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An Investigation Into Insect Chemical Plume Tracking Using a Mobile Robot

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Abstract

Insects are confronted with the problem of locating food, mates, prey and hosts for their young over long distances, which they often overcome using chemical plume tracking. Tracking a plume of chemical back to its source is made difficult due to the complexity of plume structure. Turbulence and shifts in the wind direction prevail over diffusion in the spreading of an airborne chemical from a point in most cases, producing intricate plumes consisting of filaments of high chemical concentration interspersed with regions of clean air. It has been proposed that insects achieve plume tracking in this environment through variations of anemotaxis, which involves travelling upwind when an attractive chemical is perceived. This study aimed to investigate anemotaxis through the use of a mobile robot to test the efficacy of algorithms which mimic the way insects achieve plume tracking and also to determine whether these algorithms are an effective means of plume tracking for a mobile robot under a range of conditions.

To achieve the aims of this study, various plume-tracking algorithms were implemented on a mobile robot built to model a plume-tracking insect and their performance was compared under a range of wind conditions. The algorithms tested were based upon a range of plume-tracking hypotheses. The simplest algorithm was surge anemotaxis, where the robot surged upwind in the presence of an attractive chemical and performed crosswind casting (back and forth motion) in the absence of chemical. The other algorithms tested were the counterturner, where the robot zigzagged upwind, and two bounded search methods. To allow these algorithms to be appropriately implemented, a robot model was constructed that could move in two dimensions and sense the wind velocity and ion level at a point in space. An ion plume was used instead of a chemical plume in each test as it behaves in a similar manner to a chemical plume, but ion sensors have response and recovery times far more rapid than conventional chemical sensors, similar to insects.

The plume-tracking robot was tested in three series of tests. Initially, the entire range of plume-tracking algorithms was tested in a wind tunnel with fixed wind direction for a range of wind speeds and release positions. The second series of tests compared the performance of the surge anemotaxis and bounded search algorithms, again in a wind tunnel, but with a wind shift of 20° during some of the tests. The algorithms were tested with and without a direct crosswind surge response to detected wind shifts. The third set of tests examined the performance of the simple and wind shift response algorithms outdoors using natural wind to produce the plume.

All algorithms tested achieved successful plume tracking in some conditions. The surge anemotaxis and triangular bounded search algorithms were particularly successful. The tests also showed that the paths obtained from tests undertaken in natural outdoor wind conditions varied greatly from those undertaken in a wind tunnel. This indicates the need to test plume-tracking algorithms in natural environments. This is vital both in the investigation of insect plume-tracking behaviour, as insects navigate in these environments, and in the process of producing plume-tracking robots that are capable of operating effectively in these conditions.

Statement of Originality

To the best of my knowledge, except where otherwise referenced and cited, everything that is presented in this thesis is my own original work and has not been presented previously for the award of any other degree or diploma in any university. If accepted for the award of the degree of Doctor of Philosophy in Mechanical Engineering, I consent that this thesis be made available for loan and photocopying.

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David John Harvey

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Date

Publications

Harvey, D. J., Keller, M. A. and Lu, T., 2007 "Insect-inspired mobile robot chemical plume tracking in outdoor wind conditions," in Preparation for *Artificial Life*

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Harvey, D. J., Lu, T. and Keller, M., 2003 "Wind sensor and robotic model wasp development," In *Australasian Conference on Robotics and Automation, December 1-3, Brisbane, Australia*

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