Position Control of a Quadrotor with Visual Inputs

Computer Vision and Geometry Lab

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Gim Hee Lee, Friedrich Fraundorfer, and Marc Pollefeys

Introduction

We aim to build an autonomous quadrotor that is capable of doing navigation in an indoor environment with camera as the sole sensor. The first step towards this goal is to develop a position controller that drives the quadrotor from one point of the environment to another. In this poster, we describe our development of the position controller with visual inputs.

System Description

The quadrotor is provided by one of our collaborators - the Ascending Technologies [1] (Figure 1). To fulfill our objective of visual guidance, we added a "downward looking" PointGrey Firefly camera [2] and an Overo Gumstix [3] (Figure 2). The Overo Gumstix, which runs on OpenEmbedded Linux, grabs visual inputs from the Camera and sends control inputs to the Autopilot unit of the quadrotor. Together, these form the visual control loop in our quadrotor platform.

Figure 1. Quadrotor from Ascending Technologies

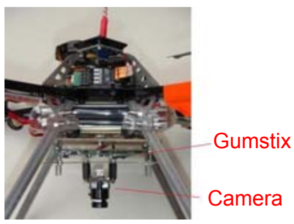

Figure 2. Gumstix and camera setup

Visual Feedback

The pose of the quadrotor must be known at all times for it to traverse safely in the environment. The ARToolkitPlus (ARTK) software [4], which is originally developed for augmented reality, is used for pose computation in our work. The software searches through each video frame for unique ARTK markers (Figure 3) that were placed in the environment, and computes the camera pose with respect to them. The ARTK is running in OpenEmbedded Linux on the Gumstix at 10-20Hz.

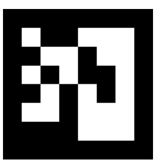

Figure 3. Example of an ARToolKitPlus marker

Position Controller: PID vs LQR/LQG

The quadrotor is assumed to behave like a point-mass which is influenced by 2 forces – the resultant thrust T from the rotors and its weight mg (Figure 4). Equation (1) gives the relation of the linear accelerations (a_x, a_y, a_z) and the attitudes (θ, φ, Φ). Three independent controllers could be implemented for each axis since the accelerations are not dependent on each other.

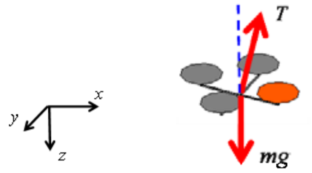

Figure 4. Free body diagram of the quadrotor

$$\begin{aligned} a_x &= -\frac{T}{m}(\sin\theta\cos\varphi\cos\phi + \sin\varphi\sin\phi) \\ a_y &= -\frac{T}{m}(\sin\theta\sin\varphi\cos\phi - \cos\varphi\sin\phi) \\ a_z &= -\frac{T}{m}(\cos\theta\cos\varphi) + g \end{aligned} \tag{1}$$

Our first attempt for position control is the PID controller (Figure 5). The input to the controller is the error computed from the difference of the current camera and the desired poses. Simulation and implementation however showed that the PID controller is not capable of handling more than 100ms of transport delay in the visual sensor, which is typical in our implementation, hence causing large overshoots in the response as shown in Figure 6.

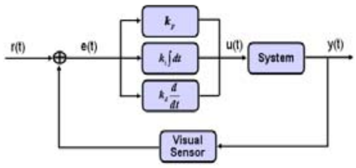

Figure 5: PID position controller

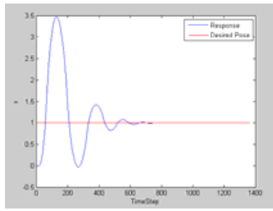

Figure 6. Large overshoot for PID controller with large transport delay

Finally, we designed and implemented a state controller with a state estimator as shown in Figure 7. The state estimator is used to reconstruct the entire state so that the undelayed state is available for control. A reference gain N and integrator gain K_i is included to eliminate steady state errors. The feedback gain K, estimator gain L and integrator gain K_i are found from standard LQR/LQG design procedure [5]. Figure 8 shows the simulated response of the controller with small overshoot.

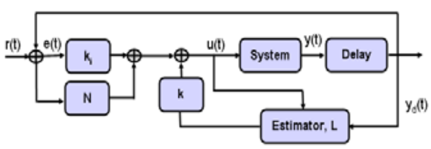

Figure 7: LQR/LQG position controller

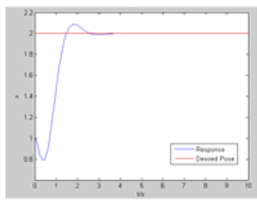

Figure 8. Response from LQR/LQG controller with large transport delay

Conclusion

In this poster, we showed our system design for position control of a quadrotor using visual inputs in indoor environment and compared the performances of PID and LQR/LQG controllers.

References

[1] http://www.asctec.de/main/index.php.
[2] http://www.ptgrey.com/products/fireflymv/index.asp
[3] http://www.gumstix.com/
[4] http://studierstube.icg .tugraz.ac.at/handheld_ar/artoolkitpls.php
[5] "Digital control of dynamic systems", 3rd edition, Addison-Wesley, G. F. Franklin, J. D. Powell, and M. Workman.