Chapter 50
Fuzzy Logic-Based Intelligent Control System for Active Ankle Foot Orthosis

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ABSTRACT

The Ankle Foot Orthosis (AFO) is an orthotic device intended to assist or to restore the movements of the ankle foot complex in the case of pathological gait. Active AFO consists of sensor, controller, and actuator. The controller used in the conventional AFO to control the actuator does not use the property of synchronization of the feet. This chapter deals with development of a fuzzy-based intelligent control unit for an AFO using property of symmetry in the foot movements. The control system developed in LabVIEW provides real-time control of the defective foot by continuously monitoring the gait patterns. The input signals for the control system are generated by the sensor system having gyroscope. DC motor is used as an actuator. The data acquisition for Gait Analysis is done using National Instrument's data acquisition system DAQ6221 interfaced with a gyro-sensor.

INTRODUCTION

Fuzzy logic controller (FLC) is a set of linguistic control rules related by the dual concepts of fuzzy implication and the compositional rule of inference. In essence, then the the FLC provides an algorithm which can convert the linguistic control strategy based on expert knowledge in to an automatic control strategy. Experience shows that FLC yields results superior to those obtained by conventional control algorithms (Chuen Lee, 1990). Conventional control techniques such as Proportional Integral and Differential (PID) control, nonlinear feedback control, adaptive control, sliding mode control, Linear quadratic Gaussian control etc. are advantageous when the values of the controller parameters are known and the control signals are generated exactly. Also, when the underlying assumptions are satisfied, many of these methods provide good stability, robustness to model uncertainties and disturbances, and speed of response. However these control algorithms are "hard" or "inflexible" and cannot handle "soft" intelligent control which may involve reasoning and inference making using incomplete, vague, noncrisp,

DOI: 10.4018/978-1-5225-1908-9.ch050

and qualitative information, and learning and self- organization through past experience and knowledge. The fuzzy control gives the optimal performance to control the DC motor and also overcome the disadvantages of the conventional control sensitiveness to inertia variation and sensitiveness to variation of speed with drive system of DC motor (Thepsatoml P, 2006). Jamal Abdaltayef & ZHU Qunxiong (2010) have implemented a DC motor position control to show that FLC responds with less overshoot and minimum settling time over conventional PID control. Fuzzy logic systems emulate human decision making more closely than artificial neural network. The main advantages are that no mathematical modeling is required as in PID since the controller rules are based on the knowledge of system behavior and experience of control engineer (Chuen Lee, 1990; Clarence W.de Silva, 1995; Pedro Ponce-Cruz & Fernando D. Ramirez-Figueroa, 2010).

Fuzzy control is a type of intelligent control whose main feature is that a control knowledge base is available within the controller and control actions are generated by applying existing conditions or data to the knowledge base, making use of an inference mechanism. The knowledge base and inference mechanism can handle non crisp and incomplete information, and the knowledge itself will improve and evolve through "learning" and past experience (Clarence W.de Silva, 1995; Pedro Ponce-Cruz & Fernando D. Ramirez-Figueroa, 2010). In particular, the methodology of the FLC appears very useful when the processes are too complex for analysis by conventional quantitative techniques or available sources of information are interpreted qualitatively, inexactly, or uncertainly. Thus fuzzy logic control may be viewed as a step toward a rapprochement between conventional precise mathematical control and human like decision making.

Since humans use bipedal walking, mobility and stability are exclusive terms. In this sense, humans need a trade-off of the two terms to achieve a task given or a goal desired. In order to do this, humans require sensory systems to gather information about surrounding environments, and control strategies utilizing information. The visual, vestibular, and proprioceptive systems are used when humans gather this information. From the perspective of locus of control, the pertinent interactions occur among the central nervous system, the peripheral nervous system, and the musculoskeletal system (Woo-Hyung Park, 2004). Human body movement is controlled by the central nervous system in the brain. The complex and nonlinear information processing is done from the brain to the body limbs. The command is first sent from the central nervous system to each muscle via neurons. It activates the muscle and causes the muscle tensions. Secondly the muscle tensions act on the related joint and cause the joint torque. Finally the joint torque realizes the motion corresponding to the joint dynamics (Vldimir Medved, 2001).

In physiological system, control strategy employs feedback control and feed-forward control. Feedback control is referred to as closed-loop, because the outputs return and influence the inputs. The role of feedback information is to provide the substrate with the detection and correction of movement errors. Thus, if feedback information is readily available then desired movements can be achieved more efficiently. However, in humans, there are two major problems in the feedback system: transmission delays leading to low feedback gain and processing overload in the neural system. Feed-forward control strategy can be used to compensate feedback control strategy by avoiding problems with transmission delays and also in reducing the amount of processing required. One of key features of feed-forward control strategy is a movement model of the future which allows planning for future events. The model is based on knowledge of the results of the dynamics involved in a movement, and also considers system constraints and future goals. This knowledge is often referred to as an internal model, or internal representation (Woo-Hyung Park, 2004). In FLC predefined rule base with an expert system is used, also called as internal model to minimize the computational delays.