Establishing Smart Driving Systems for Riverways Using Computational Approaches

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I. INTRODUCTION

In this paper we present the boat design, technology stack and processing pipelines for a semi-autonomous boat. With its sensor kit the robot absorbs the world above and below the riverway and sends this data to its thrusters. The two main contributions of this study are to design suitable control laws for the robot's four predictive thrusters, on which collective algorithms for lane keeping, active cruise control and obstacle detection and avoidance can be assessed. The second is showcasing a customer facing business that blends old world traditions (Venetian water taxis) and the modern culture that characterizes Chicago (hospitality and autonomous technology).

II. WHAT'S 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 boat design, fabrication and implementation of the sensor kit. Section IV draws out what we need to do make the technology stack. Section V thru XI describe the processing pipelines. The field testing setup and results are unpacked in Section XII. Section XIII gives way to discussion and future work. To conclude the paper Section XIV and XV present the customer facing business and policy memorandum.

III. BOAT 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: (1) color camera, (2) 2D LiDAR sensors, (2) 24 GHz radar sensors, 1 sonar sensor and 1 IMU sensor.

Item	Price	Weight
Color Camera	$177	
(2) LIDAR		
(2) Radar		
Sonar		
IMU Sensor		
Mini Computer		
Micro Controller		
Wifi Adapter		
Mobile Beacon		
4 Thrusters	$500	
Solar Panel	$180	
Boat Design+		

IV. TECHNOLOGY STACK

Sensors + RDDF File //

Perception //

Planning & Control //

UI for Boat //

Global Services //

Our tech stack breaks sensor data pixel by pixel, into digital components for our processing pipeline.

V. PROCESSING PIPELINES OVERVIEW

We decouple the optimization problem into approximately 20 modules with 5 layers corresponding to the following functions shown in Sections VI thru XI.

VI. BOAT STATE ESTIMATION

Position (GPS)
Velocity
Orientation (IMU)
Accelerometer
Gyro Biases

VII. TERRAIN LABELING

+ Pre-processing methods

For short and medium range obstacle avoidance up to 30m in front.

VIII. DEEPER ANALYSIS WITH COMPUTER VISION

Project drivable area from terrain labeling analysis into the camera image, specifically a quadrilateral ahead of the boat in the laser map. An adaptive computer vision algorithm uses the pixels inside the quadrilateral as training examples to understand the concept of drivable surface. The adaptive algorithm maintains a mixture of gaussians that model the color of the drivable terrain. This ability to create new RGB gaussians on the fly means the boat's vision can adapt to new riverway conditions within seconds.

IX. WATER PROPERTY ESTIMATION

+ Riverway Boundary
+ Wave Ruggedness Index

Helps set the maximum speed of the boat to "throttle" the maximum shock imparted on the vehicle.

X. PATH PLANNING

+ "RDDF Smoothing"

The RDDF file provided make the need for global path planning less essential. We can now intelligently change the lateral offset, much like a car changes lanes on a highway.

XI. REAL TIME CONTROL OF THRUSTERS

+ Velocity
+ Steering

Once the intended path of the boat has been established by the path planner, the most efficient throttle, brake and steering commands to achieve that part are committed.

XII. FIELD TESTS & RESULTS

A. FIELD TEST SETUP

+ East Bank Club > Goose Island
+ River Use Characteristics
+ Perception of River
+ Demographics

B. BOAT STATE ESTIMATION

C. LASER MAP TERRAIN

D. COMPUTER VISION TERRAIN

E. RIVER PROPERTY ESTIMATION

F. PATH PLANNING

G. REAL TIME CONTROL

XIII. DISCUSSION & 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 interprets wave dynamics and offer eco-routing for immediate energy savings 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 and docking. Third, better rationing materials, especially metal and exploring alternative durable materials. And finally, creating an experience piloted by our smart driving system that could impress both a safety and sustainability commissioner.

XIV. 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 obstacle detection and avoidance) 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.

XV. 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 meet the terms of the Paris Climate agreement with taxes or radical changes in human behavior. I believe it will be solved with business ideas that make business sense.

+ Should Robots be Taxed?

XVI. ACKNOWLEDGMENTS

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