Sandia National Laboratories

Strategies of Dragonfly Interception

Frances S. Chance

INTRODUCTION

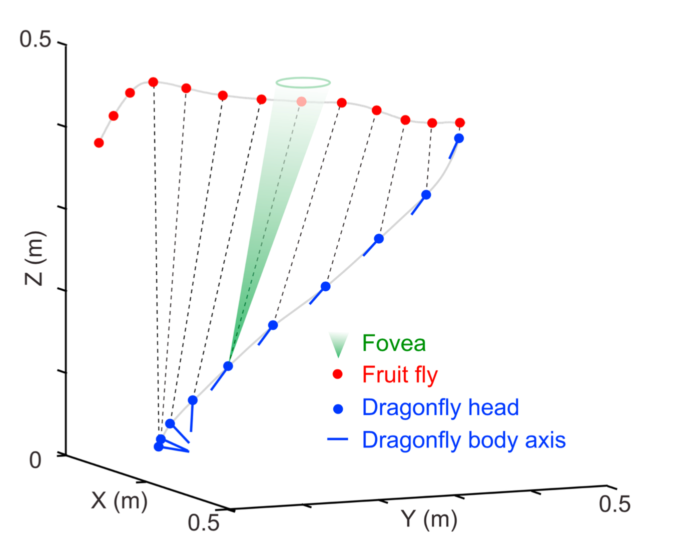
Interception of a target (e.g. a human catching a ball or an animal catching prey) is a common behavior solved by many animals. However, the underlying strategies used by animals are poorly understood. For example, dragonflies are widely recognized as highly successful hunters, with reports of up to 97% success rates (Olberg et al 2000), yet a full description of their interception strategy, whether it be to head directly at its target (a strategy commonly referred to as pursuit) or instead to maintain a constant bearing-angle relative to the target (sometimes referred to as proportional or parallel navigation) still has yet to be fully developed (see Mischiati et al 2015).


(Image: Westend61/Getty)

How are dragonflies so successful at capturing prey? Is the success of the dragonfly simply a matter of being able to fly faster than its prey or are there other adaptations (e.g. a specialized neural circuit) that make the dragonfly so good at what it does? This project focuses on developing a model of dragonfly prey interception. Longer-term, we are also interested in adapting the model for implementation on a man-made platform.

Why dragonflies for interception?

- They exhibit prey-intercept behavior
- They are good at it (90-95% capture rate)



from Lin & Leonardo 2017

Facts about dragonflies

- Fast (10-30 mph, fastest recorded was 60 mph)
- Maneuverable in the air
- Visual system is fast (equivalent to 200-300 fps) but poor spatial resolution (compared to humans)

Elements of dragonfly interception

- Computation of necessary maneuvers is very fast (see Mischiati et al 2015):
  - ~50 ms latency to react to prey steering
  - latency of head rotations (compensating for body rotations) ~4 ms
- Dragonflies foveate prey while intercepting (see below)

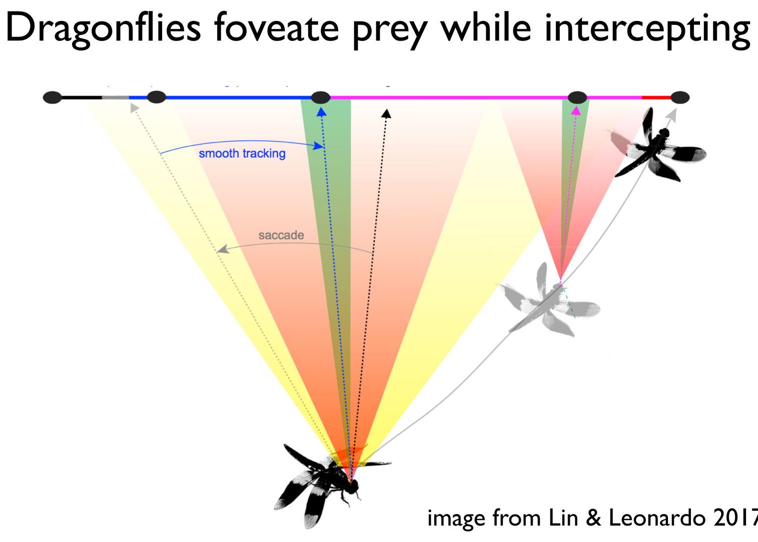
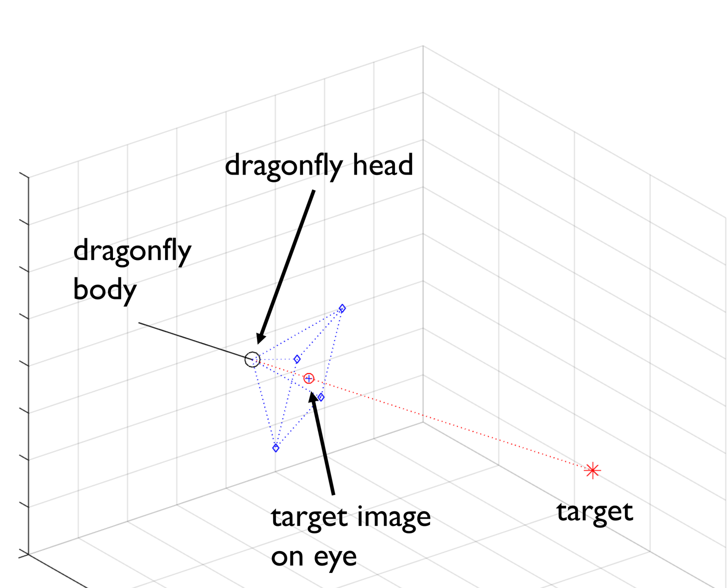


image from Lin & Leonardo 2017

MODEL AND HUNT SIMULATION

- Dragonfly "eye" is simulated as a flat screen (corners indicated by blue diamonds
- Fovea is a designated point on the screen (indicated by blue cross to the right)
- Dragonfly initially launches towards prey/target but maneuvers to keep prey image (red circle) on fovea (blue cross)
- Maximum dragonfly velocity is set equal to target maximum velocity (unrealistic but challenging case)
- Dragonfly maneuverability equals target maneuverability (unrealistic but challenging)



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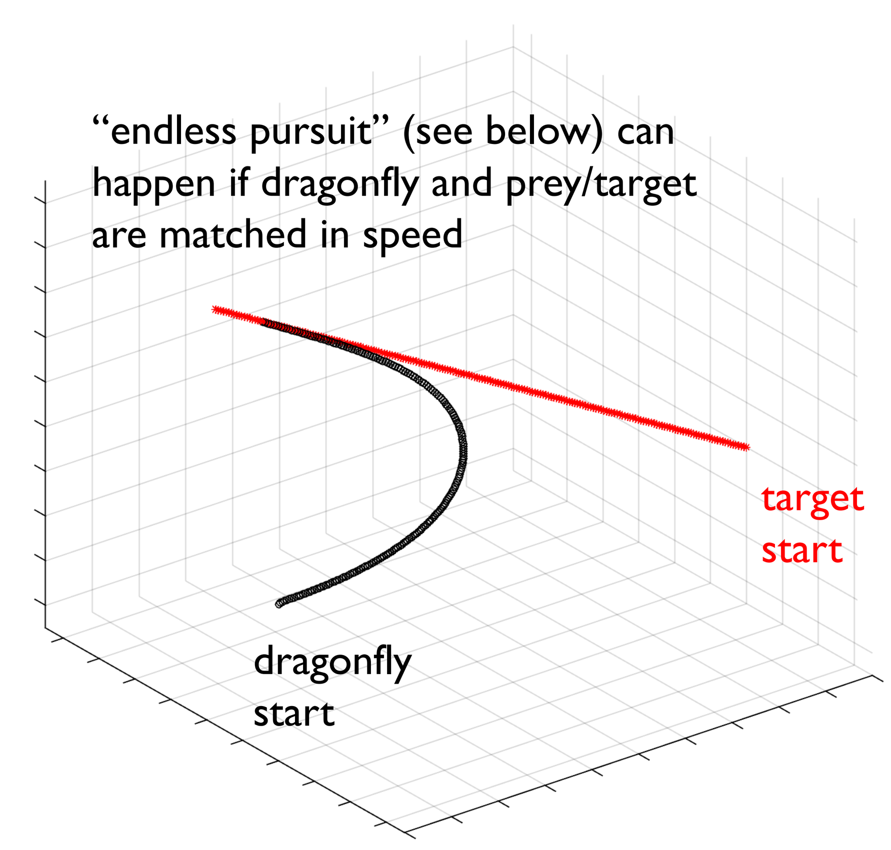
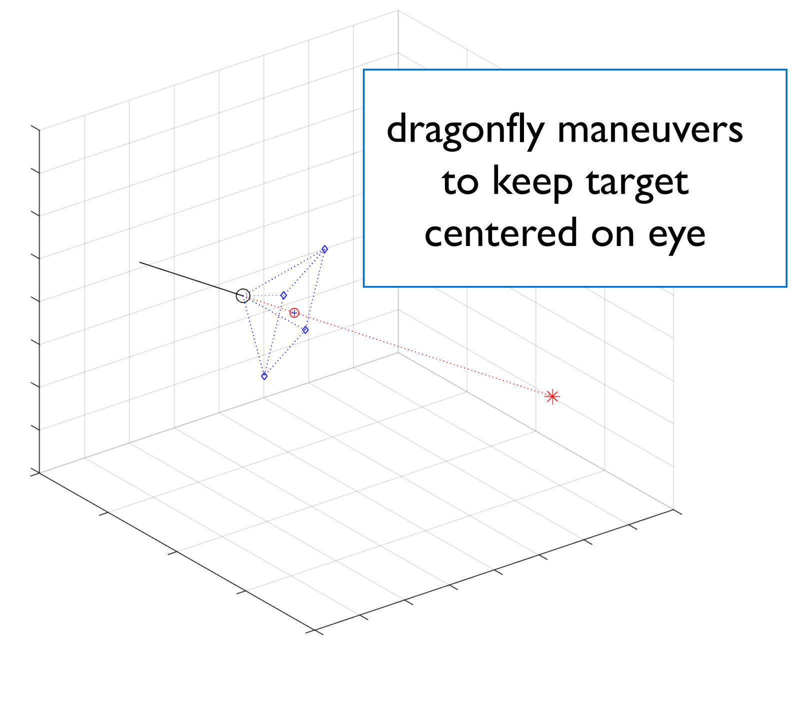
Mischiati M, Lin H-T, Herole O., Imler E, Olberg R, Leonardo, A. Nature. Internal models direct dragonfly interception steering. 2015, 517: 333-338.

Lin H-T, Leonardo, A. Heuristic rules underlying dragonfly prey selection and interception. Current Biology 2017, 27: 1-14.

RESULTS

"Pursuit" from fovea centered in eye



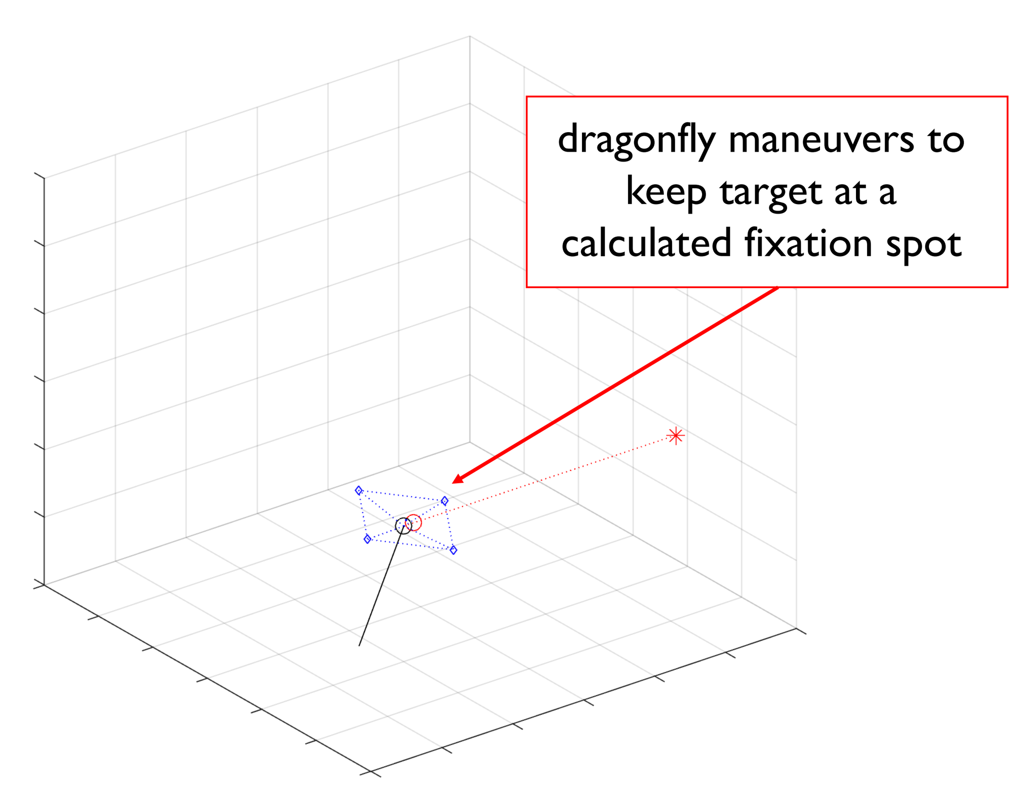


In the figures above and left, the dragonfly maneuvers to maintain the prey on the fovea (here designated the center of the screen).

The result is that the dragonfly heads directly at the prey at all times, a behavior known as classical "pursuit". (For clarity, dragonfly body and eye are not shown in the above left figure).

While this strategy is successful in some scenarios (and is the main strategy adopted by some animals), some initial conditions result in "endless pursuit" if pursuer and target are matched in speed, where the pursuer falls behind the target and never catches up (see above left).

"Proportional navigation" from calculated fixation spot (target-trajectory-based fovea)

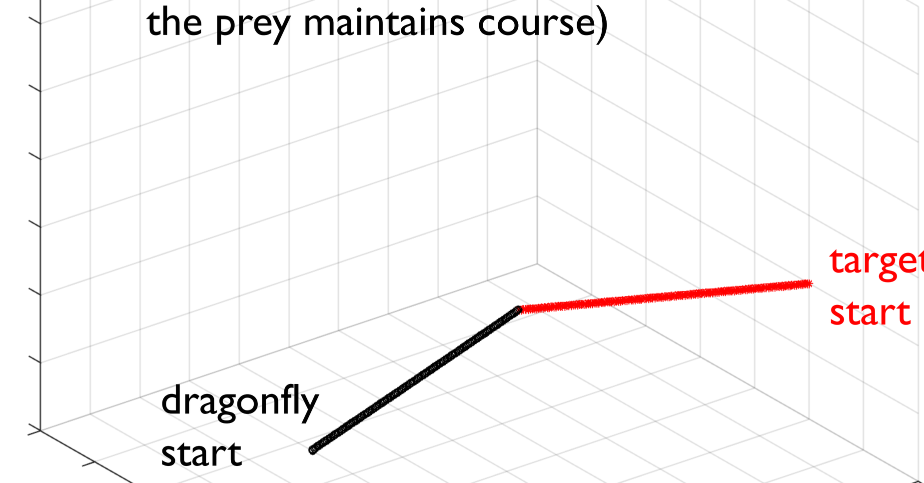


To the left, the dragonfly maneuvers to keep the prey at a designated fixation spot on the eye.

The fixation spot is calculated based upon the prey trajectory (relative to the dragonfly trajectory) and determines the interception strategy.

Proportional navigation (aka parallel or constant-bearing navigation) – this strategy produces the geometrically shortest path to interception (see right).

Below, proportional navigation follows a straight trajectory to interception (assuming the prey maintains course)



CAVEATS AND FUTURE DIRECTIONS

- Proportional navigation is vulnerable to "fake-outs" (pretending to move in one direction but then rapidly changing course to another)
- In some simulations (e.g. if prey is highly maneuverable), it may be strategic to utilize a pursuit-like strategy until relatively close to target and then switch to proportional navigation (simulations not shown). Interestingly, Mischiati et al (2013) suggested that dragonflies only utilize proportional navigation in the last 100 ms of interception.
- We are currently developing a model for how a dragonfly might adjust its trajectory for proportional navigation given prey-image slip from the dragonfly fovea.

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