Gait Adaptation Model in Human Splitbelt Treadmill Walking

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SUMMARY

In order to construct the gait adaptation model of human splitbelt treadmill walking where the speed of the right and left belt is different, we proposed a simple control model and made a 2D biped robot called 'Tetsuro' walk on the splitbelt treadmill. We combined the conventional limit-cycle based control with a newly proposed adjustment of P-gain at hip joint of the stance leg. High similarities in ratios and patterns of the measured indexes between human experiments by Bastian's group[1] and our robot experiments implied the validity of our hypotheses and the proposed model.

INTRODUCTION

Robust 2D walking of Tetsuro was achieved by the conventional limit-cycle based control consisting of joint PD-control, the cyclic motion trajectory based on the inverted pendulum, and the stepping reflex[2]. The gait adaptations in splitbelt treadmill walking was achieved by newly proposed P-gain adjustment at hip joint of the stance leg, which corresponded to muscle stiffness adjustment by the cerebellum. The course of the experiment was divided into three stages (the baseline, the adaptation and the post-adaptation). Only in the adaptation stage, the treadmill was in the splitbelt configuration.

SPLITBELT TREADMILL WALKING RESULTS

The stride length is defined as the distance traveled by the ankle joint from the time of lift to the time of landing of the leg. The stride length data measured in a robot experiment and human experiments as normal subjects are shown in Figure 1. We can see similar patterns between those data. We obtained similar results about the duty ratio. Those indexes were almost constant in the baseline stage, quickly changed at the beginning of the adaptation stage and were kept almost constant within the adaptation stage, and quickly returned almost to the original values at the beginning of the post-adaptation stage.

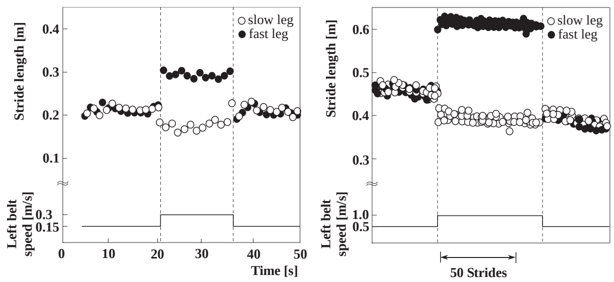
The step length is defined as the distance between positions of the ankle joints of swing and stance legs at the time of landing of the swing leg. The step length difference data measured in a robot experiment and human experiments as normal subjects are shown in Figure 2. We obtained similar results about the ratio of the double legs stance period. Those indexes gradually returned near to the original values in the late adaptation stage in spite of difference in the speed of two belts. This meant that normal subjects preferred a symmetric gait even in the splitbelt configuration. In addition, those indexes quickly changed at the beginning of the post-adaptation stage even though the speed of two belts became same. This is one of well-known phenomena called "aftereffects."

We made Tetsuro walk on the splitbelt treadmill without using P-gain adjustment in order to see the effectiveness of P-gain adjustment and construct the control model of cerebellar disease subjects. We could see neither gradually returning to the original values in the late adaptation stage nor aftereffect at the beginning of the post-adaptation stage in both human and the robot as cerebellar disease subjects.

DISCUSSION

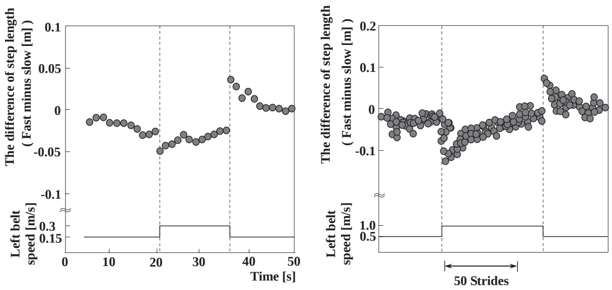
While comparing to the model mentioned by Bastian's group[1], we obtained the following gait adaptation model.

- The stepping reflex adjusts the *intralimb index* (the stride length) in spite of its style as *interlimb control*, and corresponds to the reactive feedback-driven adaptation at the brainstem.
- P-gain adjustment adjusts *interlimb indexes* (the step length difference between legs) in spite of its style as *intralimb control* while being combined with the stepping reflex (*interlimb control*), and corresponds to the *reactive* feedback-driven adaptation at the cerebellum.



(a) a biped robot: Tetsuro (normal subject model) (b) human (normal subject)

Figure 1. The stride length in splitbelt treadmill walking.



(a) a biped robot: Tetsuro (normal subject model) (b) human (normal subject)

Figure 2. The step length difference in splitbelt treadmill walking.

REFERENCES

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