Sensorized Foot Design for Robust Locomotion: A Study Using Cheetah-Cub

Massimo Vespignani, Mostafa Ajallooeian, Peter Eckert, Alexandre Tuleu, and Auke J. Ijspeert
Biorobotics Laboratory, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
{first.last}@epfl.ch

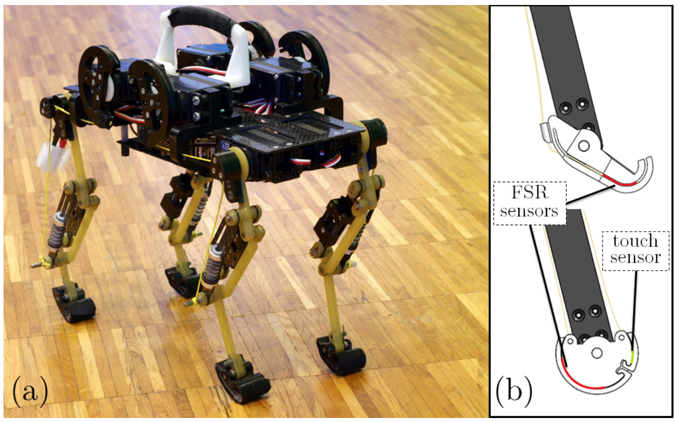

Fig. 1. a) Cheetah-Cub robot. b) Two examples of foot designs: *top*, spring-loaded foot with compliant sole and force sensor; *bottom*, ball-foot equipped with ground force sensor and stumble detector.

***Abstract*—Lightweight quadruped robots such as Cheetah-Cub need design methods and sensor equipment that do not greatly affect the overall weight and dynamics of the robot. 3d printing technology combined with off-the-shelf pressure sensors allows to quickly prototype and test different lightweight feet. We explore the application of touch sensing in modification of Central Pattern Generators with stumbling correction reflex. As a case study, we initiate gaits by height drops of about 50% of the leg-length and explore how sensory feedback can improve robustness.**

***Keywords*-Legged locomotion; robotics; lightweight design.**

I. Design

Sensory feedback such as ground contact detection can provide the necessary information to robustly tackle unexpected external perturbation during locomotion. The addition of the necessary sensors should not limit the dynamics of the system or significantly increase the total weight. This is particularly true for lightweight robots. Here we investigate the use of 3d printing to manufacture cheap and lightweight monolithic feet with the possibility of touch sensor integration.

We developed different types of stiff and compliant feet with embedded touch sensors (Fig. 1b). Contact with the ground can be detected with force-sensing resistors, which provide a rough estimate of the ground reaction force. Stumbling detection is restricted to binary information.

II. Experiments

As experimental testing platform we use the lightweight quadruped robot Cheetah-Cub (Fig. 1a, [1]). One advantage in using this robot is that is fairly simple to obtain a stable open-loop trot gait. The modular design of the robot allows to quickly change parts of the construction to test different hypotheses.

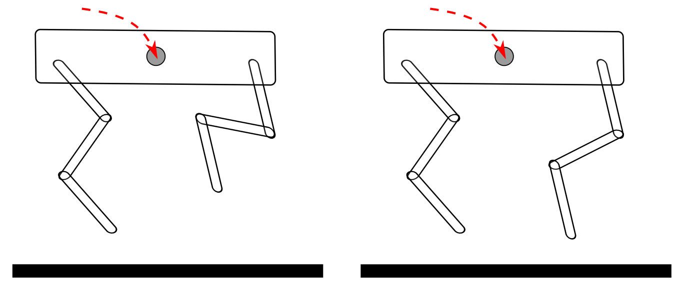

Fig. 2. Landing a height drop. *Left*, landing during CPG control. The leg pairs are asymmetrically flexed/extended. This results in an unstable landing. *Right*, with SCR control the legs will **only** flex if they have contact in the swing phase. This will prevent the aforementioned landing posture.

We compare two methods of generating locomotion profiles. The first method implements open-loop Central Pattern Generators (CPG) [2], as described in [1]. The second method is a modification of the first method where the knee CPG is replaced with a reflex-driven control. Instead of having a joint angle profile for the knee, a stumbling correction reflex (SCR) is implemented [3]. SCR is a simple reflex which flexes the leg if there is contact in the swing phase.

The second method can be useful when the robot lands after a height drop (Fig. 2). In a normal CPG control, if a leg is in stance phase and extended, the ipsilateral and contralateral legs are flexed (trot gait). This can result in an unstable landing. The case is different for the second method where all the four legs are extended as long as there is no contact. SCR initiates the continuation of locomotion after landing. An example of landing using the second method is provided in http://biorob2.epfl.ch/utils/movieplayer.php?id=276.

References

[1] A. Spröwitz et al. *Towards dynamic trot gait locomotion: Design, control, and experiments with Cheetah-cub, a compliant quadruped robot.* IJRR, 2013

[2] A.J. Ijspeert *Central pattern generators for locomotion control in animals and robots: a review.* Neural Networks, 2008

[3] M. Ajallooeian et al. *Modular control of limit cycle locomotion over unperceived rough terrain.* IROS, 2013