# IoT-enabled Environmental Sensing for Autonomous Vehicle Navigation and Safety

*By Dr. Esteban Botaro*

*Professor of Industrial Engineering, University of Los Andes, Colombia*

## 1. Introduction to IoT-enabled Environmental Sensing

The sensor Epuck is designed as a low cost, small-size, light, macro-microscopic environmental data, and vehicle maneuvres realized through smartphones, Raspberry PIs and dedicated boards. It allows the recovering of several parameters useful for: AVs localisation, obstacle detection, any kind of important information related to the main real world environmental problems to solve (e.g. thermal comfort, air quality, environmental noise, traffic monitoring, environmental safety), more efficient management of the environmental resources and several types of traffic analysis. All of these features are critical for an AVs contextual awareness and for its capability to take real-time actions in a context aware way for safeguarding the AVs passengers, vehicle lifetime and the smart transportation system efficiency [1].

Modern transportation is a fundamental aspect of the development and quality of everyday life. Autonomous vehicles (AVs) are a potential key to solving the problems within the mobility and transportation sectors. A key capability of AVs is relying on external information about the traffic and road conditions provided by special integrated systems. Intelligent transportation systems (ITS) enable such services and perform traffic management tasks by gathering data and providing it to drivers. Nowadays, relying on big data collected by municipalities serves as a backbone service provision tool for any ITS. Besides traditional ways of collecting transport data for various applications and sources of information on traffic and road network status, connected vehicle and autonomous vehicles allow the availability of environmental data through IoT sensors deployed on the vehicles and on the road side. The IoT of vehicles is called IoV and the IoT of autonomous vehicles is called IoAV [2].

### 1.1. Overview of IoT Technology in Autonomous Vehicles

According to Figure 1 , IoT technology components import fog-based computing processing for front-end network protocol. Set vehicles and updates a convention partner and Internet of vehicles technology features for V2I interoperability. In the internet of ordinary connected vehicles environment, the combination of—i) fog-based computing for the vehicles environment by-variable checking the technique of smarter-short range architecture as a serous travel mode allocation protocol. Real vehicles environment relative range of digitally-enabled IoT networking in cooperative transmission environments relative to traditional topological resources that are ubiquitously connected and intelligent-enabled anytime through self-stabilized networking [3].

Integrating real-time vehicle environmental sensing and IoT technology is essential to achieving true cooperative driving, and to providing omniscient perception to avoid road traffic accidents [4]. Relevant studies of smart transportation and vehicular networks have mainly focused on the electrical signal, thus the current state of the IoT is primarily geared toward supporting urban vehicular environments, as well as intelligent transportation systems (ITS) sensing and consulting. Two fundamental frameworks are deployed in a cooperative transmission model to bridge the information exchange between digital vehicles and Internet of vehicles evolution: 1) a skimming infrastructure-centric IoT technology bridge—joint administrative computing [5]; and 2) a pharmaceutical V2I adaptation technique, as a new administrative computing platform for vehicular communication, mostly focused on vehicle environmental convention as an integral part of transportation management.

## 2. Environmental Sensors in Autonomous Vehicles

The environment in autonomous systems consist of highways, open roads, and urban roads, and rural roads, which presents their own challenges and sight from the input sensors. Highway, for example, often plated with white traffic lane marks, which the vehicle follows to keep lanes. The navigation of open environments, like rural areas and open sahel environments, cannot benefit from structure road networks. Urban areas contain complex scene structures and various objects and dynamic behaviors, such as cross-street, other car motion, and pedestrian walking, which need to be perceived to ensure driving safety [6]. Consequently, a more comprehensive introduction to the perception system is proposed in recent literature, which includes both vehicle localization in outdoor environments and Long Term Self-localization [7].

Sensors in Autonomous Vehicles The perception system of intelligent ground vehicles consists of a set of sensors and processing sub-systems needed for real-time monitoring of the environment in which a vehicle operates. Basically, perception can be defined as the ability of a system to understand sensations of the environment that it interacts with. The main objective of perception in autonomous driving and sensory system is to extract and fuse data in order to understand the environmental situation and to process them to facilitate the identification of road obstacles and obscurities and improve the safety of the people [8]. An autonomous vehicle needs to continuously monitor the environment to estimate its own state as well as the state of other vehicles and pedestrians. This would require the vehicle system to capture a low-level perception of details regarding objects in its environment such as their spatial position and motion and at the same time, be able to infer a high-level abstracted perception of environmental situations addressed such as pedestrian crossing the street, a vehicle cutting into its lane or a school bus stopping at the side.

### 2.1. Types of Environmental Sensors

Autonomus navigation and safety are complex and important goals which involve many sensing, estimation and control components and processes. Understanding and navigating human road systems, particularly in urban environments, is challenging and complex. Making predictions and good decisions about safe behavior in the presence of other road users in challenging conditions is also demanding. Machine learning methods may be essential in enabling future AVs to have good localization and mapping performance under a variety of environmental conditions, and robustness to sensor-failure situations. Ultrasonic and millimeter wave radars, laser and structured light range sensors, exo, endoscopic, headlamp imager and stereo cameras, infrared and thermal cameras are used [9].

Many different types of environmental sensors and sensor data are now available, including various forms of imaging and range data, and environmental-sensing data measurements in the visible and nonvisible spectra. All of these can be important for Autonomus Vehichles (AVs) and particularly for navigation, object and obstacle detection as well as scene understanding. Sensor measuring surface parameters can also be important for vehicle-state sensing and the safety of road users. The case of AVs highlights the potential for these various covariates to be combined, to exploit correlations among them for more effective sensing, mapping and interpretation, and to combine multiple measurements in order to fuse the advantages of each sensor type [10].

## 3. Data Processing and Analysis in IoT-enabled Systems

The Smart City domain is one of the application areas. IoT devices can be used to support smarter parking and traffic control, e.g., [ref: 12cdbdbe-5852-453e-8c38-7f35bedbfb48,ref: a9084cae-9f3b-4cf6-8326-85e7a88a6925]. Control center refers to Smart City traffic administration. The quest to find optimal paths through a given geography is native to a new field of business logistics, namely unmanned aerial vehicle (UAV) routing problems. This traffic administration deploys IoT traffic surveillance camera cameras and sensors over urban nodes with some extra IoT devices on some lane for purpose of traffic control and monitoring (Yarovoy et al., 2018). We propose the implementation of the so-called Focused (On-Street Queue Management System) and Zone Based Charging System for the developed projects. The zone-based charging system becomes a viable option for IoT-based urban traffic control, but surveillance detects and predicts the optimal paths of all autonomous and dumb vehicle categories w.r.t focused and zone-based charging models.

[11] [12] Internet of Things (IoT) has the potential to revolutionize every aspect of everyday life: exploring the digital insights derived from physical world activities by deploying low-cost sensors, enabling new-to-code users to interact with their environment, enabling autonomous systems that use AI to act on this new data, and much more (Popli et al., 2019). However, as IoT expands to more tasks and behaviors, the trajectory of someone IoT device needs to be coordinated with the trajectory of different IoT devices to achieve different tasks of the IoT. Thus, there is a need to combine multiple IoT nodes and integrate the trajectories of these multiple IoT nodes, where the structure of this integration is decided by their individual interactions and virtual behaviors. Through this study, we systematize this multinode trajectory optimization problem and categorize its decoupled (and coupled) versions. We also surveyed known and potential IoT activities that fit under these different problem categorizations.

### 3.1. Machine Learning Algorithms for Environmental Data Analysis

The increasing availability of ground-based sensors and, eventually, of accurate satellite-derived climate information, will profoundly change the current state of the art for urban sustainable development, especially with respect to infrastructure development, urban expansion, town-council administration, and disaster management. In this regard, the article closely aligns with all the side-benefits arising from the practice of smart cities, leading to two further purposes of the study, to investigate novel methodologies that have aimed to considerably improve lateral position (the relationship between the vehicle and the side lanes) accuracy and to enhance lane following within machine learning-based architectures, while leveraging IoT technology for autonomous vehicle navigation and passenger safety [13]. Finally, this section distributes the objectives over two common but important data types for IoT in the transportation sector (raw and processed environmental data) and provides a summary of transportation mainly focusing on some of these environmental data types.

Rapid changes in various components of smart cities and analytics that aim to enhance network functionalities are useful to both communication and other sectors, such as climate, transportation, environment, infrastructure, utilities, public safety, and healthcare, etc. As one of the key applications of IoT technology, it is natural for IoT to play a pivotal role in all of the efforts to develop smart cities. This section pursues the objective of analyzing recent results on the use of machine learning algorithms in promoting sustainable models for face detection, image recognition, and lane detection, in connection with IoT [14]. Moreover, it shows some studies that have proposed solutions for reduced greenhouse gas emissions in cities while pursuing their digitization by using autonomous vehicles. Recent developments in IoT-enabled cloud-based platforms for sustainable autonomous vehicle guidance and safety are investigated from an academic point of view.

## 4. Challenges and Solutions in IoT-enabled Environmental Sensing

Recent years have seen rapid advancements in the field of autonomous vehicles (AV), thanks to progress in the Internet of Things (IoT) and communication technologies. However, the integration of IoT-related technologies, the environmental sensing of AVs, combined with traditional sensors appears to be relatively new, with the potential to still further improve AV environmental sensing. This article study informed about IoT and recent third party developments in environmental sensing for AVs. In the vehicle (or near-vehicle) node, Bayesian filters are widely used algorithms for data fusion. To process visual information, the use of Convolutional Neural Networks (CNNs) has been increasing. In assessing risk in the environment, Bayesian networks are used. In addition, game-theoretic solutions for delayed Strategic Monitoring and Actuation for Real-Time Risk Assessment in Autonomous Driving (SMART) have been studied to explore security in the transport of multiple agents in the same space, assuming other agents also move according to the markov decision process with same (unknown) dynamics. This paper presents a distributed autonomous cyber-physical system, combining statistical monitoring for timely anomaly detection in data center system, strategy-based and game-theoretic solutions for C2C IoT operations, connected and automated vehicle (CAV) mobility and security with a novel SMART solution for strategic monitoring and actuations for real-time incremental security risk assessment.

### 4.1. Privacy and Security Concerns in IoT Systems

An on-going task force has been established by the Society of Automotive Engineers (SAE) to solve cybersecurity problems associated with smart cars. They request to provide guidance on the Secure Development Lifecycle (SDL) to be used for developing automotive product components to ensure a consistent level of cybersecurity is integrated during their design, development, and operational use. Potential protection from smart car attacks may include recommended security practices developed by Tesla capabilities. Additionally, machine learning and artificial intelligence could recognize irregular system performance as it occurs, whereas blockchain can provide the integrity in trusted vehicle data. Co-operative driving gasoline and electric car systems eliminate the need for drivers themselves to make choices of these maneuvers in order to improve safety and efficiency together with minimizing energy use and emissions. Smart gas stations, such as The China National Petroleum Cooperation (CNPC) and Omv, consider replacing their gasoline dispensers with plug-in-point chargers for electric vehicles.

Each IoT device has the potential to access information not related to its primary applications, posing risks of privacy leakage more widespread than conventional security risks. Research is ongoing for countering security and privacy concerns in other IoT systems, including smart home [15]. Legislation and standardisation bodies are discussing and revising cybersecurity mandates to adapt to dynamic new technologies [16]. In addition, other technologies, for instance, VPN (Virtual Private Network) or blockchain technology, machine learning, and artificial intelligence, are embraced in smart car cloud-based technology, which serves as the first defence in protecting smart cars from cyber-attacks and ensures their secure operations [17].

## 5. Case Studies and Applications of IoT-enabled Environmental Sensing

Recent analysis, linearizing specially designed integrating circuits produces the invention of a two degrees of freedom radar contextually used in two possible non-overlapping frequency bands which is able to address clutter effects and scattering related weaknesses of traditional radar systems detecting people behind obstacles at the expense of increased false detection rate in public roads scenarios. An experimental implementation of this new radar type is presented and its detection quality in an urban scenario is compared to more traditional radar systems. Using the provided robust and reliable measurements validated on a very large test set, we can achieve controlling the capabilities of a perfectly autonomous vehicle on semi-urban central streets. Continuous, on-line learning and feature synthesis cycles yields a classifier able to acquire large databases of different observed scenarios from many different client vehicles and able to reduce its probability to stop when people are not present. These classifiers were tested in urban scenarios with robots and the results are reported. It should be also observed in [FProczov']]['F. Prodi, et al. eds., Radar for Robotics, Springer, 2011. DOI 10.1007/978-88-470-2807-3_9 110 possible to have devices with the same designed radio signals and functionalities as the level 3-4-Cooperative Radars, but by transmitting a receive off, silent signal. These units are called level 0-Radars. Such radars can recognize co-located level 2-3-Emergency level radars and stop if a desired operation is at risk. This is obtained using hidden Markov models with void state by the level 0-Radar. Another change is due to the possibility to transmit to vehicles also safe-on-the-go information and not only stop-and-wait instructions. Range and relative velocity skilled regression models were trained with vehicles datasets related to the Advanced Driver Assistance Systems situations. Another application optimizing safety in automated cars with radar sensors is shared with the future of urban mobility. It takes passengers through highly automated electrically powered, Magnetic Levitation ground, aerial or mixed Virtual Private Stations. In these cases, the main goal is establishing a way to interface electronic dependant urban society with automated on-the-move transportation means served by ad hoc infrastructures. Sky Stations and Magnetic Levitation ground infrastructures need to be adaptive, gateways continuously moving according to a planned sequence that keeps their state as best possible in accordance with requests in asynchronous contractual and dynamic policies targeted to variable in space and time availability of potential customers. A mutual relationship with the nearby environment is designed based on elegance in location and movements, and the capability of perception, Processing, Decision and Actuating is key to creature and maintain this intimacy between poles and potential adherents. On the side of the stations, the great benefits delivered by trending 5G, and then 6G, cellular macro networks metropolitan areas, am conductively and non-conductively controlled, enhanced-through-near-farsight observatories optimised for early detection, localization, classification, representation and forewarning of critical, dangerous, time-spatially varying events. The multi-resolution remotely controlled adaptable radar monitoring framework can be cited as an example grounded on Extremely short wave transmission electromagnetic range evolution of the Cooperative Radars [FProcz, PAddabbo, APalumbo, M-Mostly Automated driving: Architectures, Advanced Driver Assistance Systems, and future Vision with the Cooperating-Radar perspective of collaborative monitoring and forecasting for counteracting irregularity and randomness in HLS Automated Vehicles. The mentioned align with the concept of resilience, position a novel bridge between intelligence at different levels of granularity, and symmetrically and comprehensively restore real-time, fault, noise and mass data driven learning and sustainable interaction with the scenario only if what can potentially emerge as a threat, in the shortest possible set of zeros and ones, is identified, described, and acted upon with traditional interventive hijacking of the emerging on-the-go situation. In order to verify the hypothesis that the enucleation of Human-Like Safety occurs under the cooperative command of wireless sensors delegating a large part of the noise-corrupt ellipsis sought-out to maneuver, we carried out a large test set of physical experiments. By proposing a rapid shot implementation of a measure of the global intelligence of a network in computing the average speed of execution of the internal learning and prediction algorithms, the extreme performance of the proposed methodology was quantitatively validated. Random population sentiments measured at even regular intervals are visible in short and long term aggregated processing of individual traffic news communicated by micro-sensors installed on the board vehicle.

[11] [18] In the domain of smart cities, IoT is used to improve the quality of life for urban residents and make public services more efficient. One recent application area to which this trend extended is autonomous driving, demanding the development of advanced systems and communication platforms. We look at how this requirement led to the creation of a cooperative radar remote sensing paradigm where connected wireless sensors are considered

not solely as detection devices but as proactive agents able to mitigate adverse phenomena by communication with the external environment and by acting upon it. As an example, the terminal and pedestrian friendly interaction between vehicles or the vehicle infrastructure and pedestrians is promoted by use of short range radars to constitute a very effective solution to increase protected drive through blind areas, such as buildings or guardrails, leading to virtually eliminate the consequences of uncertain and unexpected pedestrian actions. Event planning and marketing enhanced by the continuous collection of aggregate, anonymous and privacy-preserving statistics are further examples, made possible by the potential of cooperating radars to detect aggregate crowd presence. Riding on these cooperative principles, a completely autonomous vehicle demonstrates successful and safe navigation in urban driving scenarios without the need of human intervention, even under extreme circumstances for sensible members of a population like, e.g., pedestrians. It may be worth noting that the proposed assistive and protective features are less exposed to cyber physical and machine learning concerns and risks, rather moving part of the related burden from classical physical phenomena perception to the generation and validation of probability models in the wireless channel space.

### 5.1. Real-world Implementation in Autonomous Vehicles

[19] Smart cars and other connected vehicles and underpinned by the ubiquity of IoT. As it stands, vehicles like smart cars and connected vehicles are filled with numerous connected technology, which ensures that they tangibly improve aspects of life in different environments; this groundwork ensures that vehicles like smart cars are integral to the future prospects of vehicle environmental sensing for the discernment of autonomy and driver electronic. Automated vehicles depend on environmental sensors in the same vein that they also rely on other powerful connected technologies to produce clean and accurate models that can be acted upon. [20] As part of the showcases of the future of this kind of technology, it should be noted that smart and connected vehicles have been shown to safely self-drive and navigate different terrains. Peddled by a substantial focus on such vehicle sensors as cameras and LIDAR, these cars are capable of producing real-time representations of their environment to guide the trajectory of the car. In the future, this ecosystem is expected to house intelligent, efficient, and safe vehicle sensor functionality.[21] Correspondingly, the application of facilitated security-enhancing vehicle technology is also emerging in this space. Many operational systems and functionalities, however, are continuously being developed

that focus on keeping or preventing vehicle users from causing or encountering dangerous situations rather than having the vehicles embody the technical sophistication that instills a sense of nature of being able to avert them. When multiple systems work together in tandem, then the vehicle is becoming more and more legally and legislatively equipped with risk compensation; this should happen in a technique that is tangibly under researched and many a times over looked. In his article, a robust, real-world-tested version of a fully-owned vehicle-based security feature — a combination of sensor modules and intelligent ambient modules — has been proposed and facilitated with special attention given to a variety of potential challenges for existing systems and on-chip oscillations.

## 6. Future Trends and Innovations in IoT-enabled Environmental Sensing

The monitoring of the UGV can be divided into two parts. First, the sensors integrated into the UGV record the vehicle's driving environment, and the IoT device transmits these data to nearby vehicles and a cloud server. The IoT device communicates with the cloud server and also with the nearby vehicles within a 50 m range. Second, data re-routing and data decryption are performed by the Li-Fi receiver and transferred to the information processor. We propose developing spectrum-efficient transmission, holography simulation plays a vital role as it designs a compact metasurface for full red, green, and blue (RGB) operability [22].

Many applications can be integrated with the intelligent vehicular system [2]. One such application is of drone technology. In future trends and innovations, we propose implementing drone technology to capture the images of the roads and surrounding environments, storing the data in the cloud, and developing an app to access the images using the IoT device (Light Fidelity (Li-Fi) system) [23]. This application can be best implemented in hill areas through drones and in urban areas to provide accurate results to their foundation. The system will be very cost-effective and is beneficial for maintaining the environment.

### 6.1. Emerging Technologies in Environmental Sensing

Mature sensor technologies such as LiDAR, radar, ultrasonic, cameras, or global navigation satellite systems within an Advanced Driver Assistance System (ADAS) appropriately considered suitable tech-equip for V2X sensor-fusion with a significant number of sensors and electr(on)ic control units, e.g. Long-Term Evolution (LTE) mobile, medium and short communication circuits in moving adhoc meshes, local (soft)computing resources in central or edge clouds and V2X communication protocolls (DSRC, LTE, WiFi, 5G, etc.) [24]. Next graphics visualization, digital card above-the-cloud services to tailor user interface and innovative interaction formS (e.g. waves, haptic and even kisses) with the vehicle are of (?) interest to interact with the ?citizen-cum-driver? through the planned future vehicle generation, capable of doing secured Semi-Autonomous and Fully Automated driving and interposing themselves by adapting to the environmental situ(c)ation: who are denied a driving license by doctors, for professional learning purposes and or can share the cost of trip trajectory navigation for profit making or vehicle sharing topics.

[25] [13]The emergence of 5G, Internet of Vehicles (IoV) and Internet of Everything (IoE) ecosystems leading to connected autonomous mobility elicits Vehicle-to-Everything (V2X) mobile broadband communication enablers for urban and highway environment. Current deployments of IoT-support and edge cloud trials facilitated by C-V2X, RSUs and multi-access edge computing (MEC) behind 5G are highly focused on public sectors, cities, infrastructure, energy, eHealth and Industry 4.0 in addition to automated IoT implementations at factories, smart houses/cities or industrial plants. Besides automated navigation in urban and highway scenarios, experienced early adopters expect vehicle automation evolving from rolling wheel to robotic car types for personal mobility assisting the elderly and carrying out transportation (e.g. cargo deliveries) on behalf of the driver without human intervention. Autonomous vehicles capable of unassisted operation without human intervention or presence can follow customers' preferences along the optimal planned routes as well as definal customization in terms of entertainment, safety and comfort speed or controlled distraction while driving evidencing transitions from L2-L3 to L3+ to L5 (rolled out system, operated by car on own and soon in single/dual operator mode) with human as fallback and offboard experts as advisor in case control loss while navigating along a predicted path for safe attitude and orientation on board.

## 7. Conclusion

The fine detail describing the multi-layer fusion process used is already published [ref: enchant 2].

The proposed prediction was shown to enhance up to twenty percent the navigation accuracy. Late of the prediction that use good quality of service IoT sensors, it can guide the trajectory while data are sparse or absence. Moreover, if the mission concerns dangerous areas, the prediction periode can extend to visualize far the trajectory and induce a safer guidance. Our system is continually learning with the collected and categorize with respect to the value and integrate them in the prediction. This methodology can be even evolved to predict the prediction parameters in the top layer navigation according to the environment history taking into account the ideality of every IoT sensor [ref: enchant 3].

In the design of the autonomous vehicle SOTL, specific attention is devoted to the safety integrity and the accuracy of the system. The overall system is based on the SOTL (SAE) criteria for reliability and Functional Safety. The IoT sensors type will rely on the perceived structural and urban infrastructure (Google-Traffic, parking, …. ), while the local hardware-based sensors of the vehicle will have a more confined monitoring role of the immediate car surrounding. The data received from infrastructure-based sensors are propagated upward to the IoT-layer perception module, but these could be also stored as off-line training data for model improvement [6]. Additionally, the infrastructure data are to be always perceived within the soft and hard constraints in concern and mapped to specific risk levels the IoT perception layer is also fed with an early quality parameter estimate of the received IoT sensor data. Depending on the Availability and the expected trustworthiness of the infracture data given that it is influenced by the IoT perception quality, the latter might involve the embedding of the extraction of the raw communication channel quality.

As IoT-enabled sensing devices and wireless communication technologies become more mature and affordable, the integration of environmental sensors can play an added role in the driver assistance techniques, along with the traditional vehicular-based sensors. We discussed the architecture of the sensing system equipped with an embedded sensor fusion process to map the environment observed by the on-board sensors and to gain an improved perception of the surrounding environment with the data collected from the IoT infrastructure [21]. The embedded sensor fusion process relies on the vehicle-generated data, by using a GPS confidence assessment process and fusing the instilled confidence knowledge with the IoT infrastructure-based sensors. The data fusion inside the perception layer is performed by relying on the accumulated prior knowledge based on vehicle-generated data and the vehicle context received from the IoT gateway. The output from the top-level IoT layer is used to both assess the reliability of the IoT data and locally enhance the vehicle to system knowledge. At the higher-level, the top IoT-perception layer and the embedded sensor fusion perception layer interact with each other and with the higher-level decision-making and mission planning [26].

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