Motion and Force measures on tortoises to design and control a biomimetic quadruped robot

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Abstract This paper is concerned with locomotion systems modelling and control; in particular the locomotion of bio-mimetically inspired quadruped robots. Using observations and experiments, we propose a virtual model of quadruped with no dorsal vertebrae, such as the case in the majority of legged mobile robots. This condition applies to the terrestrial tortoise and makes it a good example for bio-mimetic inspiration. Extensive experiments in vivo and in vitro are conducted to estimate the motion, the kinematics and the dynamic properties of two living subjects and a dead one. The experimental results are used to model, control and simulate the motion of a tortoise-like quadruped robot. The result is TATOR II, a successful example of robots mimicking the mechanical design and motion trajectories of animals; it is a linkage of 15 rigid bodies articulated by 22 degrees of freedom, it is built on the ADAMS-View platform and is shown to perform through animation with a motion controller. Analyses of the influence of the phase between legs on the robot speed are also presented. Conclusions and future Works are detailed.

1 Introduction

This study is achieved in the Institute of Intelligent Systems and Robotics (ISIR) with partnership with the UMR 7179 of the National Museum of Natural History in Paris. We expect that by studying the locomotion of living animals, we can find interesting parameters that could be used in mobile robotics and are invariant from specie to another. We also expect to create a model that helps to study the locomotion of current and extinct
species. Two animals are studied: the European hedgehog (J. Villanova, 2003), and the Hermann tortoise (B. Hennion, 2006). Two virtual models are built: a bi-dimensional model of the hedgehog and a 3D model of the Herman Tortoise called TATOR I. In this study, we will present a new and much precise methods for creating a bio-mimetic virtual quadruped robot inspired from terrestrial tortoises. This model is called TATOR II. The remaining of this paper is organized as follows: In section II we describe the experiments in vivo and in vitro performed on animals; in section III, we present the dynamic model TATOR II. Section IV highlights the contributions and the future perspectives. Figure 1 presents a basic summary of the study.

![Diagram](image)

**Figure 1.** Basic summary of the study

2 Experiments on animals

We perform experiments on three adult tortoises. Two are alive (subject I and subject II) and the third (subject III) is dead for natural reasons (this subject has approximately the same inertial and dimensional properties of subject I). These experiments are divided into two categories: *in vivo* and *in vitro*. We use measures on subject III to create the virtual model TATOR II, while we use those on subject I to control it. We choose two different subjects to model and control TATOR II, because the dissection is forbidden on living subjects.

2.1 Experiments *in Vivo*

The experimental bench (Figure 2) used during these experiments is composed of: a video camera filming at 25 frames per second, an X-ray generator, a brightness amplifier, a digital camera filming at 50 frames per second and four piezoelectric force sensors mounted under four beams of