Establishing Autonomy on the Riverway Using Computational Approaches

Michael Valentino Ochoa (Updated: 1/31/20)

I. INTRODUCTION

In this paper we present the boat design, sensor kit and technology stack for an autonomous boat. With its sensor kit, the boat absorbs the world above and below the riverway and sends this data to four thrusters via our technology stack. The goal is for the boat to interpret riverway data in a way similar to how humans use their senses to relate to the world around them. (i.e. Where am I? Where is everyone else? How do I get from A to B?).

The two main contributions of this study are to design suitable control laws for four thrusters, on which collective algorithms for obstacle detection, lane keeping and active cruise control can be assessed. The second contribution is showing off a customer facing business that blends old world traditions (Venetian water taxis) and the modern culture that characterizes Chicago (hospitality and autonomous tech).

II. WHAT'S THE PROBLEM? WHY SHOULD I CARE?

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 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 for the Riverway Awareness and and Warning System (RAWS). Section V thru X describe the processing pipelines for (RAWS). The field testing setup and results are unpacked in Section XI. Section XII gives way to the discussion. To conclude Section XIII and XIV 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. Next, a mini computer, micro controller, wifi adapter, mobile beacon, thrusters and solar panel are added to the boat.

+
+
+
+
+
+
+ Fig. 1. Design & Sensor Kit
+

Finally, our detachable sensor kit is added to teach the boat interpret data in a way that is similar to the way human drivers use their senses to relate to the world around them. The sensor kit, made up of: (1) color camera, (2) 2D LiDAR sensors, (2) 24 GHz radar sensors, (1) sonar sensor and (1) Inertial Movement Unit (IMU) sensor allow the boat to localize itself to centimeter level precision.

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

IV. RIVERWAY AWARENESS AND WARNING SYSTEM (RAWS)

Sensors //

Perception //

Planning & Control //

User Interface for Human Driver //

Global Services //

Our technology stack breaks riverway sensor data into digital components for our processing pipelines. These pipes decouple the optimization problem into approximately 20 modules across six interconnected layers detailed in sections V thru XI.

V. BOAT STATE ESTIMATION

+ Where am I?

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

VI. RIVERWAY LABELING

+ Where is everyone else?

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

VII. DEEPER ANALYSIS WITH COMPUTER VISION

+ Where is everyone else?

+ How do I get from A to B?

VIII. WATER PROPERTY ESTIMATION

+ How do I get from A to B?

+ Riverway Boundaries
+ Wave Ruggedness Index

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

IX. PATH PLANNING

+ How do I get from A to B?

X. THRUSTERS ALGORITHM

+ How do I get from A to B?

+ Velocity
+ Steering

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

XI. FIELD TESTS & RESULTS

A. FIELD TEST SETUP

  + East Bank Club > WMS Boathouse
  + River Use Characteristics
  + Perception of River
  + Demographics

B. BOAT STATE ESTIMATION

C. RIVERWAY LABELING

D. DEEPER ANALYSIS WITH COMPUTER VISION

E. WATER PROPERTY ESTIMATION

F. PATH PLANNING

G. THRUSTERS ALGORITHM

H. SAFETY TESTING

XII. DISCUSSION & FUTURE WORK

In the paper we extend the capacity of an autonomous driving system to understand:

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

Our goal is to help prevent crashes, especially when boat drivers have limited visibility by providing detailed images of the surrounding riverway and triggering warnings for humans override. We run open water field tests to validate the efficiency and accuracy of RAWS and thrusters algorithm, which would not only help in deterring causes of mishaps but would also provide data that boat drivers could use to proactively improve autonomous safety practices.

In the future, our work will explore the following topics. First, incorporating a neural net that interprets wave dynamics and offers energy saving eco-routing for the four thrusters. We will achieve this by generating weak labels that help the neural net remember training data but not generalize new cases. This forces the neural net to collect more evidence rather than just fit a particular phenomenon to better label riverway dynamics. Second, exploring how to better understand how mass and drag change the thruster algorithm when transporting people and docking. Third, better rationing materials, especially metal and delving into alternative durable materials. And finally, creating an experience piloted by our smart driving system that could impress both a safety and sustainability commissioner.

XIII. 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.

By targeting public transit's weaknesses — an uncomfortable and sometimes inhospitable image — a clever startup with right strategy, the right message and the right product could create a new riverway transit brand for the new decade.

Our narrow focus is on being public transit that prepares people to take on the city, a kind home-away-from-home on the river. We feel this approach best positions our business for contract work with autonomy giants, etc. We believe in letting water our robotaxis do what they do best (i.e. obstacle detection, lane keeping and active cruise control) and letting humans do what we do best (i.e. being the social and hospitable animals we are).

XIV.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 autonomous boat 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. Our bet is it will be solved with business ideas that make business sense to the community using them.

+ Brief description of policy recommendation.
+ How might it work?
+ Why status quo isn't working?

XV. REFERENCES

A.R. Girard, J.B. Sousa and J.K. Hedrick, "Dynamic positioning concepts and strategies for mobile offshore base," in ITSC 2001. *2001 IEEE Intelligent Transportation Systems*

G.E. Hinton et la., "Improving Neural Networks by Preventing Co-Adaption of Feature Detectors," eprint arXiv: 1207.0580, July 2012

Sebastian Thurn et la., "Stanley: The Robot that won the DARPA Grand Challenge," in *Journal of Robotic Systems*, September 2006

W. Wang, L. A. Mateos, S. Park, P. Leoni, B. Gheneti, F. Durate, C. Ratti and D. Rus, "Design, modeling and nonlinear model predictive tracking control of a novel autonomous surface vehicle," in *2018 IEEE International Conference on Robotics and Automation (ICRA)*, May 2018, pp. 1-5.