Generalized SLIP Model For Legged Robots

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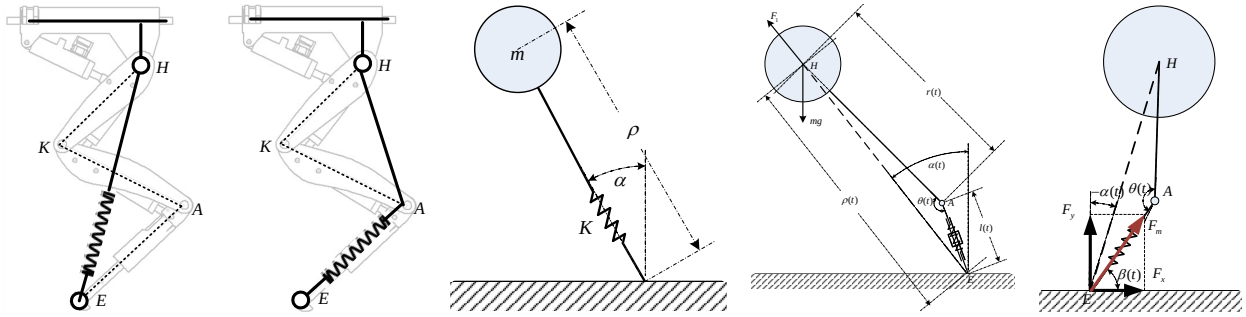
Abstract. The classical SLIP (Spring-Loaded Inverted Pendulum) model is usually employed to handle the problem of legged robots locomotion. And, SLIP model is often cooperated with Railbert's three separate parts control method. Specially, SLIP has an great significance for the running of legged robots. However, only the axial force along the equivalent leg is considered in the classical SLIP. In this paper, a generalized/articulated SLIP is proposed firstly. Both axial and tangential force along the equivalent leg are discussed. Secondly, the analytical approximation of proposed model is addressed. Thirdly, the stability of proposed model is analyzed via poincare map method. Fourthly, The modified three separate parts control method based on proposed model is investigated. Finally, comparative simulations show that the generalized/articulated SLIP would achieve better tracking performance of forward velocity.

Introduction

As shown in Fig. 1(a), the equivalent system of classical SLIP is between the foot end effector (E) and the point of hip joint (H). However, the actual spring is configured between point A and point E. That means that only the component along HE of spring action is taken in account in classical SLIP. Thus, the equivalent system of generalized SLIP is shown in Fig. 1(b), which will consider full of the spring action. The classical and generalized SLIP model are shown in Fig. 1(c) and Fig. 1(d), respectively. The force analysis in the generalized SLIP model is shown in Fig. 1(e). The dynamics model of generalized SLIP can be derived as

$$\begin{cases} \ddot{\alpha} = (g\sin\alpha - 2\dot{\rho}\dot{\alpha})/\rho \\ \ddot{\rho} = \rho\dot{\alpha}^2 - g\cos\alpha - \frac{k}{m}\frac{\rho(r\cos\theta+\sqrt{\rho^2-r^2\sin^2\theta}-l_0)}{\sqrt{\rho^2-r^2\sin^2\theta}} \end{cases} \tag{1}$$



(a) The equivalent system of classical SLIP (b) The equivalent system of generalized SLIP (c) The classical SLIP model (d) The generalized SLIP model (e) The force analysis in the generalized SLIP model

Figure 1: The SLIP-based models for legged robots

When $\theta = 180°$, the generalized SLIP degenerates into the classical SLIP. Therefore, the generalized SLIP is a general form of classical SLIP.

Results and discussion

Compared with the classical SLIP, the generalized SLIP has the following advantages: (1) The generalized SLIP is more reasonable since axial and tangential force along the equivalent leg are both discussed. (2) The analytical of generalized SLIP exists. The stability of generalized SLIP can be proven. And the control method of generalized SLIP can be obtained by modifying Railbert's three separate parts control method. (3) The generalized SLIP would improve the tracking performance of forward velocity.

References

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