International Journal of Artificial Intelligence and Machine Learning
Volume 10 • Issue 1 • January-June 2020

Autonomous Last Mile Shuttle ISEAUTO for Education and Research

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ABSTRACT

The article introduces an educational and research project ISEAUTO, targeted to using self-driving cars to solve urban mobility issues. The project focusses on the design and development of an autonomous shuttle as a collaboration between academic staff of the university, students, and a partner company. The article presents an account of the experience of developing vehicle from scratch in one year using a stock electric vehicle, widely available sensors and open source software. Technical solutions based on the latest trends in autonomous mobility are conferred, special attention is given to control and software architectures. In addition to reaching the goal of making the shuttle drive autonomously by the end of the first year of the project, it was possible to combine various tasks with teaching and award more than 460 ECTS to participating students. The project continues and a commercial version of the vehicle is in development.

KEYWORDS

Autonomous Vehicle, Autonomous Shuttle, Autoware, Freertos, ROS, Self-Driving Car, Simulation, Urban Mobility

1. INTRODUCTION

The fast development of sensor and communication technologies together with available open source software supporting vehicle autonomy as implementations of recent results in AI research has given rise to a wave of new autonomous vehicles (AV) being developed around the world (Burnett et al., 2019). The current paper presents an account of developing an autonomous last mile shuttle within 1 year starting in the Summer of 2017 and the follow up developments during year 2. The general expectations to autonomous vehicles are the ability to cover long distances in a safer way, i.e. decreasing the rate of accidents and traffic jams while providing convenient transport to ever increasing number of passengers. In the foreseeable future the autonomous vehicles are expected to share public roads with vehicles driven by human drivers, so the software for autonomy needs to have a good representation of both the traffic regulations and best practices of traffic. There are more than 10 trillion automobile kilometers driven each year worldwide, with complex and novel conditions

DOI: 10.4018/IJAIML.2020010102

generating millions of situations in which AV could fail (Daily et al., 2017). The control software of an autonomous vehicle needs to take into account road markings, traffic signs and lights, other vehicles, pedestrians, cyclists and other forms of transport on the road, while being able to cope with missing information, i.e. damaged road markings and being able to cope in congestions. Autonomous driving technology has already prominently reduced the accidents caused by human error or choice such as impaired driving, distraction, and speeding or illegal maneuvers which caused 94 percent of crashes in the US in 2017 (Automated Vehicles 3.0 Preparing for the Future of Transportation US Department of Transportation, 2018). There are still many challenges in solving autonomous driving in general because of the large number of edge cases and small permissible error margins in the real world, but there are active efforts to collect relevant data and use that towards solving the remaining problems (Fridman et al., 2019). In addition, the autonomous vehicles should be able to handle adverse driving conditions, such as rain, wet and icy roads (depending on the geographic location), the control algorithm must be able to recognize roads within a tolerable margin of error, using measuring instruments, such as cameras, lidars assisted by inertial measurements and GNSS. The autonomous vehicle software is expected to make quick decisions based on incomplete information in situations not necessarily foreseen at the time of development (Goodall, 2016).

In order to be able to develop software that is able to support autonomy it is important to be able to test it in a wide variety of situations. An important step in that direction was taken in Germany in 2017 (Daily et al., 2017), when German legislators defined the legal framework for allowing self-driving vehicles on public roads, as long as a human driver is at the controls to take over in critical situations. Similar laws are applied in the US (California and Nevada) (Greenblatt, 2016) and many other countries. Estonia has allowed the testing of self-driving cars on public roads also in 2017 by allowing an AV into the traffic for a limited testing period after completing a simple permit application procedure (Estonian Road Administration, 2017). China laid out national guidelines for testing self-driving cars in April 2018 when Beijing, Chongqing, Shenzhen, and Guangzhou, in addition to Shanghai opened their city roads to AV testing. Traffic can be as unpredictable as the weather and being able to respond to both means navigating countless scenarios. To fully test all possible scenarios in the real world by simply driving around is impossible and achieving a significant coverage of different situations may well take millions of kilometers. Therefore, computer simulations and mathematical modeling need to be incorporated into the development loop (Coelingh et al., 2018).

The current paper describes a project where a self driving last mile autonomous shuttle called ISEAUTO was developed. The project took place at the Tallinn University of Technology in cooperation with an Estonian automotive company Silberauto Estonia. The autonomous shuttle ISEAUTO is a research and educational platform targeted towards the design and development of self-driving vehicles in cooperation with a private company, university researchers and students.

The current paper is an extended and updated version of the conference publication (Sell et al., 2018).

2. SIMILAR PROJECTS

The computerisation of driving can be traced back to the 1970s, with the introduction of electronic anti-lock brakes. Today more advanced features like automated steering, acceleration and emergency braking are emerging every year. (Goodall, 2016). There are a huge number of automotive and technology companies worldwide working on self-driving car projects, such as e.g. Volkswagen, BMW, Hyundai Motors, Audi, Ford, General Motors, Honda, Mercedes, Nissan, NVidia, Tesla, Toyota, etc. It is interesting to note that large technology companies, including Google, Apple, and Uber, are seeking to become key players in this market even though their history is not directly tied to the production of cars (Montgomery, 2015).

Several Asian countries are making significant contributions to the field: in Japan, automakers are working together to make self-driving cars a reality in time for the 2020 Tokyo Olympics (Daily et al., 2017). Tata and Mahindra in India, which is one of the larger markets, are making progress in developing market-viable automated driving technologies that are relevant to local conditions, with initial deployments and expansion in farming and mining applications. In Europe, several significant autonomous vehicle research efforts, such as Eureka PROMETHEUS Project (1987–1995) (Daily et al., 2017), have been underway since the 1980s which laid the foundations for the autonomous vehicle technology. In the US, according to the Society of Automotive Engineers (SAE), autonomy level 2 systems (that is, partial automation where humans are still responsible) are available from a number of automotive manufacturers, e.g. Tesla Autopilot, Volvo Pilot Assist, Mercedes-Benz Drive Pilot, Cadillac Super Cruise.

The rapid development of affordable high-quality sensors in the optical, radar and LiDAR (light detection and ranging) domains has, with the help of a variety of algorithms including of deep neural nets, to recognize objects with improved detection accuracy and fewer false-positives (Daily et al., 2017; Goodall, 2016). 3D imaging systems allow the AVs to track their surroundings and stop in case other road users occur on the planned path. LiDARs are key sensors for autonomous vehicles because they provide precise and robust 3D point clouds across a wide range of conditions allowing the data to be used for both localisation and obstacle detection. LiDARs are complex sensors and tend to be relatively expensive at the time of writing, but the price is expected to decrease and their reliability increase (Ackerman, 2016). Some companies are developing LiDAR systems that can function in much smaller, more easily produced packages, even on a chip (for example, Strobe, Valeo, & Velodyne) (Daily et al., 2017).

Table 1 presents a summary of main technical parameters and summary sensor counts of autonomous last mile vehicles comparable to ISEAUTO that were in development when the Iseauto project started (with the exception of the Apollo minibus which was announced in 2018). The list is not to be considered conclusive because new projects emerge frequently and sensor counts tend to be changed according to progress in development. Most of the referenced projects are a cooperation of universities / research institutions and industrial companies (2getthere - we deliver, n.d.; EasyMile, n.d.; Meet Olli Local Motors, n.d.; NAVYA - Autonomous Vehicles, n.d.; See India's first Autonomous vehicle in action - Novus Drive, n.d.; WEpod project webpage, n.d.). As can be seen from the data, most of the last mile vehicles have limited speed, varying passenger counts and range in the order of 100 km. The Baidu Apollo (Apollo Open Platform, n.d.) last mile vehicle was announced in 2018, one

Table 1. Summary of technical specifications and sensor counts of autonomous last mile vehicles comparable to ISEAUTO

Name (Developer)	Max Speed (km/h)	Max Passenger Count	Range (km)	GNSS	Inertial Sensor	Odometer	Ultrasonic	LiDAR	RADAR	Camera	Software
Apollo minibus (Baidu / King Long)	40	14	130	✓	✓	✓					Baidu Apollo
EZ10 (EasyMile)	45	15	80	✓	✓	✓		6		9	Custom
Olli (Local Motors)	40	12	60	✓	✓	✓	✓	2			IBM Watson AI
Parkshuttle (2GetThere)	40	22	100	✓	✓	✓		1		4	Custom
Navya	45	15		✓		✓		4		4	Custom
Novus drive (Hi-Tech Robotic Systemz)	40		150	✓	✓	✓		5		1	Custom
Wepod (TU Delft)	25	6	100	✓	✓	✓		6	9		ROS based
Iseauto	20	6	100	✓	✓	✓	✓	3		6	ROS/ Autoware

year after the Iseauto project was started. Iseauto data is added to the table for comparison purposes, the technical details will be discussed later. The missing cells indicate that appropriate data was not available at the time of writing the current paper.

3. PROJECT SCOPE

3.1. Background and Aims

The ISEAUTO (ISEAUTO – Tallinn University of Technology & Silberauto AS, n.d.) project is a cooperation project between industry and university which has a range of objectives from both sides (Rassõlkin et al., 2018) as well as a very practical outcome. The project started in June 2017, when the Tallinn University of Technology and Silberauto Estonia agreed to jointly develop a self-driving car. The first major milestone was the presentation of an autonomous self-driving vehicle to the public in September 2018. The goal of the participating company involved both developing deeper knowledge in the self driving car technology and demonstrate their skills in developing and manufacturing a special purpose car body. However, the company also wants to support the engineering education and inspire young talented students to study engineering as well as engage new students to start their engineering studies. Figure 1 depicts the initial vision created by the designer of Silberauto on the left and the prototype vehicle at an early stage of manufacturing on the right.

The project had the following initial goals and objectives:

- Company and university contribute on an equal basis and will share the results;
- The developed vehicle is going to drive in the university campus in a pre-defined route;
- The vehicle is fully autonomous and can operate on public roads under normal weather conditions;
- The team consists of company employees, researchers and students;
- Public demo of the vehicle was to happen in 1 year from the start of the project at heart of the 100th anniversary celebrations of the Tallinn University of Technology in September 2018.

The initial goals were achieved by September 2018. Both Silberauto and Tallinn University of Technology decided to continue with the project and apply for additional funding to support further development.

3.2. Practical Project Based Study Opportunities for Students

The project was and continues to be an opportunity for the students to achieve project experience while studying motivated by research done in the field of engineering education that points out that project and problem based learning (Mills & Treagust, 2003), sometimes also categorised as inductive

Figure 1. Initial body design (left) and the first prototype implementation (right) of ISEAUTO body

learning (Prince & Felder, 2006), supports better metacognition and thus improves the learning experience of students. The participating students can engage in solving practical problems covering multiple disciplines, from mechanical engineering to electronics and from software engineering to applications of the recent research results in the field of artificial intelligence. Due to the nature of the project, skills from the students from multiple departments are required, thus we have contributions from students from the departments of Computer Systems, Software Science, Electrical Power Engineering and Mechatronics, Mechanical and Industrial Engineering, etc. Project was supported by tools and methods to ensure smooth management and development process. The systematic early design methodology proposed by earlier research (Sell et al., 2008) was applied to the mechatronic design process at the early stage (Sell & Petritsenko, 2013). Several simulation tools as well as proof of concepts were applied in mechatronic and software solution validations.

4. TECHNICAL SOLUTION

4.1. Body Construction and Technical Parameters

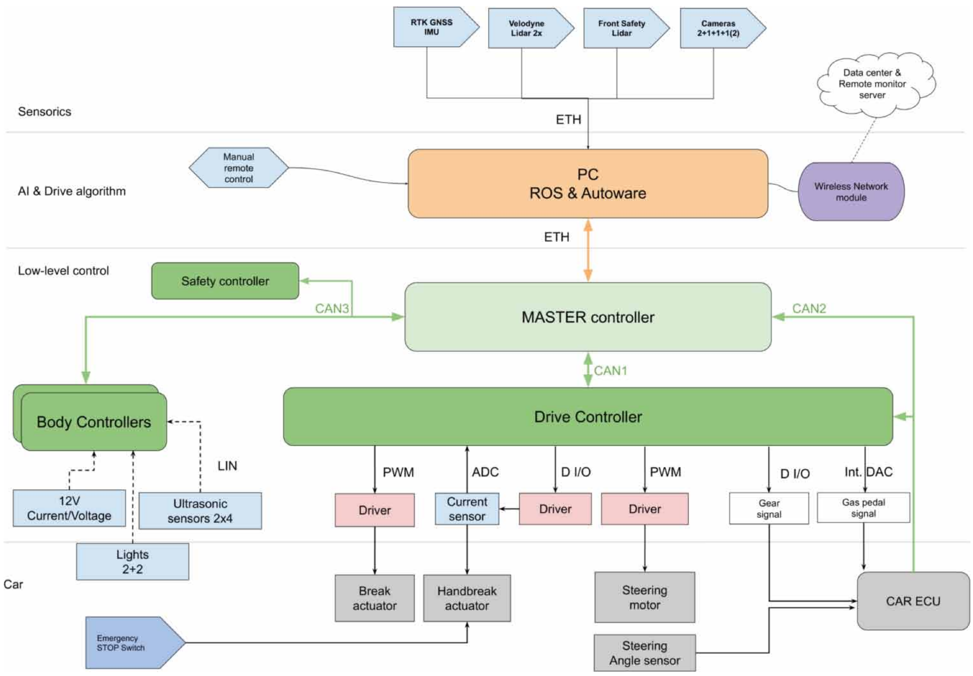
The body of the vehicle was designed and developed by the industrial partner of the project: Silberauto Estonia. All molds and panel frames were specifically designed for the project. The body design is symmetrical, meaning that the vehicle can, in principle, drive in both directions without having specific front and back side. Due to the use of a Mitsubishi i-Miev base with Ackermann steering, it is easier to control the vehicle in the traditional direction: the steering wheels in front. The sidebar lights are implemented using RGB LED matrix where all individual LEDs are independently driven. It means that the vehicle can easily change lights from red to white on both ends. The direction indicators and other visual elements can easily be provided on the same panels. The final design of the vehicle together with interior panels is shown in Figure 2.

4.2. Control Architecture

The architecture of the car control is divided into three main blocks as shown in Figure 3. The upper part is sensorics that communicates with the PC level software. In the middle, the autonomous functionality decides based on the sensor readings the speed and the angle of the steering wheel of the car. Lower part depicts the mission-critical functionality that takes care of the car control by controlling different actuators and reading feedback from the car CAN network.

Figure 2. The final design of ISEAUTO

Figure 3. The architecture of the vehicle control system

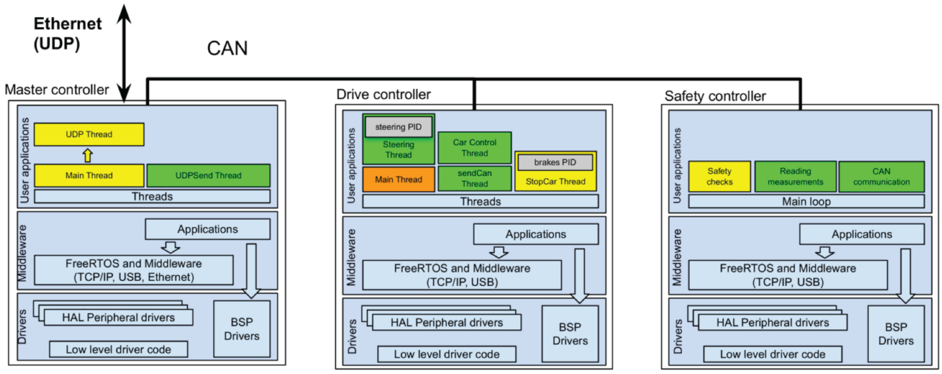


The autonomy is achieved by running Autoware (Autoware Research and Development project, n.d.) on top of the Robot Operating System (ROS) in a PC that communicates with the controllers over a dedicated Ethernet connection to minimize delays. Mission critical controllers are divided into three layers - master controller, slave controllers, and real actuators and sensors. The main task of the master controller is to forward information from and to the PC with the minimum delay. It handles communication with ROS, listens to data from the electric vehicle (EV) CAN network and communicates with the slave controllers with CAN1 and CAN3 networks. CAN1 network is dedicated to the mission-critical drive controller that manages gearbox, brakes, hand brakes, steering wheel and gas pedal. CAN3 network is dedicated to other controllers that control other actuators, interior actuators and low-level sensors, e.g., the ultrasonic sensors around the car. The number of slave controllers may vary depending on the progress of the development. The software of all controllers is based on the real-time operating system FreeRTOS kernel (FreeRTOS - Market leading RTOS (Real Time Operating System) for embedded systems with Internet of Things extensions, n.d.).

The most sophisticated low-level functionality is integrated into the drive controller. There are PID controllers implemented for acceleration and steering control. Coefficients for PID controllers were chosen with the MATLAB environment simulations and fine-tuned during many experiments in different landscape scenarios. Other slave controllers have very similar hardware and software level configuration as the drive controller.

Figure 4 describes the software architecture of the controller layer. Master controller acts as a central gateway between all nodes. All data messages between controllers and ROS are divided into different priority groups. That ensures that the most critical car driving messages are always handled with the highest priority and with the smallest delay. Most of the delays are caused by the EV CAN network speed. For example, some critical messages from EV are sent with the frequency of 50 Hz. ROS is configured to send driving messages with the frequency of 100 Hz. Most of the controller software functionality is covered with C unit tests to ensure the quality and functionality of the software.

Figure 4. The architecture of the embedded software performing low level communication with the car subsystems



In Drive controller there are in total 5 threads with different priorities. Low and normal priority threads have green, above medium priority ones have yellow and high priority ones orange background. When vehicle is powered up then all startup checks are executed in the main thread. Also handbrake and brake positions are continuously updated in the same thread. CarControl thread takes care of the gears and driving modes to actually run the car. StopCar thread has one task, stop the car immediately in whatever reason it is. SendCan thread sends all kind of driving related information to other controllers over CAN network. Steering thread controls the wheels position using PID controller.

Master controller has two threads, main thread with medium priority and UDPSend thread with normal priority. Main threads initializes all configurations, starts new UDP thread and terminated after that. Created UDP thread handles all UDP data that is received on ethernet interface. UDPSend thread takes care of sending UDP data to the ethernet.

Safety controller is physically connected with different driving related wires on drive controller to physically measure signal levels on every pin. For example, if the brakes or steering PWM signal is out of limits, safety controller applies brakes that stops the car. It acts independently no matter what other controllers are doing.

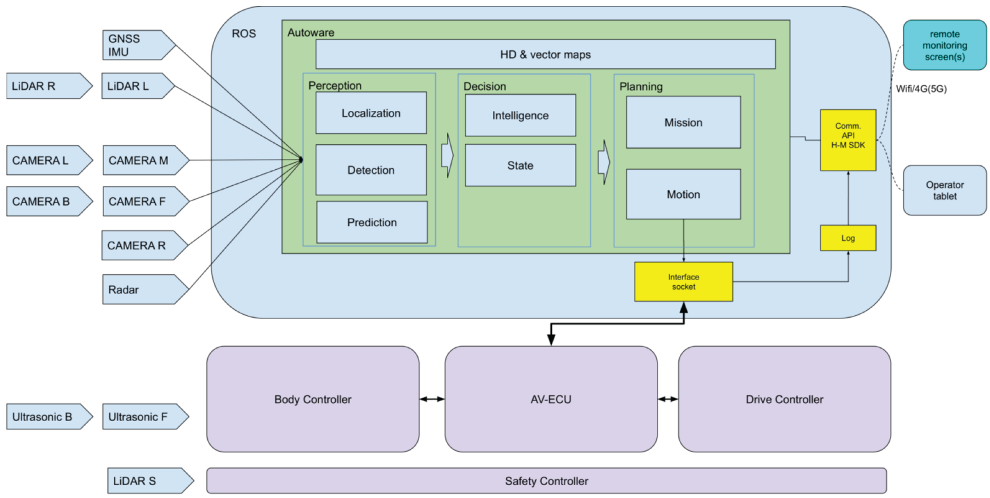
The controller hardware is chosen from the STM32 ARM series that has wide range of different types of controllers, user-friendly configuration interface and previous good experience by the developers. STMicroelectronics also provides special automotive controllers that can be used for future developments.

4.3. High Level Software Architecture

One of the intentions of the project was to keep the development open and make the project accessible to new developers and students. An open source software platform is critical in that respect: the main middleware is ROS, and software component integration is based on the Autoware stack (Kato et al., 2015). Autoware is an open-source software suite originally developed at the Nagoya University for urban autonomous driving, currently maintained by Tier IV (Tier IV, n.d.). It integrates components for 3D localization, 3D mapping, path planning, path following, vehicle control (acceleration, brake, steering), data logging, object and obstacle detection etc. The high-level software architecture of Iseauto is given in Figure 5. Since Tier IV approach is to use an external 3D map provider, it was necessary to develop a custom vector map development solution based on GIS software that enables us to align 3D point clouds with reference maps and build vector maps for the areas where our vehicle operates. As self-driving cars can pose a danger to human life, special attention is targeted to the system and integration testing of the software.

The number of cameras and radars used changes during the development because it requires numerous experiments to evaluate the contribution of various configurations of sensors and appropriate

Figure 5. High level software architecture used on ISEAUTO



software components. Initially the main focus was to make components in Autoware work, i.e. not develop new components except those specific to the platform to establish a baseline for functionality that can be further refined.

Current setup is using one radar installed to front middle of the car. The sparse radar point cloud provides a way to track and monitor objects when other sensors fail, like in the curious case of the CE30C lidar used as a safety in ISEAUTO, not detecting objects in its field of view under certain conditions. CE30C does not detect objects in its operational field: the blind spot of the Velodyne Lidars. Both the radar and the CE30C have an opening angle of around 120 degrees and the elevational angle of 30 degrees. In our experiments radar is placed under the CE30C safety lidar, so that the field of view of the sensors overlap as much as possible. First experiments show that for example thin metallic posts, diameeter of 50mm, in the middle of the road, that have small cross sections, which translates into potentially poor reflectivity for the radar and the lidar. As a result, the radar detects the object's location in its path with accuracy similar to the Lidar. At the distance where the CE30C should be able to detect the objects it does not detect them in its path, whereas the radar compensates for this by reliably detecting both objects in the way. When the objects exit the lidars field of view completely, only the radar detects the objects in its path.

5. SAFETY

Safety of the developed system is of critical importance. Safety is approached from the risk analysis and management point of view as well as technical perspective. The following measures are taken to address major risks:

- Clear software process including code reviews and code signing. The approach helps to maintain code quality and catch problems before they get executed on the autonomous vehicle. The process is very important during the development phase and also when developing new features and patches to deployed systems;
- Access to the vehicle computer systems is restricted using hardware security modules. In the Iseauto project Yubikeys are used for computer access in the car as well as access to the code repositories and signing commits;
- Extensive testing of the software both at the low-level controller and PC level. The testing is done on the vehicles as well as in the Gazebo simulator;

- Continued experimentation with various sensor types to improve obstacle detection. E.g. addition of solid state lidars into the numbers;
- Checklist based culture of running and setting up the equipment. The approach helps to minimize human error in repetitive tasks that in some cases need to performed under time pressure;
- Several safety features including a separate safety controller are designed at very low level to make sure the vehicle stops if an anomaly is detected. The safety controller was developed by an industrial partner ABB;
- The speed of the vehicle is limited, and the vehicle is operating in a limited area.

The future work involves involving a remote control room that makes it possible for a human operator to remotely control the vehicles. Such an arrangement requires the control architecture to be validated by cyber security experts and tested in appropriate challenges.

6. LEARNING EXPERIENCE

Building a self-driving car is an undertaking that requires multidisciplinary collaboration from mechanical and electrical engineers, mechatronics, electronics, computer systems and software engineers. Thus, participating in such a project helps to develop various important skills such as cross-discipline communication, working on large projects, and understanding large and complex legacy systems.

Over the course of the 2 first years of the project, there were 18 students involved in various aspects of software development, 12 students in the electronics and low-level microcontroller software development. In addition, 5+ students were involved in actually assembling the vehicles and supported the assembly of components manufactured by Silberauto AS. Of those students 21 received credits for their contributions.

The project work was integrated into the studies of students in two main ways: final theses and project courses. For example, in the software development sub team, we awarded 72 ECTS in the first half year for project courses and students achieved 60 ECTS for project courses in the second semester. During the first year 170 ECTS was awarded for MSc and BSc level theses. During the second year 162 ECTS for theses totalling 464 ECTS corresponding to the amount of credits 4 MSC students are expected to complete to fulfill their studies. Such arrangement enables students to work on the project for more than one semester as the software is complex and building up an understanding of the principles requires time. While the tasks to be solved were often hard, combining project deliverables with thesis work proved helpful in maintaining student motivation.

The project courses are set up as 10-12 ECTS courses where student teams of four to six are supposed to complete a realistic task within a semester. The first project course was a 10 ECTS start-up project course, where student teams are expected to come up with an idea and implement a minimal viable product. One of the teams chose the self-driving car project with a goal to make the self-driving car drive autonomously in the Gazebo simulator closely integrated with ROS. In that process, the students discovered that the vector maps are essential to enable autonomous driving and that the vector map creation tools are not available in Autoware. As a result, they developed a prototype vector map creation tool, based on a widely used GIS software ArcGIS. In the second project, the students were supposed to carry out a predefined software development task. The task was to make Autoware drive the car-based platform autonomously.

Combining studies with project work also involves challenges. MSc theses are expected to contain a substantial research component. On the other hand, making an existing piece of software, e.g. some package of Autoware, work, does not typically contain enough research to constitute an MSc theses, while still requiring extensive amounts of time especially for people with little background in ROS. Thus the thesis topics had to be made more general and mostly involved some empirical experiments to evaluate the outcomes.

7. RESULTS

One of the key results of the project is the detailed experience report in how create an autonomous last mile shuttle from an existing electric car platform. Initial objectives of the project were to develop the competence, both that of the academic staff and students. and to offer practical study experience for students from different faculties. These objectives were fulfilled. As a practical result a completely new autonomous last mile shuttle platform was developed and manufactured. The most important traits of the project and resulting platform are the following:

- Software solution based on open-source software;
- Body design optimised for straight forward manufacturing;
- Modular vehicle design;
- Experimentally validated sensor setup.

The vehicle has a modular structure, enabling straight forward manufacturing. It can be equipped with different sensors, based on research requirements, e.g. radar research or requirements driven by the use case, e.g. community shuttle in Florida or urban last-mile solution in a Nordic country. Different use cases require the sensor setup to be validated with respect to the operating environment.

The autonomous shuttle platform - ISEAUTO has been given to the researches of human-machine language and the general perception of self-driving vehicles among different groups of people. The initial research was focusing on the following questions: 1) What are the attitudes of people towards the general safety of autonomous driving technology? 2) How do people feel about the interaction with driverless vehicles on the university campus? 3) How could the communication between the autonomous vehicle and humans be made universal? The research was carried out in early 2019 and findings are in the process of being published separately.

One of the results of the project is focussed on the potential commercial application. In addition to the research platform a commercial prototype was manufactured and initial tests performed. Since the second quarter of 2019 two parallel AV shuttle platforms exist: the research and educational version and commercial version. The latter one is targeted to be a street legal low-cost autonomous shuttle for pilot routes in different cities around world. First pilot is scheduled to late 2019 in Tallinn and second one to early 2020 in Florida, US. Both vehicles side-by-side are presented in Figure 6.

8. FUTURE WORK

Future work is focussed on the applications of the Iseauto platform within the context of Smart Cities. The Iseauto project has to date successfully participated in two of the three phases of the pre production procurement process of the Pre-Commercial Procurement of Future Autonomous Bus Urban Level Operation Systems (FABULOS) that is supported by the European Union’s Horizon 2020 research and innovation programme under grant agreement No 780371 (Fabulos, 2018). In combination with FinEst Twins H2020 Smart City project new challenges are defined and will be actively experimented and tested in the near future. In particular, the following activities are either started or will start in the following months:

- **Human - AV interface (HAVI):** Experiments with pedestrians and language of driving for AV shuttles;
- **Control room:** Remote monitoring and remote control of the AV fleets. Experiments are started to exploit 5G network;
- **Fleet management:** Fleet management software development and integration with different manufacturers AV shuttles;
- **ROS2:** Upgrading the software platform and moving to ROS2 based solution (Autoware on ROS 2, n.d.);

Figure 6. Research (left) and commercial (right) version of ISEAUTO

- **Optimize:** The computational hardware requirements (Kato et al. 2018);
- **Testing and certification:** Real pilots are scheduled on the streets of Tallinn as well as certification process to acquire permission for driving in public roads;
- **Automotive grade low level controllers:** Replace existing low-level hardware with automotive level microcontrollers and components for increased reliability and safety;
- **Perform extensive security testing:** For the computer system before making it available for the general public.

Connected vehicles have many challenges to solve, including but not limited to, low latency communication, standardization, cloud and edge computing, traffic management, etc. In this area new experiments are scheduled to the end of 2019 where V2V communication between autonomous shuttle and delivery robot will be studied.

9. CONCLUSION

Autonomous driving is currently in very active development at most of the car manufactures and many technology companies like Google, Apple, Uber, Lyft, Baidu, etc. There is a growing demand for last mile vehicles with SAE Level 4 autonomy, but the expected numbers to be produced are significantly lower than for general passenger vehicles equipped with autonomous capabilities. In the Iseauto project it has been demonstrated that even for a small company who specializes in vehicle technology, it is possible to successfully develop a self driving prototype in collaboration with local academia. In addition, it has been demonstrated that developing an autonomous vehicle is a project that lends itself well for students to fulfill significant parts of their curriculum in the context of project based learning. In addition, within 18 months from the beginning of the project it was possible to qualify for phase 1 and 2 (of 3) of the pre-procurement for autonomous vehicles in the European Union supported Fabulos project (Fabulos, 2018). Thus the project has led to establishing an experimental base for future research and development of autonomy within the region that provides valuable data and challenges useful both in education and research.

ACKNOWLEDGMENT

The research was supported by the European Commission through the H2020 project Finest Twins (grant No. 856602). The research has also been supported by the Estonian Research Council under grant PSG453 "Digital twin for propulsion drive of autonomous electric vehicle".

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