Quadruped Robots Benefit from Compliant Leg Designs

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***Abstract*— A major bottleneck in building autonomous robots is the lack of suitable power supplies. Consequently, researchers aim for more energy-efficient locomotion. One way to achieve this is by using compliant materials in the robot bodies. In this work, we introduce Tigrillo, a small, low-cost quadruped robot platform with modular legs. The robot's legs consist of a simple two-segmented construction which can be configured stiff or passive compliant. Each leg is actuated at the hip with one motor. By thorough optimization of the open loop control signals we demonstrate that compliance not only results in gaits that are more insensitive to parameter variations, but also leads to more energy-efficient gaits.**

Keywords: quadruped robot, compliant, underactuation, energy efficiency

Currently, the focus often lies on compliant and underactuated robotics. Compliance is known to increase robustness, speed and efficiency [1], [4]. Springs, can store energy and release it when needed, similar to muscles in animals.

Batteries are still a bottleneck in making robots fully autonomous. As a consequence, energy efficiency is crucial when designing autonomous robots. In this work, we investigate whether compliance increases locomotion efficiency in terms of speed and energy consumption in a simple quadruped robot platform called Tigrillo.

Tigrillo is an easy to assemble, robust, lightweight, low-cost quadruped robot platform (see Fig. 1 for an overview). The robot frame is fully laser cut out of ABS. The electronics consist of two separate power supplies and current sensors for the front and hind legs, while speed is measured by the ultrasonic sensor. It features a single actuator per leg (hip), similar to Puppy [3] and Scout II [5]. As such, it has no active leg retraction. The legs can be configured into a stiff or compliant configuration. By means of open loop control a bounding gait can be achieved. In order to find a decent bounding gait we optimized the parameters of the control signals (frequency and shape characteristics, method similar to earlier work [2]). In total 1000 parameter combinations were tested on Tigrillo for both leg configurations.

During the experiments the robot gait was visually evaluated by the operator along with the logged data. We only considered gaits that were scored shuffling/good (SG), good (G) and very good (GG) by the operator. Other gaits were omitted. The resulting data points are plotted in a Pareto plot (Fig. 2).

In Fig. 2 we plot the power consumption in function of the (inverse) speed. Consequently, the more the gait is plotted towards the origin the more optimal in terms of

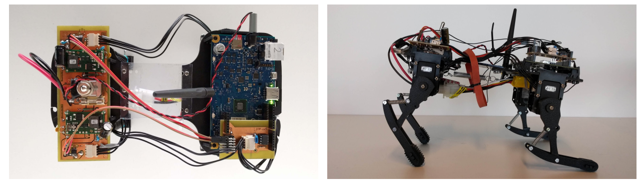

Fig. 1: Top down view and side view of Tigrillo.

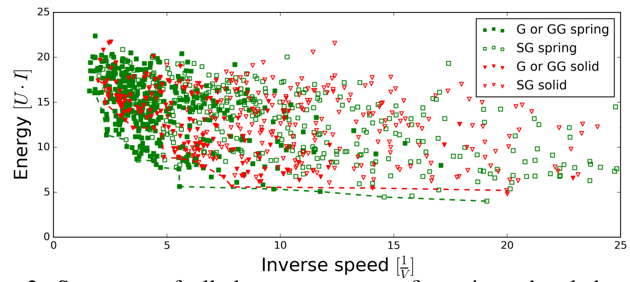

Fig. 2: Summary of all the parameter configurations that led to acceptable gaits for both, stiff and compliant leg configurations.

speed and power consumption. Additionally, we plotted the Pareto front for both, compliant (green) and stiff legs (red). One can easily observe that compliance not only lead to a higher quantity of good gaits, but also leads to more qualitative gaits in terms of speed and energy efficiency. Furthermore, by visualizing the power consumption of the hind legs in relation to the front legs, we observed that, just as its animal counterpart, the hind legs contribute significantly more to the forward locomotion. This, despite the simple leg configuration.

We conclude that after thorough experimentation with Tigrillo, compliance not only leads to less parameter-sensitive gaits, but also results in more energy-efficient gaits. In future work we tend to extend our experiment from bounding gaits to other gaits. For this we will design new legs for Tigrillo that allow active feet retraction during the swing phase.

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