A Proposal for a Parameterized Circulating Vector Field Guidance for Fixed Wing Unmanned Aerial Vehicles

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Garrett S. Clem

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A Proposal for a Parameterized Circulating Vector Field Guidance for Fixed Wing Unmanned Aerial Vehicles

by

GARRETT S. CLEM

has been approved for

the Department of Something

and the Russ College of Engineering and Technology by

Dr. Jay Wilhelm

Assistant Professor

Coadvisor's Full Name

Coadvisor's Full Title

Dr. Dennis Irwin

Dean of Students

Abstract

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A Proposal for a Parameterized Circulating Vector Field Guidance for Fixed Wing Unmanned Aerial Vehicles (20 pp.)

Directors of Thesis: Dr. Jay Wilhelm and Coadvisor's Full Name

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Acknowledgments

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Table of Contents

List of Tables

List of Figures

List of Symbols

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List of Acronyms

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1 INTRODUCTION

Unmanned Aerial Vehicles (UAVs) can be used for a multitude of complex tasks such as surveillance, reconnaissance, aerial photography, delivery, and for defense. Accomplishing these tasks require robust and fast execution of three distinct subsystems consisting of navigation, guidance, and control.

1.1 Motivation and Problem Statement

1.2 Methods Overview

1.3 Phases

1.4 Summary of Objectives

- Develop a parameterized circulation method that eliminates the singularity and guides a UAV around an obstacle and to a target. The parametrized circulation term $f(heading, closingvelocity, position, turnrate)$ and would be determined by minimizing a cost.
- Simulate and compare the parametrized circulation with a non parametrized VF guidance for circular and elliptical obstacles
- Emulate fixed wing algorithm with a ground robot to validate simulation results and demonstrate real time VF guidance is achievable with parametrized circulation modification

2 Literature Review

2.1 Unmanned Aerial Vehicles

In literature, UAVs generally occupy one of two categories consisting of fixed wing aircraft and multi-rotor aircraft. Fixed wing aircraft can carry a large payload and are ideal for long endurance missions, whereas multi-rotor aircraft are used when hovering or high maneuverability is desired. Both categories of vehicles require navigation, guidance, and control to maintain flight and accomplish their task. These processes are often automated and programmed into flight controllers that are placed on-board the aircraft itself.

2.1.1 Navigation, Guidance, and Control

Before commanding a vehicle to a given task it is paramount that the location of a vehicle with respect to some reference point is known. Measuring, filtering, and estimating the location of a vehicle generally falls under the study of navigation. Commanding a vehicles heading and general operation is provided by a guidance system. Maintaining vehicle stability and reducing any errors is the responsibility of a control system.

2.1.2 Navigation

Sensor packages containing GPS receivers, barometers, and compasses measure the location and heading of a vehicle. Data is always subject to uncertainty caused by process and measurement noise. Filtering measurements with Kalman filters produce estimates that more accurately represent the location and heading.

2.1.3 Guidance

2.1.4 Control

2.1.5 Flight Mechanics

2.1.6 Autopilot

Autopilots are responsible for maintaining vehicle stability while carrying out mission objectives such as waypoint navigation and loitering. Commercially available autopilots, such as the Pixhawk have gained popularity due to their ease of use and strong community support. The Pixhawk autopilot system is an open-source project

- Hardware and software packages
- Collect and filter sensor data
- Receive mission commands (Go-to, Loiter, Hover)
- Transmit mission critical information to ground station
- Execute missions and maintain vehicle stability
- Many autopilots are available
- PX4 is an open-source autopilot software that can be ran on a number of hardware platforms including the Pixhawk, PixRacer, Parrot Bebop, and Crazyflie. Integrating the pixhawk firmware into a companion computer is useful because more complex software can be ran on-board as well as multiple computer languages.

2.1.7 Simulation

- As new features and improvements are made to the autopilot software, it is often useful to test the performance of the software in a virtual environment. The process of simulating the autopilot software is called Software in the Loop (SITL).

2.1.8 Emulation

- An additional testbed for new navigation, guidance, and control algorithms is the method of emulation. Emulation is the process of mimicking the kinematics of a complex dynamic system on a simplified system. Fixed wing UAV emulation has been observed in [LDN+14], [RMSB07], and [LEBD16].

2.2 Path Planning

- Current state to goal state while passing through objectives
- High level obstacle avoidance
- Line or series of waypoints
- How vehicle reaches line or points not necessarily considered
- Responsibility of guidance
- Avoid collisions, seeking goals

2.3 Guidance

2.3.1 Potential Field

- Potential field (what is it) (edge of bowl, marble, goal, obstacles)
- Calculation time
  - Long time to calculate
  - Environment changes, entire field has to be regenerated
  - Improvements could be made with better computing methods . . .
- Local minimums

  - Local minimums are a significant area of study in potential field
  - Examples of how the problem is being addressed
  - Common issue across the board - No clear solution in sight
  - As missions become more complex, the problem only worsens

2.3.2 Vector Field

- First appearance of vector field (Histogram approach) [Koren 1989] (read before typing it out)
- Experiments with sonar sensor robots [Koren and B 1991]
- [BK90] Improvements on previous vector field histogram
- Ground robot
- Later work provided improvements
- Limitations, size of cells, instability and oscillations
- Problems with VF, used as a general path planner with another local path planner on top
- (transition)
- First instance of generating a field for converging onto paths made of straight line and circular segments (Nelson, Barber, 2006)
- Field construction of Nelson and Barber (More reading)
- Added benefit of VF is adding component to counteract wind
- Cooperative Standoff Tracking of Uncertain moving targets (2007, Frew)

- VF usefulness extended to loitering about an uncertain target
- Lyapunov vector field generation for a circular loiter
- Linear transformation applied to stretch the field into an ellipse shape

2.3.3 Literature Review Summary

3 METHODOLOGY

References

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APPENDIX: AN APPENDIX

A.1 A Section in the Appendix