Chapter 16
Walking Control of Humanoid Robots on Uneven Ground Using Fuzzy Algorithm

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ABSTRACT

Walking control of humanoid robots is a challenging issue. In this chapter, a method for modeling humanoid robots is presented considering the human being indices such as DOFs, mass and the moment of inertia of the segments. In the next step, a walking pattern on the flat ground is generated and the robot motion is simulated in the MSC. Visual Nastran 4D™ software. ZMP trajectory of the simulated humanoid robot in walking cycle has been obtained. An uneven ground is generated in the software, where the robot falls down during the motion. A fuzzy algorithm is employed to balance the robot; input is defined as the differences between the projections of ZMP in flat and uneven ground and output is a compensative signal to make the robot follow the flat ground ZMP pattern to refuse the robot falling. Output signal is distributed in different joints to make faster and more effective compensation. Although the type of uneven ground can be important, but the robot could successfully pass the designed uneven ground in MSC.Visual Nastran 4D.

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INTRODUCTION

Recently there are many research projects continuously in progress for control, planning and motion generation of humanoid robots. In order to accomplish complicated jobs, humanoid robots must possess intelligent abilities. A humanoid robot should be capable of both interacting with human beings and moving within human living environments. A humanoid robot capable of cooperating with human beings needs the ability to move between objects, walk on different types of ground and communicate.

Controlling the balance of a humanoid robot in complicated environments is an important issue. Vukobratovic proposed ZMP (Zero Moment Point) as an index for the stability of humanoid robots (Vukobratovic & Juricic, 1969). The ZMP stability criteria states that the biped will not fall down as long as the ZMP maintains inside the convex hall of the support polygon of the foot. Since that time, intelligent control techniques such as genetic algorithms, neural networks, and fuzzy logic and hybrid forms such as neuro-fuzzy networks, neuro-genetic and fuzzy-genetic algorithms were applied in humanoid robot control techniques (Katić & Vukobratović, 2003).

Some researchers have used fuzzy logic in tuning of gains of PID controller of humanoid robot (Vukobratovic & Timcenko, 1995). Zhou and Meng (2000) used a combination of reinforcement learning with the fuzzy gait synthesizer to track the desired trajectory. Chi- Cheng, Chen, Hu and Wong (2009) proposed a fuzzy algorithm for balancing a small-size humanoid robot to adjust the robot's posture based on an accelerometer sensor. Fuzzy logic has been used for controlling humanoid robots in facing with obstacles and uneven grounds too. Wong, Cheng, Huang and Yang (2008) implemented fuzzy system on a humanoid robot to avoid obstacles based on the obtained information of infrared (IR) sensors and electronic com-pass. Wong, Hwang, Huang, Hu and Cheng (2011) also designed a vision-based obstacle avoidance method to avoid humanoid robot from obstacles based on fuzzy control. Park, Han and Hahn (2009) proposed a fuzzy balance control algorithm using 3D (Dimensional) geometric information. A few research projects have focused on fuzzy control of humanoid robots on uneven surfaces; however, the ability of robot to move on human-base environments is an important point. In addition, the necessity of building capable humanoid robots for exploration on unknown environments is a significant issue.

Kim, Park, and Oh (2007) proposed an online control algorithm that considers local and global inclinations of the surface by which a biped humanoid robot can adapt to the floor conditions. Kong, Lee, and Kim (2008) proposed a real-time walking stabilization method utilizing a fuzzy algorithm under uneven terrain. They used ankle motors as an active joint to balance the robot using fuzzy algorithm. In this method, the ankle joints were producing great amount of torque to compensate the mass deviation of robot to refuse falling. The algorithm was verified by simulation and walking experiments on a 24-DOFs humanoid robot. When a robot is falling in sagittal plane direction, different DOFs such as ankle, upper body, hip and arms can refuse it; meanwhile that research has just focused on ankle, which increases the response time and risk of falling greatly. Human beings use different joints to balance when they are falling (e.g. Upper body as well as lower body segments).

In this chapter, we propose a method to design a humanoid robot based on human characteristics, and then a walking pattern is generated for flat ground and the ZMP trajectory of robot is obtained. In the next step, a fuzzy control algorithm has been designed, input is the difference between the projections of ZMP in the flat and uneven ground; however, output is the proper motion of the robot to control the ZMP considering the flat ground ZMP pattern as a reference to refuse the robot falling. The weighted average method is used to determine the final output of the fuzzy system. Compensation value is shared between different DOFs. The model is designed in MSC.visualNastran 4D™ software and the fuzzy

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