Reflection Document

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1 Introduction

This document contains the post-project reflections of the Master's Thesis *Towards Autonomous Landing of a Quadrotor using Monocular SLAM Techniques* performed during the spring semester of 2012 by Jonatan Olofsson. The thesis was performed as a final project in the education of *Applied Physics and Electrical Engineering* at Linköping University, the Y-program.
The goal of the thesis was to develop a control system for the LinkQuad quadrotor capable of incorporating video SLAM position measurements to stabily land the vehicle. While the algorithms failed to run real-time to enable flight, the implementation was verified in simulation with promising results, and the theoretic contributions included for instance advanced physical modeling and work on a general nonlinear controller.

2 Goals

The thesis was performed in a very independent manner, and while assistance with both practical and theoretical aspects of the thesis was available, much could be sorted out by thinking twice before asking. The tutors I received at IDA were very helpful throughout the work, even though the thesis -with its focus on SLAM, state estimation and control - did not entirely match their main field.
During the thesis, I was impressed by the assistance I received from people entirely unrelated to my project. Especially the people of ISY were very helpful with their assistance in theoretical problems and issues along the way.
Throughout the thesis, the focus was very fixed towards providing state-of-the-art control over the quadrotor to perform precision landing. Several approaches to e.g. state estimation and SLAM were tried and while simpler solutions in retrospect should have gained some precedence, the primary focus eventually resulted in the design of a modular decoupled system architecture capable of performing simulated landing using advanced, generally applicable, techniques. The implementation was fully backed up by theoretical derivations as necessary. Due to the amount of groundwork that had to be done before evaluating real flight, the project never reached the point where real flight could truly be evaluated, although the implementation was actually able to perform in real time when run on more powerful hardware than what was available on the LinkQuad quadrotor that was targeted in the thesis.

The system was evaluated using recorded data and simulation, although parts of the model would need continued model identification and verification to gain further scientific credibility to the developed physical quadrotor motion model.

3 Content

The thesis covered development and implementation of nonlinear state estimation and nonlinear control of a quadrotor. These fields are well covered by the education, in courses such as Control Theory [TSRT09] and Sensor Fusion [TSRT14], both given at ISY. The way of thinking in modular systems that is taught in the control-related courses at ISY was put to good use.
One course that was unexpectedly contributive to the thesis was the Computer Graphics course [TSBK07], due to the practical experience of treating arbitrary chained transformations of coordinate systems.
The Computer Graphics course was also helpful to understand the implementation and limitations of the libraries of Visual SLAM that were studied.
To be able to compile and get the vSLAM libraries - which are often experimental at best - running, I had great use of my programming experience, developed mainly from projects outside the University.
This thesis binds together, and extends, most all of the courses of the Y-program's profile for automatic control. The thesis couples physical, mechanical modeling with its implementation into filtering and control algorithms. The implementation was also made to run very close to the hardware that is studied in some of the computer courses of the Y-program.

4 Work

During the entire thesis, the ambition to create a well designed, advanced implementation was set high. The planning and preparations for the thesis were extensive, and included a preparatory study of the required theory and previous work. The planning was made in detail in Gantt charts and time for unexpected delays were included in the planning.
The high ambition of the project unfortunately resulted in a constantly high workload, and since there were quite an amount of components to the thesis - each taking just a bit too long to finish, far too many nights were devoted to work.
The work with the thesis was planned to follow the implementation of each implemented part of the thesis and in general, this plan was followed. The writing, and the work, was made in sprints for each of the major parts of the thesis - state estimation, control and vSLAM. Each chapter was drafted after and during the implementation of each module, so the report should not fall behind. Nonetheless, the process of proof-reading became stressful, leaving some easy mistakes for quite a while before I was able to devote the time to do a proper read-through myself. By that time, however, I had open-mindedly listened to the comments of my tutors and were able to apply their general comments better into the thesis.
Above all, the thesis allowed me to deepen my knowledge in the field that I

have spent the last five years studying for, and while the primary goal was not fully achieved, the implementation and results confirm that an engineer from the Y-program is capable of both the overview and detail needed to construct the control system of an autonomous flying vehicle, and incorporate, implement and extend advanced techniques for use in this application and others.