Establishing Smart Driving Systems for Riverways Using Computational Approaches

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I. INTRODUCTION

This paper presents the sensor kit, tech stack and customer facing business for a smart driving system. We believe in letting machines do what they do best (e.g. lane keeping, active cruise control and obstacles avoidance with predictive thrusters) and letting humans do what we do best (e.g. be social and hospitable animals we are). One of the main contributions of this study is to showcase an accurate predictive thruster algorithm with less than 1ms of latency specialized to run on Chicago's riverways.

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. 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 boat and its sensor kit. Section IV describes the tech stack and methods for identifying unknown parameters. Section V formulates the processing pipelines and predictive thrusters strategy. The field testing setup and results are unpacked in Section VI. Section VII gives way to a conclusion. To conclude the paper Section VII, IX and X present the customer facing business application, software packages and policy memorandum.

III. PROTOTYPE DESIGN & SENSOR KIT

Our prototype vessel (approximately 1:8) is shaped for maneuverability to quickly adapt to urban riverway scenarios. A rectangular shape was chosen with its dimensions being approximately .9m x .45m x .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, we add a warning light and horn, with additional safety updates to follow.

The sensor kit helps the smart driving system interpret data in a way that is similar to the way humans use their senses to relate to the world around them. The boat localizes itself with centimeter level precision by relying on: RGB-D cameras, LiDAR, thermal radars, sonar radars, IMU sensors and GPS. Then we merge these data streams together pixel-by-pixel into digital components that summarize the riverway as texture mapped 3D models. This dynamic model helps the boat and humans interpret the world above and below the water to find the most fuel efficient routes for the thrusters.

IV. TECH STACK

Application //
Driver Assistance Software

Hardware & Software //
Sensor Fusion + Mapping

Compute //
CPU / GPU / CUSTOM

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

To ensure real-time performance of lane keeping, active cruise control and obstacle avoidance along a pre-planned route 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 a processing pipeline that finds the most energy efficient thruster routes. The human-computer system runs on the Robotic Operating System (ROS) and a human safety driver with manual override for the boat. The drive mode for this prototype is guided by four thrusters along with a 40 watt solar panel for power.

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 consists of multiple layers that decouple the optimization problem and make it more easily tractable. The multiple pipelines outlined in Sections A, B, C and D consider both discrete and continuous time. Generally speaking, the processing pipeline involves two sliding surfaces. The first defines the desired vessel position and orientation, and the second layer defines the efficient thruster velocity needed to drive the boat along the preplanned route.

A. BOAT DYNAMICS

The IMU sensor collects 3 axis angular velocity data (sway, yaw, surge) and adds them to the pipeline.

B. CLUSTERING & CONTOUR TRACKING

The sixteen beam LIDAR measures the relative position of obstacles within the sensors range, and is coupled with Euclidean clustering and contour tracking algorithms as a processing pipeline for accurate estimation of static and dynamic obstacles in the distance.

C. TRAJECTORY TRACKING
The goal of the trajectory tracking problem is to design suitable control laws for the four thrusters forces that drive the error rate of selected variables to zero.

D. PREDICTIVE THRUSTERS STRATEGY

VI. EXPERIMENTS & RESULTS

A. FIELD TESTING SETUP

B. HYDRODYNAMIC PARAMETER IDENTIFICATION

C. TRACKING RESULTS

VII. CONCLUSION & FUTURE WORK

In the paper we show how to extend the capacity of a smart driving system 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 thew way similar to the ay humans use their senses to relate to the world around them. We run field test to validate the efficiency and accuracy of the predictive thruster strategy, which will be essential to establishing more advanced riverway autonomy tasks.

In the future, our work will be explore the following topics. First, incorporating a neural net to assist with interpreting wave dynamics to find the most fuel efficient routes for the predictive thrusters. Second, ###############. The long term goal is to create an experience piloted by our system that is so comfortable that it 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. The challenge has focused on engineering. But as the technology nears deployment, trying to work out how to build services in a new regulatory environment will be the next phase.

Our narrow focus is on bringing hospitable services to populations along Chicago's rivers. We believe this best positions our business for contract work with autonomy giants, etc. The customer facing business starts simple with a scale model boat, basic delivery services and a mobile app designed for Chicago's riverway communities. This gets us on the river so we can perfect our engineering systems and find the ideal business case and create an experience.

IX. POLICY MEMORANDUM

We are seeing business behavior that is technically legal, but not socially acceptable in terms of impact. That in mind, let's establish how the profits that will accrue from increasing automation could be redirected back into society. We propose a tax on semi-autonomous vehicles along the riverway between 6am — 10pm. We believe our approach will create jobs that keep carbon in the ground.

X. SOFTWARE PACKAGES

A. Perception

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

XI. REFERENCES

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