Role of biarticular muscles during the swing phase of walking

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1 Motivation

Template models can help to demonstrate and prove concepts on human locomotion such as the spring-mass model [1]. Since biarticular muscles may have specific tasks in walking [2], their action during the swing phase is investigated in this study. A new model is presented to describe the swing leg motion (Fig .1). The goal is to identify the role of elastic biarticular muscles on swing leg dynamics.

2 State of the Art and Our Approach

Mochon et al. presented a stiff-legged model including a segmented leg for the swing phase [3]. Introducing the spring loaded inverted pendulum (SLIP) model, more similar behaviors to human locomotion can be achieved [1]. In order to analyze the swing phase in walking, we combined the SLIP model with a two segmented swing leg as shown in Fig. 1a. It is assumed that each segment of the swing leg has a distributed mass. The model properties are adapted to anthropometric data [4]. For walking with upright trunk [5], the CoM of the upper body and stance leg is approximately at the hip joint. With this model, we investigate the role of hamstring and rectus femoris, by comparing the leg's behavior with and without muscles. Human walking data are used [6] to determine the initial conditions of the swing phase (at take-off). The torque produced by hamstring in knee is

$$\tau_k = max(0, r_k k((\phi_{k0} - \phi_k) - r(\phi_{h0} - \phi_h))) \qquad (1)$$

where r_k, ϕ_k and ϕ_h are the knee lever arm, knee angle and hip angle as shown in Fig. 1, respectively, and index 0 indicates rest values. The corresponding hip torque is r times knee torque in the opposite direction, where r is the lever arm ratio (r_h/r_k). The torques produced by rectus femoris is similar providing an antagonistic arrangement to the hamstring.

3 Current Result

The stiffness, lever arm ratio and rest angle for rectus femoris and hamstring are the important parameters affecting the motion. With $r = 2$, appropriate rest angles and stiffness are found to achieve a complete swing phase. The joint torques are similar to human muscle actuations shown in [2]. The angles profile resembles human leg angles, presented in [6]. The results show leg retraction before touch down which is beneficial for human walking. Therefore, human swing phase patterns can be generated by this model.

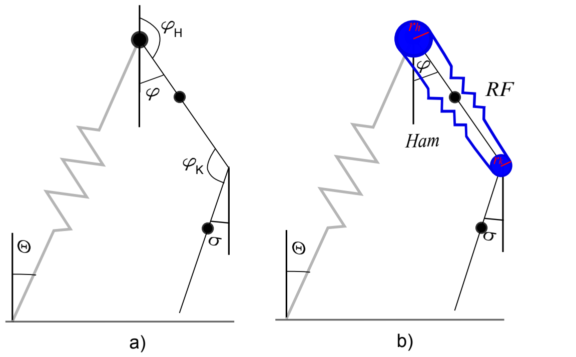

Figure 1: a) The SLIP Model with a two segmented leg as swing leg, b) Biarticular muscles' schematic representation.

4 Best Possible Outcomes

An extension of the model is to produce a complete step. Then, control strategies specially for double support could also be investigated. Further, interactions between the muscles' roles to increase the motion robustness and decrease in energy consumption could be analyzed.

References

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