Modelling And Simulation Of A Humanoid Robot Arm

Jamaludin Jalani\(^1\)*, Hairuddin Hamzah\(^2\), Sumaiya Mashori\(^3\)

University Tun Hussein Onn Malaysia – Batu Pahat Johor

Abstract

Imitating similar function of a human arm can be very challenging task for a humanoid robot arm. A simple task such as pick and/or place requires the understanding of mathematical modelling, forward kinematics and control system. Hence, this paper presents a modelling and simulation of humanoid robot arm which is based on a human arm anatomy. The model of the humanoid robot arm is developed by using Simmechanics. The robot consists of two arm manipulators, a palm and five fingers. All fingers, i.e. index, middle, ring and small finger consist of three links and three joints except the thumb finger. The thumb has four joints and four links. A previous study has shown that a human hand can safely grasp any cylindrical and cube objects of the same size within approximately one second. This is a very important target to be achieved by a robot hand as the controller should be able to perform as close as possible to human hand speed. In order to control the grasping, a conventional PID control is proposed. The results show that the PID controller is accurately performed less than 5% error better than human grasping. Note that human grasping is limited to 10% error. In addition, the robot hand is able to realize grasping within one second. The results also show that the model of humanoid robot hand is successfully developed by using Simmechanics. A development of forward kinematics is provided based on Denavit-Hartenburg technique to show x, y and z position.

Keywords— Robot Arm, Robot Hand, Simmechanics, PID Controller.

Introduction

The hand is one of the most important sensory organs and actuators of the human body. It has the capability to distinguish a touched object in various forms such as object thickness, object softness and object weight. Eventually, the hand will respond accordingly when grasping such objects without damaging them. Likewise, a robot hand should be able to perform the same tasks before entering the human environment. Significant effort has been
made to emulate as much as possible the functions and the size of a human hand: This can be found in Biggers, et al. (1986), ROBOT (2003), Zacharias (2009) and Grebenstein et al. (2011).

Grasping for the robot hand can be divided into two basic groups namely power grasping and precision grasping (Napier, 1956), (Al-Gallaf et al., 1993), (Johan Tegin, 2005). Power grasping can be seen when a larger object is held up by a simple manipulation task. For example, grasping and lifting a chair and holding a heavy tool are much easier than holding an egg or a pen. Power grasping is usually performed using the palm of the hand and almost every area of each finger during grasping or holding. (Arimoto, 2004), in his survey on intelligent control of multi-fingered hands said that power grasping can be realized without using any sensory feedback if the contact force exerted on an object can be adequately controlled. In other words, we can simply say that power grasping is closing the hand around the object without knowing the final contact points between the hand and the object.

On the other hand, when it comes to precision grasping, more delicate objects such as an egg and a pen are considered. It requires the hand to be more sensitive when it touches the surface of the object. In many cases, precision grasping uses fingertips which are equipped with more powerful sensors. In contrast to power grasping, the contact points are known during precision grasping. In order to understand grasping techniques for a robot hand, a study based on a partial taxonomy of manufacturing grasps has been proposed by Cutkosky et al. (1986). The group has done an observation on single-handed operations by machinists which were working with metal parts and hand tools. They have found that power and precision grasping can be further detailed into smaller groups such as prehensile (clamping required) and non-prehensile (clamping not required). The study also showed that, in general, grasping can be easily achieved by a hand but hardly realized by a robot hand. A lot of effort has been devoted to copy a human hand such as in Vandeweghe et al. [2004] and [Thayer &Priya, 2011], however, none of the robot hand designs so far can beat the human hand.

Objectives Of The Project

It is not a trivial task to control the humanoid robot hand. It requires a preliminary study of human hand. In general, human hand can be separated into several parts namely upper arm, elbow, forearm, wrist and fingers. The study shows that the human hand is a complex system of bones, muscles, nerves, and vessels. Hence, a simple task such pick and/or place requires a study of modeling, joint space control, forward kinematics and etc.

It is very important to show that the robot hand is able to grasp an object within approximately one second. A study by Armstrong et al. (2009) has shown that a human hand can safely grasp any cylindrical and cube objects of the same size within approximately one second from opening to closing state. Moreover, it is to note that human grasping is limited to 10% error (Choi et al., 2008). Thus, the speed and the grasping error of the robot grasping must be based on this performance. However, the work becomes more complex since the representation of robot hand consists of 19 joints. Besides, a highly sophisticated computer machine may be required for high level computation.
Hence, the objectives of this project are:

- To develop a humanoid robot hand model by using Simmechanics.
- To apply PID controller for grasping purpose.
- To achieve good motion control where the robot hand is able to realize grasping within one to two seconds.
- To attain less than 10% grasping error.
- The modeling and simulation of this project are implemented in SimmechanicsMATLAB.

Modelling And Controller

In order to achieve the objectives as mentioned in Section II, a few steps are taken. The first step is to study a physical structure and movement of human arm and forearm as depicted in Figure 1. This is very important procedure due to the fact that human hand is versatile. Although, a simple task such as grasping a glass can be very easy for a human hand but it can be very complex for a humanoid robot hand.

The information such as the mass, link, muscle and the length from the arm to the end effector (i.e. fingers) can be very useful for modelling purpose. This will ensure that a developed humanoid robot model is sufficient for control purpose. The second step requires the understanding of Simmechanics/ Matlab.

Once a model is available in Simulink, the third step will consider a suitable choice of controller to ensure that a desired grasping position is achieved. However, for the preliminary control purpose, a well-knownPID controller is considered. Figure 2 illustrates the flowchart of the development of robot hand model.