Modelling male fly courtship chasing behaviour

Why

Studying animal behavior is hard because it's hard to know the moment to moment state and goal of the animal

In behaviours such as courtship, hunting and escape we know animals' explicit goals

We can reduce the problem in the case of chasing in courtship:

- The male orients itself towards the female (controlling angle)
- The male reduces a distance from the female (controlling distance)
- The fly can walk forward, sideways, rotate on itself and turn its head (outputs)

How can the fly use its outputs to **control its inputs** in order to fulfill its goal?

How can multiple control systems work in together whilst trying to achieve a common goal?

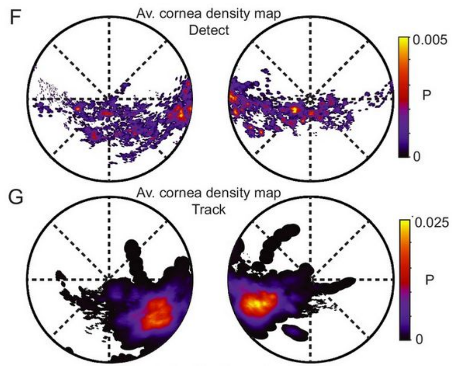
What is control theory? Where does it come from?

A subfield in engineering that started developing in the 1920s, important in e.g. chemicals and energy industries

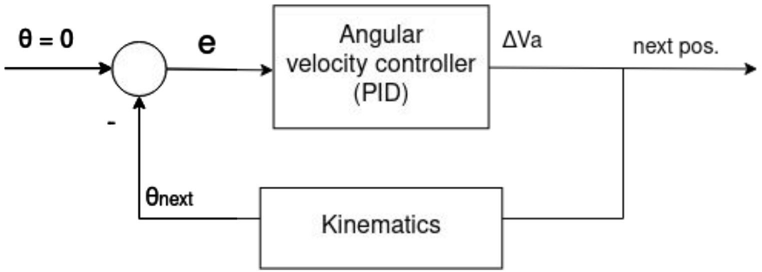
It assumes there is something to be controlled that we can sense (perception) and something that we can do to change it (action)

In neuroscience there are examples that fit within the concept of “perceptual constancy” (Bell. HC, 2014)

In the fly’s pursuit case, what they want to minimize is the error angle between its direction and the female



C.D. Holmgren, eLife, 2021

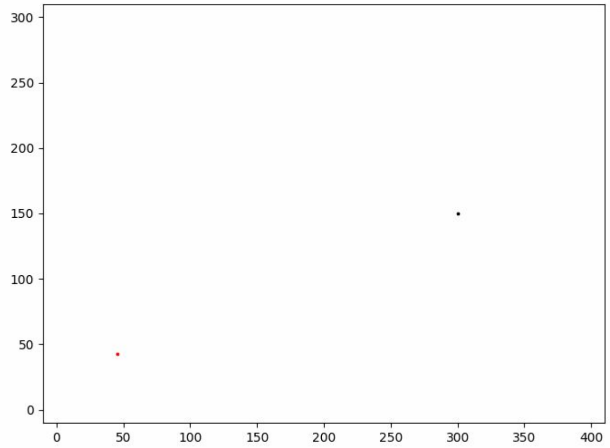


Objectives

Using control theory as a useful model for this behaviour

Implement a virtual playground with increasing levels of complexity of chasing behaviours

- How does controlling only the angle affect the distance?
- What if the virtual agent has a delay processing its inputs?

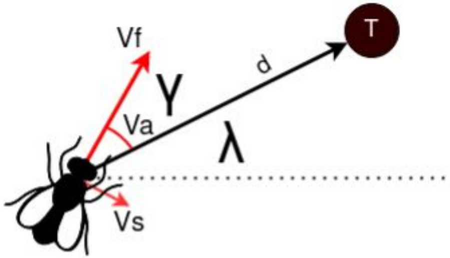


Model existing data with initial approximations and include details progressively

- Use previous literature to constraint the parameters we need to tune in the model
- Use Miguel's data to validate our model

Compare our model with others in literature

Creating a virtual playground



Minimizing e = λ-γ determines change in **angular** velocity

Vf = Vt (forwards velocity matched to that of target)

We can control Va and Vs

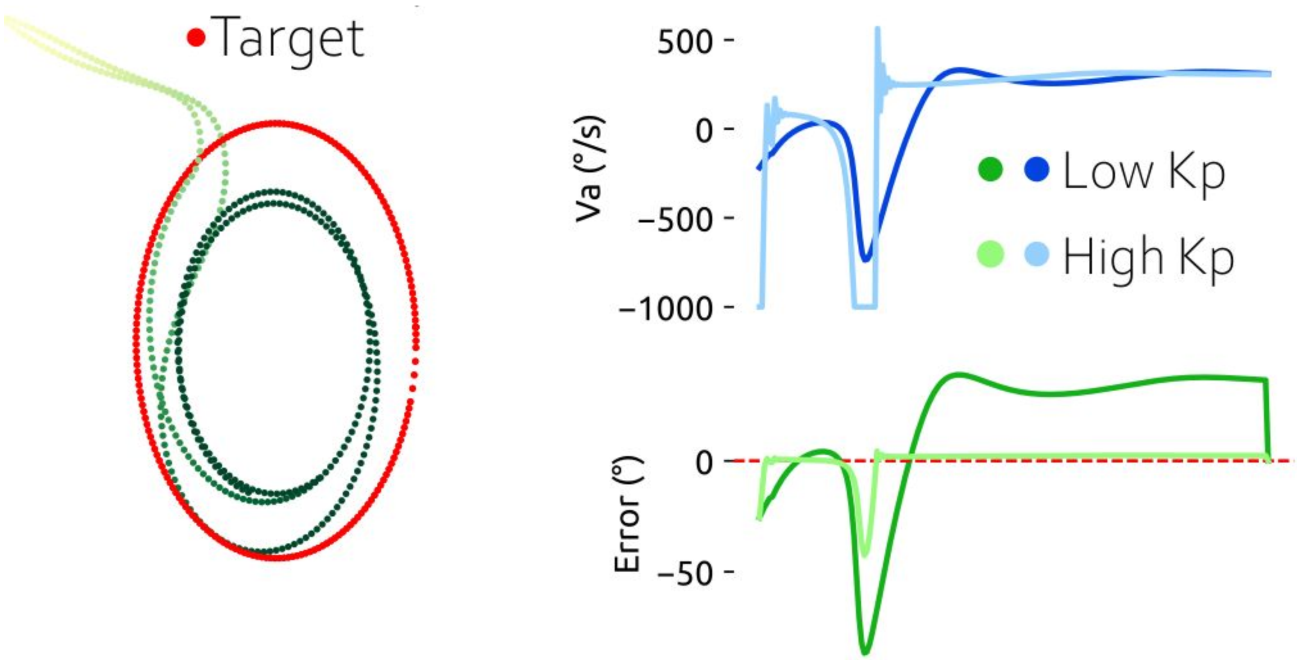
Knobs in the playground: Lead/Lag, velocity ratio, different paths

Parameters in the model, the proportional (P), integral (I) and derivative (D) components

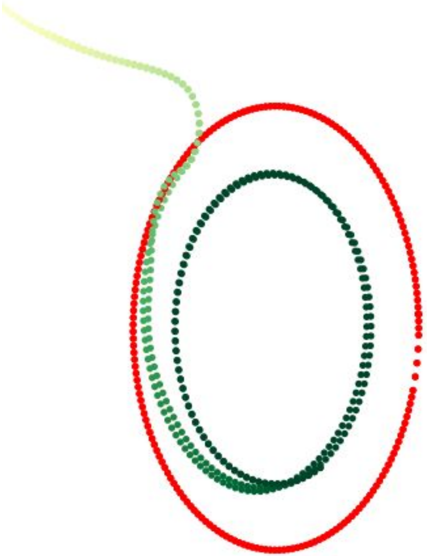
$$\theta' = K_p e(t) + K_i \int_0^{\boxed{t}} e(\tau)\, d\tau + K_d \frac{de(t)}{dt}$$

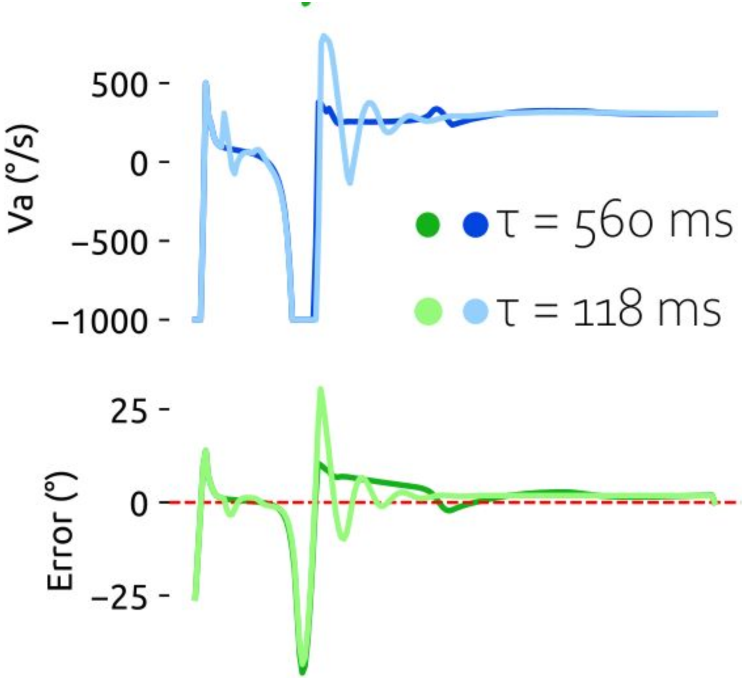
Angular controller only
effect of each P.I.D. component

Proportional component determines how fast you converge



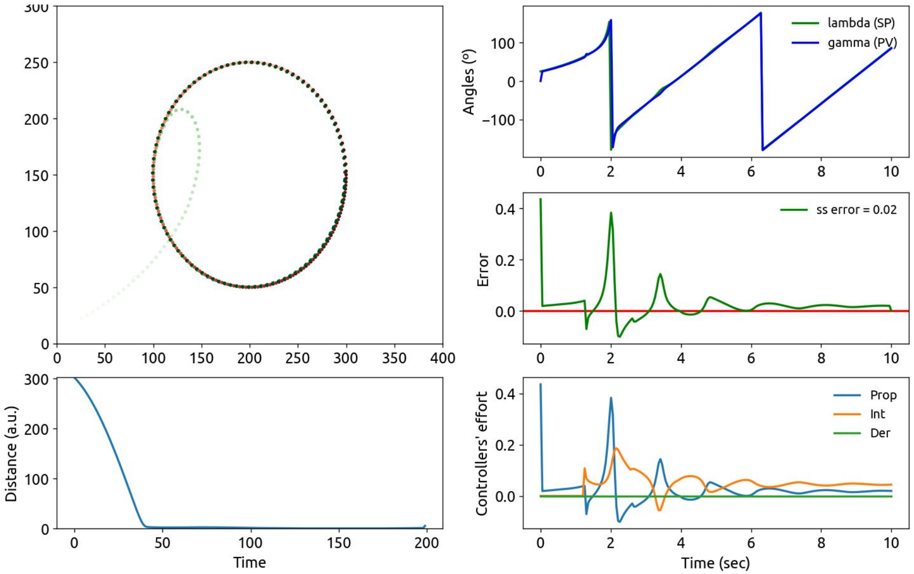
The constant of the Integral component can lead to oscillations



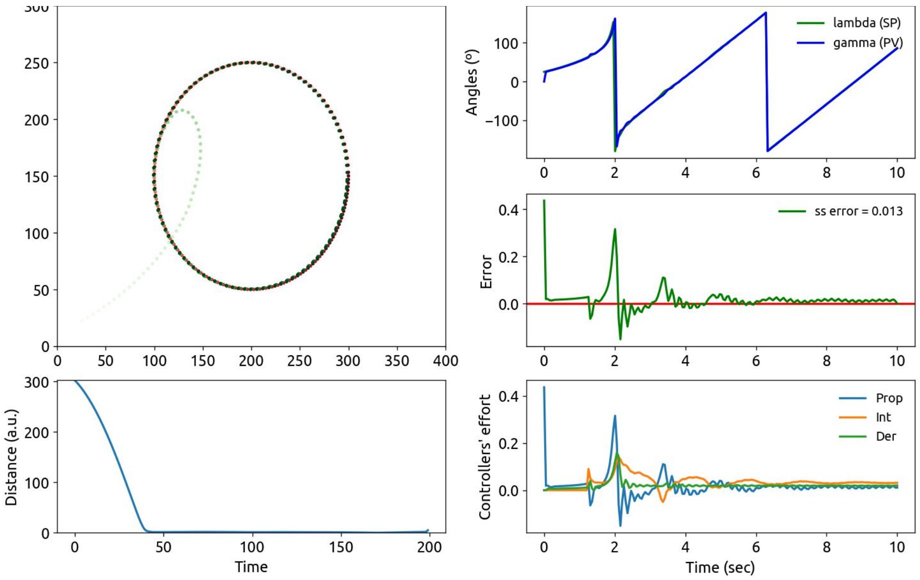


Every component working together

Kd = 0



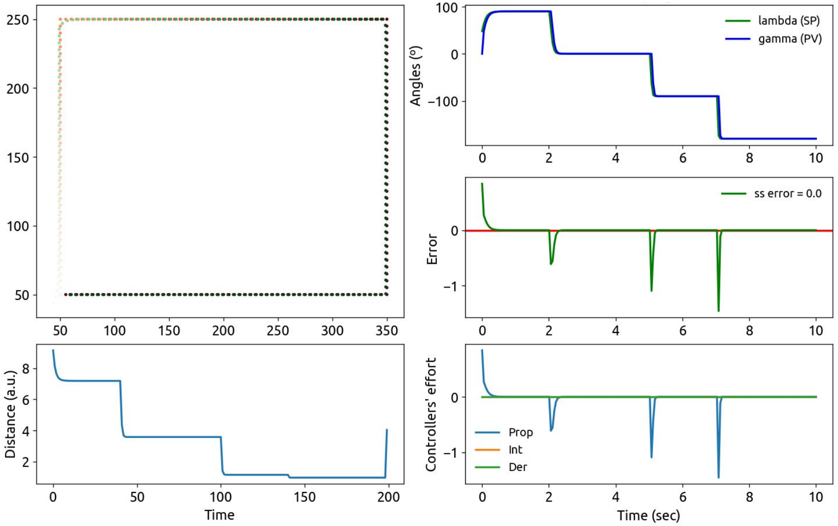
Kd = 0.2



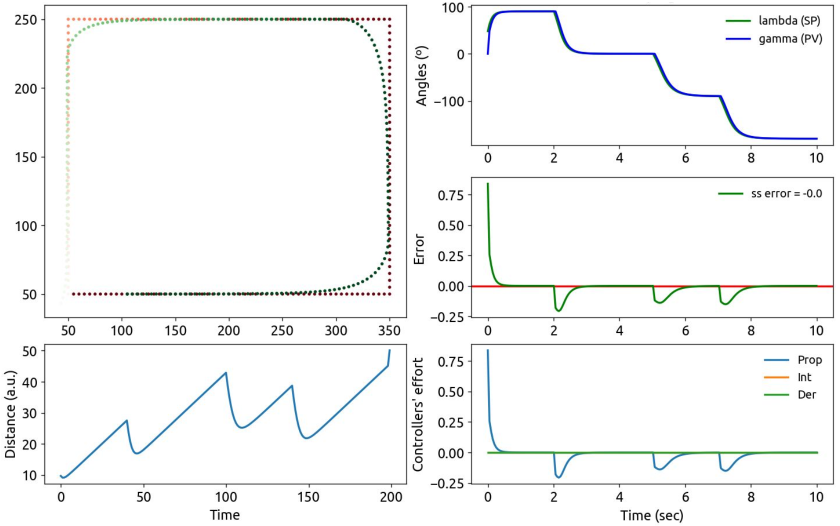
Angular controller knobs in the playground

Velocity ratio

Ratio = 1

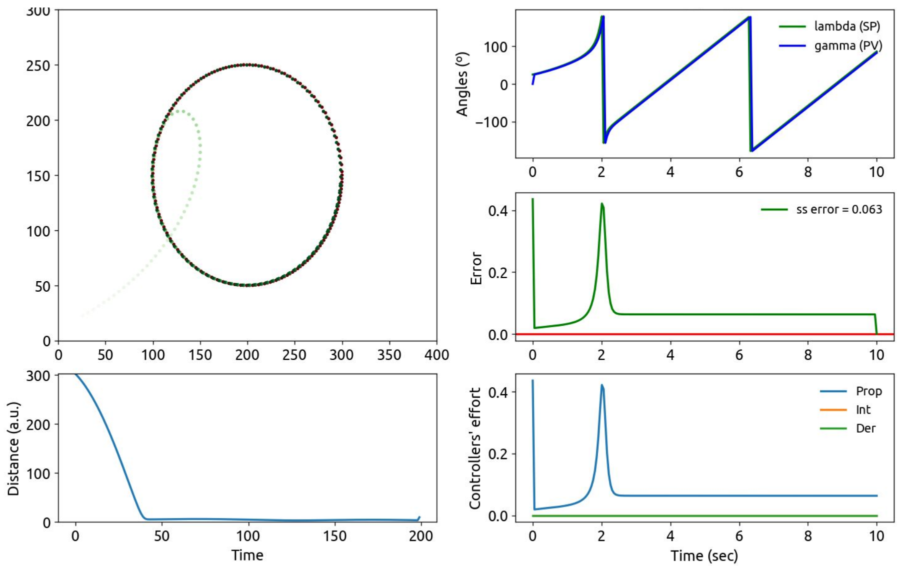


Ratio = 0.9

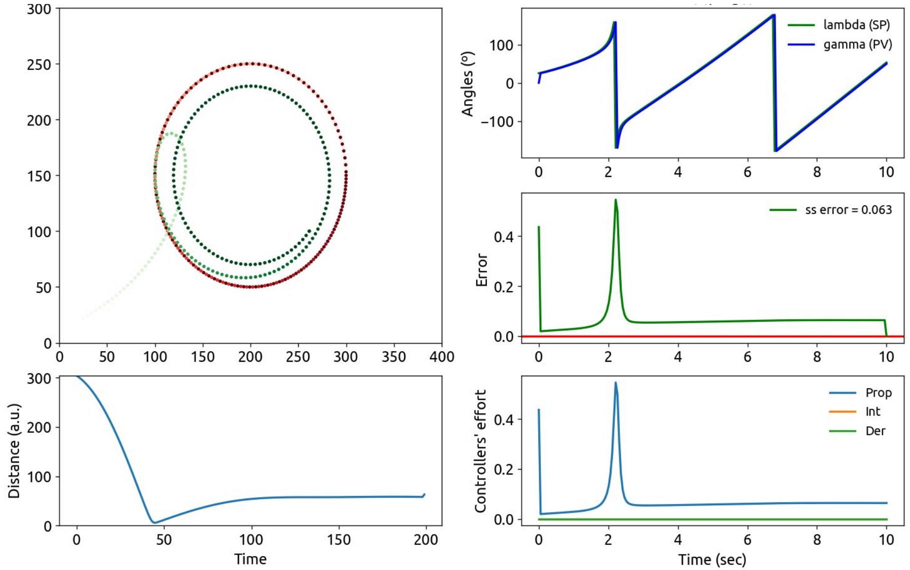


Circular path and velocity ratio

Ratio = 1

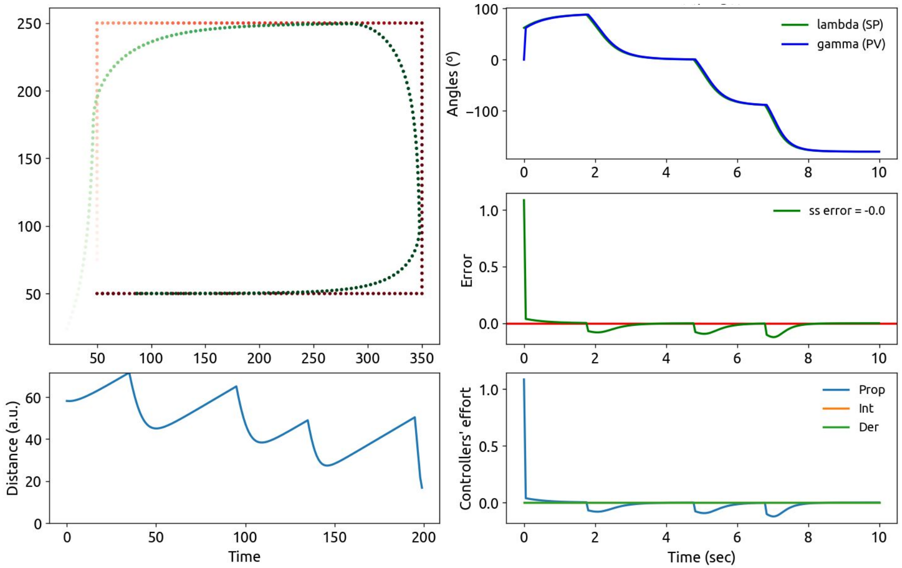


Ratio = 0.9

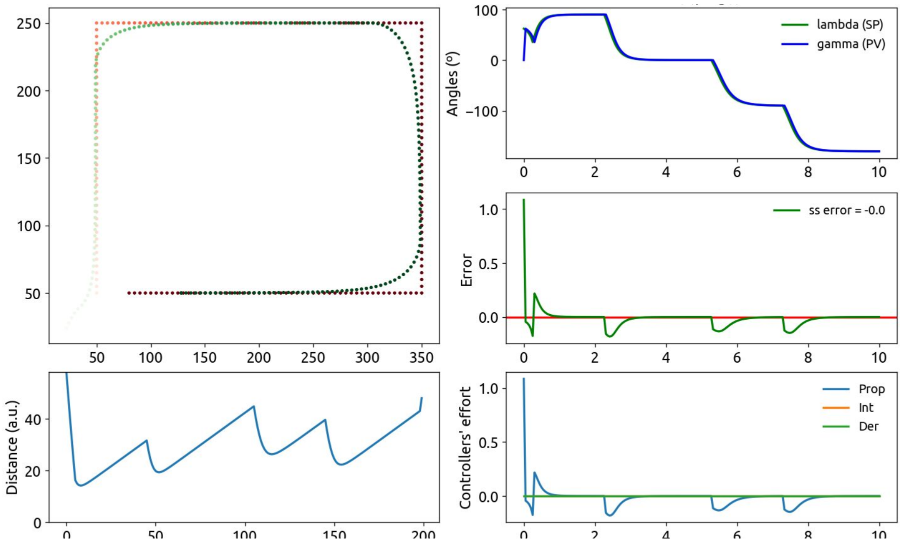


Lead/lag

Leading



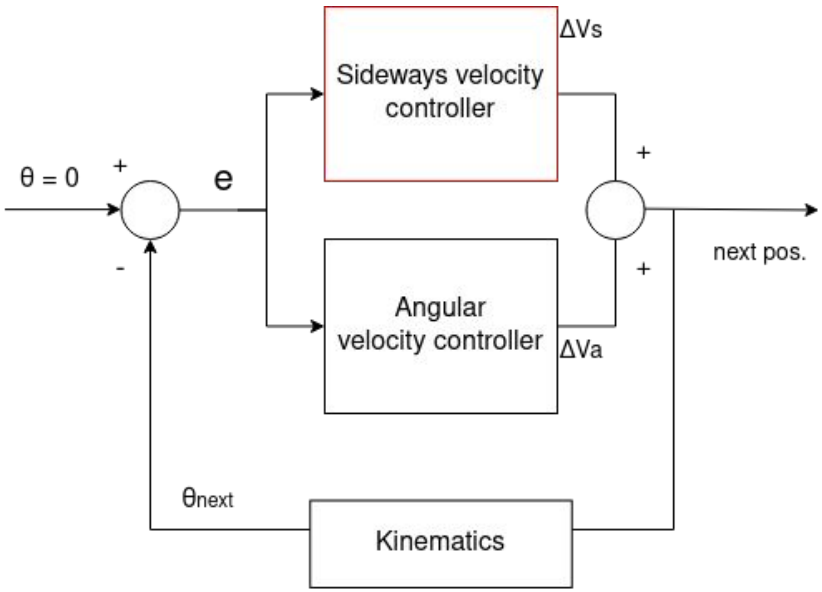
Lagging

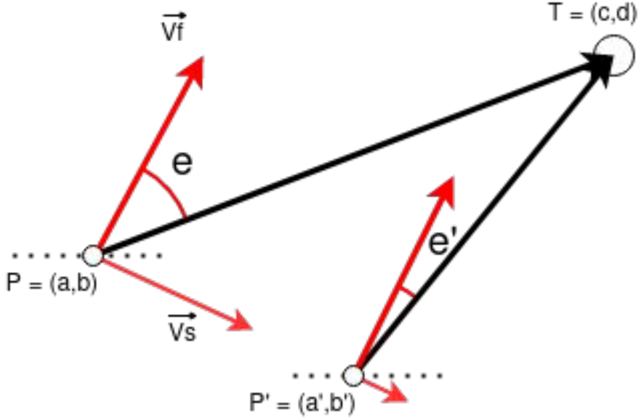


Angular and Sideways controller

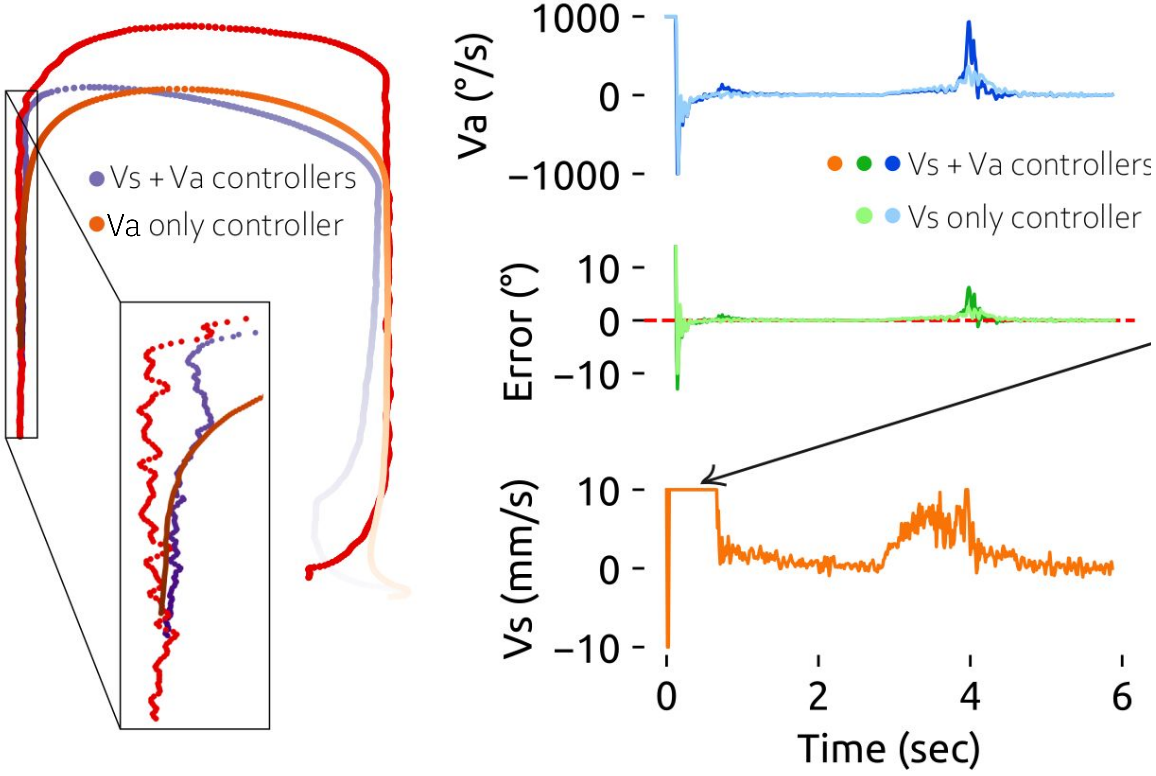
How to include control of sideways velocity?

What is the change in **Vs** that turns **e** into **e'**?



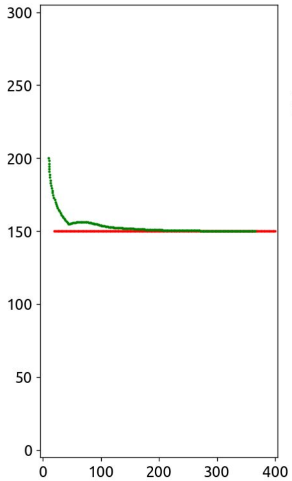


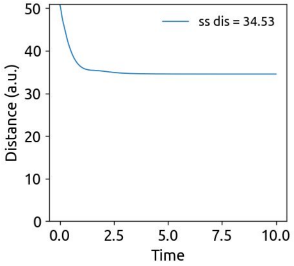
Effect of including sideways controller (no relative lag)

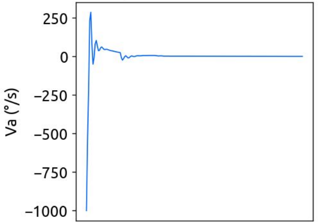


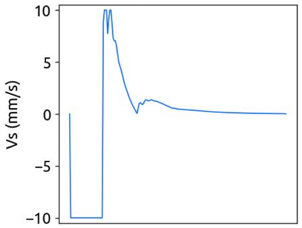
Effect of relative lag in parallel controllers

Va lags Vs



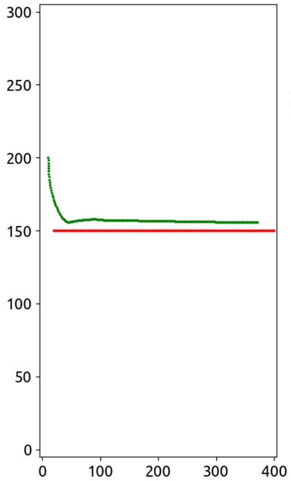


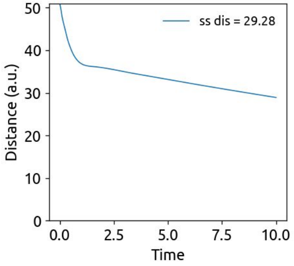


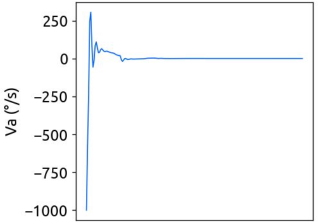


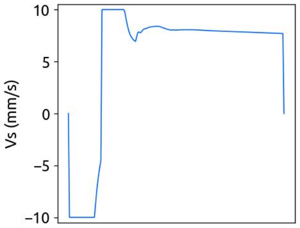
Pursuit from behind

Minimal engagement of Vs on steady state





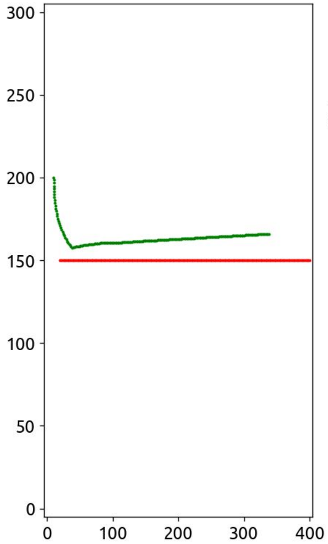


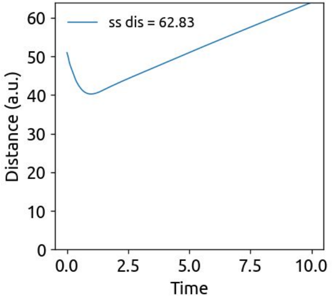


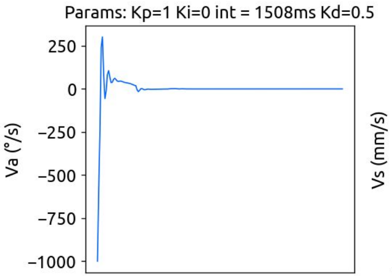
Parallel pursuit

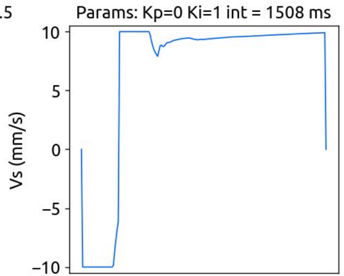
Constant activity of Vs in steady state

The limits of control: when the pursuer is slower than the target









Vs is at its limit

Parallel strategy is maintained at the cost of an increase in distance

Conclusions

Set up a playground where we can control variables

Modelled an angular and sideways velocity PID controller

Managed to emulate some characteristics of flies’ behavior in model