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STriDER: Self-Excited Tripedal Dynamic Experimental Robot

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Abstract—**STriDER (Self-Excited Tripedal Dynamic Experimental Robot) is a novel three-legged walking machine that exploits the concept of actuated passive dynamic locomotion to dynamically walk with high energy efficiency and minimal control. Unlike other passive dynamic walking machines, this unique tripedal locomotion robot is inherently stable with its tripod stance, can change directions, and is relatively easy to implement, making it practical to be used for real life applications.**

STriDER begins its step with a stable stance like a camera tripod. As the center of gravity of the robot shifts forward pass the "pivot line" defined by the two feet of the stance legs, the robot begins to fall in the direction perpendicular to the pivot line. The middle leg naturally swings between the two stance legs using the concept of actuated passive dynamic locomotion. The swing leg then catches the fall and the robot resets to its original tripod posture in preparation for its next step. STriDER can easily change its direction of walking, simply by changing the sequence of choice of the swing leg and the stance legs.

In this video, we present the concept of this novel walking machine and the mechanical design of the first prototype. The results from the dynamic simulation and a simple experiment for a single step are presented for comparison.

I. Introduction

Using legs is the predominant method of moving for animals on land. Research into legged locomotion is motivated by what is observed in nature. Legged vehicles have the advantage over wheeled vehicles by having discontinuous contact with the surface [1]. They can step over obstacles and climb up steep inclines which might be impassible by wheeled vehicles [2, 3]. An innovative walking machine with "three legs" that utilizes the concept of actuated passive dynamic locomotion proposes an original concept for a new type of practical walking system [4 to 6]. The built in dynamics of this three-legged walking machine allows for low energy efficient and minimal control.

II. Operation Concept

The concept of the single step tripedal gait is shown in Fig. 1. From its starting position (Fig. 1 (a)), as the robot shifts its center of gravity by aligning two of its pelvis links (Fig. 1 (b)), the body of the robot can fall over in the direction perpendicular to the stance triangle (Fig. 1 (c)), pivoting about the line defined by the two supporting legs. As the robot falls over, the leg in the middle (swing leg) naturally swings between the two stance legs (Fig. 1 (d)) and catches the fall (Fig. 1 (e)). As all three legs contact the ground, the robot resets its posture by actuating its joint, storing potential energy for its next gait (Fig. 1 (f)) [3]. The key to this tripedal gait is the natural swinging motion of the swing leg, and the flipping of the body about the aligned pelvis joints connecting the two stance legs. With the appropriate mechanical design parameters (mass properties and dimension of the links), this motion is repeated with minimal control and power consumption exploiting the actuated passive dynamic locomotion concept utilizing its built in dynamics.

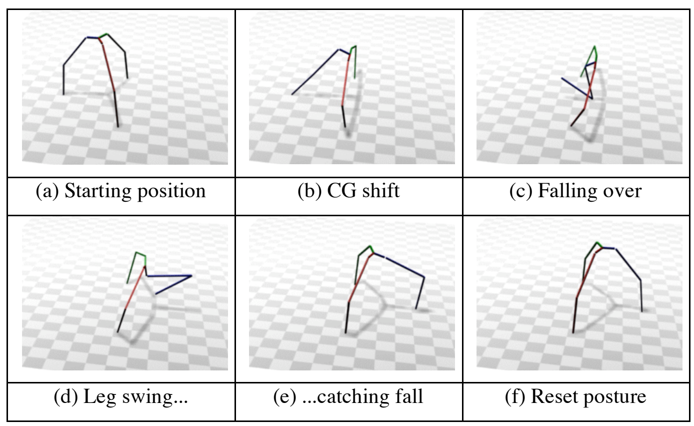

Fig. 1. Single step tripedal gait.

Gaits for changing directions are implemented in a rather interesting way: by changing the sequence of choice of the swing leg, the tripedal gait can move the robot in 60° interval directions for each step (Fig. 2).

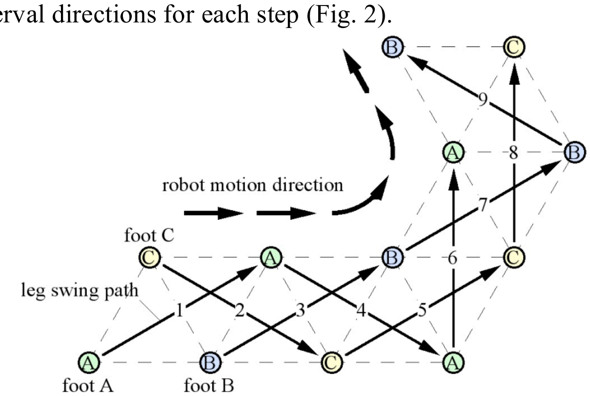

Fig. 2. Gait strategies for changing directions.

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III. ADVANTAGES

The simple tripod configuration and tripedal gait of STriDER has many advantages over other legged robots; it has a simple kinematic structure (vs. bipeds, quadrupeds, or hexapods) that prevents conflicts among its legs and between a leg and the body; it is inherently stable (like a camera tripod); it is simple to control (vs. bipeds) as the motion is a simple falling in a predetermined direction and catching its fall; it is energy efficient, exploiting the actuated passive dynamic locomotion concept utilizing its built in dynamics; it is lightweight enabling it to be launched to difficult to access areas; and it is tall making it ideal for deploying and positioning sensors at high position for surveillance, as shown in Fig. 3.

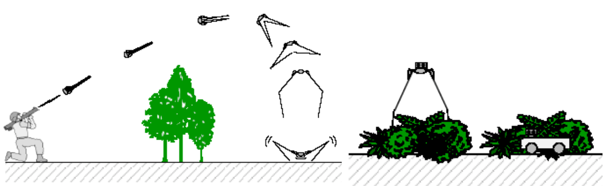

Fig. 3. STriDER aids in the deployment of sensors

IV. MECHANICAL DESIGN

The mechanical design of all three legs is identical, as shown in Fig. 4. Each leg has a total of four degrees of freedom; three at the hip and one at the knee. The hip rotator joint allows the body to continuously rotate about itself. The hip abductor joints are used to align the hip rotator joints of the stance legs so that the rotator joints rotate about a common centerline. Similar to the knee, the hip flexure joint allows for bending in the same plane as the knee of the swing leg. A working prototype of this design has been fabricated [7].

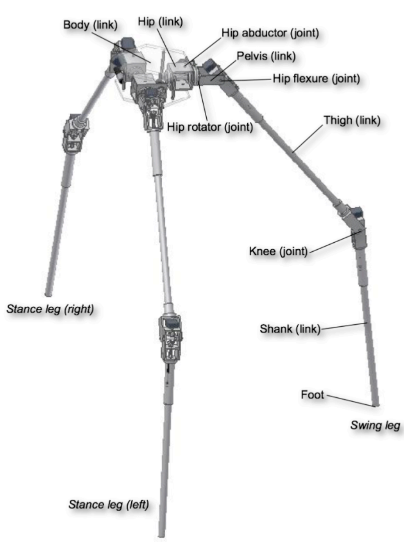

Fig. 4. Link and joint labes for the mechanical model

V. DYNAMIC SIMULATION AND EXPERIMENTS

With the right mechanical design parameters, the actuated passive dynamic tripedal gait can be repeated with minimal control and power consumption. A dynamic simulation of the tripedal gait using the optimized design parameters used for the first prototype was developed [7]. To verify our dynamic analysis, a simple experiment of a single tripedal gait was conducted using the first prototype. Details of the dynamic simulation and design parameter optimizations will be presented in a future paper.

VI. CONCLUSION

The proposed three legged locomotion exploits the concept of actuated passive dynamic locomotion. It can walk dynamically with high energy efficient and minimal control. It has a simple kinematic structure and can change directions. Moreover, it is lightweight and tall making it ideal for sensor deployment.

Future work will focus on the analysis of various strategies for changing directions and path planning. Furthermore, a detailed study of the three-dimensional kinematics and dynamics of STriDER will be conducted.

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