On the Development of an Ants-Inspired Navigational Network for Autonomous Robots

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ABSTRACT

Experimental research in biology has uncovered a number of different ways in which ants use environmental cues for navigational purposes. For instance, pheromone trail laying and trail following behaviours of ants have proved to be an efficient mechanism to optimise path selection in natural as well as in artificial situations. Drawing inspiration from biology, the authors present a new neural strategy for navigation. The authors propose a navigational network composed of a gating network, memory and two recurrent neural networks (RNN). The navigational network learns to follow a trail and to orientate based on landmarks, while continuously recording the location of the home position in case the trail is lost. The orientation was encoded as a continuous ring of neurons, while the distance was encoded as a chain of neurons. Finally, the computational analysis provides a more complete exploration of the properties of the proposed navigational network. This network is able to learn and select behaviours based on sensory clues. The proposed model shows that neural path integration is possible and is easy to achieve.

Keywords: Ants, Autonomous Robots, Bio-Inspired Robotics, Navigation, Neural Networks

1. INTRODUCTION

The ability to navigate in a complex environment is crucial for both animals and robots. Social insects routinely return to the colony after their foraging excursions, on long and winding routes (Wilson, 1971). Given their size and relatively simple nervous systems, it seems likely that insects use simpler and economical ways to navigate in the real world. An ant, for example, navigates tirelessly back to its nest after going out on foraging expeditions several thousand body lengths away from its nest, relying mainly on olfactory and visual cues when navigating over large distances. Similar principles can be applied to the design of navigational strategies for autonomous robots that may be deployed to perform tasks such as: foraging (Lerman & Galstyan, 2002); gathering (Jiménez, Shirinza-deh, Òetomo, & Nicholson, 2011); and flocking (Egerstedt & Hu, 2001).

When returning to the nest ants navigate by Path Integration (PI), chemical navigation (trail following), and visual navigation (landmark fol-
In this study navigation is interpreted as the ability to move in space determining if a target has been reached. This interpretation of navigation does not require a map like representation to find the target.

Ants’ predominant method of navigation is path integration (PI) (Collett & Collett, 2000). The principle of PI is rather simple; information from a compass and an odometer is used to continuously calculate the insects’ current position relative to the nest position. PI systems rely on the animal’s past performance and cannot correct errors by referring to a global map. Thus, all small errors successively made by the animal will accumulate. In general, PI models are stated in terms of the operations required to update the home position vector. A common assumption between different models is that the home base position is maintained by an incremental procedure. This means that an individual knows the distance (r) and direction (µ) of its home base. Desert ants, for example, measure angle directions based on wind and sky as compass (Müller & Wehner, 2007). It is not clear how desert ants measure distances: whether they count the numbers of steps or whether they measure their speed and time. However, their PI system is precise enough to let them miss the inconspicuous hole leading to their underground nest by no more than a few percent of the entire homing distance (Wehner & Srinivasan, 1981). The light polarisation of the sky has also been utilized to estimate orientation (Lambrinos, Möller, Labhart, Pfeifer, & Wehner, 2000). This compass was closely related to the spatial layout and neural processing of the ants eye. Inspired by the way honeybees use image motion for a variety of tasks in navigation, Weber et al. (1996) estimated the distance travelled from image motion by integrating the optical flow from two lateral cameras. A number of experiments in corridors at different speeds show that the values were consistent with the corridor. However, the method cannot be used in a different environment because the optical flow depends on specified features used as markings and targets for motion.

Many ants’ species use chemical navigation when foraging for food. When one of them finds a source of food it leaves a trail of pheromones in order to recruit more workers (Figure 1). The trail is continually renewed because the pheromones evaporate quickly (Calenbuhr, Cheretien, Deneubourg, & Detrain, 1992). Sharpe and Webb (1998) proposed a neural network model for pheromone. With the help of chemical cues their robot was able to walk along a path created by the evaporating chemicals. In contrast, virtual pheromones (Payton, Daily, Estowski, Howard, & Lee, 2001) are symbolic messages tied to the robots themselves rather than to fixed locations in the environment. This enables their system to become a distributed computing mesh embedded within the environment. They claim that the system can be used to compute non-local information about the environment, such as bottlenecks and shortest paths, in ways that are foreign to insect colonies.

Flying insects, such as bees, flies and wasps, can navigate with cues derived from the perceived visual motion of objects as the observer moves relative to them (optical flow) (Srinivasan, 1992). For example, Iida (2003) focused on the mechanisms of course stabilisation behaviour and visually mediated odometer. The performance test of the navigation method, a panoramic vision system, was conducted using a flying robot platform in uncontrolled...
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