A Computer Vision-based Testbed for Observing and Modeling Insect Behavior

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Robotics

1 Learning from insects

A number of leading robotics researchers (including for instance, Brooks, Beer and Arkin), claim their work was inspired in part by the behavior of insects [3, 2, 1]. In the MultiRobot Lab we are particularly interested in learning about *social insects,* as they provide an existence proof of successful large-scale robust behavior forged from the interaction of many, simple agents.

Ant behavior can offer a wealth of ideas on how to organize a cooperating colony of agents. As an example, even though they are only capable of very short range communication, ants are able to carry out complex scouting and retrieval operations over tens of meters. The techniques social insects utilize for staging such complex operations could also be employed in the design of robust multi-robot systems — it is important for us to learn what insects have to offer.

Interestingly, biologists are also beginning to draw on computer science. In a recent *Nature* article, for instance, Diane Gordon suggested that the growth of theory in social insect research has been inspired by the artificial intelligence community [5]. We believe the our lab can contribute to the study of insect behavior as well; in particular, we have developed

- **Vision-based tracking software** that can provide accurate, real-time information about the movements of animals being observed. Currently, entomologists do not have tools for automatic, simultaneous tracking and logging of the positions of multiple insects.
- **Modeling tools** able to infer the behavior of the agents being tracked. As part of a parallel research project, we are investigating how Hidden Markov Models (HMMs) can be used to provide principled statistical models of observed behavior [6].

John Rawlins, Head of Invertebrate Zoology at the Carnegie Museum of Natural History, believes these tools could have a significant impact in his field (letter of support attached). I hope this project will help spark a long term collaboration between Dr Rawlins' group and our lab.

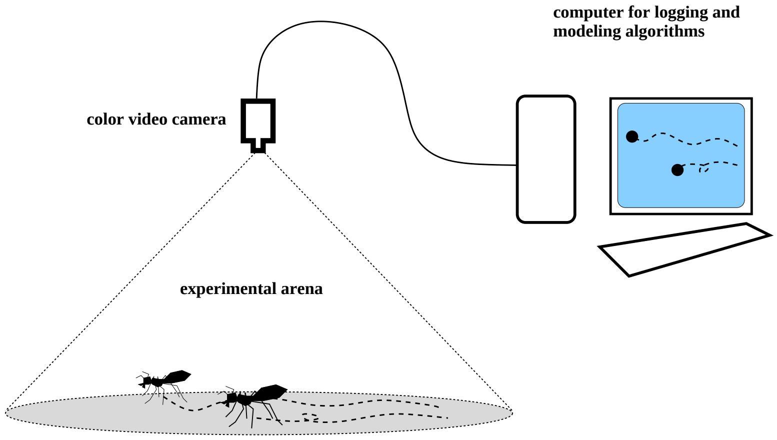

Figure 1: System overview. The output of a color video camera is processed in real-time (30Hz) to compute the locations of insects in the experimental arena. The data is logged for either on-line or off-line analysis.

2 Overview of the project

The proposal is to build a testbed system (hardware and software) that will track and model the foraging activities of the individuals in an ant colony.

A diagram of the system is provided in Figure 1. The animals being observed move about an arena monitored by an overhead color camera. The output of the camera is processed using color classification and region segmentation software developed in our lab [4]. The image processing step provides the locations of the animals being tracked. The locations of the ants over time are input to an HMM learning system that will infer behavioral models of the ants.

Several of the hardware and software components of the system have already been tested in the MultiRobot Lab; including the camera, image capture hardware and color image segmentation software. Funding provided under this proposal will support:

- purchase of hardware dedicated to the project,
- development of specialized software for locating ants in an image and logging their positions over time,
- initial development of software for analyzing the logged data — inferring behavioral models of the ants.

3 Impact

Professional development
The primary result of this work will be a working system able to monitor the activities of ants in a foraging colony. This will benefit my professional development in several ways: *(1)* it will provide convincing evidence that the proposed techniques are feasible and worthy of more substantial funding by an external source, *(2)* it will provide a non-trivial and interesting source of data for developing our new HMM learning techniques, *(3)* it will provide an opportunity for potentially fruitful collaboration with the Carnegie Museum of Natural History (John Rawlins).

Public education and external visibility
Once the system has been tested in our laboratory we hope to install it in the invertebrate zoology section of the Carnegie Museum of Natural History. Scientists there are in the process of culturing several large ant colonies for public display. These colonies will be excellent subjects for testing our observing and modeling algorithms.

Our system will provide a visual depiction of the scientific data being collected for museum visitors. As an example, it might display the traces of recent ant movements — this could be used to illustrate graphically how ants build and use chemical trails. We should also be able to distinguish between different behavioral markers and highlight specific animals that are engaged in interesting activities (this is the goal of the HMM work).

4 External funding climate

This project is rather unusual in that, as a robotics researcher, I am proposing to do biology. Without prior evidence of success, it will be difficult to secure external funding for this kind of work. Nevertheless, there is a potential for the results of this work to impact both biology and robotics — a demonstration can go a long way towards establishing that. Once the approach has been demonstrated in the results of this project, the chance for external funding will be substantially improved.

5 Budget

I am requesting funding necessary to implement a first-generation vision-based insect tracking system. The proposal includes funds for hardware and for an undergraduate programmer to implement the required demonstration software. The undergraduate programmer will integrate our existing color tracking software with the hardware, develop code to track individual ants and log their positions, and develop an initial HMM learning tool.

Dell PC, 700 MHz Pentium III	\$2048
Video capture card	\$150
Color video camera	\$390
Ant colony culture materials	\$300
Additional construction materials (e.g. lights)	\$200
Undergraduate programmer (280 hours @ \$7.50)	\$1900
Total	\$4988

I plan to employ Zia Khan, a Sophomore Biology student, on this project. Zia was recently awarded an internal CMU fellowship of \$2000 to work with me this Summer. The proposed funding will provide the additional \$1000 necessary to support him full-time (40 hours/week) over the Summer and \$900 to support him part-time (10 hours/week) in the Fall.

6 Prior funding

I have not been funded under this program before.

References

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