Developing AntBot: Visual Navigation based on the insect brain

Robert Mitchell

Master of Informatics
Informatics
School of Informatics
The University of Edinburgh
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Supervised by
Dr. Barbara Webb

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Abstract

Declaration

I declare that this disseration was composed by myself, the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

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1 Introduction

Desert ants (*Cataglyphis velox*) have the remarkable ability to navigate through complex natural environments, using only low-resolution visual information and limited computational power. It is well documented that many species of ant, and other hymenoptra are capable of very robust visual navigation; however, it is as yet unclear how the insects perform this seemingly complex task with such little brainpower. In this paper, we will focus on using and extending an existing model for visual navigation in ants using the Mushroom Body circuit, an artificial neural network which emulates the Mushroom Body neuropils in the ant brain. We will also discuss biologically plausible methods of visual Collision Avoidance using Optical Flow. A robot (AntBot) has been constructed [**?**] to allow us a testing platform on which to implement, and experiment with, the algorithms in the *Ant Navigational Toolkit* [**?**].

1.1 Motivation

Though we are able to observe, and mimic algorithmically, the visual navigational capabilities of insects, we still do not understand the precise methods by which this process takes place. The model we will look at was propsed by *Ardin et al.* [**?**], which takes the Mushroom Body (whose function was thought to be primarily for olfactory learning), and shows that this provides a plausible neural model for encoding visual memories.

The MB circuit has been implemented and tested on AntBot by Eberding and Zhang respectively, however the existing MB circuit is fairly simple. It uses binary weightings for the connections between the visual projection neurons and the Kenyon Cells, and a single boolean Extrinsic Neuron denoting image recognition. A modification was made by Zhang, whereby eight ENs were used, one for each of the cardinal directions in the Central Complex model. This will be discussed further in 2.2. The reader should note that the Central Complex (CX) model is primarily used to model the task of Path Integration and will not be discussed further (see [**?**]).

We would also like to look at methods for collision avoidance (CA) which do not involve specialised sensors such as a LIDAR or SONAR, the luxury of which, ants do not have. Models have been proposed which use

Optical Flow (OF) properties to determine whether or not a collision is imminent. These models have been propsed both in a purely robotic context [?], and biological ones [?, ?].

1.2 Goals

The project aims for the following experimental scenario to be possible: We want to send the robot on a run through an obstacle course, allowing it to navigate however it chooses through the environment. From here, we want the robot to be able to replicate this route using only visual memories, which it should store on that initial run. Finally, we would like the robot to be able to navigate home following the reverse of this route. It should be noted that this final step is not strictly accurate to the behaviour of the desert ant. *Wehner et al.* [?] demonstrated that the remembered routes have a distinct polarity, so knowledge of a route from nest to food, does not imply that the ant has knowledge of a route from food to nest.

The first stage of the project will focus upon obtaining a working collision avoidance system as a pre-requisite to gathering the route information. This CA system should be based on visual information readily available to AntBot with no additional/specialist sensors. For this paper, we assume that CA is a low-level reactionary behaviour, in that, we don not use any further processing of the detected motion (e.g. a neural model); we react based on the immediate stimulus of the flow field. We will look at two different optical flow techniques used to build CA systems. We will also discuss the effects of using different types of flow field, how the different flow techniques behave in the same situation, and different methods of response.

We then move to the Mushroom Body circuit, first estabilishing a baseline performance measure for the visual navigation task by using the orignal *basic* model from [?] with binary weightings and a single Extrinsic Neuron. A scanning behaviour will be used for this baseline; ants have demonstrated use of scanning in visual navigation but it is generally accepted that this is not the primary method they use to determine a direction after having recognised a scene, rather, this scanning behaviour only occurs in certain scenarios (e.g. when the ant becomes lost) [?].

Finally, we will report the results of the experiments performed at different stages during, and post development; we will compare these to relevant results from previous iterations of this project. We will end with a conclusion of our findings and contributions to the project, as well as discussing technical limitations and potential for future developments.

1.3 Results

This work is based on work done previously by Leonard Eberding, Luca Scimeca, and Zhaoyu Zhang [**?**, **?**, **?**].

Significant contributions:

1. An optical flow based system for Collision Avoidance
2. Results indicating the impracticality of an expansion based system for Collision Avoidance
3. *[FUTURE]* Successful replication of a route through a cluttered environment using Visual Navigation
4. *[FUTURE]* Comparison of different Visual Navigation models in a set navigational task

Note: results marked [FUTURE] are results I would like to have achieved by the culmination of the project and the writing of the final dissertation. They are not current. To be continued...

2 Background

2.1 Optical flow models for Collision Avoidance

2.1.1 Expansion

2.1.2 Filtering

2.2 The Mushroom Body for Visual Navigation

3 Platform

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