Autonomous Golf Cart

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Abstract

This report details the development of an autonomous driving system implemented on a modified utility golf cart. The system described implements both low level and high level control, realized by a Texas Instruments c2000 series microcontroller, and a Jetson edge computing device. The low level controller interfaces with the golf cart that has been modified in a drive-by-wire style to allow for automated control of steering, throttle, and brake. Likewise, the high level controller interfaces with the c2000 by providing it with velocity and steering angle setpoints, deriving these from a GPS based waypoint follower.

To support controller design, a planar vehicle model is derived that encompasses the longitudinal dynamics and lateral kinematics. This model forms the basis for the controller and simulation design. The simulation is used for controller tuning and algorithm verification before deployment to the physical golfcart.

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Nomenclature

To contain a list of all symbols and their definitions used in the report.

m	Vehicle mass
v	Longitudinal velocity
F_{drive}	Driving force at the wheels
F_{brake}	Braking force at the wheels

Chapter 1

Introduction

Introduce the project

1.1 Motivation and Project Goals

[Discuss the purpose of the project]

1.2 Project Scope and Constraints

[Discuss what is and is not included in the project]

1.3 Contributions

[Discuss my contributions to project]

Chapter 2

System Overview

High level description for the golf cart

2.1 Vehicle Platform

[Physical platform as received, brief overview of modifications physical modifications]

2.2 Sensing and Computation

[Describe sensors and computational hardware on the vehicle]

2.3 Control Architecture

[Describe the control architecture in terms of components (e.g. high-level, low level, simulation, etc)]

Chapter 3

Vehicle Hardware Rework

[Go from initial condition of the vehicle to current state. Rewire etc.]

3.1 Initial Vehicle Condition

[Describe as-is vehicle state at project start]

3.2 Component Update

[Discuss updated components (arduino/rpi to c2000/jetson)]

3.3 Electrical Rework

[Discuss golfcart rewire from wiring harness to DIN rails]

Chapter 4

Modeling

[Math models for longitudinal dynamics, lateral kinematics. Lay foundation for analytical control design.]

4.1 Mechanical Layout and Drivetrain

[Describe motor -¿ transaxle -¿ wheel and steer motor -¿ shaft -¿ encoder relationships]

4.2 Frames and Notation

[Layout coordinate frames and important pre-work notations]

4.3 Longitudinal Dynamics

[Show derivation of longitudinal dynamics]

4.4 Lateral Kinematics

[Show derivation of lateral kinematcis/bicycle model]

4.5 Combined Model

[Combine both together, unified equations for controller design]

Chapter 5

Low Level Control Design

[Derive low level control analytically from mathematical model]

5.1 Velocity Control

[Introduce velocity control as MISO seperated into 2 SISO by domain]

5.1.1 Drive Motor Controller

[derive pi controller for drive torque]

5.1.2 Brake Force Controller

[derive pi controller for brake actuator]

5.2 Steering Control

[derive pi controller for steering motor]

Chapter 6

Low Level Control Implementation

[Discuss controller implemenation on C2000 leveraging TI hardware and Matlab tools]

6.1 TI c2000 Microcontroller

[Discuss advantages of TI c2000 microcontroller over other mcus]

6.2 MATLAB Toolbox for c2000 Microcontroller

[Discuss MATLAB integration of project]

6.3 Simulink Model

[Discuss derived Simulink Model as realized control system]

Chapter 7

Simulation

[Discuss CARLA sim briefly, Gazebo sim, sim model design]

7.1 CARLA Sim

[Discuss CARLA's poor fit for project]

7.2 Gazebo Sim

[Introduce Gazebo Sim]

7.2.1 Simulation Model

[Discuss URDF]

7.2.2 Simulation Sensors

[Discuss simulated GPS, LiDAR, Encoders]

7.2.3 Simulation Interfaces

[Discuss ROS-GZ Bridge]

Chapter 8

High Level Control Design

[Discuss implementation of GPS waypoint following]

8.1 Jetson Nano

[Describe jetson nano, inputs and outputs]

8.2 ROS2

[Explain ROS2's purpose and role in project]

8.3 GPS Waypoint Line Following

[Derive waypoint line following controller]

Chapter 9

Results

[Discus results of all stages of project, design, simulation, testing]

Chapter 10

Conclusions

[Summarize project, discuss future work]

Appendix A

Derivations

[If I need to break out any math, here's where it will go]

Appendix B

Vehicle Parameters

[I might put detailed specs about golfcart here (e.g. mass, dimension)]

Appendix C

Diagrams

[If there are any diagrams that dont fit elsewhere]