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Simulation Analysis of Impulsive Ankle Push-Off on the Walking Speed of a Planar Biped Robot

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Ankle push-off generates more than 80% positive power at the end of the stance phase during human walking. In this paper, the influence of impulsive ankle push-off on the walking speed of a biped robot is studied by simulation. When the push-off height of the ankle joint is 13 cm based on the ground (the height of the ankle joint of the swing leg) and the ankle push-off torque increases from 17 to 20.8 N·m, the duration of the swinging leg actually decreases from 50 to 30% of the gait cycle, the fluctuation amplitude of the COM (center of mass) instantaneous speed of the robot decreases from 95 to 35% of the maximum speed, and the walking speed increases from 0.51 to 1.14 m/s. The results demonstrate that impulsive ankle push-off can effectively increase the walking speed of the planar biped robot by accelerating the swing leg and reducing the fluctuation of the COM instantaneous speed. Finally, a comparison of the joint kinematics of the simulation robot and the human at a normal walking speed shows similar motion patterns.

Keywords: biped robot, 2D walking, ankle push-off, ankle torque, walking speed

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INTRODUCTION

Some studies of ankle push-off with respect to stability, energetic efficiency and disturbance rejection have been conducted using simulation models and real biped robots. However, the effect of ankle push-off on the walking speed of bipedal robots has not been studied deeply. In this paper, the influence of impulsive ankle push-off on the walking speed of a biped robot is studied via a simulation method. We first review past work on the role of ankle push-off during human walking and some studies of ankle push-off in simulation models and real biped robots, followed by our simulation model and controller. At last, the results and discussion are presented.

Ankle Push-Off in Human Walking

Ankle push-off is the positive power or work generated by the plantarflexor muscles and tendons about the ankle joint at the end of the stance phase during the step-to-step transition in human walking (Zelik and Adamczyk, 2016). Ankle push-off occurs at 45–65% of the gait cycle (Zelik and Kuo, 2010). Due to its significant role in human locomotion, ankle push-off has been studied in biped robots in many previous studies. Dean and Kuo (2009) presented that the advantage of the ankle push-off function is to reduce both the velocity of the COM (center of mass) at the heel strike and the energy loss caused by the collision (Dean and Kuo, 2009). These researchers also suggested that the main function of ankle push-off is to redirect the COM velocity during the step-step transition