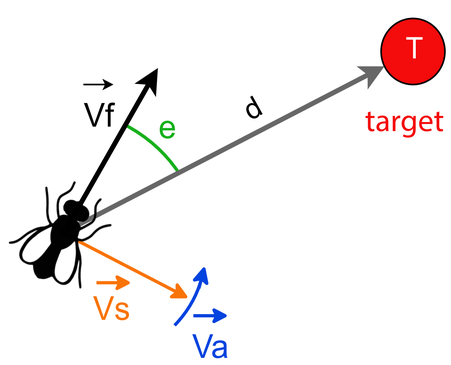
Out of synch: male fly courtship pursuit behaviour as an example of parallel control

Francisco Azevedo[1], Miguel Paço[1], Eugenia Chiappe[1]

[1]Champalimaud Research

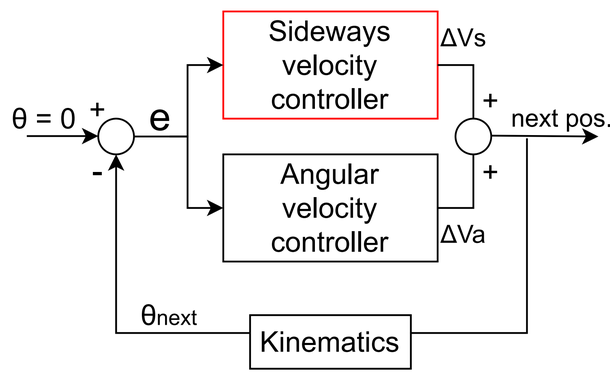
In courtship behavior, the male chases the female ("target") by minimizing the error angle (e) utilizing its outputs: forward (Vf), sideways (Vs) and angular (Va) velocity.

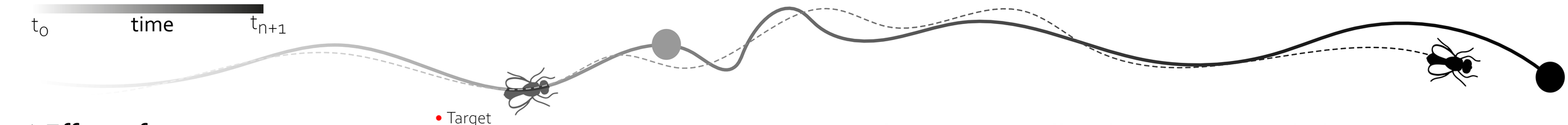
Only **angular** velocity has been used to control the error angle, however data from flies shows they use **sideways** velocity.
We simulated and agent using two **parallel, independent controllers** for angular and sideways velocity to minimize e



During pursuit the fly corrects its current angle and updates its position. On the next step, based on the target's movement, a new angle is fed back yielding a new value of e.

Each controller (angular and sideways) has inside three components: a **proportional**, which scales the current error, an **integral**, which accumulates past errors, and a **derivative**, which indicates how the error will grow





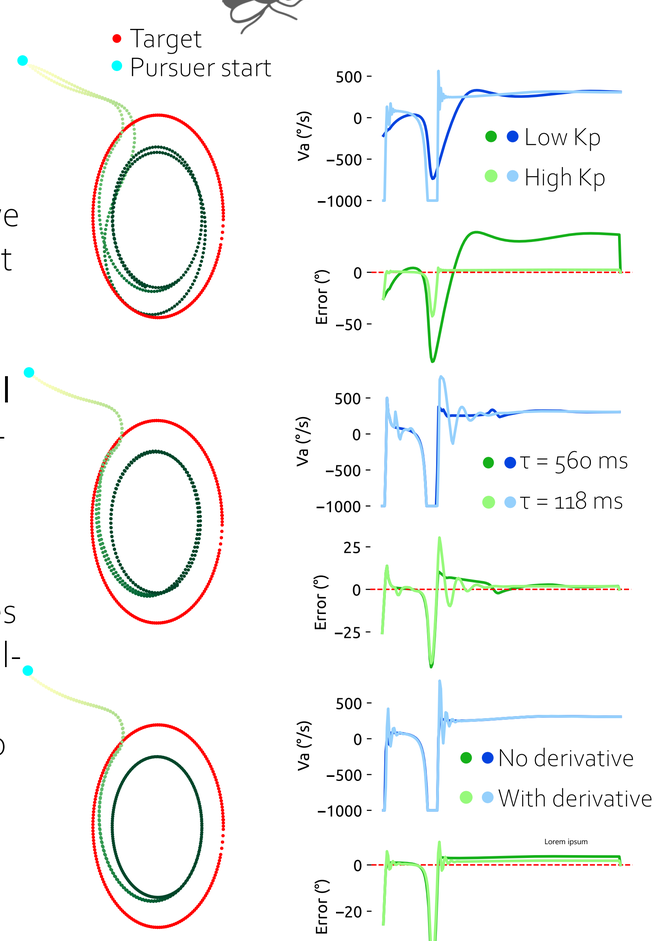
1) Effect of components on angular velocity controller

Using only an **angular** controller first, we add components one by one. The target and pursuer trajectories are shown

Increasing the value of the **proportional** component determines how fast it converges, but also leads to a less smooth control

Adding the **integral** component reduces the steady state offset, but induces oscillations by overcompensating. Decreasing the window of accumulation (560 to 118ms) modulates the oscillations

Adding the **derivative** component speeds the controller at the cost of fast changes in velocity



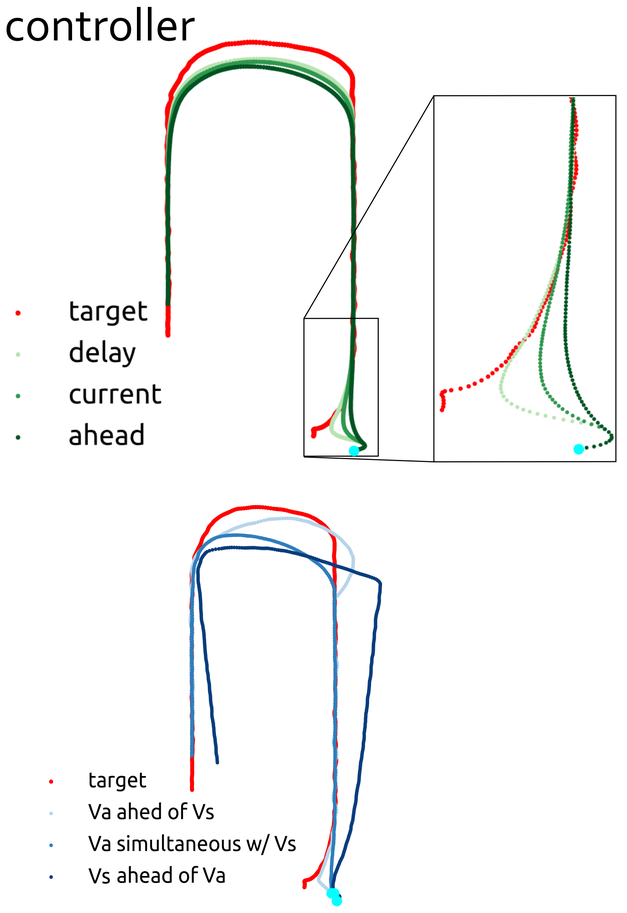
2) Sideways controller changes pursuit behavior when acting ahead of angular controller

When the angular controller (**Va**) acts alone, the information about the target location does not qualitatively affect its behaviour

When both controllers (**Va+Vs**) act in parallel, the behavior depends on the lags between them.

When both are simultaneous the behavior is similar to having Va only.

When Vs is ahead of Va, the pursuer stops following the target from behind, initiating parallel pursuit

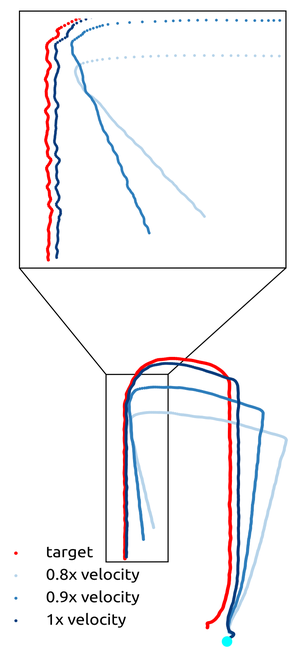


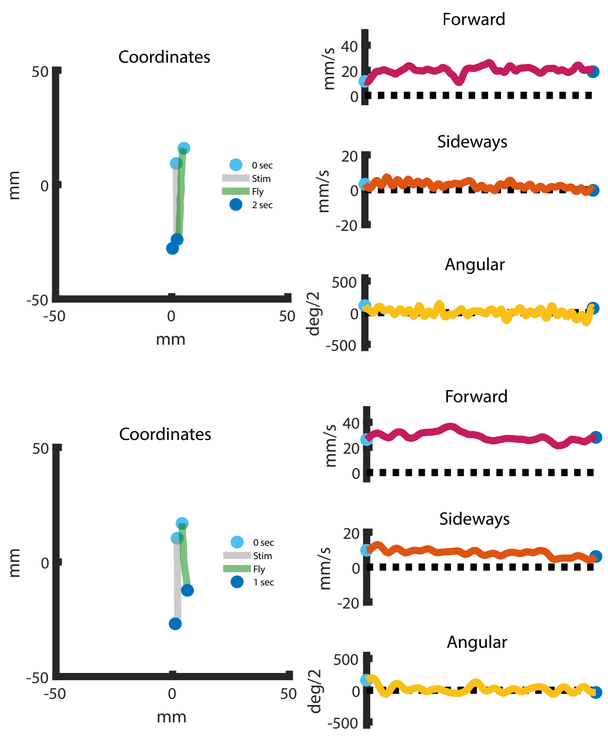
3) Velocity modulates behavior which matches real flies' behavior qualitatively

When both controllers are active and Vs is ahead, the pursuit is parallel.

However, since the fly has physical limits to its sideways velocity, the behavior changes depending on ratio of its velocity with the target.

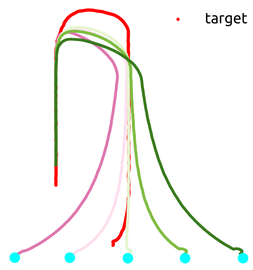
This behavior is observed in real flies and recapitulated in our model





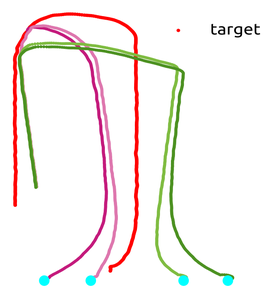
4) Convergence of different initializations to same path

Simultaneous Va+Vs

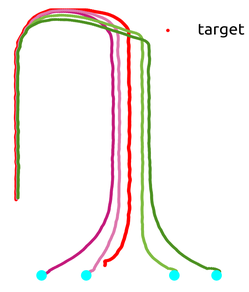


Vs ahead of Va

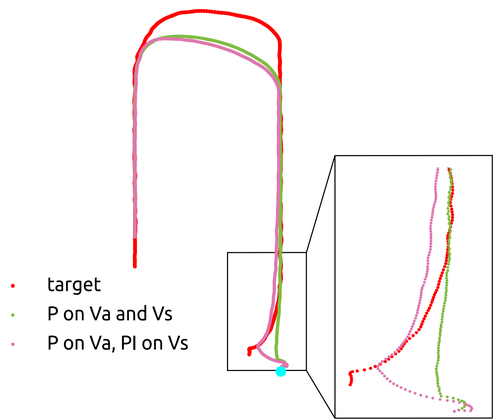
Pursuer at 0.9x of target velocity



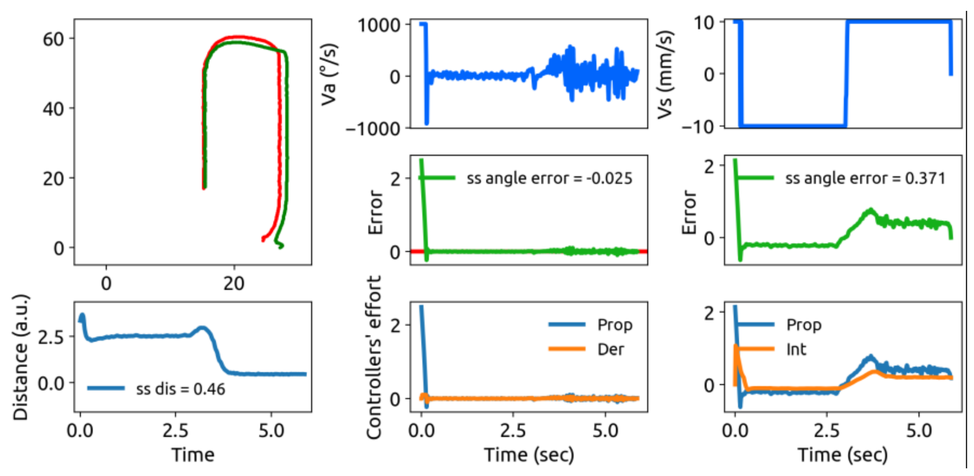
Pursuer at 1x of target velocity



5) The role of each component on each controller



6) Sideways controller enables parallel pursuit via sideway's effort



Video of real fly's behavior versus simulation