

# Automatic Tracking of Snail Movements using Vision Based Tracking Software

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## Abstract

The development of behavioral models of live animals for use in analysis can be a time-consuming and potentially error prone process when human observational techniques are required. This work presents an example of the use of Bio-Tracking techniques, applied to Pond Snails (*Helisoma trivolvis*), for use in automatically extracting spatial behavior. Through the use of color based segmentation software, a number of spatial features are extracted from multiple videos of these snails filmed in a laboratory environment. A subset of these features is presented for analysis and a discussion of future directions is provided.

## 1 Introduction

Pond snails have been widely studied and commonly used in neuro-engineering research laboratories because of their availability, low cost, and the relatively large size of snail neurons. Behavioral models of snails are useful, because they can serve as a statistical baseline. As such, the automated observations of altered animals can be compared to the baseline phenotype to determine how behavior is affected. Furthermore, when groups of snail interactions are studied, multi-agent behavioral models can be developed and applied to the study of multi-agent systems and the field of robotics.

This design of this work is to apply vision-tracking software to videotaped experiments of snails in a laboratory environment. The goal is to be able to apply this movement data for use in later analysis and behavioral model development. Moreover, once these observational techniques are refined, they can be applied to similar animals such as *Aplysia*.

## 2 Related Work

The GTrack video tracking software used in this project[3, 5] was provided by the Bio-Tracking team at the Georgia Tech College of Computing [4] and is described by Balch and Khan in [1]. In that work, videotaped experiments of ant colonies are processed

to build spatial movement data. Multiple such experiments are analyzed to show the effects of the presence of food, and interaction behaviors with other ants.

Feldman and Balch apply Hidden Markov models (HMMs) to automatic identification of bee movements [2]. Videotaped experiments involving bees are processed using the GTrack video tracking software [3, 5] to identify bee movements. A human then hand labels a training set of movements using the TeamView software [4]. A K-nearest neighbor algorithm is trained to recognize lower level behaviors (move left, move right, waggle) in the test data sets, and HMMs are used to learn higher-level bee behaviors, such as Dancer, Follower, and Inactive. These models can be applied to new videos to label the behavior of each bee during an entire session.

## **3 Experimental Setup**

### **3.1 Apparatus**

In the neuro-engineering laboratory, a tank of pond snails is available for use in experiments. For the purposes of these experiments, one or more adult snails was placed in a 15x17x4 white tray, filled with 1-inch of water. An off-the-shelf mini-dv video camera was mounted above the tray, with sufficient lighting using indirect umbrella lights. The camera was connected to a Pentium computer using an IEEE1394 capture card and cable. The camera was capable of recording at 30 fps, but the capture software was set to only grab every 5th frame. The snails moved slowly, such that only capturing every 5th frame did not result in loss of information and the resulting videos were accelerated enough to better reflect behavior when played back. The video stream was processed offline in these experiments, but could be modified for real-time use [1], if necessary.

### **3.2 Tracking by Color and Movement**

The GTrack software library [5] is a collection of tools that can be used to find objects in images and track them over time. The approach used by these tools is to segment objects in each frame using colors, recording spatial and timing information and then to associate objects across frames.

The first step involved is to define the sets of colors that define the snails in the image. As the experiments are run against a white background, this makes the segmentation task relatively easy. After performing the color segmentation using the Ctag and CMVision libraries which implements the color tracking process as described in [3], a set of .btf log files is generated which contain the spatial movements for pixels in the videos over time. Pixels that match these specific colors are grouped using bounding regions.

The next steps in the process apply time stamps to the log files and attempt to associate bounding regions to unique object ID numbers. These objects should represent unique snails in the videos, and follow them through each video frame. The GTrack software uses a least square algorithm to associate objects across frame. In these experiments, however, it was found that multiple individuals are generated for each object and these must be later merged by hand.

The TeamView library component can be used to merge and edit object identities. It can also be used to label objects and movements in the videos. Finally, the avitools library can be used to overlay the bounding rectangles onto the original video for presentation purposes. An example of an image taken from a snail video after processing is shown with bounding rectangles overlaid in Figure 1.

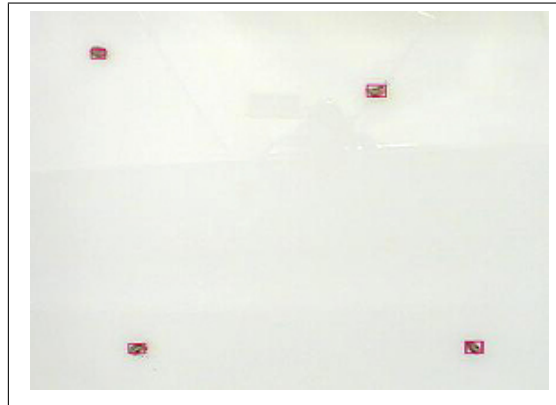


Figure 1: A Video of Pond Snails, after Processing using the GTrack Software

## 4 Results

A series of experiments were performed, using a single snail, two snails and four snails. Each experiment lasted for 30 minutes. Before each experiment, the tray was washed with a mild bleach solution (to remove any possible chemical trails or odors which might affect the next experiment), and thoroughly rinsed clean. Snails were not reused across experiments.

These experiments were performed with different numbers of snails to determine if snail behaviors were affected by the presence of other snails. It is statistically inaccurate to draw any conclusions from this small number of experiments; however these should serve as examples of the types of analysis that can be performed. Some central questions related to snails are what causes them to follow other snails and how does the presence of multiple snails affect movements? While it is known that snails leave chemical trails as they move, analysis of movement patterns may reveal how strongly one snail's path over time might affect that of another.

From these experiments, we can plot the spatial movements. If we look at spatial movements alone, Figure 2, we can see the points where one snail's path might interest another, and if there are any areas in the environment of particular interest.

We can also plot the spatial data across time, Figure 3. This will allow us to determine if one or more snails were co-located (perhaps in skirmishes or sexual behavior) for a period of time. We can also detect if a section of one snail's path mirrors that of another, perhaps reflecting a "following" behavior. Furthermore, we can use the time

axis to determine if, at a particular point in time, a snail's movements became focused rather than a random walk, perhaps due to some signal from other snails (such as to the location of a food source.)

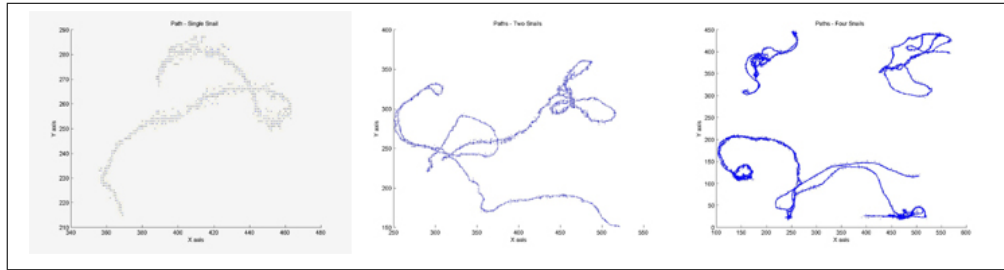


Figure 2: Tracking spatial movements of one, two and four snails. This image depicts the paths followed by the snails in each experiment, and reflects the points where paths crossed.

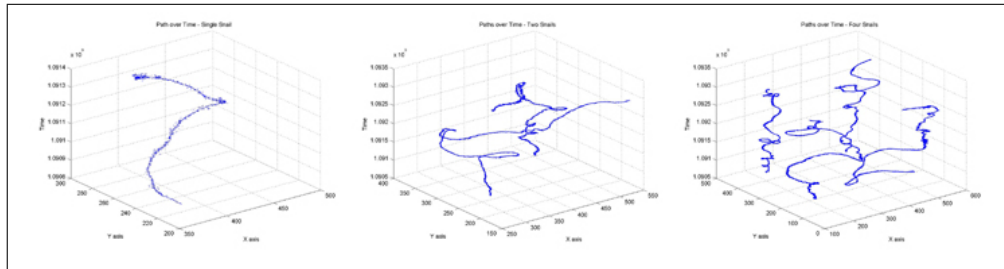


Figure 3: Tracking spatial movements across time of one, two and four snails. This image depicts the paths followed by the snails in each experiment, and reflects the points where paths crossed in space and time. Where paths intersect, direct interaction occurred. When a section of one path sits on top of another, following behavior may have occurred.

## 5 Future Directions

Future work should include the analysis of experiments with multiple snails in which food was present, and how behavior was affected with the addition of food. It would be interesting to see if the addition of food caused an increase in following behavior and how long after the addition of food did snails begin to converge together on the food source.

Hidden Markov models (HMMs) could be used as in [2] to automatically categorize high-level behaviors of snails when new experiments are performed. From the raw data, low level behaviors could be identified (such as move up, down, right, left.) When movements for each snail are correlated to movements across other snails, food

sources and time, higher level behaviors (such as follow, inactive, congregate, feed) can be automatically identified and HMMs can be trained to recognize these high level behaviors. The work presented in [2] can be extended to allow snails in each video to have a sequence of high level behaviors associated with them.

Finally, this work could be extended to other species, such as *Aplysia*. While the snails were filmed in a basic 2D environment (there was very little movement allowed in the z-axis with only 1-inch of water), *Aplysia* could be studied in the 3D environment of their tank. Naturally this would require careful selection of colors and lighting for use in color segmentation and background removal.

## 6 Conclusions

In summary, video tracking techniques were applied to track the spatial behavior of pond snails in a small number of experiments. Moving forward, further experimentation with more snails and using food sources should be performed. Lastly the development of HMMs could also be performed to improve the automatic tracking of behavior by recognition of higher level behaviors.

## 7 Acknowledgements

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