Novel test bench for robotic leg characterization

Ilya Brodoline, Stéphane Viollet, Julien Serres

Novel test bench for robotic leg characterization

Ilya Brodoline, Stéphane Viollet and Julien R. Serres

Aix Marseille Univ, CNRS, ISM, Marseille, France

1. Introduction

Legged robots are valuable platforms to mimic animals. Multiple studies compare robots locomotion, navigation and other implemented behaviours, to performances of real animals (Ijspeert et al. 2014).

Nevertheless, there is still a big challenge to define what are the performances of a legged robot in terms of locomotion efficiency and endurance. Various measurements have been conducted on walking animals. Typically, insect studies by mean of test benches are composed of motion capture, force measures (Dallmann et al. 2016), and charge transportation (Zill et al. 2004). Fewer studies dealt with the estimation of insect's energetic cost of locomotion (Lighton et al. 2016). On the other side, robot's characteristics are represented mostly by their velocity, cost of transport, energy consumption, or structure robustness. For now, regarding the available data and methods, there is still no defined procedure grouping and estimating with a single experimental setup all the meaningful characteristics of a robotic leg. Such a setup would allow researchers to compare any legs with a same procedure.

In this context, we decided to build a new robotic leg test bench, combining the measurements techniques applied on animals and robots in a one and a same test bench. Our test bench allows to establish a robotic leg's performance table, required mainly, for robot performances assessment, structure and locomotion optimization. Moreover, we used the resulting values to compare a classical hexapod robotic leg with an ant to better understand the gap between a robot and its biological model.

2. Methods

2.1. Overview

Two scenarios are performed on our test bench (Figure 1) to build the robotic leg's performance table. The first scenario corresponds to a basic walk case, the second one is a load lifting procedure.

To illustrate the use of the test bench, we performed measurements on a hexapod robot's leg. This latter was

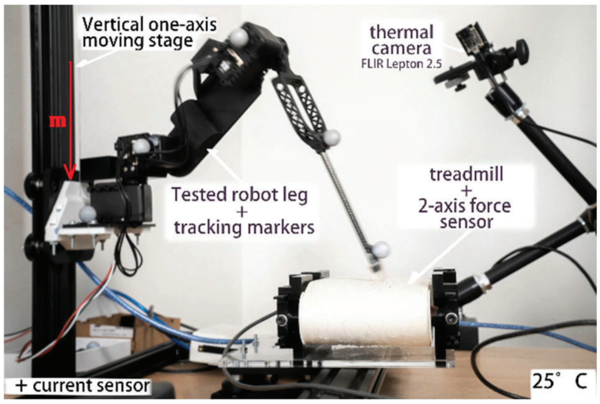

Figure 1. Leg test bench photography. ©Tifenn Ripoll – VOST Collectif / Institut Carnot STAR (2021).

actuated by 3 Dynamixel AX18 servo motors, the chosen structure represents a classical leg, widely used for insect-inspired robots (Cizeket al. 2021). Our leg dimensions fit with the scale of an ant *Cataglyphis fortis* leg.

More information about the test bench structure and components are available on the following GitHub: https://github.com/IlyaBrod/MiMiC-ANT-testbench.

2.2. Locomotion measurements

During the walking scenario, with the moving speed progressively rising from null to maximum, the locomotion parameters (Table 1) were estimated through the spatial coordinates of the leg tip, using the motion capture cameras data. Afterwards, during the same scenario, a spring was loaded inside the treadmill, giving a tangential resistance to the leg, providing the measure of the maximal propulsion force.

During the second load lifting scenario, the leg was loaded with various masses, until the input position is no longer reached. The treadmill force sensor, measure the normal leg force, and gave the information about the maximum payload of the leg.

2.3. Energetic evaluation

Using the walking scenario, with a various leg speed, the current sensor measurements, merged with motion capture data, allows us to estimate the minimal cost of transport per leg of the robot. Defined as the ratio of the motor energy by the product of mass, gravity and the travelled distance (Seok et al. 2013).

Thermal data provide a description of the leg structural design. During a maximum load and speed 15min walk at 25 °C, the deduced maximum elevation of temperature per minute, reflects the heat dissipation capacity of the mechanism and shows the structural weaknesses.

Table 1. Test bench results *vs.* desert ant data.

Parameters	Hexapod ×6 legs (scaling)	Scale factor* α=20:1	Ant
	Global characteristics		
Mass	1572g (196.5mg)	α^3	4.3 mg
Power	80W		–
	Locomotion		
Max. speed	19cm/s (0.475cm/s)	$\alpha^{\frac{1}{2}}$	9.5cm/s**
Stride length	104mm (5.2mm)	α	5–15 mm**
Stride max frequency	1.8Hz (8Hz)	$\alpha^{-1/2}$	30Hz**
Ineffective stance	13%		–
Step accuracy	±11.5mm		–
Max normal / tangent stress	12N / 1N		0.32mN/—
	Energetics		
Cost of transport***	6.18		39
Temp. Inc.	3.2°/min		–

*(Clark et al. 2007)
**(Wahl et al. 2015)
***(Seok et al. 2013)

3. Results and discussion

The first column of Table 1 corresponds to the complete robot performances, estimated from the test bench data of one leg. Therefore, it represents the worst and the best cases, giving the limits of the structural leg design. These values provide information about the usability of the robot, giving us the possibility to predict the maximum distance travelled over a flat terrain with a specific roughness.

We can see in Table 1, the performances of a classic 3 degrees of freedom Dynamixel AX18 leg, rated on our test bench are far from the values of an ant. This type of conventional robotic leg is not therefore the best suitable solution for robotic design, which will require to improvements the robustness and the long endurance.

4. Conclusions

For the first time, we depicted a test bench that allow us to compare performances between various robotic legs, then those of animal counterparts, here ants. The parameters in Table 1 depict the most important features used to describe and evaluate the robot's performances during a basic walk procedure.

In the near future, this work will allow us to build biomimetic, energy efficient hexapod to reach and overcome the animal's level of performances.

Acknowledgements

This research was supported by the French Agence de l'innovation de défense (AID), the CNRS (PEPS MiMiC-ANT Program), and the Aix Marseille University (AMU).

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Cizek P, Zoula M, Faigl J. 2021. Design, Construction, and rough-terrain locomotion control of novel hexapod walking robot with four degrees of freedom per leg. IEEE Access. 9:17866–17881.
Clark JE, Goldman DI, Lin PC, Lynch G, Chen TS, Komsuoglu H, Koditschek D. 2007. Design of a bio-inspired dynamical vertical climbing robot. Robot Sci Syst. III:9–16.
Dallmann CJ, Dürr V, Schmitz J. 2016. Joint torques in a freely walking insect reveal distinct functions of leg joints in propulsion and posture control. Proc. R. Soc. B. 283(1823):20151708.
Ijspeert, A. J. 2014. Biorobotics: Using robots to emulate and investigate agile locomotion. Science. 46(6206):196–203.
Lighton J. R. B., Duncan F. D. 2016. Energy cost of locomotion: validation of laboratory data by in situ respirometry. Ecology. 83(12):3517–3522.
Seok S, Wang A, Chuah MY, Otten D, Lang J, Kim S. 2013. Design principles for highly efficient quadrupeds and implementation on the MIT Cheetah robot. Proceedings of the IEEE International Conference on Robotics and Automation; 6–10 May; Karlsruhe, Germany.
Wahl V, Pfeffer SE, Wittlinger M. 2015. Walking and running in the desert ant *Cataglyphis fortis*. J. Comp. Physiol. A Neuroethol. Sens. Neural. Behav. Physiol. 201(6):645–656.
Zill S, Schmitz J, Büschges A. 2004. Load sensing and control of posture and locomotion. Arthropod Struct Dev. 33(3):273–286.

KEYWORDS Hexapod; cost-effective platform; bio-inspired robotics; biomimetics; biorobotics

ilya.brodoline@univ-amu.fr