Expansion of a Stochastic Model for Anelosimus studiosus Movement During Prey Capture

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Introduction

* A. Studiosus is a subsocial spider phenotype. The juveniles of the spider species stays with their mother until maturity to help on web maintenance and prey capture. Juveniles disperse throughout the web to cooperate during prey capture. The spiders use vibrational cues to detect they prey.

Data Collection

The spiders were placed in shallow plastic boxes and housed in a laboratory setting. During feeding sessions, the movement during prey capture is recorded using a high resolution camera. The movements were then digitized using a tracking software [1]. The data collected was analyzed to determine the factors involved for expanding the stochastic model.

Modified Factors

- The error in the direction the spider travels towards the prey is taken from a normal distribution with mean $e(d) = 0.0040d^2 - 0.0688d + 0.3429d - 0.0738$ (1) where $d$ is the distance from the spider to the prey.
- The duration of pauses, velocity of runs, and duration of runs are all taken from an exponential distribution using the mean found from an optimization algorithm.

The Stochastic Model

Eq. (2) was derived by Joyner and Ross et al. [3] from the work by Brillinger and Preisler et al. [2].

$dr(t) = \mu(r(t), t) dt + \Sigma(r(t), t) dW(t)$

(2)

- $r(t) = (X(t), Y(t))$ → Location at time $t$.
- $W(t)$ Brownian motion.
- $dt$ → Change in time.
- $\Sigma(r(t), t) dt$ → Diffusion component.

$\Sigma(r(t), t) = \begin{bmatrix} \sigma_x & 0 \\ 0 & \sigma_y \end{bmatrix}$, $\sigma_x = \sigma_y = \sigma$

- $\mu(r(t), t)$ → Directional component.

$\mu(r(t), t) = v_s \left[ \cos(\theta(t_i) + \epsilon(t, d_i)) \right]$

where $\theta(t_i)$ → Optimal direction.

$\epsilon(t, d_i)$ → Error in direction using mean from Eq. (1). $t_n$ → Update times $i = \{1, 2, \cdots, n\}$.

$\nu_s$ → Velocity

Expansion

Pauses and runs are included into the model using the algorithm in Figure 1. Let $D_p$ be the duration of pause, $D_r$ be the duration of run, $T_p$ be the timer for pauses, and $T_r$ be the timer for runs.

Parameter Estimation

Six parameters are estimated using a least-squares optimization algorithm such that the time elapsed and distance traveled of the actual spider match the simulated spider. The figure on the left gives a visual comparison of the parameters of each spider indicating each spider is unique.

Conclusions and Outlook

- We have expanded the model to simulate a realistic spider movement during prey capture.
- The current stochastic model now has pauses with varying duration, and the spider moves with varying velocities.
- We can further analyze the parameters to isolate a single parameter which works for each spider. If not, then we can have a distribution of parameters and isolate which parameters we can use for specific spiders.
- We can use the expanded model to determine if A. Studiosus disperse optimally by comparing dispersal configurations which are determined optimal for prey capture.

References


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