Determination of the initial condition for stable gait cycle of biped robot

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Researches are under way based on the concept of passive dynamic walking to improve the efficiency and to realize more natural gait of controlled biped robot. In this research, we investigated the energy based method to find the initial condition for stable one-period gait cycle. The energy balance method, we proposed here, is easier way than the conventional approaches in finding the proper initial condition. We derived the energy relationship during stable one-gait cycle and simulated with MATLAB based on the simplest passive walking model. This concept will be applied to the more complex models.

Keywords: biped robot, energy balance, gait cycle, initial condition, passive walker

1. INTRODUCTION

Human motion can be achieved by the interaction between neuromuscular system and brain. But during swing phase, passive walking model can make normal human gait by Mochon S. and McMahon T.A. [1]. Bipedal walking might be largely understood as a passive mechanical process. Inspired this idea, Tad MacGeer who proposed the passive dynamic walker first proved a passive walker can walk down on a range of slopes without control and actuation. The passive walker was used the gravity as an energy source. From the work of Tad McGeer[2], the concept of passive walker has been developed. Recently, many researches to improve the efficiency and realize more natural gait of controlled biped robot are under way based on the concept of passive dynamic walking [3].

The research about passive dynamic walking will give us more understanding of human walking characteristics and be helpful when control a biped robot.

Usually, for a passive walker, arbitrary initial condition leads to fall forward or backward. It is important to start from neighbourhood of the fixed point for stable gait cycle if periodical gait exists. The fixed point can get using Poincaré map and Newton-Raphson iteration from a good guess of the initial condition obtained from the nonlinear dynamic equations of motion or cell mapping method [4-5]. However, it is difficult to solve nonlinear differential equations of motion analytically if the model is complex and there is need to guide the searching area if use cell mapping method. The searching area is so large with out guideline.

In this research, we investigated the energy based method to find the initial condition for stable one-period gait cycle. The energy balance method is easier way than the conventional approaches in finding the proper initial condition. Next, I’ll explain the energy balance method and the way to find the initial condition for stable one-period gait cycle.

2. ENERGY BALANCE METHOD

The model, the simplest passive walker, is shown in Fig.1. It is the same model of Garcia et al [4]. It consists of three point masses and two massless legs. Point masses are located at the hip and each end of the leg, foot and the case where the hip mass is much larger than foot mass is considered in this research. Two rigid massless legs are connected at the hip by the frictionless hinge joint.

To get a stable gait cycle, appropriate initial condition is needed. In this research, we found the initial conditions for various slopes easily using energy balance method.

A passive walker can walk down on a ramp, because the energy lost at collision is recovered gravity. From this fact, we found the initial condition for stable gait cycle considering energy balance relationship as a necessary condition, the energy balance method.

The plots of equation satisfied the energy balance method and linearized solutions for the simplest passive walking model are showed in Fig.2. The fixed point depicted as asterisk is located on the line satisfied energy balance method. The fixed point can be found using only the energy relationship. Additionally, through the linearize solutions for the stance and swing leg, the search area
becomes narrow and more accurate. As results of simulation, stable one-period gait cycle exists for \(0<\gamma<0.0151\, \text{[rad]}\).

![Graph showing initial condition for stable one-period gait cycle](image)

Fig. 2. Initial condition for stable one-period gait cycle \((\gamma=0.002\, \text{rad})\).

3. CONCLUSION

In this research, we found the initial conditions for stable one-period gait cycle using energy balance method as a necessary condition based on the simplest passive walking model. Only using this method, it is possible to find the initial conditions for \(0<\gamma<0.0151\, \text{[rad]}\) if searching along the energy balance line. In addition to the energy balance method, the searching area will be narrow if using falling forward and backward criteria roughly derived from the solution of linearized equation motion for stance leg. Also, if consider the solution of linearized equation of motion for swing leg additionally, it meets energy balance line. The crossed point is a good initial condition for stable gait cycle because it is located the neighborhood of the fixed point.

We analyzed the model with energy balance method. This concept will be applied for not only a very simple case, but also more complicated models like the model with knee and various foot shapes.

ACKNOWLEDGMENT

This work was supported by the Korea Science and Engineering Foundation (KOSEF) through the National Research Lab. Program funded by the Ministry of Science and Technology (R0A-2005-000-10112-0), the Brain Korea 21 Project.

REFERENCES


