Tittle of Project

Stability Control with Pushing and Automatic Recovery Capabilities for a Biped Walking Robot

Abstract

Biped walking robot realizes locomotion by its pair of legs with walking gaits similar to human beings. Because of these dynamic characteristics, compared with wheeled robots, biped walking robots possess a variety of merits, such as the capability of locomotion on irregular terrains and higher affinity to humans compared to wheeled robots. A problem that biped walking robots usually confront is unknown perturbation from the environment and human beings, which may seriously jeopardize the walking stability. The purpose of this project is to develop a system which takes advantages of the inner stability and posture change of the biped walking robot to make it capable of dealing with unexpected external disturbance and returning to its stable state.

Problem Statement and Motivation

The biped walking robot as a service robot in the future is supposed to work in a human living environment. When the robot moves in a complicated environment, it is highly likely for the robot to endure a variety of unknown disturbances from its surroundings. Under unexpected external force, the walking state will be changed in a short period of time, including its velocity, position, angular momentum, and etc., and the robot may diverse from its stable walking state and fall down. This work hopes to analyze the extent to which the robot can tolerate perturbations and if the perturbation exceeds the tolerance, what strategies should be adopted to overcome it and recover to stability. We hope that based on this proposed stability control system, the real biped walking robot can overcome perturbation in its walking process.

Research Approach and Innovation

We adopt a biomimetic way to tackle this problem and obtain an elementary understanding. The Fig. 1 shows human reactions when a tester is pushed from his back or front:

1.When the push is not very fierce, the tester rotates his trunk Fig. 1-b and swing his swing leg quickly Fig. 1-c to maintain his balance.
2.When a more fierce force is applied, the tester needs to take a larger step Fig. 1-a or reverse his swing leg Fig. 1-d.

From this test, we see that trunk and swing leg rotation are supposed to play important roles for stability control. According to this, we propose strategies based on two kinds of walking patterns (ZMP Based Walking & Limit Cycle Walking) to enhance the walking robustness by designing optimal walking gaits.

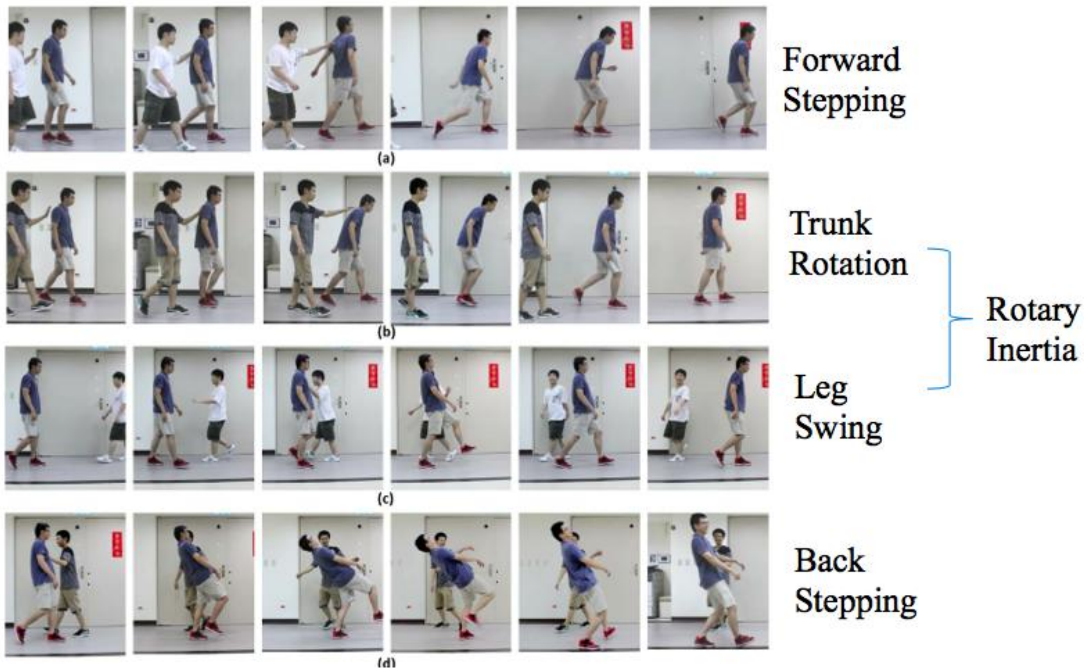

Fig. 1. Human reaction if pushed

ZMP Based Walking:
Based on the ZMP criterion, a more widely used method to realize biped robot walking is to design its walking gaits according to ZMP criterion. As long as the ZMP is satisfied, various walking gaits and velocity can be achieved. Fig. 2 shows the architecture for walking pattern generator. And the safety region of support foot is shown in Fig. 3.

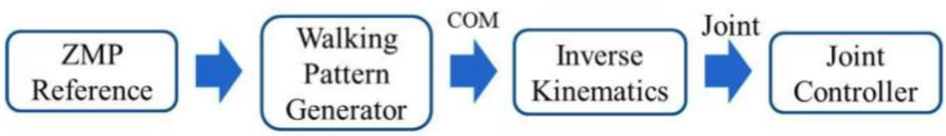

Fig. 2. Architecture for walking pattern generation

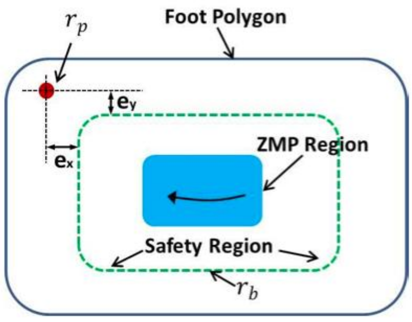

Fig. 3. Safety region of the support foot

Based on the analysis of how to counteract the external perturbation during walking and achieve recovery, the timetable of the whole control architecture is shown in Fig. 4 and Fig. 5.

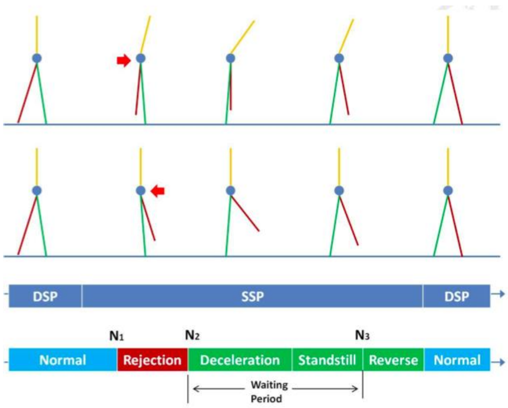

Fig. 4. Timetable of Control Architecture

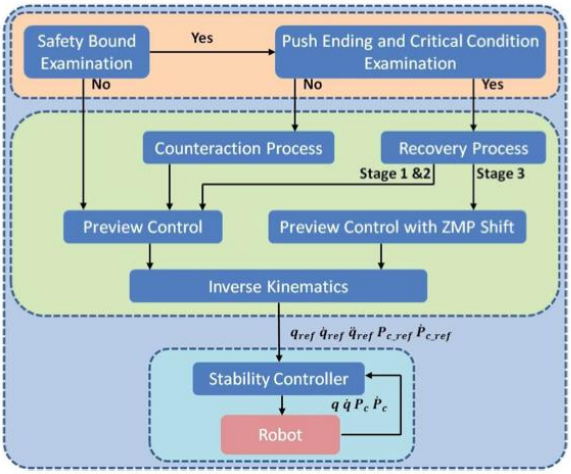

Fig. 5. Block diagram of perturbation counteraction and recovery strategy

Expected Results

In the first experiment, the biped walking robot is pushed from its back and the point of force application is located at its trunk. As a result, the robot rotates its trunk forward to counteract a pushing force from its back as shown in Fig. 6. Besides, the hip tracking performance and the ZMP performance are shown in Fig. 7 and Fig. 8.

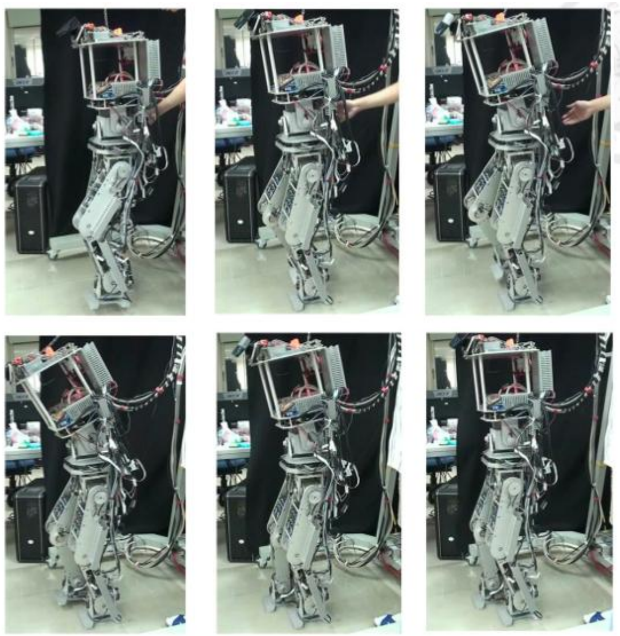

Fig. 6. Experiment with push from the back

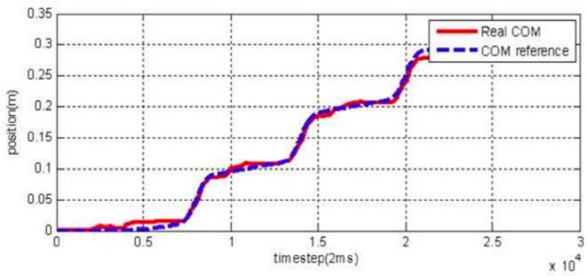

Fig. 7. COM performance with push from the back

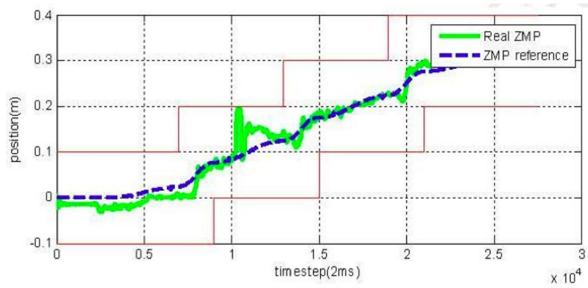

Fig. 8. XMP performance with push from the back

Fig. 9 is its corresponding magnified view, we can see that real ZMP is limited in the safety bound (yellow dashed) in the whole walking process. And the trunk pitch trajectory is shown in Fig. 10.

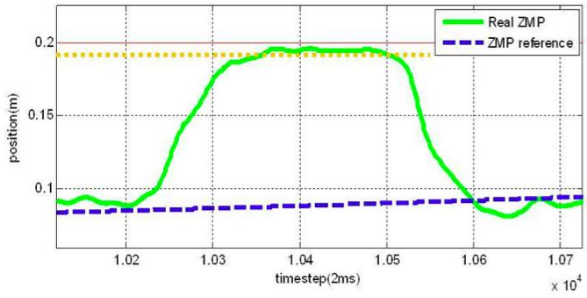

Fig. 9. Zoomed ZMP performance with push from the back

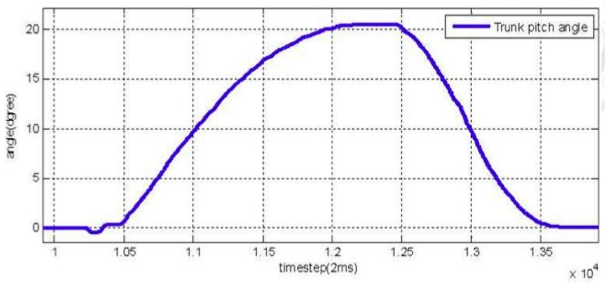

Fig. 10. Trunk pitch trajectory with push from the back

Similarly, the walking robot is pushed from its front, the robot rotates its swing leg quickly to counteract the perturbation as shown in Fig. 11. And the COM tracking performance and the ZMP performance are shown in Fig. 12 and Fig. 13.

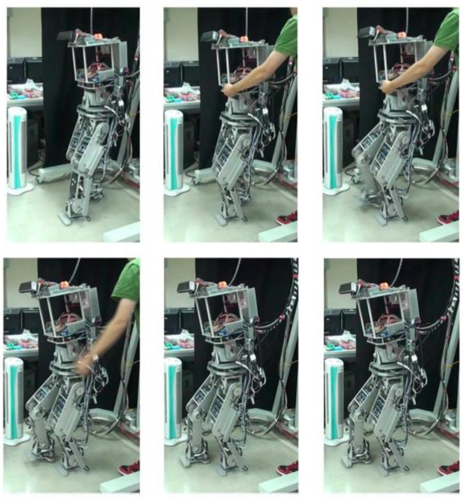

Fig. 11. Experiment with push from the front

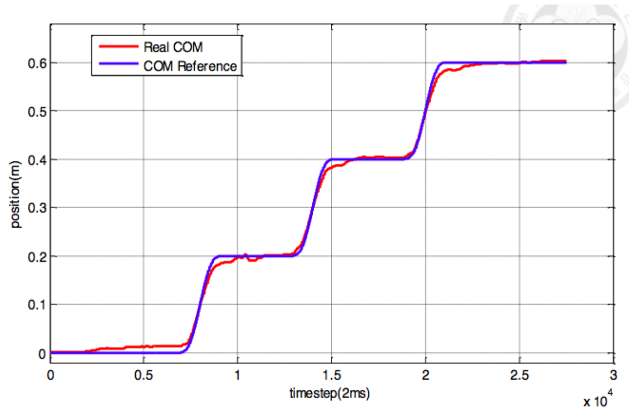

Fig. 12. COM performance with push from the front

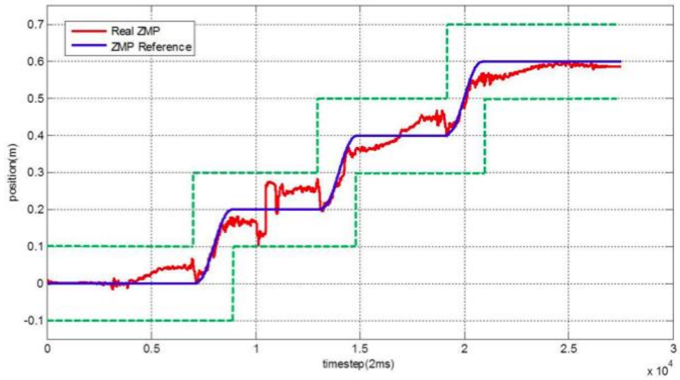

Fig. 13. ZMP performance with push from the front

Fig. 14 shows how ZMP is controlled inside the safety bound (yellow dashed) and Fig. 15 shows the joint trajectories of swing leg and it shows abrupt change of motion when the stability controller is applied to counteraction the push.

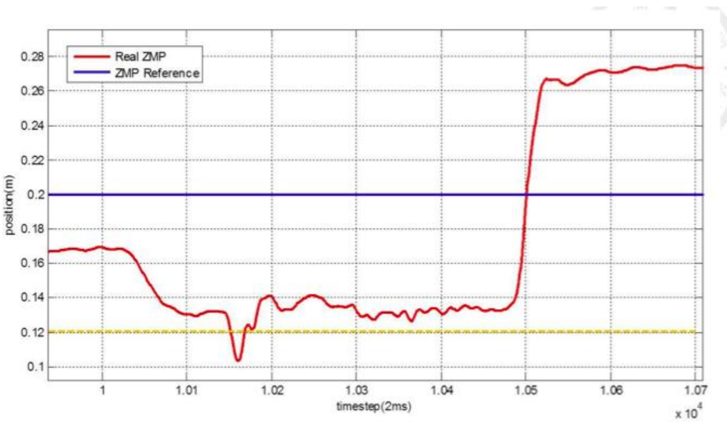

Fig. 14. Zoomed ZMP performance with push from the front

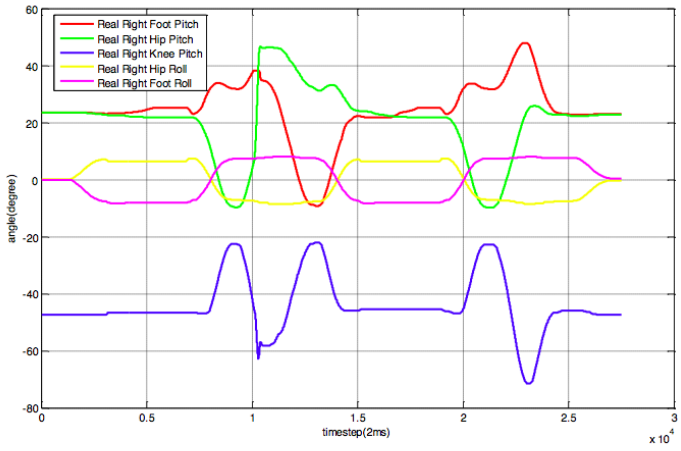

Fig. 15. Swing leg trajectory with push from the front

Industrial Applications and Its Impact

The purpose of this project is to construct the intelligent humanoid robot system. This system can help people and be actually used in our daily life. As an intelligent robot service system, it should be able to work in a complicated human living environment and endure a variety of unknown disturbances from its surroundings. So that the robot can walk freely and complete services tasks ordered by human users.

Therefore, stability control is a core and fundamental technology for the functions of biped walking robots.