

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

A thesis presented to
the faculty of
the Russ College of Engineering and Technology of Ohio University

In partial fulfillment
of the requirements for the degree
Master of Science

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May 2018

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

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ABSTRACT

CLEM, GARRETT S., M.S., May 2018, Mechanical Engineering

A Proposal for a Parameterized Circulating Vector Field Guidance for Fixed Wing
Unmanned Aerial Vehicles (18 pp.)

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

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ACKNOWLEDGMENTS

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LIST OF SYMBOLS

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LIST OF ACRONYMS

Insert your list of acronyms here or comment out this line

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 $f(\text{heading}, \text{closingvelocity}, \text{position}, \text{turnrate})$ 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.

- Tasks (path following, waypoint navigation, loitering)

2.1.1 Flight Mechanics

- Lift - Thrust - Drag
- Kinematics - Dubins equations of motion - Dynamics - Need more literature
- Forward velocity constraints, turn rate constraints - Transition could be the autopilot ensures that the vehicle does not violate these constraints or attempt to - Autopilot (combination of hardware and software, takes mission objectives and produces necessary actuator output)

2.2 Navigation

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.

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.

2.3 Guidance and Control

Guidance and control are intermingled in many UAV systems. . . etc

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

2.4 Simulation and Emulation

- 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).

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].

2.4.1 Literature Review Summary

3 METHODOLOGY

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APPENDIX: AN APPENDIX

A.1 A Section in the Appendix