

OPENPODCAR v2: HARDWARE AND SOFTWARE FOR HUMAN-ROBOT INTERACTIONS

RAKSHIT SONI, CHRIS WALTHAM AND CHARLES FOX

SCHOOL OF COMPUTER SCIENCE, UNIVERSITY OF LINCOLN, UK

ABSTRACT

Self-driving cars and autonomous last-mile delivery vehicles must exhibit social intelligence to manoeuvre in human social areas. One of the key areas that demands robust solutions is the deployment of autonomous vehicles in the real world in critical scenarios. University of Lincoln's open-source hardware vehicle, OpenPodCar is an AV based on ROS1 for autonomous operation and SVMs and Bayes tracking for the detection tasks which are now out-dated. As more robust detection neural-network approaches involving segmentation tasks achieve promising results, it is necessary to develop a more sturdy version of the OpenPodCar including an updated PCB control system, ROS2 based navigation and path planning, and deployment of deep neural network-based visual and multisensory perception (visual and LiDAR) for pedestrian detection and tracking.

PRACTICAL TRIALS

OpenPodCar has previously driven autonomously around Lincoln campus, including interacting with members of the public under suitable health and safety procedures. We want to scale up these trials to larger runs and more complex interactions.



New experimental protocols for the practical trials need to be designed and run to test new game theoretic actions based on the new perception and action systems. They must also be completely safe.

OPEN-SOURCE HARDWARE PCB UPDATE

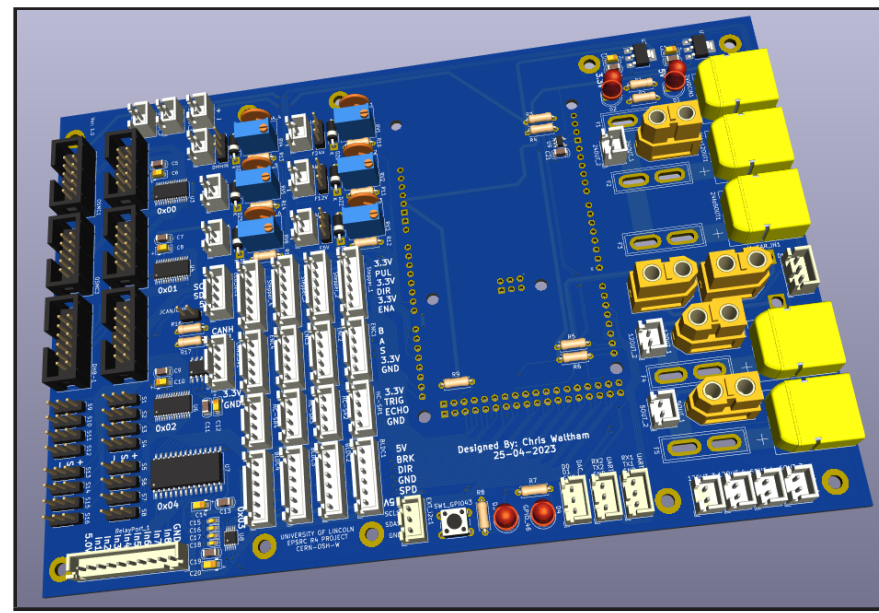


Figure 1: OSH PCB

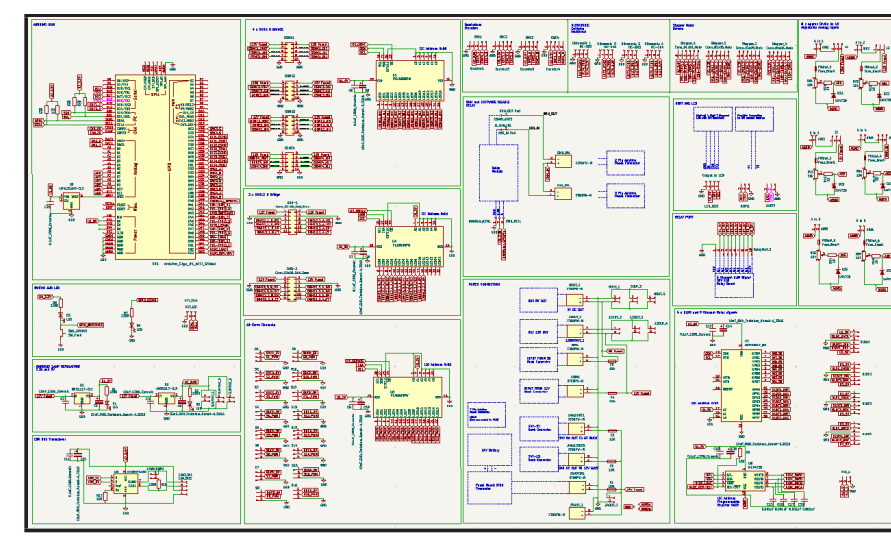


Figure 2: Schematic

OpenPodCar v1 is based on a mobility scooter

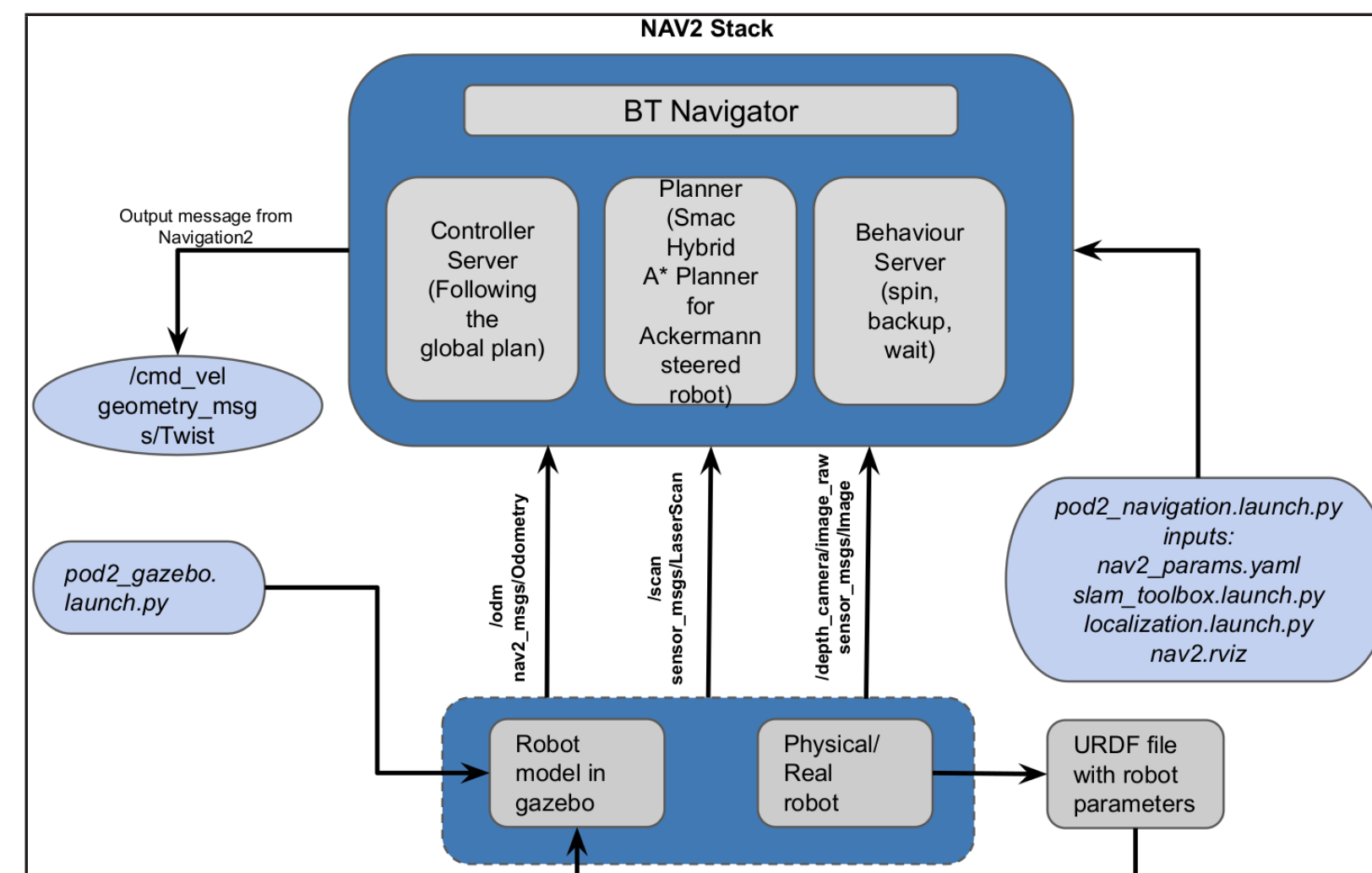
donor vehicle, extended with a custom open source hardware PCB which intercepts and modifies the vehicle's control signals and links them to ROS1. We are extending this PCB to a general-purpose PCB which acts as a large, robust, Arduino shield suitable for interfacing ROS to *any* medium sized robots based on standard OSH motor drivers – including open hardware delivery, agricultural, and arm robots.

PEDESTRIAN DETECTION AND TRACKING UPDATE

Onboard object detection and tracking demand accuracy but low-power computation, for which one-stage or end-to-end DNN based methods such as YOLOv3/5 can be used for baseline testing. However, in real-time, data may come from previously unseen domains which can confuse the detector and could lead to degradation of performance. To encounter this, we plan to modify the existing baseline architectures based on the approach of recent study of domain generalization which gained promising results over Out-of-domain (OOD) data. Recent work of DG-FCOS and DG-FRCNN has shown strong outcomes (Seemakurthy&al., ICRA 2023) which gives the room to inherit this notion for real-time purposes. Mask-RCNN might be similarly domain-generalised to enable pose tracking.



ROS2 STACK UPDATE

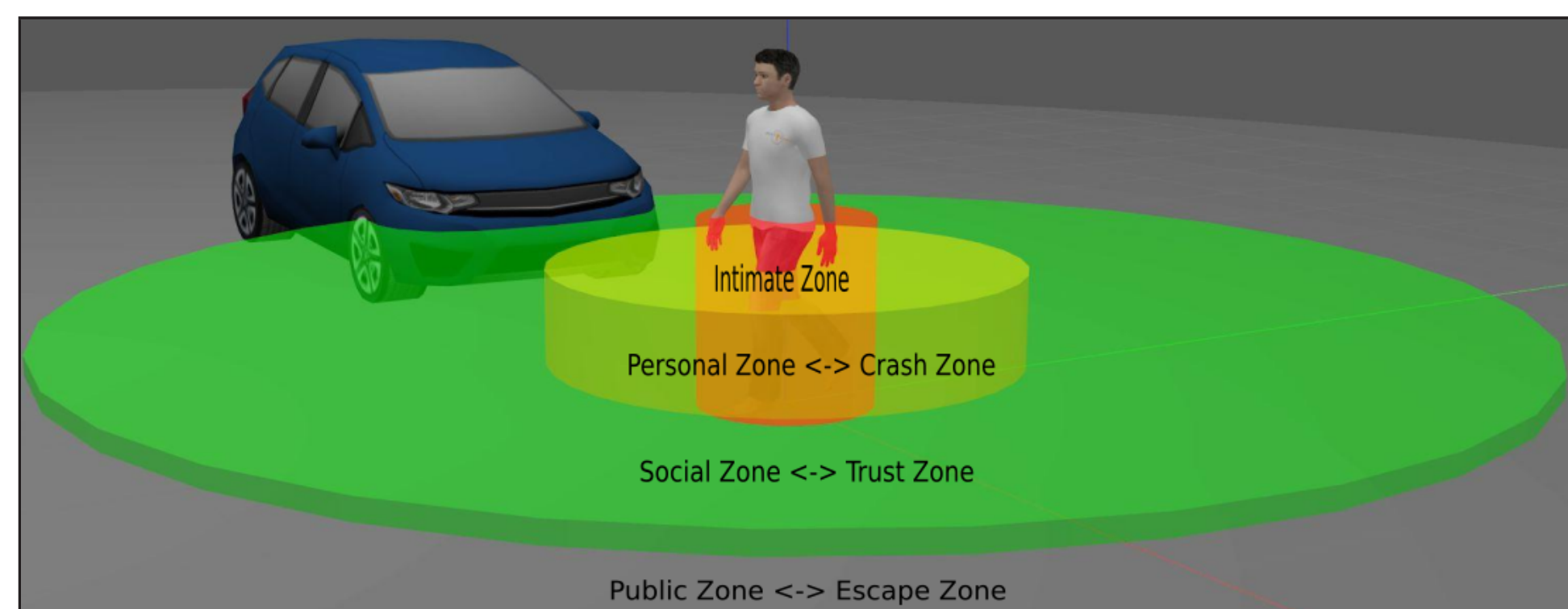


ROS2 features more flexibility with real-time performance and a new navigation stack (NAV2) architecture providing newly developed path planners and controllers for Ackermann-steered robots and vehicles. For mapping and localization, *slam_toolbox* adds new functionality.

ROS2 Ackermann control package: Robots may feature numerous types of controls namely; Differen-

tial drive control for two-wheeled, 4-wheeled drive, skid-steer drive, holonomic. However, most cars and other vehicles are equipped with Ackermann steered mechanism in which both front wheels of the car at the time of turning approach at different steering angles in order to minimize the slippage. In practice, the outer wheel turns at a smaller angle while the inner wheel turns at a larger angle. Navigation is one of the critical operation for any robot and ROS2 is featured with new packages and more structured way of implementing algorithms. Global Planners are used to compute the shortest path for the robot in the environment. New planners which support Ackermann and legged-robots are introduced namely; Smac Hybrid A* Planner, it supports Dubin and Reeds-Shepp motion models while controllers (local planner in ROS1) are used to follow the global plan and for obstacle avoidance.

NEW GAME THEORY INTERACTION MODELS



Previous work (Fox&al,2018) has shown that pedestrian interactions with autonomous vehicles can be modelled using the 'game of chicken' from game theory. In its basic form this requires the vehicle to maintain a small but deliberately non-zero probability of collision with pedestrians in order to avoid the 'freezing robot problem'. However it also shows that collisions can be replaced with more frequent but less severe threats, such as causing discomfort by invasion of personal space. To enable this, new

work needs to address:

- The chicken model is currently quantised, but real life and ROS are continuous. Need to create ROS2 interfaces which real-time quantise real life sensors to format of the game theory model.
- Estimates of the utilities involved in space invasion are available (Camara&Fox, IJSR 2021), these need to be integrated into the chicken model.
- Our previous models have been discussed with the Department of Transport and cited in the Law Commission's (2018) now-implemented recommendations to change UK law on autonomous vehicles. Future models may have similar impact whose policy implications need to be considered.

REFERENCES

- Fox, Camara, Markkula, Romano, Madigan, & Merat. When should the chicken cross the road?: Game theory for autonomous vehicle - human interactions. Proc. VEHITS 2018.
- Camara, Romano, Markkula, Madigan, Merat, & Fox. Empirical game theory of pedestrian interaction for autonomous vehicles. Proc. Measuring Behavior 2018.
- Camara, Cosar, Bellotto, Merat, & Fox. Towards pedestrian-AV interaction: method for elucidating pedestrian preferences. IROS Workshop Towards Intelligent Social Robots, 2018.
- Camara, Giles, Madigan, Rothmüller, Rasmussen, Vendelbo-Larsen, Markkula, Lee, Garach, Merat, & Fox. Predicting pedestrian road-crossing assertiveness for autonomous vehicle control. Proc. ITSC, 2018.
- Law Commission. "Automated vehicles: a joint preliminary consultation paper." Law Commission Consultation Paper 240, 2018.
- Camara, Merat & Fox. A heuristic model for pedestrian intention estimation. IEEE Intelligent Transportation Systems Conference, 2019.
- Camara, Dickinson, Merat, & Fox. Examining pedestrian-autonomous vehicles interactions in Virtual Reality. Transport Research Arena 2020.
- Camara, Cosar, Bellotto, Merat, & Fox. Continuous game theory pedestrian modelling method for AVs. Human Factors in Intelligent Vehicles. River Publishers, 2020.
- Camara, Bellotto, Cosar, Nathanael, Althoff, Wu, Ruenz, Dietrich & Fox. Pedestrian Models for Autonomous Driving Part I, IEEE T-ITS, 22(10):6131-6151, 2021.
- Camara, Bellotto, Cosar, Weber, Nathanael, Althoff, Wu, Ruenz, Dietrich, Markkula, Schieben, Tango, Merat & Fox. Pedestrian Models for Autonomous Driving Part II: High-Level Models of Human Behavior, IEEE T-ITS 22(9):5453-5472, 2021.
- Camara, Dickinson & Fox. Evaluating pedestrian interaction preferences with a game theoretic autonomous vehicle in virtual reality, TRF 78:410-423, 2021.
- Camara & Fox. Space Invaders: Pedestrian Proxemic Utility Functions and Trust Zones for Autonomous Vehicle Interactions. Int J. Social Robotics 13:1929-1949, 2021.
- Camara & Fox. Extending Quantitative Proxemics and Trust to HRI. IEEE RO-MAN 2022.
- Camara & Fox. Game Theory, Proxemics and Trust for Self-Driving Car Social Navigation. ICRA Workshop on Social Robot Navigation: Advances and Evaluation, 2022.
- Seemakurthy, Bosilj, Aptoula, & Fox. Domain Generalised Fully Convolutional One Stage Detection. ICRA, 2023.
- Camara, Waltham, Churchill & Fox. OpenPodcar: An Open Source Vehicle For Self-Driving Car Research. arxiv.org/abs/2205.04454v1