Adapting Motion Method to Rough Terrain for Biped Robots

80817374　　　　(Kei Mikami) Supervisor :　　　　(Kouhei Ohnishi)

1　Introduction

In order to use humanoids practically, stably biped walking on the rough terrain is necessary. The environmental mode compliance controller has been proposed as an adaptation method to environment for the biped robots [1]. By introducing idea of the environmental modes, the biped robots can recognize their contact state with environment. The environmental modes consist of four modes; heaving, rolling, pitching and twisting.

This paper focuses on the heaving mode e_h. In this paper, e_h is defined as the reaction force from the ground. The environment which has the depression is not consider in the conventional studies. In conventional studies, height of the center of gravity (COG) comes down when the robots walk such environment. It is better that up-down of the COG is smaller when the robots convey something. Therefore, the environmental mode compliance controller for the depressed environment is proposed. The robots can walk the depressed environment by controlling the reaction force from the ground. The validity of the proposed method was confirmed by the experimental results.

2　Proposed method

The environment modes are related to the zero moment point (ZMP) which is one of the popular indexes stability of biped walking. The ZMP corresponds with the center of pressure of the ground reaction force. If the ZMP is inside the supporting polygon, the biped robots can stand and walk without falling down. It is necessary to shift the ZMP from rear leg to front leg in double support phase. e_h of the rear leg goes on decreasing for the double support phase(Fig. 1). In addition, the e_h of front leg goes on increasing for the double support phase. The command of e_h is generated by the ZMP reference position.

Tip of the swing leg comes down by command of the heaving mode for the swing leg e_{hsw}^{cmd} when the robot detects the depression environment. The COG height also comes down because the command of the heaving mode for the support leg e_{hsup}^{cmd} is decreased (Fig. 2). To solve this problem, e_{hsup}^{cmd} is kept constant until the swing leg contacts the ground (Fig. 3). In the proposed method, e_{hsup}^{cmd} is switched by contact state between the ground and the swing leg. e_{hsup}^{cmd} is obtained as follows:

$$e_{hsup}^{ref} = (e_{hsum}^{cmd} - e_{hsup}^{res}) - Ce_{hsw}^{cmd} \qquad (1)$$

When the swing leg contact with the ground, C becomes 0. e_{hsup}^{cmd} becomes e_{hsum}^{cmd}. After contacting, C becomes 1. e_{hsup}^{cmd} becomes $e_{hsum}^{cmd} - e_{hsw}^{cmd}$. Depending on contact state, command of e_h is changed. Therefore, the robots can walk the depressed environment while keeping the COG height.

3　Experimental Results

The experimental results are shown in Fig. 4. The depression environment was -0.04m. The robot detects the depressed environment at shaded area.

Fig. 4(a) shows the ZMP response, the ZMP reference and the boundary line of the supporting polygon. The ZMP
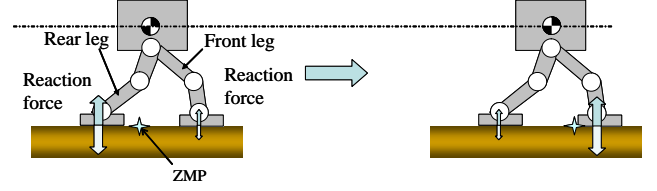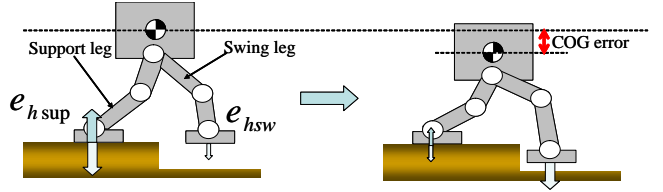

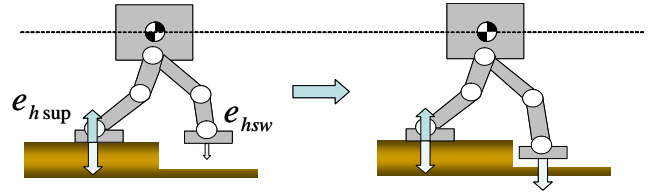Fig. 1: ZMP and reaction force on foot

Fig. 2: Conventional method

Fig. 3: Proposed method

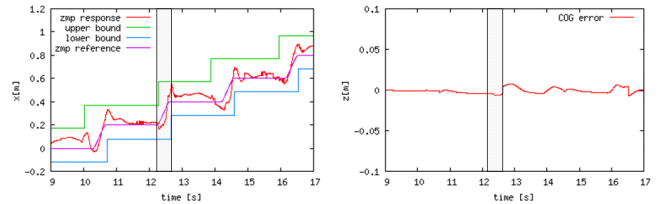(a) Result of ZMP　　　　(b) Result of COG error

Fig. 4: Experimental results

response was in the supporting polygon. Therefore, the walking was stable with the proposed method.

Fig. 4(b) shows the COG error which is difference from desired constant value of the COG height. The COG did not come down at shaded area. The validity of the proposed method was confirmed by the experimental results.

4　Conclusions

The environmental mode compliance controller for the depressed environment was proposed. By the proposed method, the robots could walk on the depressed environment without coming down of the COG height. The validity of the proposed method was confirmed by the experimental results.

References

[1] E. Ohashi, T. Sato, and K. Ohnishi: "A Walking Stabilization Method Based on Environmental Modes on Each Foot for Biped Robot", *IEEE Trans. on Industrial Electronics*, Vol. 56, No. 100-115, pp. 3964 - 3974, 2009.