Ribbeting Content: A Frog Pursuit Model

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INTRODUCTION

Many species of frogs are known to exhibit 'toe twitching' while feeding. The exact reason for this behavior is unknown, but researchers speculate the vibrational and visual stimulation from this process encourages prey movement (Sloggett & Zeilstra, 2008).

OBJECTIVES

We aim to create an agent-based model for a system of one *Kaloula pulchra* and one *Blaptica dubia* which quantifies the impact of toe twitching and movement of each individual in the system. To construct this model, we recorded observations in a controlled environment during feeding encounters.

OBSERVATIONS

- Insects appear to move randomly when uninfluenced by frog
- Twitching appeared to draw insects towards frog
- Frog remained stationary unless in pursuit
- Frog begins pursuit once insect appears, moving, in field of vision

MATHEMATICAL APPROACH

The model needs equations for the velocity and acceleration of each agent. The acceleration equations will be constructed using first principles and the information obtained via observations.

Each agent in our model needs a self propulsion term to exponentially enforce a constant movement speed. This is the first term in our system on the right. In the roach acceleration equation, we can simply use a white noise function with diffusion *D* to represent their erratic movements.

Figure 2. Still frame from feeding recording. Roach is above the frog

Figure 1. Two male *Kaloula pulchra* displaying their long toe and distinctive stripes

Next, we can use the normalized difference between frog and roach position to represent the effect of twitching on the roach. We assume the frog twitches while the roach is not seen, so we create an indicator function, ϕ, that depends on the angle between the agents. Similarly, we can represent the frog's pursuit as the normalized difference between roach and frog position.

We get the following system after combining these components.

$$\begin{cases} \dfrac{dx_r}{dt} = v_r \\ \dfrac{dv_r}{dt} = \alpha_r v_r\left(v_{0r}^2 - \|v_r\|^2\right) + DW_t + (1-\phi_\theta)\gamma\,\dfrac{x_f - x_r}{\|x_f - x_r\|} \\ \dfrac{dx_f}{dt} = v_f \\ \dfrac{dv_f}{dt} = \phi_\theta\left[\alpha_f v_f\left(v_{0f}^2 - \|v_f\|^2\right) + \beta\,\dfrac{x_r - x_f}{\|x_r - x_f\|}\right] \end{cases},$$

where the indicator function is defined

$$\phi = \begin{cases} 1, & |\theta| < \dfrac{\pi}{2} \\ 0, & \text{otherwise} \end{cases}$$

Because we want twitching to occur when the roach is not visible, we multiply the twitching term by $1-\phi$. To ensure the frog is moving only while the insect is visible, we multiply its acceleration by ϕ.

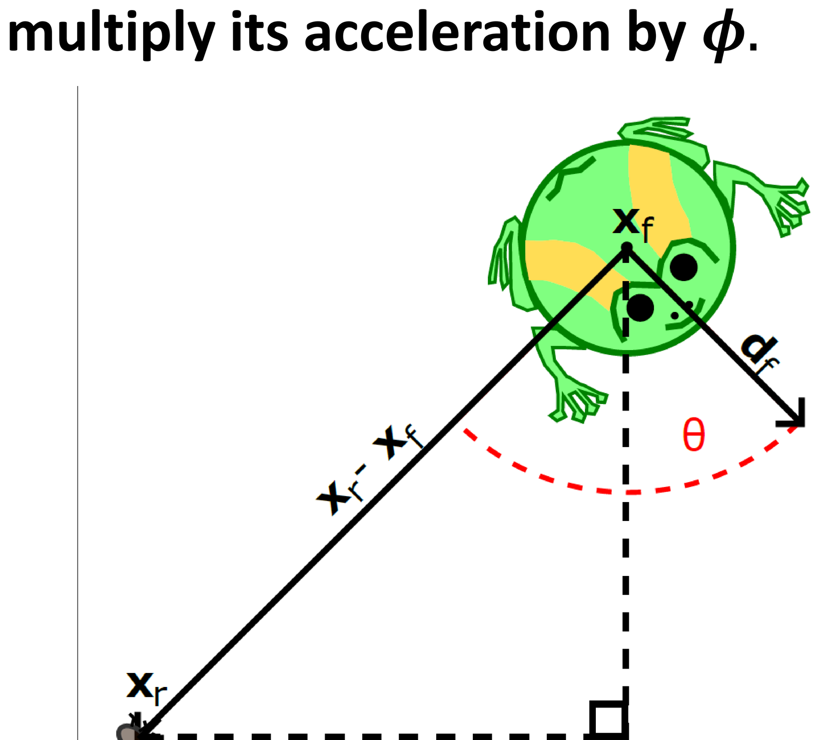
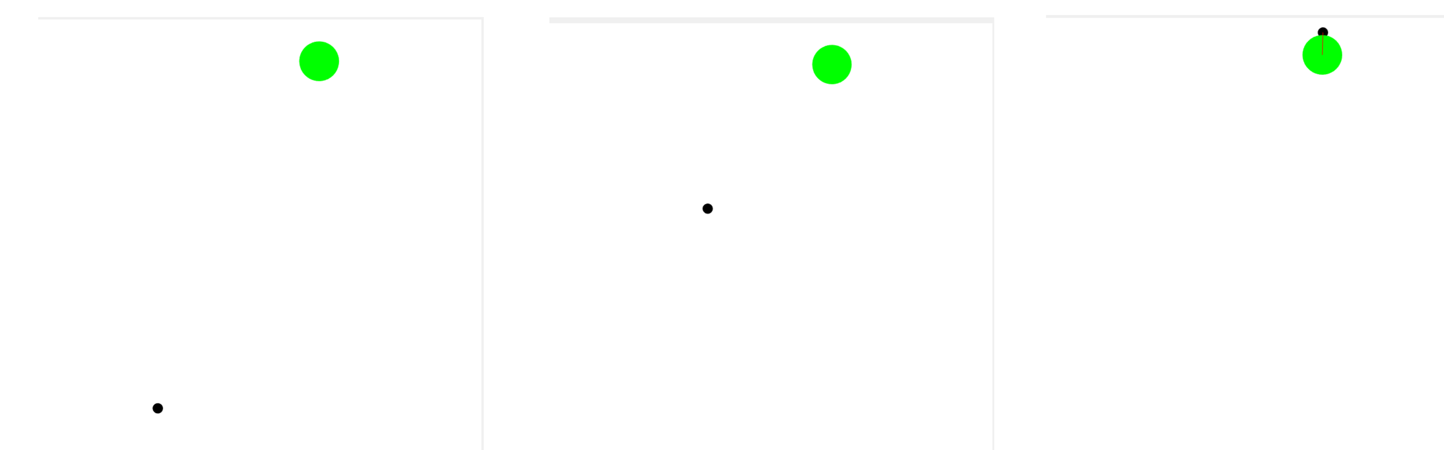


Figure 3. A diagram illustrating the process of computing θ

RESULTS

We wrote a MATLAB script to run simulations using the model we created. Upon running the script, the simulations match the observations recorded during feeding sessions. The frog remained stationary as the roach slowly traveled towards it, until ultimately getting devoured.



Initial Position Hunting Capture

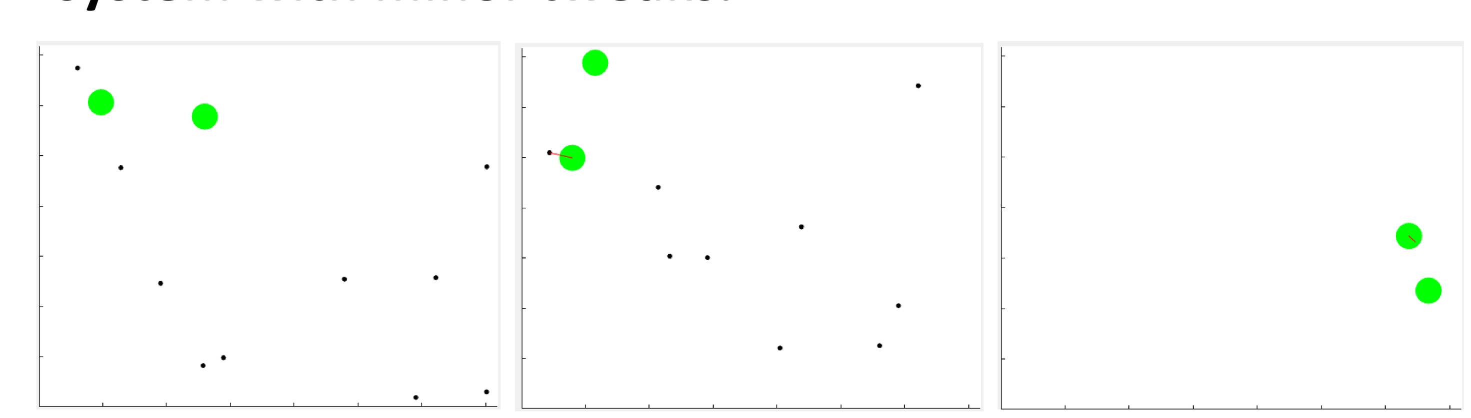
Figure 4. Still frames from a simulation in MATLAB

CONCLUSIONS

Our current hypothesis on the effects of toe twitching on *Kaloula pulchra* prey is that it encourages the prey to move in the direction of the frog and act as a lure. We believe this may be because the vibrations replicate the movements of multiple bugs, which tricks the roach into thinking there is a safe space nearby.

FUTURE WORK

We plan to nondimensionalize our system to simplify the model and remove units. We can also increase the number of frogs or roaches in the system with minor tweaks.



Initial Position Hunting Capture

Figure 5. Still frames from a simulation in MATLAB with multiple frogs and roaches

References

Sloggett, J. J., & Zeilstra, I. (2008). Waving or tapping? Vibrational stimuli and the general function of toe twitching in frogs and toads (Amphibia: Anura). Animal Behaviour, 76(5), e1–e4. https://doi.org/10.1016/j.anbehav.2008.08.005

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