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).
By integrating a sensor kit and tech stack into a smart driving system we demonstrate accurate trajectory tracking along preplanned open water routes. One of the main contributions of this study is to showcase a predictive thruster algorithm with less than 1 ms 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. We believe 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 describes the tech stack and methods for identifying unknown parameters in the model. 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 boat is shaped rectangularly for maneuverability withs 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. Finally, we add a warning light and horn, with additional safety updates to follow.

Our 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 radar, sonar radar, IMU sensors and GPS. We then merge these data streams together into digital components that summarize the riverway as texture mapped 3D models. This 3D model helps the smart driving system find the most energy efficient routes for the thrusters.

IV. TECH STACK

Application //
Driver Assistance Software

Hardware & Software //
Sensor Fusion + Mapping

Computations //
CPU / GPU

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 routes for 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. The drive mode for this prototype is guided by four thrusters along with a 40 watt solar panel.

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. Generally speaking the processing pipeline outlined in sections A, B, C and D 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?

The dynamics of this smart driving system can be described by the equations outlined below:

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, 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 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 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 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, better understanding how the mass and drag change when transporting people and goods. 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 the upcoming mega developments on the Chicago River's north and south branches. We believe this best positions our business for contract work with autonomy giants,

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

IX. REFERENCES

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