Quadruped Running Using a Flexible Torso and Momentum Management Techniques

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During the last 40 years, a diverse set of legged robots have been developed in order to be used in real-life applications. Legged robots exhibit increased mobility and versatility, benefits that render them ideal for motion on terrain with obstacles, discontinuities, or loose ground. However, it was not until very recently that significant research efforts aiming at fast-legged locomotion, led to the biomimetic design of quadruped robots [1], [2], which take advantage of the special features of their natural counterparts.

In nature, elite sprinters such as the Cheetah (Acinonyx jubatus), owe their astonishing performance in part to the flexibility of their spine. Several researchers have studied this issue and demonstrated the significance of the flexible torso in increasing the forward speed and enhancing running efficiency. This is achieved by the use of spine musculature elements, located at the torso and loaded mainly during galloping [3]. Furthermore, many quadruped mammals have long tails, which aid them to balance and manoeuvre at high speeds. Kangaroo rats use their long tails for righting and turning in mid-air. Black rats can impressively enter a building by balancing along a 2 mm wire. In studying hopping by kangaroos, one may be amazed to see how they use their tails to counteract the body pitching induced by the motion of their legs. In general, legged animals mostly use their tails for fine adjustments to perturbations, when their legs are otherwise occupied, [4].

The aim of this talk is to highlight the consequences of a flexible torso and a tail-like system in robotic quadrupedal high-speed locomotion. As far as flexible torso is concerned, different flexible torso designs, such as implementation via a revolute and implementation via a translational joint will be presented, (see Fig 1a). Our attention will be restricted to the cyclic bounding motions generated by a reduced-order passive sagittal model of a quadruped robot. The proposed flexible torso designs will be compared in terms of performance and stability.

Regarding the momentum management techniques, a simplified model of a quadruped robot on the coronal plane is introduced (see Fig 1b). The model incorporates a tail-like system, which controls the attitude of the main body of the robot during the flight phase. In this way the control tasks concerning the attitude of the robot body that are assigned to the legs during stance phase are significantly decreased. Momentum management techniques aiming at disturbance rejection during high speed locomotion will be presented.

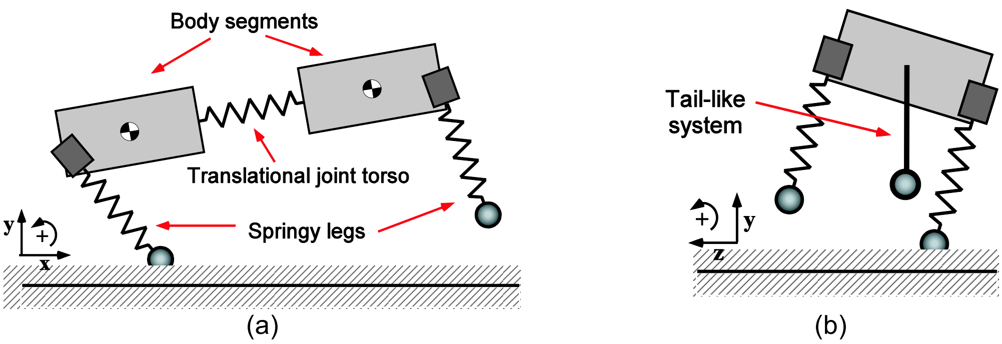

Figure 1: (a) Simplified sagittal model of quadruped robot with translational joint segmented torso. (b) Simplified coronal model of quadruped robot.

References

[1] Seok, S., A. Wang, M. Y. Chuah, D. Otten, J. Lang, and S. Kim, "Design principles for highly efficient quadrupeds and implementation on the MIT cheetah robots," in Proceedings of the IEEE International Conference on Robotics and Automation, IEEE, 2013, pp. 3307–3312.

[2] Khoramshahi, M., A. Sprowitz, A. Tuleu, M. Ahmadabadi, and A. Ijspeert, "Benefits of an active spine supported bounding locomotion with a small compliant quadruped robot", in *Proceedings of the IEEE International Conference on Robotics and Automation*, IEEE, 2013, pp. 3329 - 3334.

[3] Alexander, R., N. J. Dimery and R. F. Ker, "“Elastic Structures in the Back and their Role in Galloping in some Mammals," *Journal of Zoology A*, vol. 207, 1985, pp. 467-482.

[4] Hickman, G.C., “The mammalian tail: A review of functions” *Mammalian Review*, 1979, pp.143-157.

Acknowledgments

This research has been financed by the “IKY Fellowships of Excellence for Postgraduate Studies in Greece – Siemens Programme” in the framework of the Hellenic Republic – Siemens Settlement Agreement.