

AN EMBODIED MOVEMENT INSPIRED BIPEDAL ROBOT DESIGN WITH CORE-LOCATED ACTUATION

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Abstract—From embodied movement analysis, such as the Basic Six in Bartenieff Fundamentals, Thigh Lift, Forward Pelvic Shift, and Lateral Pelvic Shift play a major role in walking. Inline with this understanding, we have designed a biped model with two mechanical links acting as legs and a mass acting as core at the hip, that can move forward and backward along the direction of travel in accordance with the Forward Pelvic Shift. For the simplified model, gait is generated using feedback linearization giving a stable walk. The alignment of the biped model to the human movement strategies may be beneficial as a form of bio-inspired design. Moreover, variable gait synthesis in a bipedal model, the ultimate goal of this work, may be essential to incorporating robots in dynamic, human-facing environments, where systems need to modulate motion profile for appropriate nonverbal communication.

I. INTRODUCTION

Human gait can be analyzed from an embodied perspective where externally experienced principles of movement and internally perceived body connections are examined, including those as articulated in Irmgard Bartenieff’s Fundamentals (BF). In particular, her Basic Six movement sequences [1] are designed to create a supportive relationship between body organization and movement intention. All of these movements are related to accessing efficient and effective fundamental body connections in any activity, but three of these sequences, namely, Thigh Lift (TL), Forward Pelvic Shift (FPS), and Lateral Pelvic Shift (LPS), are particularly useful lenses through which to describe walking. The isolated action of these has been shown in Fig. 1.

Inspired from this understanding of human walking, a robot design is proposed [2] that incorporates core-located actuation. This design emulates the effect of the human pelvis with a tray structure allowing a heavy ball to roll on a curved path. The tray structure is attached to a bipedal robot platform. The ball rolls in the channel from one end to the other by the rotation of the tray about the pitch axis Y , thus replicating the effect of pelvic shift.

II. SIMPLIFIED PLANAR BIPED MODEL FOR CORE-LOCATED ACTUATION

A planar model simplification of the bipedal robot from [2] is presented. As shown in Fig. 2, to model the core in

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Fig. 1: Three exercises within Bartenieff’s Basic Six. Thigh Lift in the left panel; Forward Pelvic Shift in the middle; and an exaggerated Lateral Pelvic Shift, both sides (right and left), in the right, are shown.

humans, the planar model has a piston mechanism moving a heavy mass forward and backward using a force actuator. The orientation of this mechanism is fixed at a right angle with the vertical. In the swing phase, the biped acts as a three link planar robot fixed at the stance leg foot. The Euler-Lagrange equation for this phase give the following equations of motion:

$$D_s \ddot{q}_s + C_s(q_s, \dot{q}_s) \dot{q}_s + G_s = \Gamma_s, \quad (1)$$

where $q_s = [q_{st}, q_{sw}, d_t]^T$ is the set of generalized coordinates. This phase is active until the swing leg impacts the ground. Resultantly, an update in the joint positions and joint velocities occurs. At this moment, the two leg joint angles simply exchange their roles while the core mass displacement from the hip remains the same. The joint velocities, on the other hand, are determined using the assumptions of impact without a slip and rebound.

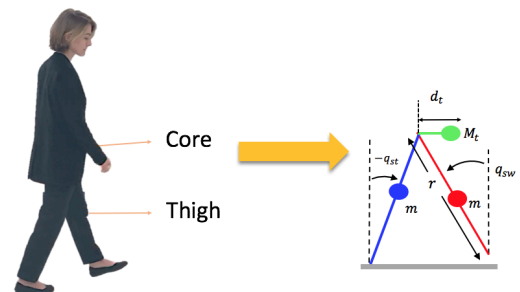


Fig. 2: Human-inspired planar biped model with core-located actuation. Core is replicated by a prismatic joint moving the mass M_t forward and backward by displacement d_t . The thighs are imitated as two mechanical links of mass m rotating about the hip.

