Analysis of the influence of the joint position of the trunk on gaits of a quadruped robot

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1 Introduction

Creatures show adaptive movements to the environment where they live. To realize such adaptive locomotion, there are many studies even in robotics. In previous research to reveal such adaptive locomotion mechanism, there is an interesting research on interlimb communication in a quadruped walking robot with autonomous decentralized control [1]. In this study, although each leg was controlled independently, various gaits were realized by coupling them mechanically, On the other hand, in our previous study [2], it was confirmed that the gait of quadruped passive dynamic walking robot was changed according to the trunk part which connected the front and hind legs. From these result, we consider that the trunk part plays an important role to generate interlimb coordination, and that the derived gaits will change depending on the structure of trunk. Therefore, in this study, in order to clarify how the change of trunk structure affects gait which is generated by autonomous decentralized control, we analyzed the influence of trunk structure on it's gait focusing on a degree of freedom of the trunk and the position of joint.

2 Quadruped robot that has segmented trunk

An overview of the robot used in this research is shown in Fig. 1. The robot was constructed on ODE(Open Dynamics Engine). The trunk part connecting the front leg and hind leg is divided into 6 from the front by $l_s = 0.05[m]$. Only one of the joints can be given a degree of rotational freedom of either yaw, roll or pitch (Fig. 2). By giving elasticity to the joint, it behaves like an angular spring according to the applied displacement.

Each leg is controlled by using TEGOTAE-based control [1], which is one of autonomous decentralized walking control method. In the TEGOTAE-based control, independent phase oscillators are assigned to each leg, and joints of each leg are controlled so as to realize a leg tip trajectory corresponding to the phase. And, a pressure sensor is mounted on the tip of the leg, and the following pressure feedback is applied to the phase oscillator in each leg;

$$\dot{\phi}_i = \omega - \sigma N_i \cos\phi_i, \tag{1}$$

where ω is an intrinsic angular velocity, σ is a positive constant describing the magnitude of the feedback to the corresponding oscillator, N_i is the ground reaction force acting on the ith leg.

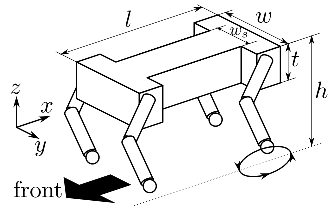

Figure 1: Overview of the robot that has segmented trunk

3 Simulation Result

Fig. 3 shows the walking speed when any feedback control was not used($\sigma = 0$). The indicated walking speed is relative value to the walking speed when the rigid body were used. Fig. 4 shows the walking speed when TEGOTAE-based feedback control (Eq. (1)) was used($\sigma = 0.1$). If it is larger than 1 (red part), it means that the walking speed is faster than the case when the rigid body were used. Conversely, it is smaller than 1 (blue part), it means that the walking speed is slower than the case when the rigid body were used.

When the degree of freedom in the roll direction was used at low speed when a walking period $T(= 2\pi/\omega)$ was set to 3.0 s, the speed was faster than the case when using a rigid body(Fig. 3a). When the degree of freedom in the pitch direction was used, there was no significant increase or decrease in the walking speed except when the elastic

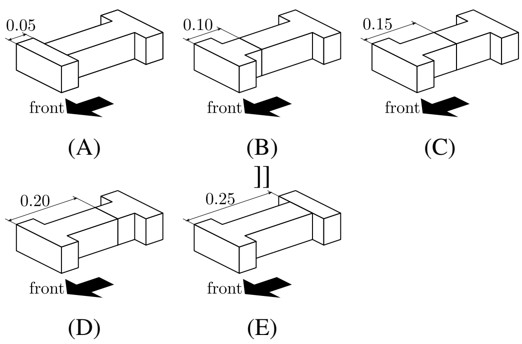

Figure 2: Five types of trunk

coefficient was quite small. When the degree of freedom in the roll direction is used, the walking speed changes greatly depending on the joint position, although it is not dependent on the elastic coefficient. At the middle speed ($T = 1.0$ s), it was confirmed that the increase and decrease of the walking speed are small at any degree of freedom(Fig. 3b).

When the degree of freedom in the roll direction and TEGOTAGE-based control were used at the low speed($T = 3.0$ s), either gait of diagonal sequence(D-S) walk or lateral sequene(L-S) walk occurred(Fig. 4a). When D-S walk occurred, the walking speed decreased compared to other cases. Also in the case of the degree of freedom in pitch direction, the walking speed decreases under the condition where the D-S walk was occurred as well. The gait in the case of giving the degree of freedom in yaw direction was L-S walk in any condition. At the middle speed($T = 1.0$ s), when the degrees of freedom in roll or yaw was used, there was no notable change in robot‘s walking(Fig. 4b). On the other hand, the walking speed decreased extremely only when the degree of freedom in the pitch direction was used.

4 Discussion

Because the same tendency as the influence of freedom of the trunk on walking were observed between when using the feedback control was used and when it was not used at low speed, it is considered that the degree of freedom of the trunk does not greatly affect the feedback control at low speed. On the other hand, at middle speed, there are a difference between when using feedback control and when not using no matter where direction of freedom of the trunk was. In particular, when the degree of freedom in pitch direction was given, the walking speed decreases. It is considered that the propulsion by hind legs caused bending of the trunk, thereby canceling the propulsion of robot between the front and hind legs. In other degrees of freedom, the walking speed did not change as a whole, but there was some parameters which caused the increase of walking speed only when the feedback control was used. This seems to be because that the efficient gait was generated by the proper coupling between TEGOTAGE-based feedback control and physical characteristics of the robot. Gait analysis when multiple joints are used or investigation of effective joint setup for generating various gait patterns are left as future works.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Numbers JP26870337, JP16H04381 and CREST, JST.

References

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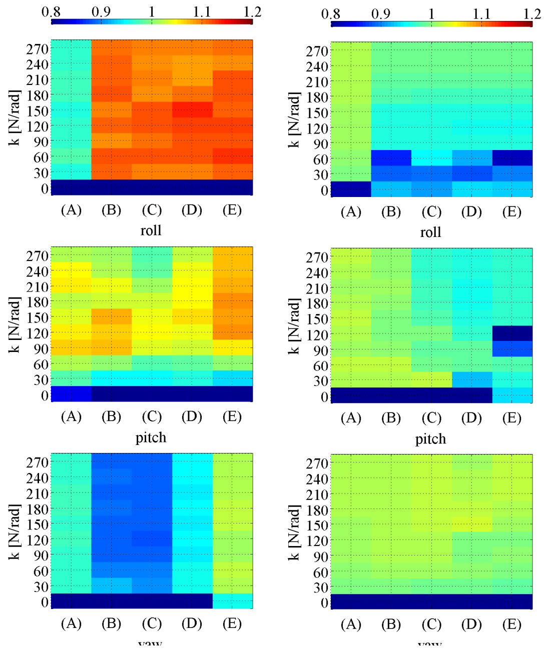
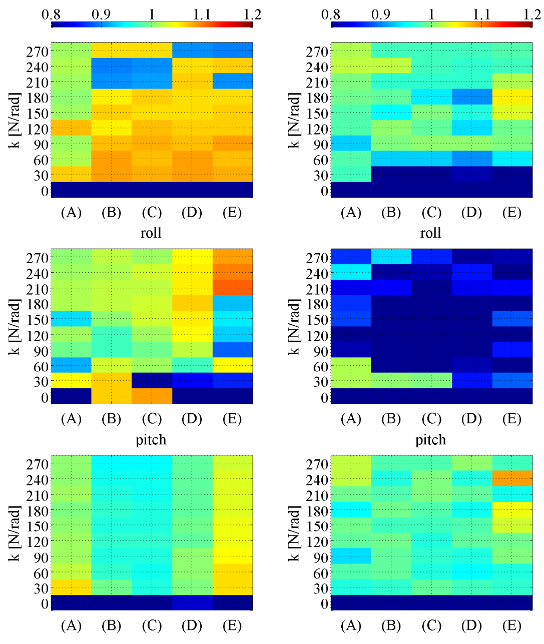


(a) $T = 3.0$ s (b) $T = 1.0$ s

Figure 3: The Summary of walking speed at each elastic modulus k without feedback control($\sigma = 0$)



(a) $T = 3.0$ s (b) $T = 1.0$ s

Figure 4: The Summary of walking speed at each elastic modulus k with feedback control ($\sigma = 0.1$)