The Smart Road Project at ENEA

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Extended Abstract

The Smart Road is a rather fuzzy concept which has gained the limelight in recent years together with its companions: Smart City, Smart District, Smart Building, Smart Home. They all describe the concept of pervasive computing: all the parts of the nowadays life can be made smart with the help of some processing power, communication capabilities and, above all, data. The trigger (and effect) of this smart wave is the so-called Internet of Things (IoT), i.e. the possibility to equip nearly every electronic device with communication and elaborative powers, together with an ever decreasing costs. The Smart Road concept has been instantiated and implemented in different ways in different places, but it is intimately linked to the Intelligent Transportation System (ITS) framework [1]. The idea is that transport and mobility must be reconsidered as an integrated and above all dynamic system where control, information and management operate synergistically and synchronously.

Three laboratories of ENEA and the Engineering Dept. of the University of Perugia are currently involved in a multidisciplinary project to set up an experimental Smart Road in order to study applications and solutions for a better quality of life and energy saving in the framework of the Triennial Plan 2019-2021 of the National Research on the Electrical System (*Piano Triennale 2019-2021della Ricerca di sistema elettrico nazionale*), funded by the Italian Ministry of Economic Development.

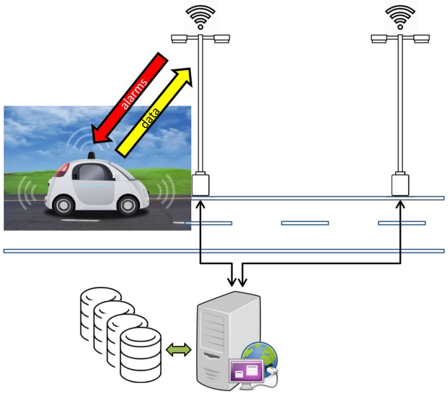

Fig. 1 The Smart Road architecture

A. The Project

The basic architecture is shown in Fig. 1. Through the communication network of the roadside lamps, the electric/autonomous vehicle is able to dialog with the Smart City computing centre. In one direction the vehicle furnishes data gained with proprioceptive sensors (e.g. position, speed, battery charge, etc.) or exteroceptive ones (e.g. air temperature, pollution, road surface conditions, etc.) acting as a sort of mobile sensor device. In the other direction the vehicle may receive from the computing centre relevant information which it cannot directly and locally access: e.g. an alarm condition on the future path to be followed or a meteorological alert of any kind. In addition, the vehicle can receive instructions concerning its recharging, e.g. where and when, compatible with the overall status of the electrical grid and the wishes of the vehicle itself, such as being near to the trip destination.

The project is concurrently addressing four different areas of research: a) the realisation of two on-board exteroceptive sensors; b) of an electric autonomous vehicle; c) the development of several SW procedures and applications for the processing of the data in a geographical information system and d) the setting up of a test road infrastructure.

B. The exteroceptive sensors

Besides the typical proprioceptive sensors such as odometers, IMU, gps, etc. two additional monitoring sensors will be mounted on board the vehicle: a chemical monitoring system and a road surface analysis one. The chemical monitoring system measures pollutant and particulate concentrations and some atmospheric physical parameters around the car, which are then relayed to the Smart Road and the Smart City computing centre in a georeferenced way. Some preliminary results and the overall system use are described in [2]. The second sensor is a visually based deep learning system for the classification of road defects. It is composed of a camera connected to a NVIDIA Jetson board where a Single Shot Detector architecture is employed to locate in the image road defects such as potholes or patches in the asphalt, cracks and zebra crossing. All the data are georeferenced and relayed to the Smart City for the monitoring of the road state.

Fig. 2 The experimental vehicle

C. The autonomous vehicle

An experimental electrical vehicle (a quadricycle) [3] is currently being customised in order to have it drivable by-wire with the final aim of autonomous driving (Fig. 2). The vehicle will be equipped with three gigabit cameras, frontal radar, 360° lidar and with safety devices and communication capabilities. The ROS based software will control steering (4-wheel steering), brakes, throttle and will read all relevant sensors. The algorithms and strategies to let the vehicle be autonomous are in progress. Their aim is to provide the robot with localization, mapping and navigation capabilities. In particular, Visual and Visual-Inertial Odometry and SLAM algorithms will be used to estimate the vehicle pose by processing the image streams collected by the cameras. Different state-of-the-art approaches will be considered, such as those presented in [4], [5], [6], [7] and [8]. Furthermore, vision-based estimates will be refined by fusing them with localization and mapping approaches that rely on range sensors (e.g., Lidar-Inertial Odometry [9]). Navigation will then be achieved by exploiting path planning and obstacle avoidance strategies, considering also data-driven solutions ([10], [11]). The overall localization and navigation pipeline will be initially tested and tuned on photorealistic simulated environments (Fig. 3) designed with the Unreal Engine framework [12]. Afterward, it will be deployed on the electrical vehicle for real-world experiments.

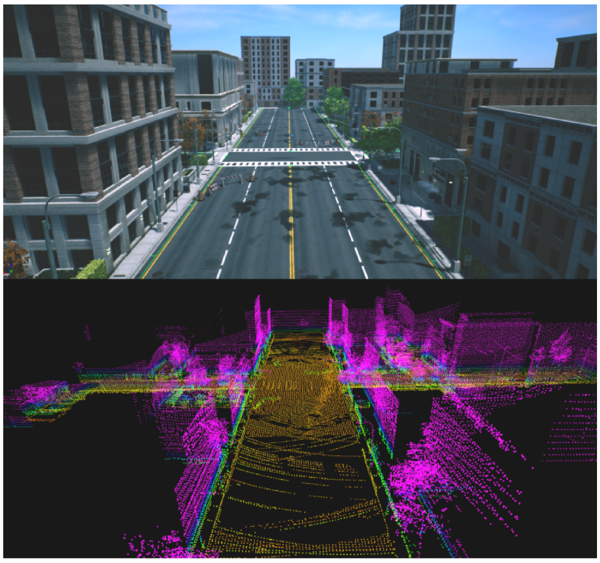

Fig. 3 Simulated environment and relative lidar data

D. The geographical information system

All the data collected by the smart road will be processed and displayed in a GIS-based decision support system (the CIPCast platform [13]) able to assess the risks on infrastructures due to natural hazards such as meteorological extreme events, floods or earthquakes. The current research is addressed towards the development of new features of the already existing system for the management of urban infrastructures, namely roads and recharging stations. Also the information from or to the vehicles with the management of data and alarms is addressed.

E. The road infrastructure

A road infrastructure is presently being set up in the Casaccia Research Centre of ENEA, north of Rome. The Smart Road is half a kilometer long and 6 meters wide, is serviced by 22 street poles that will host a lighting unit each and several additional sensors such as cameras, Bluetooth devices, communication devices. The light can be remotely dimmed by the Smart City data centre depending on the road traffic and meteorological conditions. The Bluetooth devices may help in counting the number of devices in the area near the roadside lamps (e.g. smartphones) or carry on some measurement such as illumination or chemical concentrations. On board some of the poles WiFi access points are installed in order to communicate with the autonomous vehicle driving in the road. First experimental activities in the Casaccia Smart Road are expected by spring 2021.

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