Chapter 16
Control of a Biomimetic Robot Hand Finger: Classical, Robust, and Intelligent Approaches

Yunus Ziya Arslan
Istanbul University, Turkey

Yener Taskin
Istanbul University, Turkey

Yuksel Hacioglu
Istanbul University, Turkey

Nurkan Yagiz
Istanbul University, Turkey

ABSTRACT

Due to the dexterous manipulation capability and low metabolic energy consumption property of the human hand, many robotic hands were designed and manufactured that are inspired from the human hand. One of the technical challenges in designing biomimetic robot hands is the control scheme. The control algorithm used in a robot hand is expected to ensure the tracking of reference trajectories of fingertips and joint angles with high accuracy, reliability, and smoothness. In this chapter, trajectory-tracking performances of different types of widely used control strategies (i.e. classical, robust, and intelligent controllers) are comparatively evaluated. To accomplish this evaluation, PID, sliding mode, and fuzzy logic controllers are implemented on a biomimetic robot hand finger model and simulation results are quantitatively analyzed. Pros and cons of the corresponding control algorithms are also discussed.

1. INTRODUCTION

Due to the high functional properties of biological systems, many scientists were inspired by the nature to find solutions to problems in medicine and engineering. There have been many important advancements in the biologically inspired technology that is especially developed in the area of robotics and mechatronics (Habib, 2007; Habib, 2011). Human inspired robotic technology has made a significant improvement over the past two decades (Schaal, 1999; Breazeal and Scassellati, 2002; Chen et al., 2011; Chen and Huang, 2012). Especially, there have been many promising advancements in the field

DOI: 10.4018/978-1-4666-7387-8.ch016

of bio-inspired robotics hands. For the state of the art and current trends in the development of dexterous robotic hands, refer to the review articles of Shimago (1996), Biagiotti et al. (2004) and Mattar (2013). One of the main challenges in executing manipulation task is how to control the robot hands such that they can produce motions with the same dexterity and intuition as human hands (Al-Gallaf et al., 1993). To handle the motion control problem of humanoid robotic hands, different types of control algorithms were introduced and implemented (Pons et al., 1999; Hacioglu et al., 2008; Arslan et al., 2009). In this study, to evaluate the trajectory tracking performances of widely used control methods, namely PID, sliding mode and fuzzy logic controllers were implemented on a biomimetic robot hand finger model and simulation results were comparatively discussed. Because of the similar biomechanical properties and kinematic structures of the hand fingers to each other's except thump, motion control of only one finger, i.e. index finger has been considered. Hence, in this study, analyzing the flexion motion of the human hand is reduced to examine the single finger motion.

Since it has relatively simple algorithm for application and provide successful performance, PID controller is probably the most widely used control approach in industrial applications (Ang et al., 2005; Åström and Hägglund, 2006; Åström and Murray, 2008). The PID controller algorithm involves three separate constant parameters: the proportional gain, the integral and derivative times. The weighted sum of three actions is used to adjust the control process. For specific control tasks, those parameters are tuned according to the requirements of the process (Kelly, 1995).

Due to its invariance properties, sliding mode control (SMC) is a widely used robust control method, especially in the field of robotics (Yagiz et al., 2007; Feng et al., 2002; Engeberg and Meek, 2013). It is a special class of variable structure control systems in which the control law is deliberately changed during the control process according to some predefined rules depending on the states of the system (Edwards and Spurgeon, 1998). The fundamental concept of the SMC is to drive the system states to the so-called sliding surface and then keep the system within a neighborhood of that surface (Utkin, 1977). During the sliding motion, the system is insensitive to parameter variations and external disturbances (Yagiz et al., 2010).

Fuzzy logic control (FLC) is a knowledge-based control method and it is based on the fuzzy set theory (Zadeh, 1965). Because it has applicability to systems with unknown mathematical model and it has a rule-based structure, this control approach has become widespread (Feng, 2006; Hacioglu et al., 2011). In this method, the experience-based knowledge can be expressed by fuzzy rules and they are used for the control signal calculations. Fuzzy logic has the advantage comparing with other machine learning systems such as neural networks that the solution of the control problem can be defined in such a way that human operator can understand; therefore operator's experience can be used in the design of the controller. Because of these attractive properties, fuzzy logic has been used in wide range of control applications (Taskin et al., 2007; Arslan et al., 2008; Yagiz and Hacioglu, 2009).

2. PHYSICAL MODEL OF THE BIOMIMETIC FINGER

The biomimetic hand finger, on which the controller methods were applied, was modeled as a kinematic chain of three cylindrical links that mimics the inertial properties of the proximal, middle and distal phalanges of the index finger (Figure 1). Spherical elements were added to the articulations of the model to represent the joint masses of the finger.