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New technologies for testing a model of cricket phonotaxis on an outdoor robot

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Abstract

If biological inspiration can be used to build robots that deal robustly with complex environments, it should be possible to demonstrate that 'biorobots' can function in natural environments. We report on initial outdoor experiments with a robot designed to emulate cricket behaviour. The work integrates a detailed neural model of auditory localisation in the cricket with a robot morphology that incorporates principles of six-legged locomotion. We demonstrate that it can successfully track a cricket calling song over natural terrain. Limitations in its capability are evaluated, and a number of biologically based improvements are suggested for future work.

Keywords: Outdoor robotics; Cricket phonotaxis; Neural modelling; Neuromorphic systems

1. Introduction

The ability of animals to deal flexibly with complex environments is often advanced as a reason to adopt a biology-based approach to robotics. This suggests that robots designed to emulate biological systems should be tested in natural conditions. But to date there are only a few examples of such evaluations e.g. the Sahabot using polarised light navigation in the Tunisian desert [1]; or recent testing of Robolobster in the Red Sea (Frank Grasso, personal communication).

We have built a series of robots based on cricket phonotaxis, that is, the ability of female crickets to locate a mate by moving towards male calling songs (both simulated and real). These robots have been shown to reproduce many aspects of the insect's behaviour, including sound localisation in noisy conditions, preference for conspecific pattern in the calling song, distin-

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guishing between competing sound sources, and using optomotor correction to do phonotaxis with motor output biased or randomly disturbed [2–5]. The most recent robot uses an auditory processing circuit closely based on cricket ears and is controlled by a realistic neural network that replicates known neural connectivity in the cricket [6]. In this paper we aim to evaluate the performance of this system when implemented and tested on an outdoor robot, to explore the issues raised by the natural habitat for this behaviour.

These issues fall into three broad areas. The first concerns the nature of the stimulus—how the sound is propagated and what kinds of interference and distortion occur. To what extent does the auditory localisation system we have implemented on the robot to date need to be altered to deal with this, since we know that sound propagation on grass outdoors is very different from that in a lab environment? The second area is motor capability: the cricket can traverse rough terrain, while our algorithms have been developed for a wheeled robot on a flat floor. Can we control a robot with a cricket-like morphology using such algorithms? The third area (in which only preliminary results are detailed in this paper, but which is the subject of ongoing research) is physical plausibility. The robot used here is too big to interact which the outdoor environment in a manner directly comparable to that of crickets, such as how it detects and deals with obstacles that might block its path towards the sound. In order to approach this problem we must look at methods which will allow us to reduce the size and power demands of the robot controller so that it will fit onto a smaller robot. A promising technology is Very Large Scale Integration (VLSI) implementations of *neuromorphic circuits* [7], of the type described in Section 2.1.4.

The robot platform we use here is inspired by insect walking. Insects such as cockroaches and crickets typically use a tripod gait, in which the front and rear legs on one side of the body move in phase with the middle leg on the other side. Close studies of cockroach locomotion [8] also reveal that the front legs normally swing head-high to surmount many obstacles without changing gait, but when larger barriers are encountered the gait changes, and contralateral legs move in phase. These strategies have been incorporated into a robot morphology called 'Whegs'™, that unlike RHex [9], uses only a single drive motor and embedded passive compliance [10]. It uses six hubs which each have three protruding legs that rotate as the robot moves (see Section 2.1.1). The three-spoke design and torsional compliance in the drive train allow it to climb up and down shallow stairs and inclines and easily traverse most terrains, such as asphalt, grass, mud, gravel, and light brush. The platform used in this study could move at a speed of up to 4 body-lengths per second and has a turning radius of 1.5 body-lengths.

Full details of the methods used to integrate the previous robot controller onto this platform have been described in Horchler et al. [11]. Here we analyse the performance of this implementation, to address some of the issues of hearing and responding to sound outdoors.

2. Methods

2.1. Hardware

2.1.1. Robot base

The robot base was the Whegs™ Autonomous Sensor Platform (Whegs™ ASP), shown in Fig. 1a. It is based upon a lightweight 60 cm long × 15 cm wide aluminium chassis. It has six 15 cm-radius three-spoke wheel-legs, each of which is arranged 60° out of phase from adjacent wheel-legs. This allows the robot to move with a nominal tripod gait with all six wheel-legs powered by a single 90 W Maxon motor and transmission. The torque delivered to each wheel-leg passes through a torsionally compliant mechanism that permits a wheel-leg to comply if an obstacle is encountered, thus moving into phase with the contralateral wheel-leg. Additionally, large compliant feet at the tip of each spoke cushion and smooth the robot's vertical motion without seriously compromising its climbing ability. To turn, front and rear rack-and-pinion steering is activated with two electrically coupled Futuba servomotors. Two 3000 mAh battery packs connected in parallel provide 5 V to the servos and 8.4 V to the drive motor via an Astro-Flight electronic speed controller (ESC). A third electrically isolated battery pack was used to power the control system (see below).

2.1.2. Sensors

A pair of miniature microphones were mounted to a four-bar mechanism attached to the front steering, allowing them to pivot with the front wheel-legs. They