Pneumatically-driven Quadruped Robot with Biomimetic Legs and Flexible Spine

Yugo Kajiwara*, Shuhei Ikemoto*, Koh Hosoda*
*Graduate School of Engineering Science, Osaka University, Japan
kajiwara.yugo@arl.sys.es.osaka-u.ac.jp

1 Introduction

Compliance of the musculoskeletal body structure greatly contributes to quadrupedal animals' adaptive and fast running. The flexible spine can comply with the change of terrain and extend the stride so that the animal can increase its running speed. Compliance of the leg absorbs energy of the touchdown impact. Some quadruped robots take this function into account [1]. Witte et al. proposed "pantograph leg" based on findings regarding animal leg kinematics during cyclic locomotion [2], therefore it has been used many quadruped robots leg [3, 4]. Khoramshahi et al. developed a quadruped robot "Bobcat-robot" that had an active spine and showed that its movement improved running velocity [5].

This report describes a pneumatically-driven quadruped robot "PneuTerrier"; it is driven by pneumatic artificial muscles (PAMs) and has biomimetic legs and a flexible spine(Figure. 1). This report shows the robot's leg structure and spine mechanism and preliminary results of running experiment at trot gait.

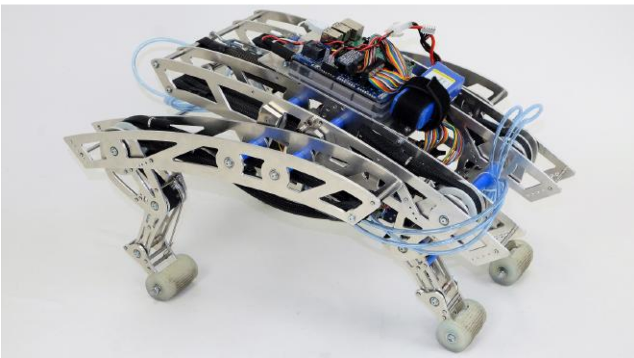


Figure. 1: PneuTerrier: a pneumatic quadruped robot. The length, width, and height of the whole body are around 430, 320, and 260 mm, respectively. The robot weights 4.20 kg. The number of muscles used the robot is 13.

2 Robot Design

2.1 Leg Structure

Figure. 2 shows the structure of PneuTerrier's legs. It is designed to be lightweight due to fast running, therefore the muscles that are attached near the trunk have been implemented as PAMs and other muscles have been implemented springs or omitted the implementation.

Figure. 2 (a) shows the structure of the forelimb. The shoulder joint is driven by two PAMs, Supraspinatus and Latissimus dorsi. The elbow joint is extended by a PAM, Triceps brachii and flexed by a spring, Brachialis. The carpal joint has passive element by a spring, Flexor carpi radialis.

Figure. 2 (b) shows the structure of the hindlimb. The hip joint is driven by two PAMs, Gluteus medius and Iliopsoas. The stifle joint is extended by a PAM, Vastus lateralis and flexed by a spring, Gastrocnemius. The tarsal joint has passive element by Gastrocnemius because it is bi-articular muscle, contributes to extension of the tarsal joint and flexion of the stifle joint.

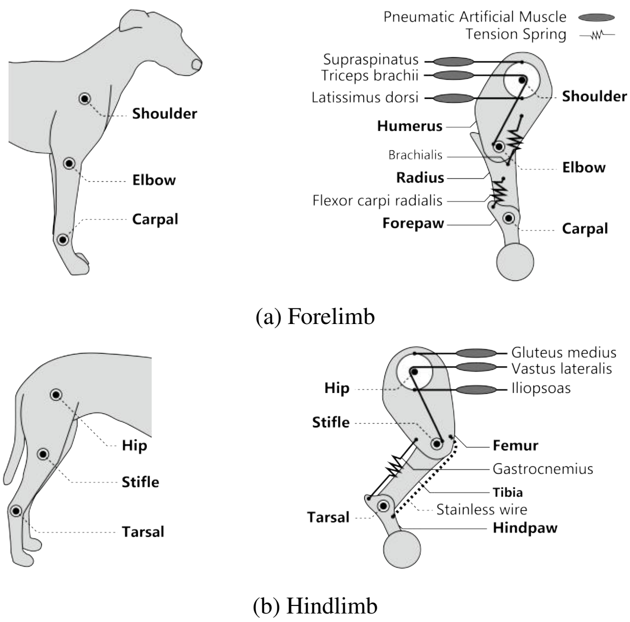


Figure. 2: Legs structure. PneuTerrier has been implemented with three-segment legs. It is designed from the musculoskeletal structure of a dog.

2.2 Spine Mechanism

Figure. 3 shows the spine schematics. This spine has four-bar linkage. It is designed to take realization wide range of motion and decreasing DOF into account. Contracting the PAM extends the spine and relaxing the PAM flexes the spine by tension spring. It makes realize wide range of motion with simple control. Figure. 4 shows the spine movements.

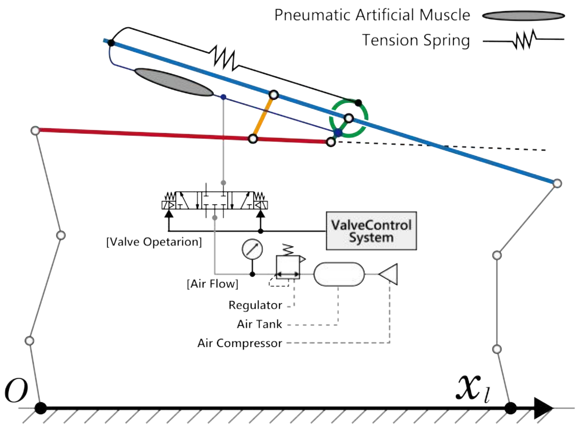
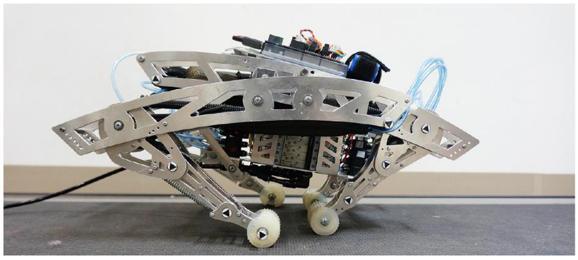
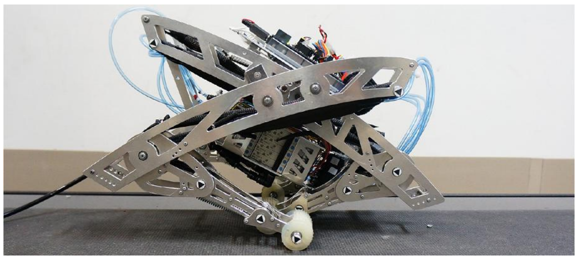


Figure. 3: Spine schematics. Define x_l as the distance between forepaw and hindpaw.



(a) Extension



(b) Flexion

Figure. 4: Spine movements. $|\Delta x_l|$ was changed about 105mm.

3 Experiment and Result

We have tried to make the robot run on the treadmill with open-loop controller. The pressure of compressed air which was supplied the robot has been 0.75MPa. Figure. 5 shows the snapshot of running experiment. It shows that this gait accelerated the robot to 3.4km/h. Then, period of one cycle was 250ms, and gait was trot because we thought it is relatively stable gait.

4 Conclusion and Future Work

In this study, we developed pneumatically-driven quadruped robot with biomimetic legs and flexible spine in order to be aimed at fast locomotion. The spine that is four-bar linkage made realize wide range of motion with simple control. In the running experiment, PneuTerrier was able to run 3.4km/h at trot gait.

In the near future, we will try to make the robot run at bouncing and galloping gait and confirm effectiveness of the spine. Also, we will improve the robot's hardware and software and aim further to run fast.

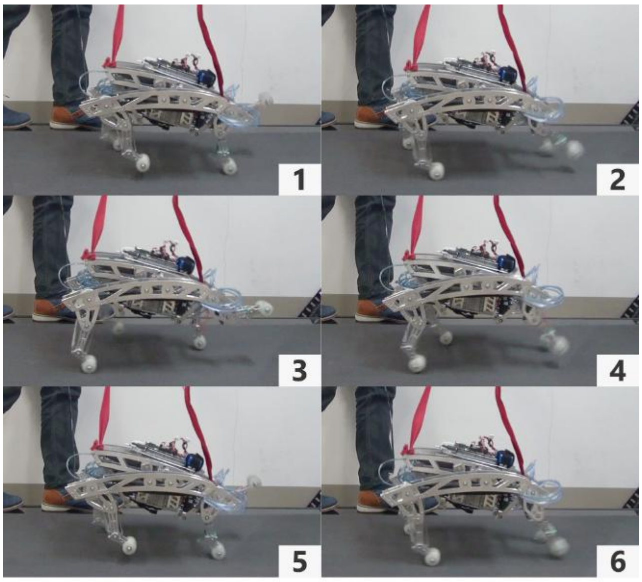


Figure. 5: Snapshot series of PneuTerrier trotting. This gait accelerated the robot to 3.4km/h. Gait cycle frequency is 4Hz.

References

[1] Sangok Seok, Albert Wang, Meng Yee (Michael) Chuah, David Otten, Jeffrey Lang, and Sangbae Kim. Optimally scaled hip-force planning: A control approach for quadrupedal running. In *2012 IEEE International Conference on Robotics and Automation (ICRA)*, pages 3307–3312, 2012.

[2] H Witte, R Hackert, W Ilg, J Biltzinger, N Schilling, F Biedermann, M Jergas, H Preuschoft, and MS Fischer. Quadrupedal mammals as paragons for walking machines. In *International Symposium on Adaptive Motion of Animals and Machines, Montreal, Canada*, 2000.

[3] Kenichi Narioka, Andre Rosendo, Alexander Sproewitz, and Koh Hosoda. Development of a minimalistic pneumatic quadruped robot for fast locomotion. In *Robotics and Biomimeticss (ROBIO), 2012 IEEE International Conference on*, pages 307–311, 2012.

[4] Alexander Sproewitz, Alexandre Tuleu, Massimo Vespignani, Mostafa Ajallooeian, Emilie Badri, and Auke Jan Ijspeert. Towards dynamic trot gait locomotion: Design, control, and experiments with cheetah-cub, a compliant quadruped robot. *The International Journal of Robotics Research*, Vol.32(No.8):932–950, 2013.

[5] M. Khoramshahi, A. Sproewitz, A. Tuleu, M. N. Ahmadabadi, and A. J. Ijspeert. Benefits of an active spine supported bounding locomotion with a small compliant quadruped robot. In *2013 IEEE International Conference on Robotics and Automation (ICRA)*, pages 3329–3334, 2013.