Project - Fast, Predictive Gimbal Tracking System

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1 Introduction

1.1 Background

This project is interfaces with project #5425 at VISL Laboratory (Continue of project #5155 at VISL). The complete system of this project will be described later. The mentioned project has dealt with the computer vision challenges. A major part of this project is the need to control a motor to follow a signal, and today this control was implemented without any attention to the Control Theory, thus it operates pretty bad. In this project we will replace the motor with better ones and focus on the control side according to the popular approaches.

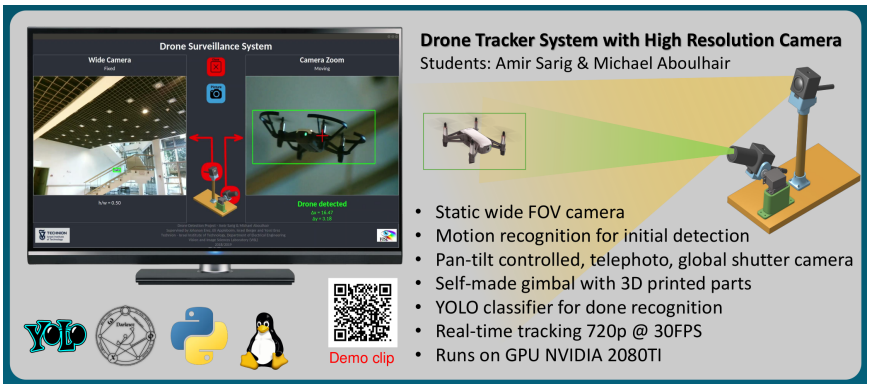

Figure 1: Part of the project #5155 academic poster

1.2 Motivation

Implementing a good target following camera may be useful for various applications such as: (1) record fast moving object like birds, bats or insects. (2) Shooting down military invasive targets (3) Maintaining beam based communication with a moving system. Doing it well enough using relatively cheap, off-the-shelf parts makes a nice challenge.

1.3 Operational Objective

Let there be a copter drone flying freely near our system. We would like to point a laser beam to this drone as accurately as possible.

1.4 Educational Objectives

- Understand the main consideration of designing a discrete controlled follower system
- Learn the right development workflow of such system
- Feel the main bottlenecks of such a system including noises, delays, amplifications etc.

- Get a scene of the limitations of such a “cheap” setup makes a good challenge

10 Meetings Summary

10.1 Consult Meeting (Face to face)

Date: 12.03.2020

Participants: Amir, Idan, Ilan

Disscussion Topics:

- Presenting the idea of the project
- Planing initial steps

Conclusions:

- The idea has a good potential
- A single academic article was found

Actions:

- Understand which gimbal can serve us for the project and how will we work with it

10.2 Consult Meeting (Phone call)

Date: 19.03.2020

Participants: Amir, Idan, Ilan

Discussion Topics:

- First steps: A suggestion to read an article

Conclusions:

- Start with reading about relevant topics for the project
- A suggestion to read the article "Direct Versus Indirect Line of Sight (LOS) Stabilization (29 January 2003)"

Actions:

- Read the suggested article
- Summarize the mentioned article and send it for review

10.3 Work Meeting

Date: 20.03.2020

Participants: Amir, Idan

Work progress:

- Read the article "Direct Versus Indirect Line of Sight (LOS) Stabilization (29 January 2003)"
- Discuss about topics raised in this article

How we continue next time:

- Set a meeting with Ilan and share our feelings: this article does not seem very relevant for our needs in the project

What we need to ask the instructor:

- How shall we continue from here?
- Will working with stepper motors be fine for this project?

10.4 Consult Meeting (Phone Call)

Date: 25.03.2020

Participants: Amir, Idan

Discussion Topics:

- Insights & discussion about article #1
- Summarize the article together

Conclusions:

- The article is not very useful for us
- Stepper motors shall be fine although their control is a bit tricky

Actions:

- Search for more related articles, focusing on **Predictive Control**
- Send few suggestions of articles to Ilan

10.5 Consult Meeting (Phone Call)

Date: 26.03.2020

Participants: Amir, Idan, Ilan

Discussion Topics:

- Share Insights & discussion about article #1 with Ilan

Conclusions:

- The artice is not very useful for us
- We should start with reading few relevant chapters on the book: "Feedback Control of Dynamic Systems 6th Edition"

Actions:

- Read above mentioned material, regarding closed loop angular control of continues & disrete systems
- Start building and simulation basic system in Matlab

10.6 Work Meeting

Date: 01.04.2020

Participants: Amir, Idan

Work progress:

- Start playing with Simulink in order to model our system
- Sketch various systems on paper while trying to understand the shape of ours

How we continue next time:

- We must get our hands on a working gimbal, so we can feel how it behaves and reacts to commands, thus know how should we model it

What we need to ask the instructor:

- Meet with Kobi Kohai to discuss the options for gimbal

10.7 Consult Meeting

Date: 08.04.2020

Participants: Amir, Kobi

Discussion Topics:

- Which gimbal can CRML supply us?

Conclusions:

- We found a really nice gimbal: FLIR PTU E46 (link)
- It's size is good, and it looks as it has a rich & comfortable control interface (API)

Actions:

- Attempt to move this gimbal

10.8 Work Meeting

Date: 01.07.2020

Participants: Amir, Idan

Work progress:

How we continue next time:

- Set nominal distance & zoom
- Find the conversion between pixels and angle
- Solder the micro-stepping pins

What we need to ask the instructor:

- Did we model the system well?
- Is it right to use the LQR controller in our case?

10.9 Work Meeting

Date: 20.05.2020

Participants: Amir, Idan

Work progress:

- Trying very hard to control the PTU
- The PTU does not respond to any of our commands
- The PTU moves oddly regardless what we send it

How we continue next time:

- Ask for assistance with controlling the PTU

What we need to ask the instructor:

- Can someone help us with this issue?
- Can we have the last documented project used this PTU?

10.10 Work Meeting

Date: 28.05.2020

Participants: Amir, Idan

Work progress:

- Open (disassemble) the controller's box
- Discover there is no original controller inside it, but an Arduino Nano + A4988 Driver instead

How we continue next time:

- We need to understand the consequences of this new discovery
- We want to know what limitations we face due to this situation

What we need to ask the instructor:

- Nothing

10.11 Work Meeting

Date: 04.06.2020

Participants: Amir, Idan

Work progress:

- Understand how does the Arduino controls the motors
- manage to achieve preliminary basic movements with serial commands

How we continue next time:

- We need to further understand how to control the driver better
- We need understand the behavior of serial commands
- We need to find a way to control 2 axes simultaneously
- Find the speed and acceleration limit of the motor

What we need to ask the instructor:

- How do we model the step motor?
- How do we handle discrete behaviors of the system?

10.12 Work Meeting

Date: 22.07.2020

Participants: Amir, Idan

Work progress:

- Improve Arduino C code
- Understand the behavior of serial commands
- Found a way to control 2 axes simultaneously using a scheduler
- Found the frequency (speed) limit of current configuration (for given voltage etc.)

How we continue next time:

- Start implementation of basic control loops

What we need to ask the instructor:

- What is the input for our system?

10.13 Work Meeting

Date: 01.08.2020

Participants: Amir, Idan

Work progress:

- Read the theory of Kalman filter and LQR contoller
- Implement Kalman filter in python code
- Implemnt LQR contoller in python code
- test both and observe good tracking results

How we continue next time:

- According to the instructor's guidance

What we need to ask the instructor:

- Did we model the system well?
- Is it right to use the LQR controller in our case?

10.14 Consult Meeting

Date: 06.08.2020

Participants: Amir, Idan, Ilan

Discussion Topics:

- Did we model the system well?
- Is it right to use the LQR controller in our case?

Conclusions:

- No need to use complex filters yet
- We have understood the basic shape of the system's block diagram
- Discuss delay handling shortly - we just use predictions of many steps ahead

Actions:

- Rewrite the project's objective according to what we have defined with the laser fixed to the camera.
- Draw a block diagram of the system
- Simulate the system on the computer as accurately as possible.
- Find the most significant noises using the simulation.

10.15 Work Meeting

Date: 09.08.2020

Participants: Amir, Idan

Work progress:

- Identification of systems noises (detection uncertainty) with an experiment
- Identification of system unit conversion factors (angle to pixel etc.)
- Calculate angular speed, acceleration

How we continue next time:

- Update python code to fit with the Simulink diagram

What we need to ask the instructor:

- Nothing

10.16 Work Meeting

Date: 16.08.2020

Participants: Amir, Idan

Work progress:

- Update python code to fit with the Simulink diagram
- Bug fixes in the Arduino
- Build classes for gimbal control, kalman filter and graphing
- Add feature for the Arduino to send live commands

How we continue next time:

- Add classes for speed control, overall class to control tracking
- Try working with the Tello python control library
- Perform an experiment, plot graphs, to compare simulation and real system performance

What we need to ask the instructor:

- Is our block diagram ok?

11 To Do

Below is a list of the tasks left to complete:

1. Perform real life experiment and measure it's behavior
2. Perform an accurate computer simulation and compare it to the real life experiment
3. Show that the simulation is valid and representative
4. Raise up the "Type" of the system and compare performance
5. Test a second kind of controller for comparison
6. Optimize the system using the computer simulation
7. Find adequate adapter, and test the system with higher voltage supply
8. Perform final tests, deduce the system capabilities and sum it up
9. Clean up & tidy code, code documentation
10. Finish the project report
11. Integrate with the system of project #5425 at VISL
12. Prepare Final presentation

12 Finish Deadline

Our main motivation for early completion is the ending contract of our apartment in Nesher **(September 30, 2020)**. Afterward it will be much complicated for us to reach and work near the Technion.

According to current progressing pace, it seems reasonable to meet this goal.