Bee SLAM: A probabilistic framework for studying orientation flights in bees and wasps

Bart Baddeley
Centre for Computational Neuroscience and Robotics
Department of Informatics
University of Sussex
0044 1273 872664
bartbaddeley@googlemail.com

Andrew Philippides
Centre for Computational Neuroscience and Robotics
Department of Informatics
University of Sussex
0044 1273 872664
andrewop@sussex.ac.uk

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1. INTRODUCTION
Flying insects locate the position of their inconspicuous nest entrances using local visual landmarks in the presence of high environmental noise with simple visual systems and limited computational resources. To cope with these difficulties, insects have evolved innate behaviours which simplify visual learning. A remarkable example is the orientation flight performed by bees and wasps when they leave the nest to forage [1]. This behaviour includes a number of stereotyped flight manoeuvres which appear to mediate the active acquisition of visual information [4]. However, there has been little work investigating how, and what aspects of, the flight lead to an improvement in learning. In mobile robotics, one extensively studied approach to the problem of localising an agent is the Simultaneous Localisation And Mapping (SLAM) methodology [2]. Here we use a SLAM framework to investigate the influence of the orientation flight on visual learning.

A successful solution to the SLAM problem involves building and maintaining a map of features sufficient for successful localisation during navigation. The map is built incrementally using noisy measurements and a stochastic model of the agent-environment interaction. Given knowledge of the initial conditions and a perfect movement model, a perfect estimate of position can be maintained by integrating the agent's estimated movements across time. Alternatively, a perfect sensory system could remove the need for any sort of internally generated position estimate. In practice neither movement model nor measurements is perfect and the best performance can be obtained by considering and combining both sources of information. Assuming Gaussian noise, the Extended Kalman Filter (EKF) provides a probabilistic framework for optimally combining these sources of information.

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The explicit dependence of localisation performance on the accuracy of movement and measurement models means that SLAM provides an opportunity to explore how the details of the orientation flight affect visual learning. Considering the problem from the perspective of a bee or wasp, we can assume that measurement accuracy is fixed by the physical constraints of the visual system and optics. The accuracy of the movement model is not fixed however, and will vary according to the flying conditions and the flight manoeuvres being executed. It is plausible that the stereotypical dynamics of the orientation flight make movements easier to predict and thus improve the insect's ability to localize itself.

To test this hypothesis we have developed movement and sensor models for a simulated agent localizing itself with respect to a fixed landmark. We consider a movement model inspired by the characterisation of orientation flights as a series of arcs at different radial distances centred on the nest [3] with noise added to each control channel. By varying the amount of noise in each channel, we can investigate the effects of uncertainty on localisation performance. As might be expected, improvement in localisation can be achieved through reducing noise in either dimension. Moreover, by exploring agent performance after free flight with and without a learning flight, it can be seen that once a set of landmarks has been learned, the accuracy of the movement model can be relaxed without uncertainty in the positional estimate becoming unbounded, due to errors in the path integration system.

2. REFERENCES
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