for Stroke Patients

Bernadus Kristyanto(✉), Brilianta Budi Nugraha, Suyoto Suyoto, Anugrah Kusumo Pamosoaji, and Kristanto Agung Nugroho

Department of Industrial Engineering, Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia
b.kristyanto@mail.staff.uajy.ac.id

Abstract. Analysis of human arms' movements using Therbligh principles is now used to study the movement therapy for stroke patients. The study aims to design robot arm as a preliminary result to design artificial shoulder-attached-dual-arm robot to imitate human arms' movements that will help stroke patients for movement therapy. For modeling the dual human arm movements, a DH-parameter based on forward-kinematics of the arms is used. Human hands hold objects with various weights and volumes. We take into account the unpredictability center of mass of the entire arms as uncertainty. The model must follow human's base behavior. Therefore, human arms anthropometry is required to determine the movement's parameters. Movement limitation of stroke patients must also be considered as the limitation. Result simulations are presented and will be used as the model for movement controller. Synchronized and symmetrical arms' movement is expected to improve the balance of the brain's control system.

Keywords: Human arms motions · Human anthropometrics
Stroke movement therapies · Denavig-Hartenberg paradigm
Forward kinematics systems

1 Introduction

Stroke is a disease in which a person's blood supply towards the brain is interrupted causing lack of oxygen that affects the brain's function as the control center for movement, speech, or thinking. If the control center for movement is disturbed then it will cause trouble to move all or parts of the body due to loss of motor skills. Severe stroke can result in total paralysis and it is hard to recover. Mild stroke will cause paralysis in some part of the body such as part of the arm or leg. Recovery through movement therapy is possible even though it might not fully reverse the damage. With the help of regular and proper therapy, patients can return to their normal activities. Without therapy, patients will suffer from permanent paralysis due to deteriorating nerves and muscles caused by the cut off of blood supply carrying essential nutrients and oxygen. Nerves and muscles can recover through therapy because they are stimulated by the movements that helps blood flow to the nerves and muscles of the body parts that have lost its motor function. Motor functions will also be stimulated and

T. Ahram et al. (Eds.): IHSED 2018, AISC 876, pp. 1018–1024, 2019.
https://doi.org/10.1007/978-3-030-02053-8_155

gradually it will improve the brain's control system in controlling body parts that were previously paralyzed. Movement therapy for patients with mild stroke is usually simple movements for the arm and leg especially for ball-and-socket and hinge joints, for example: flexion and extension movements for the arm. In this experiment, the movement therapy will be done using the study on Therbligh motion. Therbligh motion study describes the movement of 2 (two) arms at once in one complete activity process that is usually done by a person. Therbligh motion model is learned by people that study efficient movement in work assembly system. The assumption is this model can be implemented after initial therapy in form of simple movements. In other words, Therbligh-based movement therapy model or work assembly movement study is an advance or continuance movement therapy model. As we know, the study of human hands' motions at assembly works have been carried out and developed by so many researchers. Various studies are focused on motions at manual assembly works. It was concluded that human works are accomplished by two hands. Particularly, all manual works consists of relatively few fundamental repetitive motions. For instance, "picking up" and "putting down" are two of the most frequently used groups of motions. Nowadays, these studies are useful as a basis for designing artificial tools for the rehabilitation of paralyzed patients such as Harmony Exoskeleton Arms robot for arm or back injuries therapist developed by Texas University of Austin [1], etc. In order to accelerate the rehabilitation, it is necessary to build a system that mimics the human arms and their motion. Therefore, an artificial shoulder-attached double-arm robot to imitate human arms' motions is designed.

The arms are important parts of human body that always move and on top of that value investment for working tools. At manual assembly the arms motions inspire the basic system design of arms robot assembly such as those reported by Van Zutven [2], Smith et al. [3], Adrien Dataset. Datas et al. [4], Benerji and Banavar [5]. Human arms have few connected joints such as upper hand (link 1), forehand (link 2), and hand (link 3) which is in the humanoid robot system known as EndEffector. All the joints of arm system give possibility for arm to move or do the motion.

As typical procedures used in robotics field, a kinematics analysis using Denavit-Hartenberg (DH) paradigm is developed to model the motions of human arms. The DH parameters are obtained by Therbligh motions measurements. Therefore, the designed robot arms can represent humans' anthropometric.

2 Methodology

Work activities in this study is planned in 4 stages. Stage 1 studies and determines Therbligh principle to become the model or reference in forming a movement cycle in an activity. Stage 2 designs the robot arms to imitate movement according to the reference model and simulates the model to see dominant movements on the joint or motor. Stage 3 observes the limitation of movement ability on stroke patients and use it as the base for motor rotation program reset. Stage 4 redesigns the robot arms based on Therbligh movement that has been set using the limitation model and program that imitates the human arm motion model.

2.1 Therbligh Motions as a Basic Model

In order to let the arms moving as a human-like manner, the arms should have degree of freedom to, at least, perform the basic movement for manual assembly that will be designed. Therefore, through this paper a study of human arms motions on the stroke patient need to be performed as a basis of designing robot arms for patient stroke motion therapy.

Model and Motion Approaching. For the simplicity of analysis, the model of motions that were examined is applied using Therblick motions [6]. It was assumed that the Therblick motions represent the basic motions for a human activity in general. These motions, such as “reach”, “move”, and “release” (where in rest of this paper, the motions are represented as REACH, MOVE, and RELEASE, respectively) have been developed from simple manual assembly (Fig. 1).

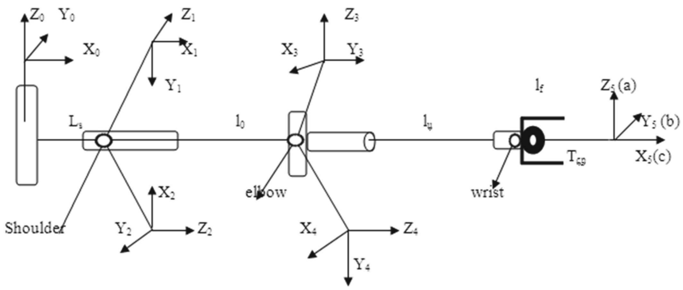

Fig. 1. Kinematic model structure on the arm [2].

Human arms have 7 DOF’s [7], i.e., three on the shoulder, two on the elbow, and two on the wrist. The effect of two DOF’s in the wrist can be negligible. However, the wrist joint only has one DOF which gives full control over the orientation of the gripper. Each DOF has a corresponding link: The upper and lower arms both are the links to be considered. The lengths of the links are determined from the ratio between bodies segments expressed as a fraction of the total height [8]. The arms can be modeled by using Denavit-Hartenberg (D-H) approach [9]. The D-H paradigm uses 4 parameters for each link, i.e., θ_i, α_i, a_i, and d_i defined as the rotation angle about z-axis of the initial joint, the rotation angle about x-axis of the initial joint, the distance of the next joint in gtion of z-axis of the initial joint, respectively. The kinematic analysis using Denavit-Hartenberg (D-H) approach towards arms movement with Therbligh principle has been done by Kristyanto et al. [10].

2.2 Robotic Arm Simulation Model Replicated

By applying the D-H model, the REACH motion can be achieved by combining vertical flexion and horizontal flexion. Therefore, the involving joints are θ_2 and θ_4. In addition, the MOVE motion can be achieved by combining horizontal flexion and horizontal extension. In other words, θ_4 and θ_3 contribute to this type of motion.

The last motion is RELEASE, i.e., the motion of releasing object after being executed. Here, θ_4 is rotated.

For obtaining actual values of vertical flexion, horizontal flexion, and horizontal extension for each motion, a measurement applied to two volunteers was done. According to the measurements, we obtain results for actual Therbligh REACH, MOVE, and RELEASE that are shown in Table 1. Note that the motion simulated uses an assumption of constant average angular velocities of all joints. Note that the measurements of actual human anthropometry were performed by using manual manner. Therefore, the results are not highly accurate. However, to handle this problem, we measure the accomplishment time in Table 1. It makes sense that the accomplishment time is the result of human muscles' efforts to compensate the gravitational effect causing by the mass of the arms.

Table 1. Characteristic of Therbligh motions.

No	Left						Therbligh	Right					
	L1			L2				L1			L2		
	Motion	Angle (°)	Time(s)	Motion	Angle (°)	Time(s)		Motion	Angle (°)	Time(s)	Motion	Angle (°)	Time(s)
1	Vertical Flexion	45	1	-	-	-	REACH	Vertical Flexion	45	1	-	-	-
2	-	-	-	Horizontal Flexion	35	0.9		-	-	-	Horizontal Flexion	35	0.9
	-	-	-	Pronasi	90	0.9		-	-	-	Pronasi	90	0.9

No	Right Arm						Therbligh	Left Arm					
	L1			L2				L1			L2		
	Motion	Angle (°)	Time(s)	Motion	Angle (°)	Time(s)		Motion	Angle (°)	Time(s)	Motion	Angle (°)	Time(s)
1	Horizontal Extension	50	0.7	Horizontal Flexsion	55	0.7	MOVE	Horizontal Extension	50	0.7	Horizontal Flexsion	55	0.7

No	Right Arm						Therbligh	Left Arm					
	L1			L2				L1			L2		
	Movement	Angle (°)	Time(s)	Movement	Angle (°)	Time(s)		Movement	Angle (°)	Time(s)	Movement	Angle (°)	Time(s)
1	-	-	-	Horizontal Ekstension	10	0.9	RELEASE	-	-	-	Horizontal Ekstension	10	0.9

From the simulation, it can be concluded that the REACH motion depends on the 2nd and 4th joint, the MOVE motion depends on the 3rd and 4th joint, and the RELEASE depends on the 4th joint. The results will be considered for the next step of the research, i.e., the design of adaptive control and the involvement of the weight of human arms and motors instead of Link 1 and Link 2.

Consequences of simulation based on the model give us that high considerable should have to joint 2 and joint 4 which is upper arm movement that connect to system of the bicep muscles when therbligh movement of REACH. Considerable 2 is joint 3 and 4 where this is movement of forearm that connect to triceps muscles when doing MOVE. Considerable 3 is joint 4 where mostly movement of it is forearm when doing RELEASE.

From those movements, joint 4 shows the heaviest movement. Movement of joint 4 bears the load of all the arm's weight, thus extra power is needed to move this joint. It is almost impossible for stroke patients to bring out this extra force. Therefore a helping tool is needed to support those movement of entire whole arm. Moving joint 2 and 3 needs extra power but not as much as moving joint 4.

Based on the biomechanics calculation for the whole weight of the arm, we found the Torque to move the whole arm. Therefore, the motor for joint 4 should rise-up to this torque at a minimum.

The arm's movement is in fact not only supported by the bones but also muscles. Therefore, the muscles' ability to help the arm's movement according to the Therbligh movement standard should also be calculated and considered. However, the muscles of stroke patients suffer from many deteriorations due to paralysis.

2.3 Stroke Patient Arm Movements Limitation

Striated muscles are found on everyone, it is called skeletal muscle or cross-fiber muscle. Striated muscles are controlled by the brain, therefore these muscles are also known as conscious muscles. They are found on the thigh, stomach, chest, and cheek. They are called antagonistic muscles. It means that two or more muscles always work the opposite to each other at one joint. If one muscle relaxes, then the other contracts. The example is the arm that functions to move the forearm. Lifting or lowering the forearm needs two skeletal muscle, which are biceps and triceps muscle. Biceps are located at the front part of the arm and triceps are at the back part of the arm. If the biceps contracts and the triceps relaxes, then the forearm is lifted. If the triceps contracts and the biceps relaxes, then the forearm will be lowered and the hand will be straight again.

Stroke patients will usually experience arms, legs, or facial muscle weakness. Usually, only one side of the body will be affected. Stroke that affects body coordination can result in movement difficulty even when muscle weakness is not experienced. Rehabilitation is an important part of stroke recovery, patients are lucky to be able to start physical therapy or occupational therapy after stroke. When muscles aren't used, a condition called atrophy happens. Atrophy is wasting away of muscles because it has not been used for a long period of time. Physical practice in gyms will train muscles, triggers the muscles to become stronger and bigger, the opposite of atrophy. Lack of muscle activity causes muscles to deteriorate and weaken. After stroke patients are ready to move, muscle atrophy added with muscle weakness from stroke will make physical exercise a challenge.

One of the methods of physical activity before patients are ready for therapy is slowly moving the patients' arms and legs. This is done many times in hospitals for stroke patients that haven't been able to do any activity. One of the benefits of moving passive muscles is to reduce chances of wounds due to pressure when lying or sitting down on only one part of the body for a long time. It also helps prevent blood clots on arms or legs that cannot be moved. Passive movements are also believed to minimize several nerve damage and muscle rigidity that usually happens when muscles aren't used for a long time. Affected muscles due to stroke can still get better with long term passive movement. It helps coordination and health at the same time. One solution to help the exercise of passive movement is by using the robotic arm.

2.4 Robotic Arm for Stroke Patient Therapy

Many methods have been developed by using robot arms to help the movement exercise for stroke patients. However, the existing methods are automated and not customized. They also need many guidance in doing the exercise. Therefore, this research proposes that patients can exercise by themselves using customized measurements based on their own ability and pain from moving the arms slowly using self-control. This control allows the movement of the paralyzed arm to be controlled by the driver, which is the other arm that is not paralyzed, by attaching sensors to the driver. With the help of a sensor that is placed on the patient's arm (on the base of the arm and on the inner elbow), the patient's movement limitation can be measured. The result of the measurement will be used to design the robot arm's movement and then programmed. To do symmetrical self-training movement exercise, the Therbligh motion principle is suitable to be applied. For the implementation, the research is still ongoing in Indonesia at Universitas Atma Jaya Yogyakarta and supported by a grant from Indonesian government. The movement limitation measurement is still an ongoing study. Therefore, it cannot be presented yet in this paper.

3 Conclusion

An analysis of human arm motions has been studied as a preliminary result prior to the design of an artificial shoulder-arm robot to imitate human arms' motions for helping movement therapy for stroke patients that is based on self-training method. A forward kinematic model of the arms using Denavit-Hartenberg approach has been done for modelling purpose. Simulations of the model's behavior for each REACH, MOVE, and RELEASE Therbligh motion has been performed. Imitating movements symmetrically and in sync is hoped to stimulate both the left and right part of the brain well.

Acknowledgments. This research is supported by the Research Funding (Hibah Penelitian) granted by the Indonesia's Ministry of Research, Technology, and Higher Education.

References

1. Andy, Y.: Harmony exoskeleton, robot for back injury therapy (2015). http://www.Jatimtech.com
2. Van Zutven, P.: Modeling, identification and stability of humanoid robots, M.Sc. Thesis, DCT report, Technische Universiteit, Eindhoven (2009)
3. Smith, C., Karayiannidis, Y., Nalpantidis, L., Gratal, X., Qi, P., Dimaragonas, D.V., Kragic, D.: Dual arm manipulation-a survey. Robot. Auton. Syst. **60**(10), 1340–1353 (2012)
4. Datas, A., Chiron, P., Fourquet, J.-Y.: A singular value approach for humanoid motion analysis and simulation. In: 12th International Conference on Control, Automation, Robotics and Vision, (ICARCV 2012), Guangzhou, March 2012
5. Banerji, A., Banavar, R.N.: A dual arm cooperative robot. IRCC, India. http://www.ircc.iitb.ac.in/IRCC-Webpage/PDF/update/Issue1_2007/Dual-armCooperativeRobot.html

6. Barnes, R.M.: Motion and time study: design and measurement of work. Wiley, New York (1968)
7. Asfour, T., Dillman, R.: Human-like motion of a humanoid robot arm based on a closed-form solution of the inverse kinematics problem. In: Proceedings of 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems, Las Vegas, pp. 1407–1412 (2003)
8. Williams, M., Lissner, H.R.: Biomechanics of Human Motion. W.B. Saunders Company, London (1962)
9. Siciliano, B., Sciavicco, L., Villani, L., Oriolo, G.: Robotics, Modelling, Planning, and Control. Springer, London (2009). http://www.ncbi.nlm.nih.gov
10. Kristyanto, B., Nugraha, B.B., Pamosoaji, A.K., Nugroho, K.A.: Analysis of human arm motion at assembly work as a basic of designing dual robot arm system. In: Proceeding International Conference on Industrial Engineering and Engineering Management, Singapore (2017)