Establishing a "Driverless System" Along the Riverway Using Human-Machine Symbiosis

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I. ABSTRACT

In this paper, we present the design, sensor kit and processing pipelines for a "driverless system". Generally speaking, we are extending the capacity of a hybrid system (of human safety driver coupled with water robotaxi) to understand: Where am I? Where is everyone else? And how do I get from A to B? Our sensor kit absorbs the world above and below the riverway to formulate a dynamic model. Based on this model the robotaxi designs suitable efficient control laws for its four predictive thrusters to match changing hydrodynamic parameters. To determine the control action of thrusters it solves an open-loop optimal control problem. The robotaxi's objective is learn suitable control laws for: lane keeping, obstacle avoidance, trajectory tracking and active cruise control along preplanned open water routes. We believe a human safety driver combined with the rational analytics of a computer will help both get smarter together.

II. WHAT IS THE PROBLEM?

As Earth's cities become filled with smog and traffic jams, new solutions must surface to solve our global transit challenge. Existing infrastructure cannot support another generation of gas guzzling vehicles on the roads. The lost time, wasted fuel and climbing costs of doing business are not sustainable. We must begin chipping away at this problem. To solve some of this challenge will require "incentivizing" water taxi services.

III. HOW DO WE SOLVE THE PROBLEM?

To leapfrog some of the archaic transit paradigms established we draw upon engineering, hospitality and urban economics to solve some of our global transit challenge.

We deploy a "hybrid system" made up of a robotaxi & human safety driver to chip away at this challenge. The "hybrid system" blends the rational analytics of a computer integrating inertial, optical and thermal data with human strategic guidance. The goal is to optimize collaboration between both. We believe in letting machines do what they do best (lane keeping, obstacle avoidance, trajectory tracking and active cruise control), and lettings humans do what we do best (be the social and hospitable animals we are). Our narrow focus on blending autonomy with hospitality means our transit does more than provide convenience, it's a space that prepares you to take on the city — a kind of home-away-from-home on the river.

IV. PROTOTYPE DESIGN & FABRICATION

Our scale model (approximately 1:8) "hybrid" water taxi:

RENDERINGS 1

A rectangular shape was chosen to accommodate two horseshoe shaped booths described in Section XI. Our prototype is approximately (0.9m x 0.45m x .15m). We 3D-print as its proven to be a swift, solid and low cost method for prototyping. We machines the hull from 16 separate pieces (inspired by the "architectural ornaments" of Louis Sullivan). The pieces are then married together by bolts, plastic O-rings and several layers of fiberglass. Next we add a warning light, horn and leak sensor for safety, with additional updates to follow.

V. "WATERWAY WHISKERS" (AKA SENSOR KIT)

To ensure the real-time performance of lane keeping, obstacle avoidance, trajectory tracking and active cruise control along pre-planned open water routes our "driverless" water robotaxi uses a Gigabyte Mini PC (Intel Core i7-6500U) with 32 GB of memory running Ubuntu 16.04 as the main controller. While, a 32-bit micro-controller gathers GPS and IMU data and sends it to a processing pipeline that fine tunes the control action of thrusters. The drive mode is guided by four thrusters and the power supply, for now, a rechargeable battery. Diversified sensors, including real-time GPS, IMU, thermal radar, depth camera and voltage sensor are also installed aboard. All together the

”driverless system” runs on the Robotic Operating System (ROS) coupled with a human safety driver that sits idle at the helm of manual override wheel as the robotaxi navigates its planned route.

ISOMETRIC VIEW RENDING

VI. BOAT DYNAMICS ESTIMATION

Following in the footstep of other academics the current state estimation can be generally described by a nonlinear differential equation.

VII. WATER PROPERTY ESTIMATION

VIII. PROCESSING PIPELINE: TRAJECTORY TRACKING

IX. PROCESSING PIPELINE: CONTROL ACTION OF THRUSTERS

Our control architecture consists on multiple layers that decouple the optimization problems and make the problem tractable. Our layer layers interact with sensors and actuators to produce desired position and tracking performance, and our higher layers are used for maneuver coordination, fault identification and tracking performance. Our three layer control architecture `considers both discrete and continuous time and is built upon human supervisory layer (to minimize fuel consumption and assist with manual override for trickier maneuvers, etc.). Additional layers include a coordination layer (for safe execution of basic maneuvers and event management) and a stability control layer (interfaces directly with hardware and contains dynamic positioning algorithm, sensor data processing, fault detection monitoring and signals changes in environmental conditions).

Generally speaking, the processing pipelines outlined in sections VIII and XI involves two “sliding surfaces”. The first surfaces defines the desired vessel position and orientation, and the second defines desired velocity, if maintained to drive vessel to desired position (i.e. L2+ autonomy).

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X. FIELD TESTING & RESULTS

A. FIELD TESTING SETUP

B. RESULTS: HYDRODYNAMIC PARAMETER IDENTIFICATION

C. RESULTS: TRAJECTORY TRACKING

D. SAFETY TESTING

XI. $$$ CUSTOMER FACING BUSINESS

Long lasting businesses require three things: a great idea, the engineering talent to execute and the business savvy to turn into a successful service/product.

We recognize there's an immense amount of noise in the autonomous transit industry, so we aim to master the things we understand. Our narrow focus is on building "waterway whisker kits" — plug and play hardware and software — for custom built venetian style water taxis. We believe a "hybrid system" of hospitable service paired with robotaxis specialized to run on Chicago's rivers best positions our service/product for contract work with autonomy giants, etc.

By constraining our technology problem to Chicago river ways we target an environment that has a clear and distinct need for mobility. We're going to start simple with a few stops and delivery services for communities along the North Branch of the Chicago River. Our belief is that by starting simple we can speed up our ability to expand and outmaneuver bigger rivals as the autonomy industry shifts from perfecting its systems to finding the ideal business case.

CONCEPTUAL RENDERING

XII. CONCLUSIONS & FUTURE

This paper presents the body design, "whisker" sensor kit and processing pipeline for a "driverless" water robotaxi. Our proof of concept is easy to manufacture, omni-directional and capable of: lane keeping, obstacle avoidance, trajectory tracking and active cruise control in open water environments. We run field tests to validate this efficiency and accuracy of the proposed thruster strategy, which will be essential for accomplishing advanced autonomy tasks.

In the future, our research will explore multiple topics. First, better acknowledging the changing mass and drag brought on by transporting people and goods the along the riverway. Second, better addressing the wave disturbances that exist in open water. Third, presenting a latching system that enables boats to link and join with each other and riverway docks. Our goal is to create an experience piloted by a "driverless" system that is so comfortable that it could impress a safety commissioner.

XIII. REFERENCES

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XIV. APPENDIX: POLICY MEMORANDUM (DRAFT 1)

We propose a tax on "driverless services" along the riverway within a downtown zone between 6am — 10pm.

How will the profits from that accrue from increasing automation be redirected back into society to benefit riverway communities?

— Why status quo isn't working?
— Anticipate opposition.
— Offer my recommendation