TALLINN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF SOFTWARE SCIENCE

A problem statement report on the thesis topic

“Gait Generation of a Quadruped Robot on Flowable Terrains”

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Introduction

Legged robots, especially quadruped, have considerable advantages over tracked or wheeled robots on land because of their ability to traverse various complex terrains. Unlike wheeled mechanisms with rollers in continuous contact with the ground, legged mechanisms can make discrete terrain contacts and avoid undesirable footholds [2]. This characteristic makes it particularly appealing for space exploration, underground mining, disaster response, and rescue applications, as these terrains are complex, unpredictable, and somewhat unknown.

One significant limitation to the widespread adoption of legged robots is how difficult it is to control. This control complexity refers to synchronising a leg and body motion sequence that may move the robot down a path while achieving stable motion. This motion pattern is known as a gait. According to Song and Waldron (1989), "*A gait is defined by the time and the location of the placing and lifting of each foot, coordinated with the body's motion in its six degrees of freedom, to move the body from one place to another*". Gait generation is thus the formulation and selection of a sequence of gaits that propels a legged robot along the desired route.

Problem Statement

Many studies on legged robot gait generation have been conducted over the years. A slew of these experiments have yielded successful gaits that have been tested on real robots in natural surroundings. Among these accomplishments are ANYmal, developed by ETH Zurich and ANYbotics [8], MIT Cheetah [9], Stoch I [7], and others. While these robots have achieved excellent success on solid ground (i.e. flat surfaces, rocky surfaces, etc..), sloped terrain, obstructions, and so on, there has been little to no advancement on robot mobility on flowable terrain.

Flowable terrains are particularly complicated because of their unique property; they can have solid-like or fluid-like qualities. Furthermore, recent studies of legged robots moving on granular media such as sand have shown that at an instant of time during a step, each leg element passes through the substrate at a certain depth, orientation, and movement direction during a step, all of which can alter over time [2].

All of the research on robot mobility over flowble terrain has focused on establishing models that characterize the physical relationship between the robot body and granular material. The goal of this thesis is to enhance some of these models such that they can implement custom gaits that can be evaluated on a real robot.

Related Study

A brief review of the history of gait generation research reveals the following initial milestones in the development of gait for multi-legged robots: Hildebrand's classification of animal gaits in 1965, McGhee's mathematical gait formula in 1968, McGhee and Frank's optimum wave gaits for quadrupeds in 1968, Kugushev and Jaroshevskij's initial formulation of free gaits in 1975, McGhee and Iswandhi's completion of the formula of free gaits in 1979, and Kumar and Waldron's investigation of adaptable gaits in 1989 [1].

Recent research has built on these past achievements, employing a range of methodologies to explore gait formation in granular media. Dholakiya et al. (2019) constructs rhythmic patterns using bio-inspired techniques such as central pattern generators. Li et al., (2013) creates a new model that characterizes and predicts legged locomotion on flowable ground, and Kingsbury (2016) establishes a general principle that guides the behavior of legged locomotion within flowable substrates. The empirical resistive force model serves as the foundation premise.

Carpentier and Wieber (2021) examine recent advances in the control of legged robot mobility. They discovered that present legged robots are excessively dependent on real hardware, expensive, and brittle because to their reliance on state estimate and feedback, and proposed that sensor-based control could be an alternative. They also emphasize the importance of numerical trajectory optimization in dealing with alternating contacts and the accompanying limits on contact forces.

Proposed Plan

The purpose of the thesis, as stated in the problem statement, is to improve some of the models from previous studies and develop custom gaits that can be evaluated on a real robot. A summary of a probable course of action might include:

- Understand fundamental principles such as robot kinematics, dynamics and trajectory planning.
- Extend proposed models from previous research to create custom gaits in Robot Operating System (ROS) simulation for the Go1 quadruped robot.
- Validate custom gaits on a real robot in a controlled environment, and then in a natural environment.

Go1, a 12kg quadruped robot with 5 sets of stereo cameras, 3 sets of ultrasonic sensors, 4 foot force sensors, an IMU, and 12 motors (3 per leg), will be used to evaluate the gaits. It is powered by three Jetson Nano CPUs and runs Ubuntu 18.04 and ROS Melodic.

References

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