Exercise Optical Flow Landing

# Learning objective

* Students will be able to design and analyze biologically inspired control strategies that do not use traditional state estimates (position, velocity), but optical flow observables.

# Introduction

In the lecture, we saw how optical flow cues capture information on the environment relative to the observer’s speed. In the context of landing, two important optical flow cues are “ventral flow”, which is often defined as vx / z, and “relative vertical velocity” (captured by the divergence), defined as vz/z. These definitions assume that z is the *height* of the observer above the landing surface, and not a quantity such as the altitude above mean sea level. Both z and vz are defined as positive up, and negative down.

Both of these optical flow cues are kept constant by honeybees when landing [1,2], and roboticists have tried to copy this behaviour [3,4]. In this exercise, we will focus on the optical flow control of purely vertical landings.

**Please download the required Python files (exercise\_landing\_python.zip) from brightspace**

# Constant divergence landing

An often used – and very simple – controller to perform a constant divergence landing is to determine the upward thrust by means of the formula:

, where u is the upward acceleration in m/s2, taking into account gravity and the mass of the vehicle, P is the proportional control gain, D\* is the desired divergence (vz/z), and D is the estimated divergence.

# 1 – Landing with perfect measurements

The standard script has a control law for constant divergence landings.

1. Run the script. Only run the control with “perfect measurements”.
2. Look at *control\_with\_perfect\_measurements* and *f\_perfect\_measurements*. What does it mean to have “perfect measurements”?
3. The python script has multiple parameters you can change, such as the gain P, the time step dt, and the initial conditions x0. What are the effects of changing these parameters?
4. The script sets the desired\_div to x0[1] / x0[0]. What are the effects of setting the desired divergence to a constant other than the initial actual divergence? How good is the control if you look at the plot of the divergence and desired divergence?

# 2 – Introducing zero-order-hold and delay

In a digital system, the thrust commands will not vary in a continuous way, but will typically have a zero-order-hold. Moreover, and more importantly, in a real vision system, the observations of are always delayed (even in a continuous system). Please set *DELAY* and *ZOH* to *True*.

1. Run the script again. What do you observe? Can you explain what happens?
2. Can you fix what happens? Can you at least delay the phenomenon that you observe to happen outside of the time range that is simulated?

The explanation for the phenomenon in 3(b) and how it can be exploited for control and even distance estimation is given in [6].

# References

[1] E. Baird, N. Boeddeker, M.R. Ibbotson, and M.V. Srinivasan. A universal strategy for visually guided landing. PNAS: Biological Sciences - Neuroscience, 2013.

[2] M.V. Srinivasan, S.W. Zhang, M. Lehrer, and S. Collett, Honeybee navigation en route to the goal: visual flight control and odometry. The Journal of Experimental Biology 199, 237–244 (1996).

[3] Herissé, B., Hamel, T., Mahony, R., & Russotto, F. X. (2012). Landing a VTOL unmanned aerial vehicle on a moving platform using optical flow. Robotics, IEEE Transactions on, 28(1), 77-89.

[4] Kendoul, F. (2014). Four-dimensional guidance and control of movement using time-to-contact: Application to automated docking and landing of unmanned rotorcraft systems. The International Journal of Robotics Research, 33(2), 237-267.

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