Establishing Smart Driving Systems for Riverways Using Computational Approaches

Michael Valentino Ochoa (Updated: 1/21/20)

I. INTRODUCTION

This paper presents the sensor kit, tech stack and processing pipelines for a smart driving system that follows a preplanned route. Our idea is to take something old (Venetian water taxis) and mix it with something new (autonomous tech and hospitality). The main contribution of this study is showcase a vision-based robotaxi capable of absorbing the world above and below the riverway, and creating its own control laws for four predictive thrusters designed to efficiently follow a preplanned open water route.

II. WHAT IS THE PROBLEM?

Global sea level rise will be one of the greatest challenges facing our society this century, and understanding how this phenomenon will reverberate onto riverway communities will require a regular riverway presence. We believe our smart driving systems can be that regular riverway presence.

This paper is laid out at follows. Section III presents the design, fabrication and implementation of the prototype and sensor kit. Section IV draws out what we need to do make the tech stack. Section V describes the processing pipelines and predictive thrusters algorithm strategy. The field testing setup and results are unpacked in Section VI. Section VII gives way to discussion and future work. To conclude the paper Section VII, IX and X present the customer facing business, software packages and policy memorandum.

III. PROTOTYPE DESIGN & SENSOR KIT

Our prototype is rectangular shaped for maneuverability with its dimensions being approximately (0.9m x 0.45m x 0.1m). We 3D print the hull as its proven to be a swift, solid and low cost method for prototyping. We fabricate the hull from 16 separate pieces (inspired by the "architectural ornaments" of Louis Sullivan to bring the material to life). The pieces are then married together by bolts, plastic O-rings and several layers of fiberglass. Finally, we add a warning light and horn, with additional safety updates to follow.

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+ Fig. 1. Design & Sensor Kit
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Our sensor kit helps the smart driving system interpret data in a way that is similar to the way human drivers use their senses to relate to the world around them. The boat localizes itself with centimeter level precision with the following sensors: RGB-D cameras, LiDAR, thermal radar, sonar radar, IMU sensors and GPS.

IV. TECH STACK

Application //
Driver Assistance Software

Hardware & Software //
Sensor Fusion + Mapping

Computations //
CPU / GPU

Sensors //
RGB-D Camera
LiDAR, Thermal, Sonar
GPS, IMU

Our tech stack breaks sensor data pixel by pixel, into digital components for our processing pipeline. These digital components help the smart driving system find the most energy efficient routes for its four thrusters. To ensure real-time performance our system uses a mini computer with 32 GB of memory running Ubuntu 16.04 as the main controller, and a 32-bit micro-controller that gathers GPS and IMU data and sends it to our processing pipeline to discover the most energy efficient routes for our thrusters. The smart driving system runs on the Robotic Operating System (ROS) and a human safety driver at the helm of a manual override switch.

Item	Price	Weight
RGB-D Camera	$177	
IMU Sensor		
LIDAR		
GPS		
Thermal Camera		
Sonar		
Mini Computer		
Micro Controller		
Wifi Adapter		
Mobile Beacon		
4 Thrusters	$500	
Solar Panel	$180	
Hull, etc.		
Warning Light		
Horn		
Leak Sensor		

V. PROCESSING PIPELINES

The processing pipelines decouple the optimization problem into multiple layers to make it more easily tractable. Generally speaking, the pipelines outlined in sections A, B, and C extend the capacity of our smart driving system to understand:

— Where am I?
— Where is everyone else?
— How do I get from A to B?

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+ Fig. 2. Force Vectors on Boat
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The dynamics of this smart driving system can be described by the equations below:

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A. BOAT DYNAMICS

The IMU sensor collects 3 axis angular velocity data (sway, yaw, surge).

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+ Math/Pseudocode
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B. CLUSTERING & CONTOUR TRACKING

The sixteen beam LIDAR, thermal radar, sonar radar and RGB-D camera measures the relative position of obstacles within the sensors range, and is coupled with Euclidean clustering and contour tracking algorithms for accurate estimation of static and dynamic obstacles in the distance.

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C. PREDICTIVE THRUSTERS ALGORITHM

The goal of the this algorithm is to design suitable control laws for the four thrusters forces that drive the error rate of selected trajectory tracking variables to zero. The drive mode for this algorithm is guided by four omni-directional thrusters powered by a 40 watt solar panel.

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VI. EXPERIMENTS & RESULTS

A. FIELD TEST SETUP

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B. BOAT DYNAMICS RESULTS

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C. CLUSTER AND CONTOUR TRACKING RESULTS

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D. PREDICTIVE THRUSTER ALGORITHM RESULTSS

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VII. CONCLUSION & FUTURE WORK

In the paper we extend the capacity of a smart driving system on the riverway to understand:

— Where am I?
— Where is everyone else?
— How do I get from A to B?

Our goal is interpret data in a way that is similar to the way humans use their senses to relate to the world around them. We run open water field tests to validate the efficiency and accuracy of the predictive thruster algorithm, which will be essential to establishing more advanced autonomy tasks.

In the future, our work will explore the following topics. First, incorporating a neural net that better interprets wave dynamics to find the most energy efficient routes for the four thrusters. We will achieve this by automatically generating weak labels that can be used to train a deep convolutional network that labels various water dynamics within riverways. Second, better understanding how mass and drag change when transporting people. Third, creating an experience piloted by our smart driving system that could impress both a safety and sustainability commissioner.

VIII.CUSTOMER FACING BUSINESS

We recognize there is an immense amount of noise in the autonomous transit industry. For years the challenge focused on engineering, but as autonomous technology becomes increasingly commodified, trying to work out how to build services in a new regulatory environment will be the next challenge. Our narrow focus in on bringing an intimate space to a small group of riverway commuters. We believe in letting water robotaxis do what they do best (e.g. lane keeping, active cruise control and obstacles avoidance with four predictive thrusters) and letting humans do what we do best (e.g. be social and hospitable animals we are).

We want our smart driving system to be transportation that prepares people to take on the city, a kind of home-away-from-home on the river. We believe this approach best positions our business for contract work with autonomy giants, etc.

IX. SOFTWARE PACKAGES

ada_autonomy1: filters LIDAR, thermal and sonar data based on environment and task

ada_autonomy2: filters RGB-D data based on environment and task

ada_core: manages sensors, low-level communications and actuators

ada_launch: expedites task setup by calling packages with configurations

ada_localization: localizes boat with LIDAR, IMU, thermal and RGB-D camera data. Manages EKF filtering and visual odometry.

ada_utils: utility scripts for commanding boat from manual override joystick from laptop, configuration files and installer scripts

point_cloud_lib (pcl): formatting and processing toolkit for point cloud data

drivers for LIDAR, IMU, RGB-D camera

X. POLICY MEMORANDUM

We are seeing business behavior that is technically legal, but not socially and ecologically acceptable in terms of impact. At a time when our generation faces ecological, economic and values crises, some of the most essential tech in navigating the path ahead is not the smart driving system we outlined above — they are empathy and collaboration. I don't think we solve the climate change with taxes or radical changes in human behavior. I believe it will be solved with business ideas that make business sense.

We propose making the accounting practices of companies using autonomous transportation technology public to convince business leaders and policymakers that this business model is profitable and keeps carbon in the ground.

XI. REFERENCES

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