Dynamic modeling and analysis of contact interaction of a passive biped-walking robot

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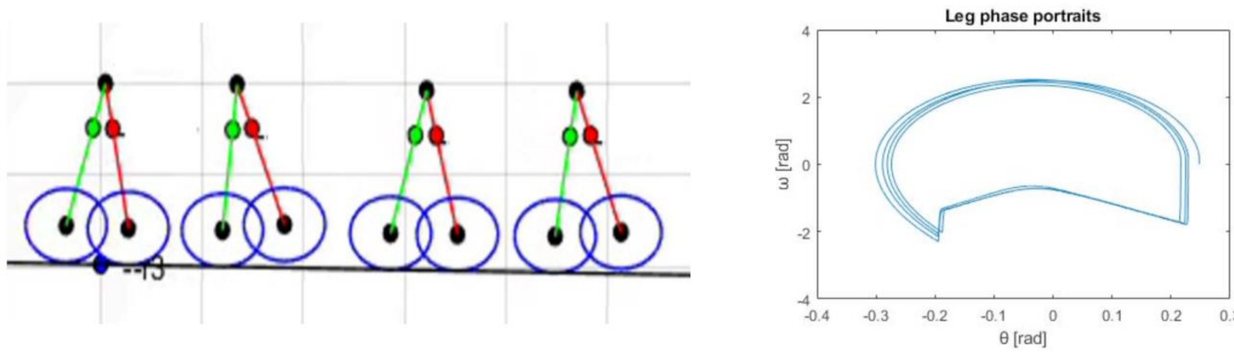
The main purpose of this work is to present and discuss a general approach for the dynamic modeling and analysis of a passive biped walking, with particular focus on the feet-ground contact interaction. This study aims at examining and comparing several forces models dealing with different friction phenomena in the context of multibody system dynamics. For this purpose, a passive walking and the contact and friction force are discussed. The preliminary results obtained are quite promising of the passive biped-walking robot utilized.

The passive walking is a new concept of biped walking. Researchers have been working on this area with both theoretical and experimental analysis ever since McGeer [1]. Over the decades, many authors have shown that completely unactuated and uncontrolled machines could walk stably downhill on a gentle slope, powered only by gravity, both in numerical simulations and physical experiments. In fact, different research groups have developed robots based on passive walking techniques [2], namely the one-meter length Robot Ranger of Cornell University [3], with three joints in each of its long legs. Robot Toddlers from MIT University [4] is a small robot that has only a single passive pin joint at the hip and the 3D movement is achieved by means of the feet surface design. The model developed at the Nagoya Institute of Technology has two legs, includes a stability mechanism and is able to walk about 4000 steps (35 minutes) without power supply [5, 6]. Moreover, some actuated prototypes have been constructed based on passive dynamics [7]. The biped "PASIBOT" of Universidad Carlos III de Madrid is able to walk in a steady mode with only one actuator/drive [8, 9]. The robot can walk in a similar way to human, by means of the balance and the dynamic of the natural swinging, in order to consume the minimum energy to walk. This proves that biped robots based on passive walking have good energy efficiency and can perform more natural gaits. It seems that the mechanical parameters of these walkers work better than the complicated control system of the conventional robots in generating natural looking gaits.

Thus, this work deals with a study of a biped-walking robot based on the multibody systems formulation. In a simple way, the planar multibody model considered here includes two legs with spherical feet that can act with ground, which is assumed to be rigid, flat and smooth. Figure 1a, shows a general picture of the motion produced by the passive biped-walking robot in different phases of the gait.

The main purpose of this investigation is to address the supporting foot slippage and contact-impact forces of the biped robot-walking model and to develop its dynamics for simple and double support phases. For this purpose, a general methodology to handle the contact detection between the feet and ground is developed and implemented. Within the spirit of this methodology, special attention is paid to the contact detection itself, both in terms of computational accuracy and efficiency [10]. The normal contact forces developed during the dynamic walking of the robot are evaluated using a Hunt and Crossley based force model that accounts for both elastic and dissipative force components [11]. In turn, the friction forces are computed with different models with the purpose to appraise the most relevant and appropriate options [12]. In the sequel of this process, several parameters associated with the friction forces models utilized here are considered in order to get an appropriate physical and realistic behavior of the passive biped-walking robot. Then, the dynamic simulations of multibody models used in the context of this work are carried out using general multibody Matlab code named MUBODYNA [13]. This code is able to perform forward dynamic simulations for spatial multibody systems, using several different multibody formulations [14].

Figure 1b illustrates the phase portraits of one leg relative to a dynamic simulation. It must be said that the response for both legs is the same due the symmetry of the model. In a broad sense, the dynamic behavior of the passive biped-walking robot is consistent with the literature [15]. In particular, Fig. 1b indicates that the passive biped gets into a stable walking. The ends of the lower part of the graph are the hit and the lifting of the foot. It can be noted that during the hitting the floor, the swing leg changes into a stance one and its angular velocity changes rapidly. It must be highlighted that the dynamic response of the robot is quite sensitive to the initial conditions and to the values of the contact-impact force parameters, namely those associated with the friction models available for this type of multibody systems. These aspects will be described and discussed in detail in the presentation of this work.



(a) (b)

Fig. 1: (a) Passive biped-walking robot multibody model; (b) Leg phase portraits

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