Establishing L2+ Autonomy on the Riverway Using Computational Approaches

Michael Valentino Ochoa (Updated: 1/6/20)

I. ABSTRACT

Generally speaking, we are extending the capacity of a system to understand: Where am I? Where is everyone else? And how do I get from A to B?

In this paper, we present the sensor kit, processing pipelines and system designs for a L2+ autonomous water robotaxi. Our sensor kit absorbs the world above and below the riverway to formulate a dynamic model. The goal of the system is for its processing pipelines to establish energy efficient thruster routes for four predictive thrusters used for >> lane keeping, active cruise control, trajectory tracking and obstacle avoidance.

Our goal is to combine a human safety driver with the rational analytics of a computer to establish L2+ level autonomy on the riverway. We believe the future belongs to the people who can best partner and collaborate with computers.

II. WHAT IS THE MOTIVATION?

Existing infrastructure cannot support another generation of gas guzzling vehicles. The number of hours we've lost to traffic delay, the costs of gridlock and fuel wasted in stalled traffic are not sustainable. The age of autonomy will bring new form of traffic jams, but less so on the riverway if we plan for it.

III. HOW DO WE SOLVE THIS PROBLEM?

To leapfrog some of our archaic transit paradigms we draw upon hospitality, engineering and design. We deploy a human-computer system made of up of a L2+ autonomous water robotaxi & human safety driver. Our system blends the rational analytics of a computer integrating inertial, optical and thermal data with human guidance, judgment, intuition, empathy and moral compass. We believe in letting machines do what they do best (lane keeping, active cruise control, trajectory tracking and obstacle avoidance along a pre-planned route) and letting humans do what we do best (be the social clever and hospitable animals we are). Our focus on human-computer systems means our system does more than provide convenient transit, it's a space that prepares you to take on the city — a home-away-from-home on the river.

IV. SYSTEMS DESIGN: HULL FABRICATION

We draw out what we need to do to make the system work:

— Hull Diagram

Our scale model (approximately 1:8) vertically integrated riverway transit service is currently shaped for maneuverability in urban riverway scenarios with speed and steadiness in rough waters a future area of research interest. A rectangular shape was chosen for the prototype and is 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 20 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, horn and leak sensor, with additional safety updates to follow.

V. SYSTEMS DESIGN: SENSOR KIT & THRUSTERS

— Diagram of system

To ensure real-time performance of lane keeping, active cruise control, trajectory tracking 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 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 water robotaxi. The drive mode for this prototype is guided by four thrusters along with a 40 watt solar panel for power.

To make its way thru urban waterways the boat localizes itself with centimeter level precision. To achieve this our sensor kit relies on LIDAR, RGB-D camera, thermal camera, sonar, IMU and GPS. 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. Next the data from a RGB-D camera, thermal camera and GPS data are folded into the processing pipeline. Finally, the IMU sensor collects 3 axis angular velocity data (sway, yaw, surge) and adds them to the pipeline. To bring it home, these sensory data pipelines are broken pixel-by-pixel into digital components for an energy efficient thruster allocation scheme for an open water route.

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

Horn		
Leak Sensor		

VI. CLUSTERING & CONTOUR TRACKING: PIPELINE 1

VII. TRAJECTORY OPTIMIZATION: PIPELINE 2

VIII. BOAT DYNAMICS IDENTIFICATION: PIPELINE 3

IX. CONTROL ACTION OF THRUSTERS ("DIGITAL SENSORY ARTICULATOR")

The processing pipelines break sensory data, pixel by pixel, into manipulatable digital components as "wave dynamic textures" for the four thrusters to better plan energy efficient routes.

The control architecture consists of multiple layers that decouple the optimization problem and make it more easily tractable. Our multiple layer architecture also considers both discrete and continuous time. The lower layers interact directly with the sensor kit for dynamic positioning, thruster allocation strategy, sensor data processing and fault detection monitoring. Whereas, the middle layers are used for the safe execution of basic maneuvers. While the highest layer is a human supervisory layer that, assists with manual override for tricky maneuvers, safety, etc.

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 robotaxi along the preplanned route.

— Miscellaneous Math

XI. FIELD TESTS & RESULTS

A. FIELD TEST SETUP

B. RESULTS

XI. CUSTOMER FACING BUSINESS

We recognize there is an immense amount of noise in the autonomous transit industry, so we aim to master the things we understand. Our narrow focus is on brining hospitable services to L2+ level autonomous robotaxis specialized to run on Chicago's rivers. We believe this best positions our business for contract work with autonomy giants, etc. By starting simple with convenient transit stops, delivery services and mobile app designed for Chicago riverway communities we can better outmaneuver bigger rivals as the autonomous transit industry shifts from perfecting its systems to finding the ideal business cases. We believe the next phase of the digital revolution will come from businesses that link beauty to engineering and hospitable service to running code.

— Conceptual Rendering

XII. CONCLUSION & FUTURE

This paper presents the sensor kit, processing pipelines and system designs for a L2+ autonomous water robotaxi. Our proof of concept (approximately 1:8) is easy to fabricate, less than $xxxx and capable of lane keeping, active cruise control, trajectory tracking and obstacle avoidance in open water environments. We run field tests to validate the efficiency and accuracy of the proposed thruster strategy, which will be essential to establishing more advanced autonomy tasks. The long term goal is to create an experience piloted by our hybrid system that is so comfortable that it could impress a safety commissioner.

In the future, our research will explore multiple topics. First, better acknowledging how our four thrusters handle the changing mass and drag brought on by transporting people and goods along the riverway. Second, better addressing the wave disturbances that exist on the open water so less people get seasick. Third, establishing a latching system that enables boats to link and join with each other and riverway docks. And finally, documenting the system architecture, design and requirements needed for a teleoperation kit that control multiple water robotaxis with one human monitoring from a distance.

XIIV. SOFTWARE PACKAGES

A. Perception

ada_autonomy: filters LIDAR 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 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

B. Trajectory Optimization

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C. "Digital Sensory Articulator"

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XIV. APPENDIX: POLICY MEMORANDUM

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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 accrue from increasing automation could be redirected back into society. Lets creatively and humanely deploy hospitable humans to the rivers to show how our business is interested in managing the consequences of automation. We propose a tax on L2+ autonomous vehicles along the riverway within a downtown zone between 6am — 10pm. We believe our approach will create jobs that keep carbon in the ground and surprise many of the climate change pessimists.

XII. REFERENCES

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.

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*

D. Swaroop, J.K. Hedrick, P.P. Yip and J.C. Guerdes, "Dynamic Surface Control of Nonlinear Systems", *in Proc. Of the 1997 American Control Conference,* Albuquerque, New Mexico, 1997.

D. Chevitarese, D. Szwarcman, R. Mozart D. Silva and Emilio Vital Brazil, "Seismic Facies Segmentation Using Deep Learning" AAPG Annual Convention & Exhibition, Salt Lake City, Utah (2018)