Expansion of a Stochastic Model for *Anelosimus Studiosus* Movement During Prey Capture

Alex John Quijano[1] | Dr. Michele L. Joyner[1,3] | Dr. Thomas Jones[2] | Nathaniel Hancock[2] | Michael Largent[2] | Chelsea Ross[1]
Department of Mathematics and Statistics[1] | Department of Biological Sciences[2] | Institute for Quantitative Biology[3]
East Tennessee State University
Johnson City, TN 37614

CRAWL
Collaborative Research on the Arthropod Way of Life
NSF grant #1128954

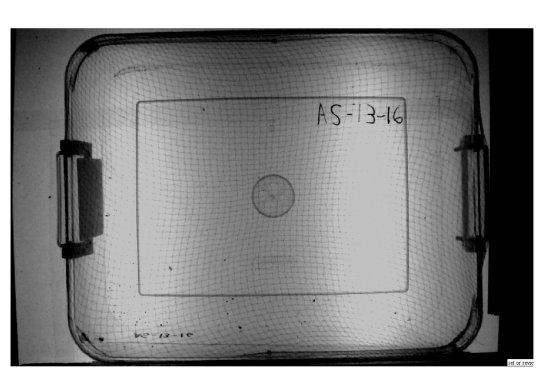
Introduction

A. Studiosus is a sub-social spider phenotype. The juveniles of the spider species stays with there 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.

Goal

To expand the stochastic model in order for us to simulate a realistic movement during prey capture of *A. Studiosus*.

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

$$e(d) = 0.0040d^3 - 0.0688d^2 + 0.3429d - 0.0738 \quad (1)$$

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].

$$d\mathbf{r}(t) = \mu\{\mathbf{r}(t), t\}dt + \Sigma\{\mathbf{r}(t), t\}d\mathbf{W}(t) \quad (2)$$

- $\mathbf{r}(t) = [X_s(t), Y_s(t)]' \to$ Location at time t.
- $\mathbf{W}(t) \to$ Brownian motion.
- $dt \to$ Change in time.
- $\Sigma\{\mathbf{r}(t), t\}dt \to$ Diffusion component.

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

- $\mu\{\mathbf{r}(t), t\} \to$ Directional component.

$$\mu\{\mathbf{r}(t), t\} = v_s \begin{bmatrix} \cos(\theta_o(t_i) + \epsilon(t, d_i)) \\ \sin(\theta_o(t_i) + \epsilon(t, d_i)) \end{bmatrix}$$

$\theta_o(t_i) \to$ Optimal direction.
$\epsilon(t, d_i) \to$ Error in direction using mean from Eq. (1).
$t_{u_i} \to$ Update times $i = \{1, 2, \cdots, n\}$.
$v_s \to$ 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.

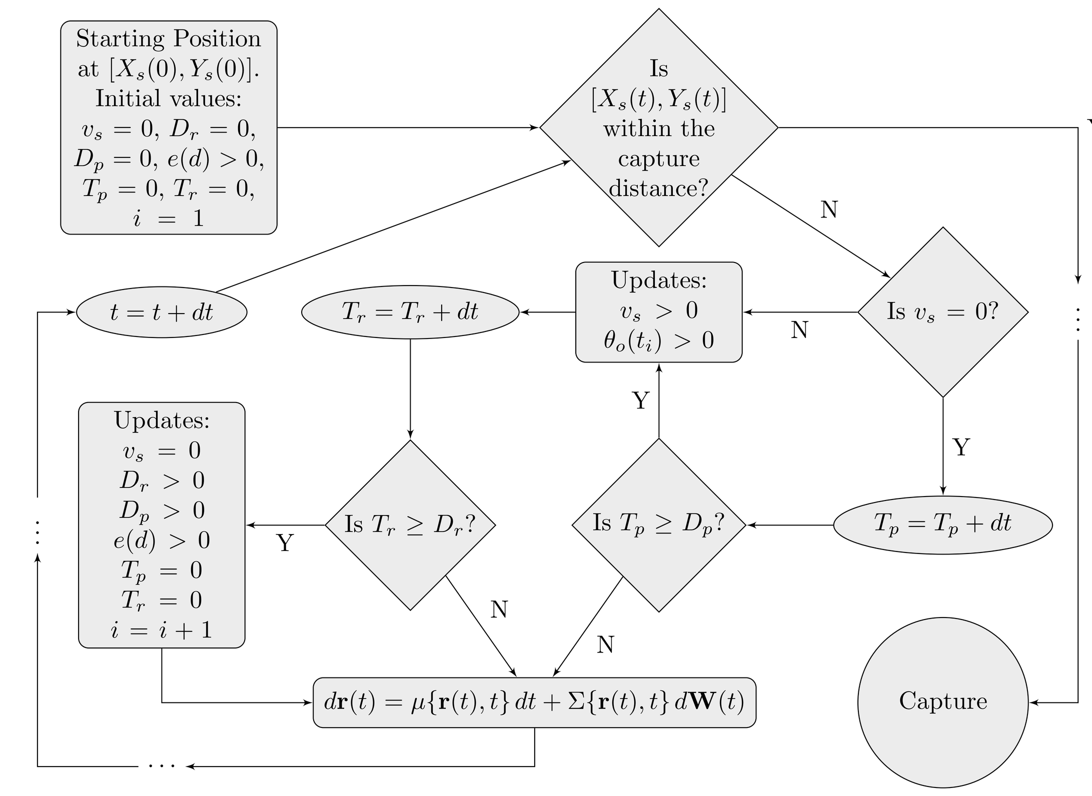
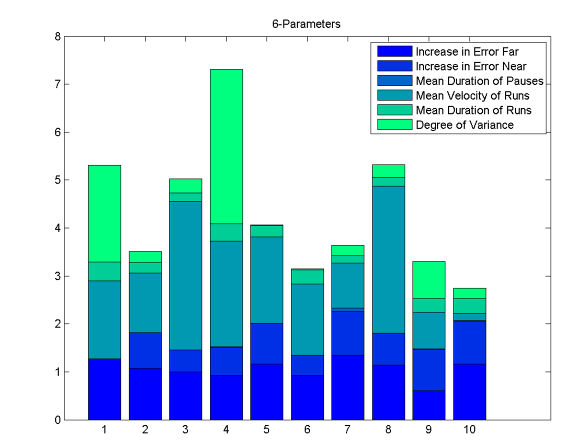


Figure 1: The Stochastic Model Algorithm.

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

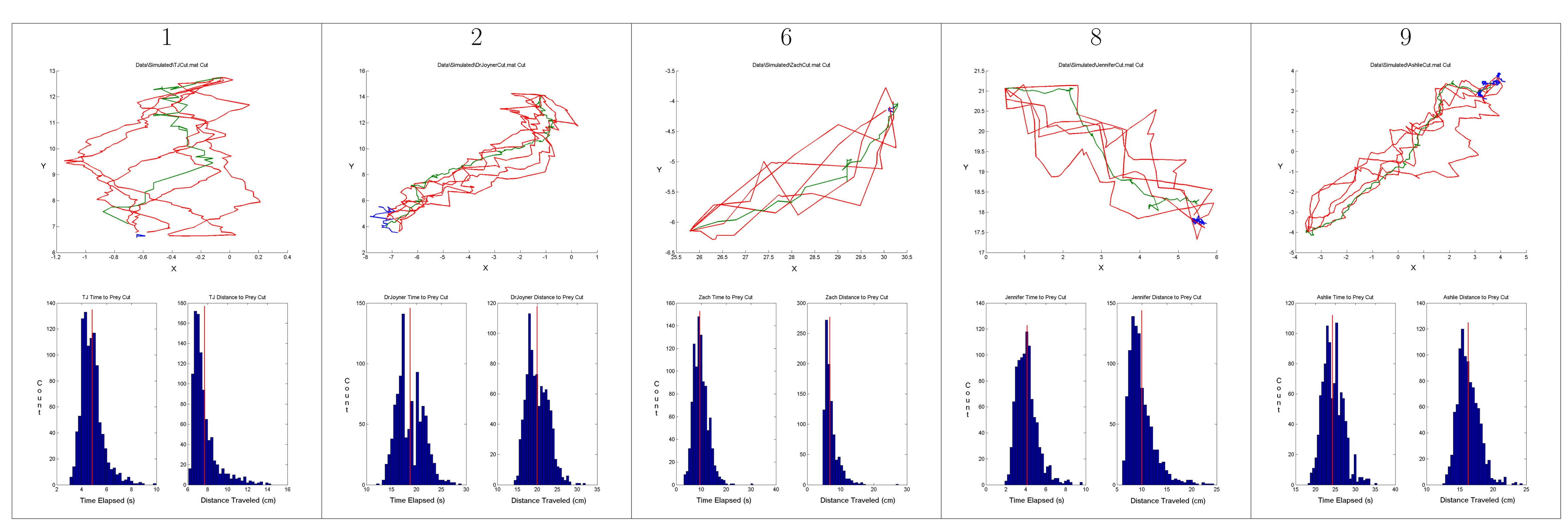
- We have expanded the model to simulate a realistic spider movement during prey capture.
- The current stochastic model now has pauses with varying duration, and the spider moves with varying velocities.
- We can further analyze the parameters to isolate a single parameter which works for each spider. 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.

Results

Spider	1	2	3	4	5	6	7	8	9	10
Act. Time Elapsed (s)	4.8380	18.7180	2.2690	6.2070	4.5045	9.4000	8.5502	4.1291	24.2325	87.1704
Mean (1000) Sim. Time Elapsed (s)	4.8168	18.7428	2.2591	6.4080	4.5103	9.8384	8.5169	4.1002	24.3806	87.1152
Time Elapsed Rel. Error	0.0044	0.0013	0.0044	0.0324	0.0013	0.0466	0.0039	0.0070	0.0061	0.0006
Act. Dist. Traveled (cm)	7.6733	19.9008	5.7477	14.7958	6.6750	6.7534	4.8273	9.9694	16.2675	12.0595
Mean (1000) Sim. Dist. Traveled (cm)	7.6500	20.0214	5.7235	15.2653	6.7318	7.1328	4.8187	9.8921	16.2862	12.0618
Dist. Traveled Rel. Error	0.0030	0.0061	0.0042	0.0317	0.0085	0.0562	0.0018	0.0078	0.0011	0.0002

A relative error of less than 0.1000 indicates a good match.

Selected Figures



Top: Actual spider (Green), 5 Sim. spiders (Red), Actual prey (Blue) | Bottom: Distribution of 1000 sim. spiders, Actual time elapsed and Actual distance traveled (Red vertial line)

References

[1] B. Douglas, *Tracker: Video Analysis and Modeling Tool*, Tracker version 4.80, Copyright(c) (2013) Douglas Brown, http://www.cabrillo.edu/ dbrown/tracker, Free software

[2] D.R. Brillinger, H.K. Preisler, A.A. Ager, J.G. Kie and B.S. Stewart, *Modelling Movements of Free-Ranging Animals*, Tech. Rep. 610, Department of Statistics, University of California, Berkeley (2001)

[3] M.L. Joyner, C.R. Ross, C. Watts and T.C. Jones, *A Stochastic Simulation Model for Anelosimus studiosus during Prey Capture: a Case Study for Determination of Optimal Spacing*, Mathematical Biosciences and Engineering (Submitted for review), (2013)

Acknowledgements

This research project was supported by the National Science Foundation Grant #1128954. This research project was also partially supported by the Access and Diversity Initiative from the Tennessee Board of Regents, grant #210024. We would like to also acknowledge Colton Watts for all his work on this project.

Contact Information: Alex John Quijano → quijano@goldmail.etsu.edu