



Contents lists available at ScienceDirect

Arthropod Structure & Development

journal homepage: www.elsevier.com/locate/asd

Mantisbot is a robotic model of visually guided motion in the praying mantis

Nicholas S. Szczecinski ^{a,*}, Andrew P. Getsy ^a, Joshua P. Martin ^b, Roy E. Ritzmann ^c,
Roger D. Quinn ^a

^a Case Western Reserve University, Department of Mechanical and Aerospace Engineering, USA

^b Colby College, Department of Biology, USA

^c Case Western Reserve University, Department of Biology, USA

ARTICLE INFO

Article history:

Received 30 May 2016

Received in revised form

24 February 2017

Accepted 11 March 2017

Available online xxx

Keywords:

Computational neuroscience

Robotics

Praying mantis

Descending commands

Locomotion

ABSTRACT

Insects use highly distributed nervous systems to process exteroception from head sensors, compare that information with state-based goals, and direct posture or locomotion toward those goals. To study how descending commands from brain centers produce coordinated, goal-directed motion in distributed nervous systems, we have constructed a conductance-based neural system for our robot MantisBot, a 29 degree-of-freedom, 13.3:1 scale praying mantis robot. Using the literature on mantis prey tracking and insect locomotion, we designed a hierarchical, distributed neural controller that establishes the goal, coordinates different joints, and executes prey-tracking motion. In our controller, brain networks perceive the location of prey and predict its future location, store this location in memory, and formulate descending commands for ballistic saccades like those seen in the animal. The descending commands are simple, indicating only 1) whether the robot should walk or stand still, and 2) the intended direction of motion. Each joint's controller uses the descending commands differently to alter sensory-motor interactions, changing the sensory pathways that coordinate the joints' central pattern generators into one cohesive motion. Experiments with one leg of MantisBot show that visual input produces simple descending commands that alter walking kinematics, change the walking direction in a predictable manner, enact reflex reversals when necessary, and can control both static posture and locomotion with the same network.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Praying mantises make visually-guided saccades toward prey while hunting (Mittelstaedt, 1957; Lea and Mueller, 1977; Rossel, 1980; Yamawaki et al., 2011), making them ideal model organisms for the study of descending commands and goal-directed motion. Their saccades consist of rotating the head, prothorax, and thorax in near-unison in ballistic, predictive pivots, during which they are apparently insensitive to changing visual input (Lea and Mueller, 1977). This system requires that the mantis locate prey in its visual field, predict its position sometime in the future, remember this position, and execute a planned, coordinated motion with its neck, jointed prothorax, and legs. If starved, mantises

will also pursue prey, requiring them to redirect their locomotion toward their visual goal. All of these tasks require that the animal receive visual input, process it, plan corrective motions, and then communicate these motions to the thoracic ganglia that control motion via descending commands. We present a conductance-based neural controller, based strongly in the literature on mantis saccades and insect locomotion, for our robot MantisBot (Szczecinski et al., 2015a). This controller serves as a hypothesis of how the thoracic ganglia are organized to produce static posture and locomotion, and how descending commands from the brain may alter their function to accomplish a goal.

Much is known about how insects control locomotion (for a review, see Buschmann et al., 2015). Each joint has its own central pattern generator (CPG), which can produce rhythms, even when deafferented (Ryckebusch and Laurent, 1993; Büschges et al., 1995). Sensory signals such as joint motion (Hess and Büschges, 1997, 1999; Bucher et al., 2003) and leg strain (Ridgel et al., 1999; Akay et al., 2004) provide feedback to the oscillators, adjusting their relative

* Corresponding author. Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106, USA.

E-mail address: nss36@case.edu (N.S. Szczecinski).

phase and coordinating motion. Drastic changes in coordination, such as those seen while insects turn or walk backward, are thought to be the result of reflex reversals, wherein a sensory input causes the opposite transition in a CPG (Akay and Büschges, 2006; Mu and Ritzmann, 2008; Hellekes et al., 2011; Szczecinski et al., 2014).

Many studies with insects have sought to explain what type of descending commands are sent from navigational centers in the brain to the thoracic networks to direct locomotion (for reviews see Ritzmann et al. (2012) and Borgmann and Büschges (2015)). Neurons in the central complex are known to predict the direction and speed of cockroach locomotion (Guo and Ritzmann, 2013; Martin et al., 2015), and stimulating these neurons can elicit the same reflex reversals observed when the animal changes its walking direction (Martin et al., 2015). These studies, however, do not elucidate what information the thoracic ganglia are receiving from the brain. In the fruit fly, an individual neuron (called “Moonwalker descending neuron”, or MDN) has been identified in the brain whose stimulation is necessary and sufficient to reverse the direction of walking, suggesting that in some cases, descending information may be as straightforward as tonic signals (Bidaye et al., 2014). In our controller, the thoracic networks are provided only with two pieces of information: whether to walk or stand still, and in what direction to orient the body. This simplicity is reminiscent of the MDN, and is consistent with the highly distributed nature of insect locomotion control systems (Cruse, 1990).

The effect of descending commands has been the focus of an increasing number of modeling and robotics studies (Schilling et al.,

2013), especially reflex reversals observed when insects walk backwards or along a curved path (Rutter et al., 2011; Knops et al., 2012; Toth et al., 2012; Szczecinski et al., 2014). These falls into two main categories: centralized models used to produce detailed descending commands, and simple descending commands used to modify the function of sensory-motor networks. Walknet and the associated robot Hector use a navigational network (Navinet) to direct the stance-phase motion of the legs toward a goal. This is accomplished through a marionette-like internal body model, implemented as a recurrent neural network, which enables Navinet to “pull” the body in the desired direction, and then command the resulting motion to the motor controllers. Such a centralized approach is in contrast with the distributed approach of models from Daun-Gruhn et al., which focus on reversing the phase of some joints' motion by changing the sign of the connections between the CPGs and motor neurons (MNs) (Knops et al., 2012; Toth et al., 2012). Previous work from our group has built computational (Szczecinski et al., 2014) and robotic (Rutter et al., 2011; Klein et al., 2014) models that accomplish this same phase shift by changing the sign of sensory information that coordinates the CPGs in one leg. It is possible that the nervous system uses one or all of these methods to direct locomotion (Buschmann et al., 2015). Our controller for MantisBot supports the hypothesis that simple descending commands may change low-level network function to direct locomotion, but tuning this network relies on a kinematic model of the whole robot, representing a compromise between these two approaches.

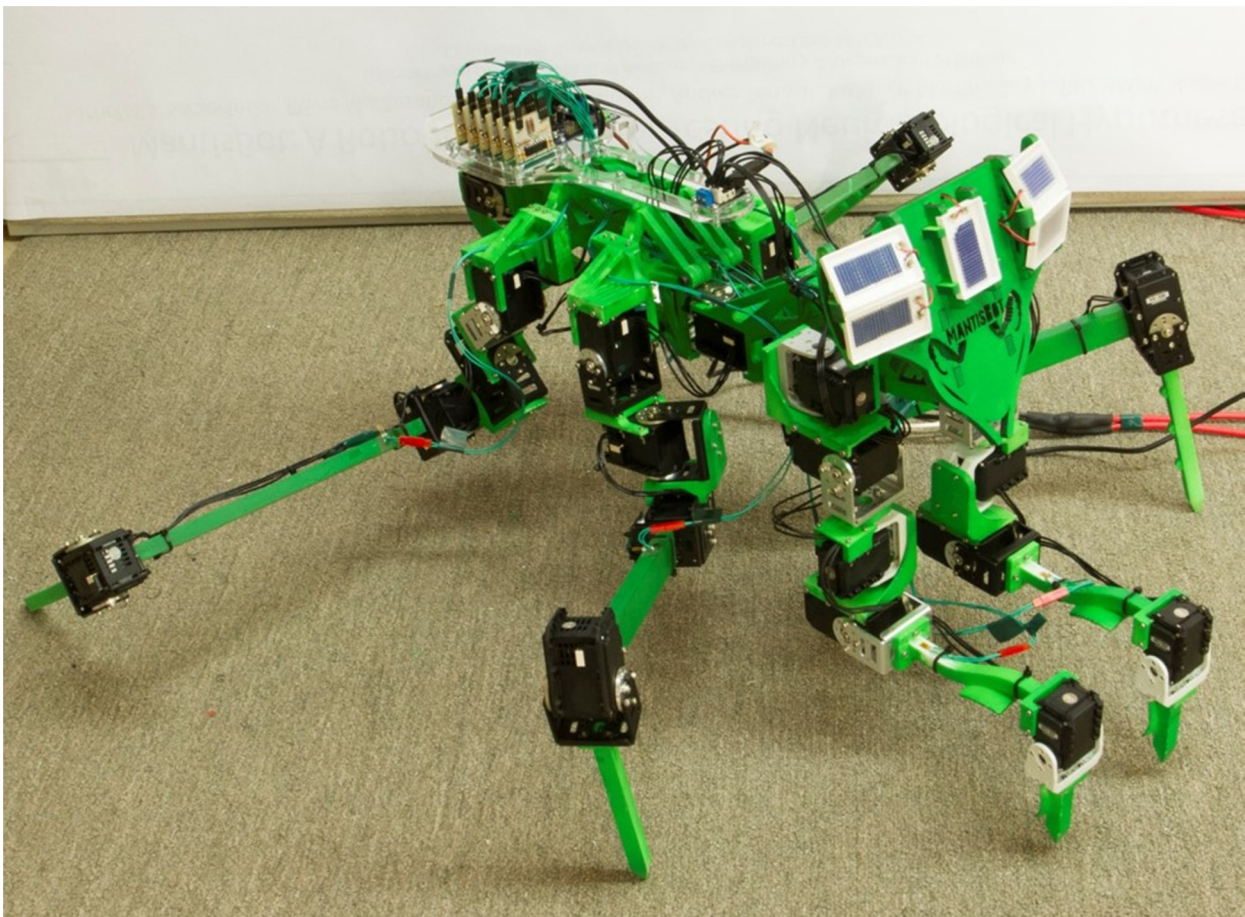


Fig. 1. Photograph of MantisBot supporting its weight on four legs.

Download English Version:

<https://daneshyari.com/en/article/5584981>

Download Persian Version:

<https://daneshyari.com/article/5584981>

[Daneshyari.com](https://daneshyari.com)