Reflex-Based Walking Controller for Real Bipedal Robot
— From Phase-based to Reflex-based —

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1 Introduction

This research aims to investigate the contribution of the reflex existing in human's muscular-skeletal system to adaptive bipedal walking. A simulation study has been proposed to the reflex-based walking model [1] validated by showing the consistency between myoelectric data, leg ground reaction force (GRF) and human data [2, 3]. Our research goal is to build reflex-based walking starting from a phase-based walking strategy.

This research report explains how we derive a reflex-based controller from a phase-based controller and show preliminary experimental results. We developed a musculoskeletal biped robot driven by 7 muscles including 2 biarticular muscles. The robot walks 8 steps on a treadmill with a phase-based walking controller for one single experimental trial.

2 From Phase-based to Reflex-Based

We are going to derive a reflex-based controller from the phase-based behavior of the biped robot (Figure 1). First, we realize bipedal walking by the musculoskeletal robot based on the phase-based controller. The controller is derived in an empirical approach [4]. The robot is equipped with several types of sensors, such as foot force sensors, trunk attitude sensors, and muscle tension sensors. Based on the measurements of the sensors, we are going to derive a reflex-based controller. For example, a control input obtained from muscle sensor signals can be a stretch reflex. After we obtain such reflexes, we validate the new controller by conducting experiments with the reflexes and showing adaptability against the changing of terrain. By obtaining sensor signals of various muscles, we expect that there are many combinations of the sensor signals that can reproduce the phase-based inputs. We can consider how different combinations of the muscle reflex contributes to the stable walking by comparing some walking experiments.

3 Robot Design

Figure 2 (a) shows the photo of the musculoskeletal robot. The mechanical design of the robot is based on the

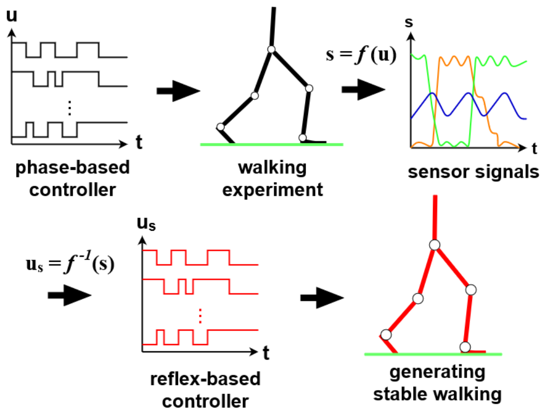
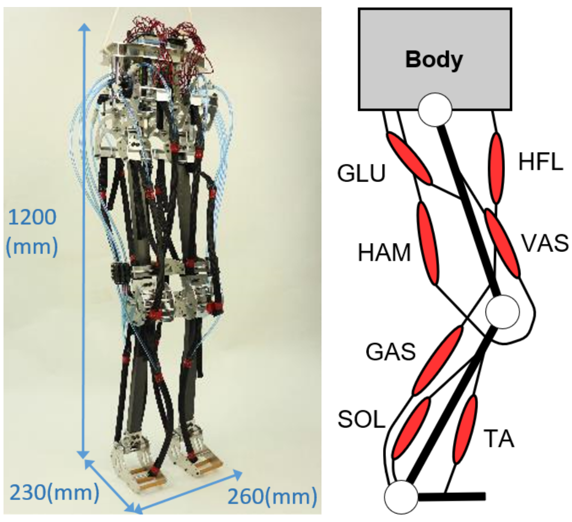


Figure 1: Conceptual diagram of Creation Method

Geyer's 2D walking model [1]. The weight is 7.7kg and the size was determined by referring to human size. Figure 2 (b) shows the muscle's setup of the robot. This robot has 7 muscle on a leg and it has three pairs of antagonistic structures, hip flexor(HFL) and gluteus maximus(GLU), vastus medialis(VAS) and hamstring muscles(HAM), tibialis anterior(TA) and gastrocnemius(GAS), soleus(SOL). It is important to use a human muscle like actuator for verifying reflex-based controllers. We use McKibben type pneumatic artificial muscles (PAMs) for the robot.



(a) Photo of the robot **(b)** Muscle's setup

Figure 2: Musculoskeletal biped robot

4 Experiment and Result

We show the result of the walking experiment with the phase-based controller. We applied a simple phase-based control which determines the air pattern of the PAMs by using the parameters based on empirical experiments. The air pattern of muscles is shown in Figure 3. The internal plessure of the PAMs is 0.6 MPa. To constrain the robot within to 2D sagittal plane, we developed a device composed two joint arms and slide rails. Figure 4 is one set of the snapshots taken during the experiments. We achieved 8 steps of walking on the treadmill in one experimental trial. By analyzing the gaits, we plotted the graphs of each joint angle by DIPP-Motion2D. Then we compared the model reported by [1]. The comparison between the results and the model's results is shown in Figure 5. The joint angles of the walking experiment indicated the robot matched with the model to a certain extent, besides of the ankle joint.

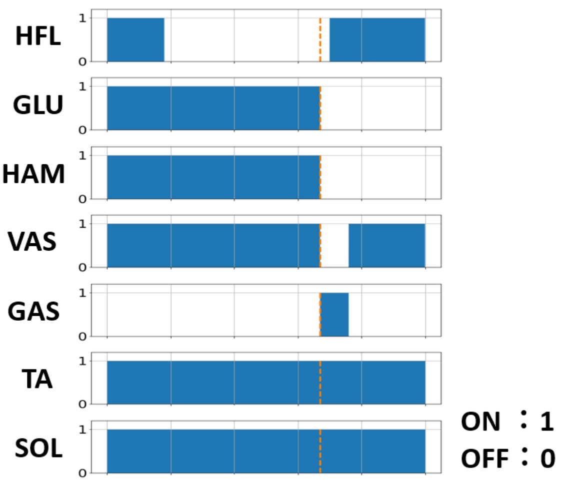


Figure 3: Control pattern of muscles in one cycle. Vertical dotted lines indicate toe off.

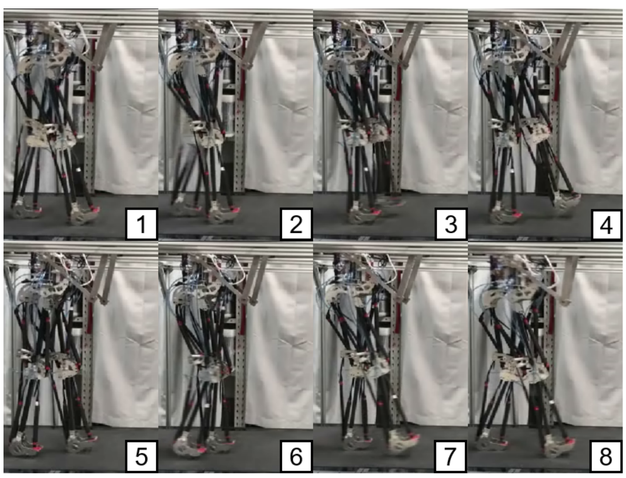


Figure 4: Snapshot of the robot walking(35fps)

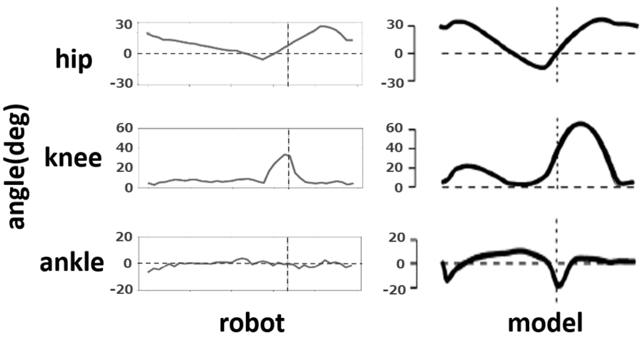


Figure 5: Comparing between each joint angle of the robot and the model's results in one cycle [1]. Vertical dotted lines indicate toe off.

5 Conclusion and Future Work

In this study, we developed a musculoskeletal robot to verify the human muscle-reflex walking model. As a result, We achieved 8 steps of walking on the treadmill with the phase-based controller in one experimental trial. From the comparison between the walking results and the model, we found some differences (Figure 5). Especially, there are major difference at ankle joint. The PAMs of TA and SOL were supplied with air at all times in order to keep ankle stiffness. Therefore, the robot could not kick the ground (Figure 3). This creates a small phase difference of the knee joint angle. During the robot's kick motion, the trunk will lean behind as the reaction. We need to develop a system including an attitude sensor of the trunk to maintain the walking stability even if the robot kicks.

In the near future, we aim to realize the stable walking along Section 2. The first step we have to take is to equip with the foot force sensor to the robot. Then, we can obtain a feedback factor to improve the phase-based controller. The robot is also equipped with the trunk attitude sensor, and muscle tension sensors. We need to take into account the tuning of muscle reflex such as the balance between the sensor signals from the muscle tension and the lean of the trunk.

References

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