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AVINT: AUTOMATED VEHICLE DESIGN, IMPLEMENTATION AND PILOT TESTS IN THE CITY OF TRIKALA, GREECE

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ABSTRACT

Automated vehicles is one of the more exciting areas of the automotive industry today. The general perception is a fully automated car where the driver can handle other matters while the car is driving by itself, and this will start becoming reality within the next years [1],[2].

In many cases the purpose is not to transport the driver from one point to another as in a private car but instead perform tasks at a work site. Even if the equipment will be able to carry out the work without support from an on-board or on-site operator, there is a need for supervision, to take control remotely if something unexpected happens. For this to function a system must be designed, configured, and built as a control center. In this control center an operator will be able to supervise and monitor the status of several vehicles (up to 4 in the Greek legislation). If needed the operator can give the vehicle appropriate commands for the vehicle to be able to continue its task [4].

The purpose of the work carried out is to specify requirements for, design and implement a prototype of a system for operation of a normally autonomous vehicle. The existence of standards is investigated. The standards are taken into account in the development and implementation of the system. In any case a general and scalable solution that can be used on several types of vehicles is developed. An interface towards the autonomous vehicle is created together with a control center with controls and information from the vehicle.

KEYWORDS: Autonomous vehicles; CAN BUS, Control Centre; controller; lidar equipment;5G network.

1. INTRODUCTION

A. AVINT Project Basic Elements

In this paper, we provide a description of design implementation and integration of an autonomous vehicle retrofitted by SuburVAN, France (www.suburvan.com) within AVINT project (**A**utomated **V**ehicles **INT**egrated within the urban context) funded by the Greek Secretariat of Research and Technology-GSRT (www.gsrt.gr)under the EDK program. Participants of AVINT project are e-trikala (www.e-trikala.gr), Technical University of Athens-Institute of Communications and Computers (www.iccs.gr) and SPACE HELLAS SA (www.space.gr). The aim of the project is to study the integration of autonomous passenger transportation into the urban traffic environment of the city of Trikala via the pilot implementation of an automated minivan line that connects the city centre with the Trikala University Faculties terminal, in a route of 7.85 km, via a viable service, which can be seamlessly integrated with the urban transport network and provide priority to the minivan. The route is shown in the following figure.

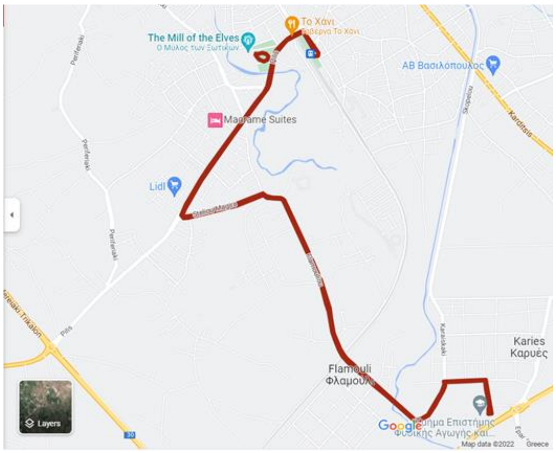

Fig. 1. Route within Trikala, (Greece) urban context to be followed by the automated van

The research project ‘AVINT’ focuses on the integration aspect of the autonomous vehicles within the urban context through a real-life demonstration and evaluation of the system in the city of Trikala in Greece. The participating partners studied the urban transport context in Trikala city and implemented a transportation line supported by autonomous vehicles (minivans) fully integrated with the city transport network within mixed traffic without dedicated lane based on the national legislation framework for vehicles without a driver voted in 2022. The real-life demonstration includes three phases: a) pilot phase without passengers and an operator on-board, b) trials with passengers and an operator on-board and c) passenger trials with no operator on-board. The presence of a remote-control driver is mandatory in all the aforementioned phases.

B. Level of Autonomy

There are many ways of controlling a vehicle, but the most common way is still with the operator sitting inside the vehicle driving it manually. Other ways are remote and autonomous control, and these technologies are often divided into three levels of control. The first is manual remote control [11], which contains no autonomous functions. The operator controls the vehicle from a near distance where the vehicle can be viewed directly while operated. This is often referred to as line-of-sight control.The next level is remote monitoring where the operator is located off site and some sort of monitoring is needed i.e. cameras, force feedback control or other sensor data. Remote monitoring [12] can both be local where the operator is located close to the machine but not in visible range. It can also be global where communication needs to be relayed via the Internet or by a satellite link. At this level, different kinds of autonomous tasks can be done by the operator.

The third level is a fully autonomous vehicle [13] that can carry out tasks on its own with no guidance of an operator. The requirements are significantly higher at this level in terms of positioning, operation and safety. The tasks can be predefined and depending on situation the vehicle must be able to make its own decisions.

C. Monitoring

While autonomous vehicles could revolutionize mass transportation as we know it, their safety has been widely debated. To address this concern, remote operation brings a safety mechanism that allows autonomous vehicles to be monitored by a remote operator from a distance, if needed. The vision of operators scanning screens and on-hand to intervene, if necessary, should contribute to public acceptance of autonomous vehicles. Network requirements for remote operation include broad coverage, high data throughput and low latency to enable continuous video streaming and to send commands between a remote operations centre and a vehicle [14]. 5G will bring several benefits to remote control systems, including core network slicing that will enable priority service provisioning, and radio access to bring ultra-low latency and beamforming for high throughput and capacity [10].

2. EVALUATION VEHICLE

The vehicle that is used is a prototype based on a Peugeot e-traveler 2020 van, equipped with a variety of additional sensors such as an IMU (Inertial Measurement Unit) to measure orientation, LiDAR (Light Detection and Ranging) sensors to measure distance to surrounding objects and centimeter precision positioning using RTKGNSS and GPS. It has been retrofitted for automation by SuburVAN, France.

The van has autonomous capabilities implemented and can follow a pre-recorded path with the position, orientation and desired speed of the van at discrete waypoints along the path. As of right now there exists no other path planning except manually driving and recording a path. Actuators and interfaces for steering and controlling brake and throttle are available. The vehicle is also implemented in simulated software for validation.

Basic technical characteristics are illustrated in the table below:

Table 1. Vehicle technical characteristics

Vehicle Brand	Peugeot
Vehicle Model	e-Traveler
Vehicle Model Year	2020
Fuel and battery type	Full 50 kWh capacity
Number of seats	6 + 2
Continuous Operation	Estimation is 220 Km.

3. PHYSICAL ARCHTECTURAL DIAGRAM

The vehicle will be equipped with sensors like cameras, radars, GNSS and LIDARs. The central computer processes and fuses data of these sensors to provide the best possible perception around the vehicle. With the support of perception and decision logic functions, the command unit develops a control path to be followed. A monitoring unit will evaluate the route planning for safety and consistency.

The central computer's task is to process the data (data fusion), do the path planning, and translate this into commands for steering, braking, acceleration, park brake and the vehicles' accessories (lights, blinkers, horn, etc). The responsibility for correct command execution will be given to external organs, devices, and actuators external to the Electronic Control Unit (ECU). The ECU will provide the following interfaces:

- Power supply both internal and external
- CAN bus to cover all the other devices
- Ethernet interfaces

All communication interfaces allow for bidirectional communication, and they interact with the vehicle communication busses. In this way, the ECU will have access to all the information available and can interact with every subsystem. For inputs and outputs, all the data that the ECU will process is fed in and out via communication busses as presented in the following table:

Table 2. Data types and communication interfaces

Name	**Type**	**Data**	**Interface(s)**
LIDAR	RawData	Distance Vector, cloud point	Ethernet
Camera	Objects	Lines, Signs, Pedestrians	USB
RADAR	Objects	Obstacles	CAN
Ultrasounds	Objects	Obstacles	CAN

These components provide information, and the actuators are required to perform the necessary action for the system to behave according to specification. The system physical architecture has the following components:

Table 3. Physical Architecture components

Name	**Description**

Sensors	
Lidar	The LIDAR provides a point cloud from which with the distance to surrounding objects is measured. This information is sent basically over Ethernet in RAW format.
Radar (Front)	The front radar, as the name suggests, are radars mounted in the front of the vehicle. These devices will provide distance and orientation to the visible objects to the ECU via a CAN Bus.
Corner Radar	The vehicle corners are secured by use of Corner radar that communicates over one or two CAN busses the detected objects.
Cameras	The Multi-Functional Camera is a set of video cameras that is used to read the road-signs, road-lines, and detects a set of road obstacles.
Supervisor	The supervisor is a function whose allocation is not explicit. The primary role is to activate and deactivate the ECU based on user requests and to validate the commands by comparison with valid command ranges.
Actuators	
Acceleration	The acceleration or motor control is the system in charge of the longitudinal control acceleration or deceleration.
Steering	The steering system is the unit of the vehicle that handles the lateral control.
Brakes	This system is in charge of the vehicle deceleration and stopping.
Park brakes	The system that will lock the brake when the vehicle is stationary.
Lights	The ECU controls signaling and warning.
Infotainment	The system will display the status of the ECU, and that will activate or deactivate the automated driving system.
Backup	The system that assures the control of the vehicle for 10 seconds in case of ECU failure.

4. LOGICAL PHYSICAL ARCHTECTURAL DIAGRAM

The logical architecture represents the connection between the different subsystems that process the sensors' data to turn them into commands for the actuators that ultimately make the vehicle drive. The following diagram represents the logical architecture.

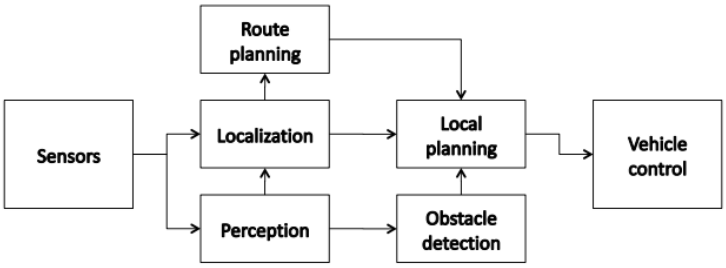

Fig. 2. System Logical Architecture

A. *Perception Subsystem*

The perception subsystem oversees the processing of sensors data to provide the information required by the other subsystems.

B. *Localization subsystem*

The localization subsystem is made of several information layers that provide the vehicle the position reference necessary to make a trip. The first layer is a local laser-based map of the whole operating area (Operational Design Domain – ODD) built a priori. The map uses features in the environment as reference points. The vehicle's real-time perception system uses this reference points to estimate the vehicle's position and orientation.

The second reference map layer is made of the a priori reference trajectories that the vehicle can follow inside the map. These reference trajectories represent all the potential positions that the vehicle can occupy safely in the road network. Their combination allows the vehicle to go from a trip's origin to its destination. The third layer is made of the reference speed information. This information defines the maximum safe speed that the vehicle can sustain at every point of the road network. This information is defined through a risk assessment carried out on the road network. The fourth and final layer is made of the semantic information of the road network, which describes each segment's name, speed limit, direction, etc. This is the information that end users use to define the origin and destination address of their trip.

C. Obstacle detection subsystem

The obstacle detection subsystem identifies static and mobile objects in the vehicle sensor's line of sight. Depending on their position and eventual direction of movement relatively to the vehicle and its planned trajectory, the vehicle's local planning subsystem will consider this and plan a collision avoidance maneuver accordingly.

D. Route planning subsystem

The route planning subsystem is a system that transforms a trip request or mission sent by the fleet management system into a sequence of reference trajectories that the vehicle has to follow to go from a trip origin to a trip destination. This route is then sent to the local planning subsystem.

E. Local planning subsystem

The local planning subsystem is a system that defines the vehicle's movements in the next 100 meters, in function of the reference trajectory, reference speed and obstacle detection systems. This local trajectory plan is then sent to the vehicle's actuators and updated to establish the subsequent vehicle movements.

F. Vehicle control subsystem

The vehicle control subsystem transforms the commands sent by the local planning subsystem into actions to be performed by the vehicle's actuators. In practice, the local planning subsystems' commands are transformed into power signals sent to the vehicle's steering, accelerator and/or brakes.

5. PILOT TESTS AND RESULTS

The pilot test campaign involved the collection of 3D lidar and GPS data to create the reference map used to automate the vans in the AVINT project. This data was acquired by driving all along the AVINT route. A SuburVAN partner processes the raw lidar data and creates the 3D map of the route. This is the initial version of the map, which was further completed in subsequent phases of the trial's preparation.

The developed sensor set up equips the vehicles and enables their operation in real time. A partial sensor set was used to collect raw sensor data of the AVINT route. The data was acquired by driving all along the AVINT route under different conditions and times of the day. 4 round trips were made on the AVINT route. This raw data is now being used to test and improve the automation (perception) algorithms under the specific operating conditions of Trikala. Each single trip between the railway station and the University of Trikala, which took around 15 minutes, produced, with this partial sensor set, 50 Gb of data, which equals to 200 Gb of raw data per hour. For the automated operation, this amount of data will have to be multiplied by 4. The estimate amount of data that will be produced is therefore around 800 Gb per hour, and 9,6 Tb per day per vehicle. Therefore, the storage and transfer of this data will be a challenge for the actual service operation, in a safe, controlled and cost-effective way. Following the data collection done in Trikala in July 2022, an initial version of the reference map was created. The images below show a visualization of the reference map at different zoom levels.

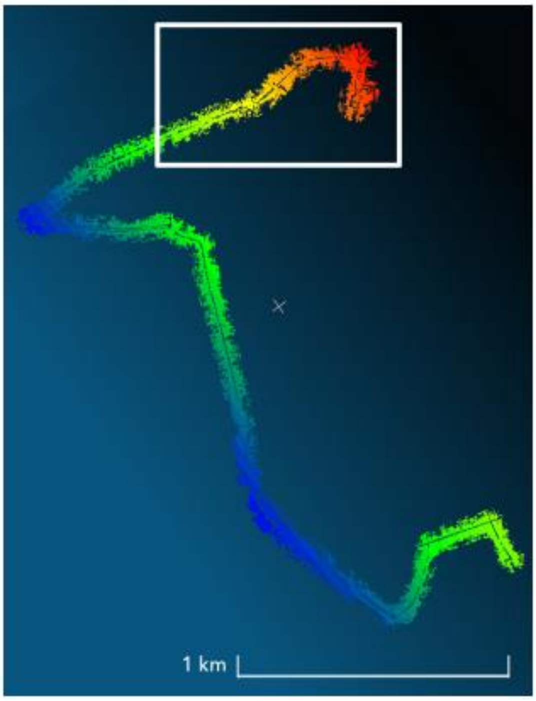

Fig. 3. Top view of the whole site's 3D reference map

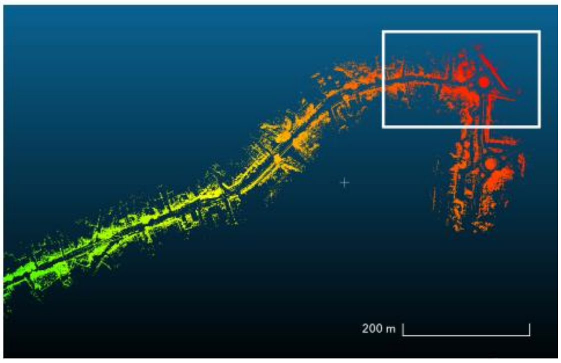

Fig. 4. Close-up top view of the site's 3D reference map

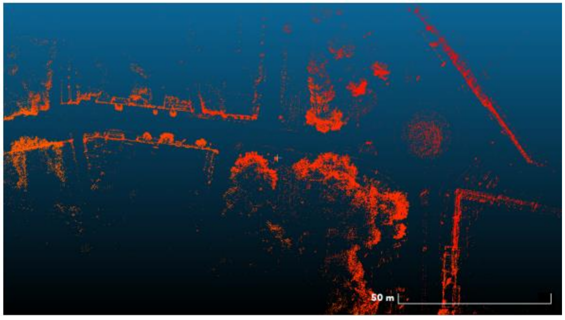

Fig. 5. Close-up view of the site's 3D reference map (roundabout intersection between urban streets and railway crossing)

6. CONCLUSION

In this paper we presented the requirements to design and develop autonomous v. Several challenges create constraints in the deployment of these vehicles for providing automated mobility on demand services. We have studied initial steps for route planning, localization, perception and tests under 5G communications. Nevertheless, there are several technical [8] [9] economic and social challenges that need to be addressed before the large-scale deployment of high or full automated road transport systems occurs.

7. ACKNOWLEDGEMENTS

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