

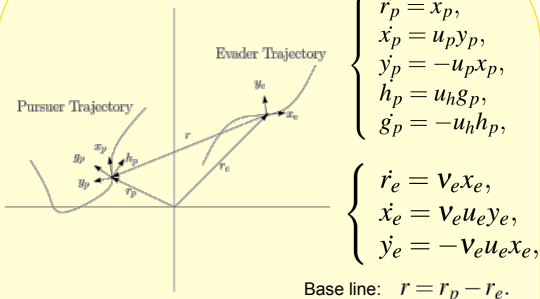
Modeling and Simulation of Pursuit Control Laws in Bat Prey Capture

Ermin Wei, Eric W. Justh, P. S. Krishnaprasad

Introduction

- Pursuit is a subject of interest in various contexts. What are different pursuit strategies?
- What control law enables bats to successfully capture prey?
- What in the course of evolution caused bats to behave in the way they do now?

Planar Model Set-up



Subscript p for pursuer
Subscript e for evader
r is position vector
x is unit vector tangent to its trajectory
y is unit vector normal to x
h is unit vector indicating head direction
g is unit vector normal to h
Pursuer is moving at unit speed, evader speed is $v_e < 1$.



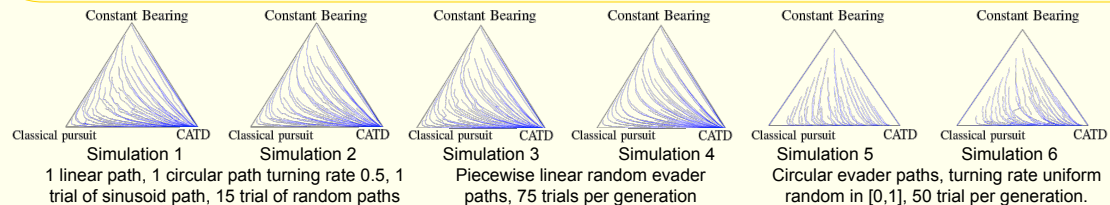
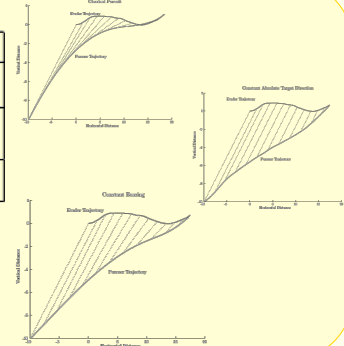
Photo by Sven Dear

Three Pursuit Manifolds and Controls

THREE CONTROL LAWS

Strategy	Cost Function	Control Laws
Classical pursuit	$\Lambda = \frac{r}{ r } \cdot x_p$	$u_{pcp} = -\mu \left(\frac{r}{ r } \cdot y_p \right) - \frac{1}{ r } \left(\frac{r}{ r } \cdot \dot{r}^\perp \right)$
CATD ¹	$\Gamma = \frac{\frac{d}{dt} r }{ \frac{d}{dt} r } = \frac{r}{ r } \cdot \frac{\dot{r}}{ \dot{r} }$	$u_{pcatd} = -\mu \left(\frac{r}{ r } \cdot \dot{r}^\perp \right)$
Constant Bearing	$\Phi = \frac{r}{ r } \cdot R(\theta)x_p$	$u_{pcb} = -\mu \left(y_p \cdot \frac{R(\theta)r}{ r } \right) - \frac{1}{ r } \left(\frac{r}{ r } \cdot \dot{r}^\perp \right)$

Three pursuit manifolds are defined using cost functions, from which control laws are derived. Classical pursuit: Pursuer's velocity is pointing directly toward the evader. CATD (Constant Absolute Target Direction): Pursuer keeps the absolute target direction constant, i.e. baselines are parallel. Constant Bearing: Pursuer keeps the bearing angle (angle between base line and pursuer velocity vector) constant.



Evolutionary Game²

- Population was broken into three subpopulation groups, which use CP, CATD, CB respectively.
- The three subgroups are given as three proportions, p_i , with

$$\sum_{i=1}^3 p_i = 1 \quad 0 \leq p_i \leq 1, \forall i$$
- The population distribution is evolved as

$$p'_i = \frac{p_i W_i}{\bar{W}} \quad \text{where} \quad \bar{W} = \sum_{i=1}^3 p_i W_i$$

p'_i represents the proportion of successive generation to p_i and W_i is payoff for that population
- For simulation 1, 3, 5, the payoffs are defined as (1), for simulation 2, 4, 6 the payoffs are defined as (2)

$$W_i = \frac{1}{n} \sum_{k=1}^n \frac{1}{\tau_k} \quad (1) \quad , \quad W_i = \frac{1}{\frac{1}{n} \sum_{k=1}^n \tau_k} \quad (2).$$

Conclusion

- The simulated evolutionary game shows that CATD under various circumstances yields a better payoff when measured by time. This can help explain why bats today use CATD pursuit strategy in prey capture.
- Derived control laws can also be used to analyze head motion of the bat head.

1. E. W. Justh, P. S. Krishnaprasad, Steering laws for motion camouflage, *Proceedings of the Royal Society A*, Jun 27, 2006, pp. 3629-3643.
2. Ermin Wei. Senior Thesis. 2007.