Development of Multi-legged Passive Dynamic Walking Robot

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Abstract: This research realizes and analyze Multi-legged Passive Dynamic Walking(PDW). Although various PDW studies have been conducted based on its interesting features, most of them dealt with bipedal robots. There are many kinds of multi-legged creatures, not only quadrupedal animals but also creatures with more than six legs. In this paper, we focus on a "Multi-legged PDW," which is a PDW with more than four legs. We develop multi-legged Passive Dynamic Walking robots, Jenkka-I, II and III, and discuss whether these robots can be realized and whether they can change its locomotion depending on such factors slope angle or their structure through simulations and experiments.

Keywords: Passive Dynamic Walking, multi-legged, locomotion transition

1. INTRODUCTION

Recently, Passive Dynamic Walking (PDW), which was first studied by McGeer[1], has been focused on in the research of walking robots. It is well known that PDW shows various interesting features. Although various studies of PDW have been conducted based on the PDW's interesting features[2], most previous studies dealt with bipedal robots. However, many walking creatures have more than four legs in nature and the animal that routinely travels bipedaly are humans only. And it is also well known that many multi-legged animal shows various locomotions depending on variety factors, such as a size of the animal or a locomotion speed. To reveal the walking principle, it is important to determine whether a PDW robot with four legs or more can be realized.

As for a quadrupedal PDW, some research has already been carried out, but they were only simulation-base studies [3, 4]. So, the research of multi-legged (more than four legs) PDW remains inadequate. In this paper, we focus on multi-legged PDW, which have more than four legs or more and verify the capability using real walking robots. And we dealt not only quadrupedal PDW but also Super-multi-legged[1] PDW that had more than six legs. There are many other kinds that have more than six legs exist. The realization and investigation of Super-multi-legged PDW will also provide significant insights into their interesting locomotion.

2. JENKKA

We developed a multi-legged PDW robots named "Jenkka." The concept of Jenkka series is as follows: (1) its fundamental structural component is a bipedal Passive Dynamic Walker, (2) by connecting each component to a **body**, it can become a Multi-legged Passive Dynamic Walker with more than four legs, (3) there is no direct leg-synchronizing mechanism, and (4) Only through the body, each component interacts indirectly. Based on this concept, three types of Jenkka have been made. Jenkka-I is q quadrupedal PDW robot, that is, the multi-legged PDW robot with four legs (Fig. 2(a))[5]. The second type "Jenkka-II" has six legs. It was redesigned to be downsized and the size of Jenkka-II is about 50% of Jenkka-I. The latest is Jenkka-III (Fig. 2(b)). At present, it has up to 20 legs, that is, 10 bipedal elements. However, the number of legs on these robots is not fixed and can be increased based on the concept of Jenkka.

In our previous simulation study, it was shown that the degrees of freedom of the body element, which corresponds to the spine of Jenkka, played a crucial role in the realization of stable walking or locomotion transition. Then, we designed a few types of bodies and these bodies

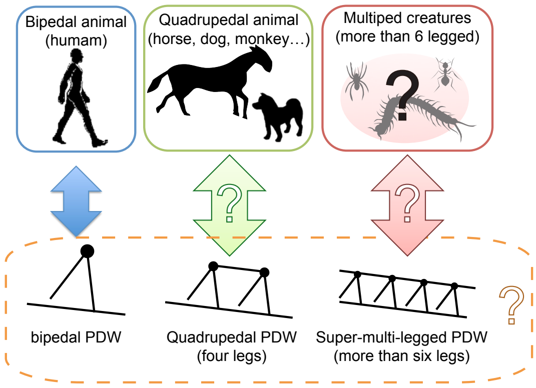
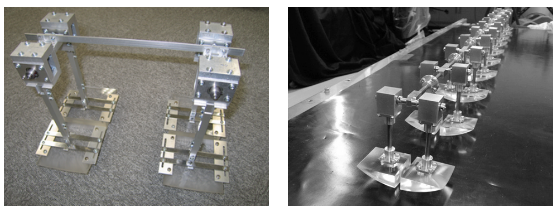


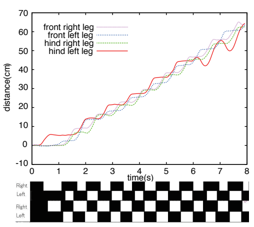
Fig. 1 Concept of Multi-legged PDW



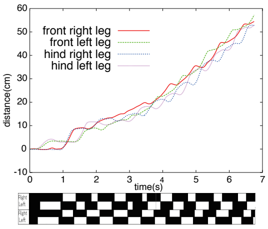
(a) Jenkka-I (b) Jenkka-III

Fig. 2 Multi-legged PDW robot "Jenkka"

[1]To distinguish from Quadrupedal, we use the word "Super-multi-legged" as a more than 6-legged.

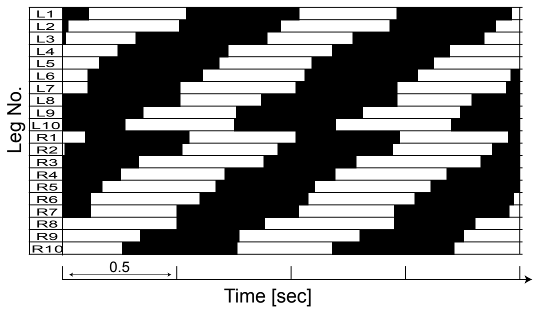


(a) Pace gait(with rigit body)

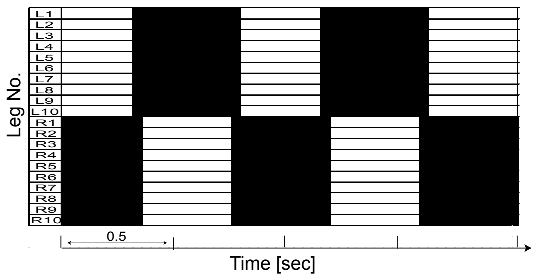


(b) Trot gait(with rollable body)

Fig. 3 Experimental Results of Jenkka-I



(a) with the pitch rollable body



(b) with the pitch and roll rollable body

Fig. 4 Experimental Results of Jenkka-III

were tested in the follwing walking experiments.

3. EXPERIMENT RESULTS

3.1 Jenkka-I

Fig. 3 shows the experimental result of Jenkka-I. In the case of Fig. 3(a), a flat rigit body was used and Jenkka-I showed a pace gait. On the other hand, in the case of Fig. 3(b), a rollable body was used and Jenkka-I showed a trot gait. From these experimental result, it can verified that not only q quadrupedal PDW can be realizable but also it can show some different locomotions depending on the degree of freedom of the body.

3.2 Jenkka-III

Figure 4 show the experiments result of Jenkka-III.Figs. 4(a) and 4(b) show a gait chart of Jenkka-III with a pitch rollable body and with a pitch and roll rollable body, respectively. As it can be easily seen, these gait are clearly different. Fig. 5 shows a snapshot of the locomotion with the pitch and roll rollable body. In this case, ipsilateral legs touched down on the ground in sequence (from hind leg to front leg). This walking corresponds to a walk gait of a 4 legged creature.

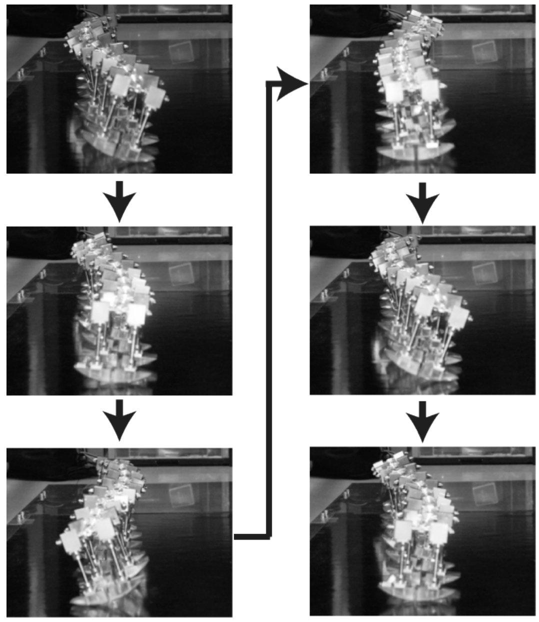


Fig. 5 Snapshot of Jenkka-III Gait

4. CONCLUSION

In this paper, we investigated the multi-legged PDW. Through experiments with multi-legged PDW robots Jenkka-I, II and III, we verified that the quadrupedal PDW and Super-multi-legged PDW can be realizable. We also showed that a multi-legged PDW robot could exhibit various locomotions depending on its structure or parameters. It is quite interesting that the locomotion and locomotion transition were induced absolutely passively based on the structure of the robot and the interaction between the robot and the environment and these results are very significant for the follow-on research of multi-legged PDW.

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