Ethical Considerations in IoT Sensor Deployment for Autonomous Vehicle Safety

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1. Introduction

Other safety-relevant automotive issues such as a cyber-physical "pathogen" that affects the vehicle's systems or control are also competitive in terms of market solutions and do not receive adequate attention from regulators. By connecting the potential pitfalls of these competitive institutional designs to the theoretical literature on robust institutional design, we reach more general conclusions in the final methodological section of the paper. This literature cautions the ethics of rules to strategically ignore subjective features of future institution designs: rules about autonomous vehicle control switching from non-resident to resident in hostile regulatory environments. It is difficult to imagine the design, testing, and deployment of more general AI rules on the premise that regulators and manufacturers are perfectly benevolent or acknowledge the need to interpret their own choices in this way.

Cyber-physical systems based on the Internet of Things (IoT) have the potential to greatly increase vehicle safety and enable large-scale societal deployment of autonomous vehicles. An increasing percentage of cars on the road already use IoT sensors in advanced driver assistance systems. These same IoT sensors are also candidates for use as an input to autonomous vehicle control, enabling further features. Ethical research suggests how to deploy IoT sensors to improve safety, even beginning with these early deployments of advanced driver assistance systems. In a survey of automotive regulatory documents worldwide, we find that the question of where to place sensors is neither prominently nor satisfactorily addressed. This conclusion is not unique; today's autonomous vehicle speed and brake control command priority is also the result of market competitiveness and liability costs. These problems motivate the first institutional recommendation of this paper regarding sensor location.

1.1. Background and Significance

One of the main beneficiaries of the deployment of CAVs will be vulnerable users such as pedestrians, cyclists, motorcyclists, and e-mobility device users. The provision of enhanced and affordable access to transport services for those who are currently transit-poor would be a welcome social benefit of increased automation. However, there may be potential unintended consequences of the deployment of CAV technology unless the collective digital infrastructures and codes of connection that need to facilitate CAVs—devices, procedures, data flows, sensors, and support services—are itself deployed with ethical considerations at their core. In recent years, researchers and practitioners have started to discuss ethical considerations in the CAV domain, including the development of consensus on the critical principles that will guide the public, private, philanthropic, and academic stakeholders in their deployment and governance.

The development and deployment of connected and autonomous vehicles (CAVs) have the potential to make an unprecedented impact on issues such as road safety, congestion, and pollution. As a result, significant resources have been invested in the testing of V2X and other data-sharing mechanisms, supporting complex functionalities such as sensor data sharing and cooperative perception. However, there has been limited research and development into the technical and ethical issues that need to be addressed in the real-world deployment of Vehicle-to-Infrastructure (V2I) technology to enable these advances for the common good.

1.2. Purpose and Scope of the Study

The scope of this research is outlined next. Specifically, it is focused on IoT sensor (which could be any variety of IoT sensor: long or short-range radar, lidar, ultrasonic, cameras) sensor deployment upon highway rights-of-way for the benefit of enhancing sensory AV systems collectively. Rather than the use of these sensors by a single proprietary system in a single car, the sensors are available to all AV developers. In this way, the work does not delve into the sensor outputs or the operation of any proprietary AV company. Rather, it is about the care, operation, and potential sensor interference of all autonomous vehicles using the sensors. This focus is unique among papers exploring spectrum use and autonomy, which typically focus exclusively on cellular modems or C-V2X units, potentially discounting the importance of sensory AV system performance.

Autonomous vehicle (AV) safety is a complex problem involving human behavior, motor vehicle law, and vehicle technology. The purpose of this chapter is to examine ethical

considerations in deploying wireless sensors, which together comprise the Internet of Things (IoT), for the purpose of enhancing AV sensory systems and sensor networks. These devices communicate wirelessly with other devices to issue commands automatically, undertake actions, or provide information aspects that are particularly important due to the safety-critical nature of AVs. To review and analyze existing IEEE, NHTSA, and state-of-the-industry IoT sensor standards and learn what is currently best practice for usage of these devices in safety-critical applications, it will be critical to extend the conclusions drawn herein to this technology as well.

2. Fundamentals of IoT Sensors in Autonomous Vehicles

Autonomous vehicles may have a range of additional supportive systems, with additional sensor systems that are integrated to handle user needs. The functional safety of autonomous vehicle systems is typically designed around two specific frameworks.

Level 5 – Full Automation: An autonomous vehicle will not require any human or automated system to drive the vehicle under any conditions.

Level 4 – High Automation: Autonomous vehicles with defined and operational design domains may be driven by an automated driving system without human engagement. Although the vehicle may request human assistance, the automatic system may, however, have a slightly longer intrusion to system re-engagement capability.

Level 3 – Conditional Automation: An automated driving system is responsible for all driving control and monitoring tasks in a conditional operational design domain. This allows the human driver to disengage from driving, but only under certain traffic or environmental conditions. In case of a system failure, the vehicle may request human assistance at short notice.

Level 2 – Partial Automation: An automated system is responsible for the controlling of both user-facing and driving automation tasks, but only under certain conditions. The human driver must continue to monitor the driving environment at all times. Both the human driver and the automation are engaged in monitoring the driving environment and the inducing task.

Level 1 – Driver Assistance: At least one user-facing task, such as acceleration and deceleration, lateral and longitudinal vehicle control, and/or steering, is partially performed by an in-vehicle system. Both the human driver and the automation are engaged in the user-facing task.

Level 0 – No Automation: A human driver is responsible for controlling the vehicle in all situations.

The primary functional components of autonomous vehicles, as defined by the Society of Automotive Engineers International, are divided into four levels of system capability.

The use of Internet of Things systems as the primary controlling sensor system of autonomous vehicles raises significant ethical issues related to security, privacy, and the potential for the loss of human decision control posed by autonomous vehicles.

In recent years, significant advances in the development of sophisticated deep learning systems for image recognition, as well as in the miniaturization of computer systems and sensors, have made it possible to turn our vision of a future with autonomous vehicles into a reality. However, significant safety, regulatory, and insurance-related questions remain to be resolved prior to deployment.

Autonomous vehicles are an emerging technology that holds promise for revolutionizing the way that people and goods travel in the future. The expected benefits in terms of vehicle safety, system efficiency, user access to transportation, and reduced environmental and social externalities have motivated investment from the automobile and information technology industries, national and local governments, not-for-profit organizations, and others.

2.1. Definition and Types of IoT Sensors

Sensors (Signal-to-Data Converters or Signal-to-Information Converters) play a key role. Sensing technology, environment perception, localization, decision making, and navigation are interdependent and key issues for deploying Autonomous Vehicles. There are specific IoT and IoV sensing requirements that an individual sensor in an IoT and IoV deployment can be designed to comprehensively address, through participating in both vehicle internal communication and vehicle-infrastructure communication. The key perspective of the sensing project is about deployment. For example, on which part of the autonomous vehicles should

the sensor be deployed to better assist the autonomous vehicle in being environment-aware? If an IoT sensor is for multiple sensing requirements, should it be capable of omnidirectional viewing? Will the sensor be able to discern the environment details? Generally, an IoT sensor is a solution addressing sensing requirements which are not only about the measurement of the sample locations but also about responding to what types of collection, and how data collection should happen. Note that the detection mechanism makes possible different technologies or principles for measuring the response to collection requests, such as detection of sound or magnetic signals.

The Internet of Things (IoT) leverages sensors to connect smart and everyday physical objects with cloud computing, enabling user interaction and collecting data for further analytics. Smart applications have been emerging from home, industry, agriculture, precision medicine, autonomous driving, and vehicle environmental sensor arrays for future smart cities. The emergence of the autonomous vehicle is indeed one of the most fascinating goals of our time, where connected autonomous vehicles will promise to greatly improve commuters' quality of life due to a significant reduction in the loss of time during commutes, freeing up drivers for other tasks that are unrelated to driving, and also freeing up parking space linked to better traffic flow. Autonomous vehicles serving as robotaxi and robotic delivery vehicles could revolutionize the way companies operate, with a significant reduction of greenhouse gas emissions.

2.2. Applications in Autonomous Vehicles

As IoT technology matures, intelligent sensors have become powerful tools to support various applications, and the development of AV is booming in the intelligent transport system. Several different sensors support the control systems of the AV and navigation algorithms, including light detection and ranging (LiDAR), cameras, sensors, remarks, and the inertial unit (IMU), which provide environmental and operational information in real time. Since it is unfathomable to connect all AV to a wire or external energy supply is unreliable, the continuous-necessity sensor of long-term energy supply with internal power supplies is essential. Hence, as in the production of information towers by Polast, the autonomous energy supply framework for AV sensors is considered to be a challenge to investigate. With sensitive data, resolution of output mV and the duty of one may become. With sensitive bias, used in versatile systems and knowledge may not be perfectly matched to each other. Even if the

energy supply is successful, there is a real-time energy failure while responding to the needs to make the energy device prepared for a suitable choice of devices and algorithms realistic.

This section discusses the use of the Internet of Things (IoT) in the field of autonomous vehicles (AV). As engine sensors are necessary to monitor and record the physical state of a vehicle in real time, I discuss the work of energy suppliers for IoT-supported tools, power supplies, and algorithmic designs that can supervise the energy flows and failures related to cars. The sensors also support the control systems of the AV and the navigation algorithms by providing environmental and operational information. The experimental results and performance analysis demonstrate the application prospects of the presented multisource energy supply.

3. Ethical Frameworks in Technology

There is a large current literature on safety-by-design approaches in safety-critical system design that encourages proactive design for and assurance of safety before operation. For vehicle operation, all states (including sudden system failures) must be within the safe set, L_fc(δ), given the current and potential future sensor inputs to the connected vehicle, BV, and controllers, CF. Without loss of generality, L_τ is defined as a set of all vectors of sensor inputs or sensor measurements possibly used by BV. Finally, U_m is defined as the set of unknowable future sensor outputs that may be observed only beyond a sensor fusion.

3.1 Safety In the field of occupational health and safety, an emergent concept is designing for safety-as-appropriate. Such an approach could relieve technologists of complete blame if accidents occur by designing systems that are fault-tolerant and condition-monitoring, to pick up human error, and make engineering systems or products more safety-aware. These systems will protect users from undertaking dangerous activities, particularly if the required safety is beyond the capacity of the users to appreciate.

We now present a range of ethical approaches in the area of information and communications technology. We end this section with a discussion of how these considerations may be applied to IoT sensors in the autonomous vehicle domain. We will identify how IoT sensor deployment synthesizes these ethical considerations from safety, security, effectiveness, and privacy perspectives.

3.1. Utilitarianism

Some businesses believe that if their act will bring happiness to the greater number of people, the decision is an ethical one. Take, for example, if sensors in autonomous vehicles are designed for the highest capacity of safety with cost. Utilitarians would assume that with the lowest risk of problems, the greatest number of people will benefit from the results. Some utilitarians may believe that if new technology is meant to improve public safety, it should not be put on hold due to the fact that statistically someone was affected negatively. The cost of any innovation is easy to pinpoint in the capital invested to drive the invention, but the social cost of the invention can be devastating. The utilitarian view could potentially mean that designers will build in interference in the sensors to help lower the number of pedestrians physically affected by vehicle malfunctions. It may also lead to designers taking even bolder steps to implement technology that removes human life from these sorts of critical split-second decisions in general.

Utilitarianism is the moral principle that says to do what will produce the greatest amount of happiness or good for the greatest number of people. Under this principle, one would have to take into account the self-interest of both oneself as well as others. This might lead to instances where you could unintentionally cause harm to another, while at the same time producing a greater benefit. This is why many criticize this principle, as non-consequentialists claim that it is morally acceptable to intentionally allow someone to die in order to support the greater good. It is common for businesses to hold the utilitarian point of view in order to maximize profits and decrease costs. However, in doing so, businesses have an ethical, moral, and social, as well as economic, duty.

3.2. Deontology

People often switch between distinct and incompatible normative models in their intuitions and reasoning when confronted with ethical problems. This occurs particularly when trying to resolve moral dilemmas, which are situations in which an action is deemed morally imperative regardless of consequences. Consider the well-known moral dilemma in which five innocent individuals are going to be killed unless a person drops a heavy object in their path thereby killing another individual. The deontological response is to save the five while the utilitarian response is to kill the one. People sometimes view an argument in favor of a particular moral judgment as merely the uncovering of the rationalization that can explain the

intuition, at other times, people regard the argument as the key factor in producing the moral judgment.

In deontological or duty-based ethics, the rightness of an action is based not on the consequences of the action but on whether or not it has adhered to a rule or a duty. It was introduced by Immanuel Kant and formulated as: "Act only according to that maxim whereby you can at the same time will that it should become a universal law." Kantian ethics focus on consistency with moral laws. Kant argued that moral duties are rooted in the nature of human rationality. This school of ethics is concerned with universal maxims, rights, and duties that all share and abide by. An action is considered right or wrong based on whether it can be extrapolated to all possible similar actions. Deontological investigations do not ask people what they want but identify the kinds of interaction that they have reason to regard as permissible/obligatory. Particular duties are obligations applied in particular circumstances. Once a decision has been made in an action situation, people then consider additional normative dimensions.

3.3. Virtue Ethics

A development of this way of thinking is manifested by the proposal that businesses themselves should have character and this should be one founded on traditional notions of justice, and these virtues of the organization would be reflected in managers' actions. But there are a number of problems associated with it. The most central, for our purposes, is that we do not seem to use autonomous virtue in the way that we first set out. That is, we do not, for instance, actually utilize compassion or the sense of balance living in a state of reflection and we can behave virtuously in the commercial world, even though the commercial world does not encourage or build towards virtue. So is this model of use to hyper-connected systems? It would seem not, and that hyper economy has no mechanism for the iteration necessary for the practical reasoning necessary überhaupt to become virtuous. So, unless somehow a 'personal' state is transmitted to the concern, this mode does not help answer our overall question.

In this philosophy, the emphasis lies less on rules and their application and much more on the character of the agent. There are common and classically held virtues, but mostly in terms of their extremities. So, the virtue of honesty should not involve lying, but probably still involves never commenting on dress choice, for example. The aim of the virtuous person is to become

moderate in their judgments and behaviors. This is particularly true with respect to conditions that people find themselves in and the correct course of action will vary with the individual and the context. Knowing what such an action is depends on the complex virtue of wisdom. Applied to business life, the model becomes less Aristotelian, but the notion is still that the virtues of trustworthiness, fairness and impartiality should be allocated and these, it is assumed, would help to overcome crises of judgment and bad behavior.

4. Ethical Challenges in IoT Sensor Deployment for Autonomous Vehicle Safety

Ethical principle-based approaches can be sources of guidance in the development of such policies. IoT sensors designed to keep autonomous vehicles as safe as possible should be activated, regardless of the broader collective moral dilemma related to vehicle safety design. Thus, policies designed to ensure sensors that could help should be activated during the operational autonomy of the vehicle. This is not unlike current policies that require that seat belts and other safety devices be functioning properly prior to putting a vehicle on the road. Autonomous vehicles should be required to have all sensors active and calibrated in any driving environment, including rain or snow. Currently, policy and regulatory attention seem to be focused on preventing the kind of large-scale tragedies that occur during testing on public roads. First and foremost, sensors should be activated when and where people typically engage in their dangerous behaviors.

Our final category of ethical challenges in IoT deployment for autonomous vehicle safety concerns the practices of the deployment itself. In essence, ensuring all sensing devices are activated in order to minimize harm associated with driving behavior. First and foremost, the context of deployment is critical to the problem of ensuring all relevant IoT sensors are activated. When designing a policy to ensure the operationalization of all the IoT devices/sensors, this policy should not be overly simplified. Autonomous vehicles travel in real-world contexts and encounter changing and dynamic environments that influence the incoming data and the strategies for using that data. What is immediately visible on a sunny day is quite different from what is easy to see on a rainy day. Regardless of weather, the attributes of the road (for example, surface, width, and condition) or the presence of motorcyclists, bicyclists, pedestrians, or animals crossing the road all influence the need for sensors.

4.1. Privacy Concerns

Security is used as chronicle insulation and enforcement model and enforcement consideration, and characterizes compromised developer cost, liability losses, vulnerability disclosure and regulation, and informs facility investment and liability capital policies. Networks, facility asset planning, also allows implementation and enforcement policies and financing approaches, to be modified as environmental data and control are installed in public and private spaces to create new smart applications. When the environmental assessment network serves a mandate, investment priorities and the network.

Regional planning for network installation allows consideration of public investment to better protect and serve vulnerable groups. To date, policy development and discussions have focused on individual smart city components or implementations, but because of the important interrelations and integrated policy directions, we recommend a decision makers' framework to master smart sustainable metropolises. The device, based on basic security considerations, suggests policy development depending on installer.

Privacy is a critical customer concern in sensor deployment, and a standard response is to never have sensors record private spaces. Maintenance security work and civil liability laws cover expected maintenance and accident response. Associated costs may or may not be covered in usage policies, particularly as they depend on use classification systems. Usage policies apply well-defined economic incentives to provide for access and offset incompletely private networks and to provide for maintenance preparation.

4.2. Data Security Risks

To improve data security and manage the risk of data theft, the sensor-controller circuits and federated vehicle system data processing links could be made more secure to prevent unauthorized customer access to the sensor system and vehicle information link using firewalls to protect vehicle sensors from proprietary third-party applications like autopilot and servobox. For data sharing, each primary sensor fusion domain owns and publishes image data files with unique sensor capabilities and a selected image space region, necessitating manufacturer support for an effective and direct camera information-sharing capability. Sensor signals can also be combined in an onboard vehicle Systems Monitoring and Reporting Tool (SMART) Field Programmable Gate Array (FPGA) to support physical vehicle system monitoring and problem notification. SMART FPGA's powerful security partition also supports trusted sensor signal processing, allowing advanced sensor system

data like Automotive Grade Digital Video Recorder (DVR) or sensor system domain security to be set and logged. SMART FPGAs have an embedded security manager that allows checks, encryption, and authorization codes to ensure system and data privatization while verifying that a customer's big data operations are secure, legal, and legitimate.

If system security is breached, data loss, unauthorized use of secured data image person or private data streams become real consequences that could lead to compromising the privacy, security, and safety of individuals and institutions. Camera sensors transmit captured image data over a network to the ADAS control system. After preprocessing, a camera sensor can carry image or video data up to several megapixels to the parallel image data processing units (IPUs). In the data preprocessing stage, the identified high-resolution data payload may contain environmental feature data that permit driver distraction, for example street advertisements or crash scenes, to be detected and passed along downstream. Information data can also support applications that facilitate context-aware cross-system data sharing, for example combining vehicle information with traffic and road infrastructure data to provide better congestion information during emergency vehicle operation. For the data-sharing construct, factory-installed OEM data-sharing intra-vehicle links are usually logically separated from required automaker customer data-sharing inter-vehicle links, and customer-installed third-party data-sharing in-car data links or internet connectivity are designed to be closely monitored and separate to prevent unauthorized customer information access to link data.

Strong vehicle sensor security should also be a primary focus to mitigate data vulnerability. Anonymous data extraction and unidentifiability to the system or entity would be preferable so that hacker-derived vehicle geographic location or vehicle identity information could be minimized in the event of unauthorized third-party access. Quality algorithms and data anonymization can serve as preventative measures. Disclosures of security measures and full responsibility and accountability to potential parties involved with data access and exchanges could also help minimize this particular security risk. Physical security of the sensor system, data, and data-sharing agreement entities that support the sensor data may require additional protective measures, including camera tampering tools, controller unit enclosures, and telecommunication data fencing. Furthermore, improving redaction performance to obfuscate sensitive data like recognizable individuals, license plate numbers, and private residential or

business addresses could play a role in reducing the attractiveness of the potentially sensitive data.

5. Regulatory Landscape and Standards

In the 2006 Intelligent Transportation Systems Strategic Plan, the U.S. government seeks to significantly reduce transportation-related fatalities by addressing three factors: human error, environment, and vehicle condition. In the transportation systems of the future, the U.S. government provides incentives for the development and use of advanced safety systems that prevent accidents, override driver errors, and inform drivers about the condition of their vehicles. For example, the National Highway Traffic Safety Administration established incentives by setting standards on tires containing underinflation pressure monitors. The Low Volume Motor Vehicle Manufacturers 2015 Act prevents the National Highway Traffic Safety Administration from limiting the production or performance of vehicles for which less than 500 replicas will be produced per year.

Construction Specification for Robotic Cars. However, a review of how ADASs can reduce crashes is not provided. The Phrases for usage in driving automation systems for on-road vehicles. IEEE 2846-2018 is a dictionary that provides standard definitions of terms to be used in vehicle automation systems. This dictionary includes terms for behavior control of the vehicle and sensor measurements of the environment and vehicles. The dictionary also contains definitions for system–infrastructure communication and driving automation capability.

Advanced Driver Assistance Systems (ADASs) are mentioned in Section 10004 Crash Prevention Technologies in the U.S. Moving Ahead for Progress in the 21st Century Act or Map-21. In addition to government requirements of vehicle safety systems, companies can voluntarily commit to meeting automotive safety standards, which include the SAE Levels 0–5 standards and the IEEE standard 2846-2018 Phrases for usage in driving automation systems for on-road vehicles that is expected to improve safe driver-vehicle–road communication.

This section describes the regulatory landscape and standards for vehicular safety in the U.S. Cost reductions facilitated by standards tend to shape the automotive regulatory environment. In the late 1990s, U.S. regulators required that tire pressure sensors be installed in motorcycles, passenger cars, and light trucks and that they alert drivers when the tire

pressure is significantly below the recommended level. This standard serves to mitigate accidents and deaths from underinflated tires.

5.1. Current Regulations in Autonomous Vehicles

Some of the recent regulations on autonomous vehicles include the NCHRP report 7-50 on automated vehicles, the Directive 2014/53/EU, the legal regulations in the Federal Register, different guidelines by the International Society of Automotive Engineers (SAE), and different states like California, Nevada, and Michigan. For instance, the UK has recently implemented different regulations to govern autonomous vehicles, including the Electric Cars Act 2018, the Transport Act 1968, amongst others. These regulations involve mobility on demand service, which ensures the safe operation of autonomous vehicles, e.g., by providing data sharing, security of data, cybersecurity risk management, and public perception and consumer acceptance among other things.

The types and number of autonomous vehicles have notably increased in recent years, and thus different regulations and guidelines have been released. These regulations have been released at varying levels (international, national, regional, municipal). Some of these guidelines are voluntary, whereas some are mandatory based on the implemented regions. These guidelines are developed to provide a safe and clear context for managing multiple streams of vehicles on public roadways.

Regulatory frameworks outline the responsibilities and roles of stakeholders, as well as the legal obligations governing these participating parties. There are sparse regulations in the area of autonomous vehicles currently existing. However, with the increasing threat against road safety, new regulations and directives necessitate implementation.

5.2. Proposed Standards for IoT Sensor Deployment

Numerous standards and guidelines currently exist and are in development for sensor deployment in IoT applications. In the domain of autonomous vehicles, cooperative driving and road safety (C-FCD) applications are an important form of IoT that will depend on a reliable deployment and operation of Intelligent Transport Systems. Additionally, research has suggested the need for standards that address three critical areas to support V2X: architecture, information security and privacy, and access technology. For the most part, V2X penetration rates have been too low for DOTs and automakers to decide on standards.

However, there are some IoT use cases that are already benefiting from international standards. For example, a society for automated vehicle systems at SAE International has invested considerable time and expertise from industry, including V2X specialists from automakers, to develop a series of technical reports for the design of V2X applications and environments that address critical public safety needs. Employing these standards can provide a well-performing, secure enough, and interoperable base for IoT operations, along with additional regional regulations and correct privacy policies that could be tailored to the needs and operational constraints derived from public safety considerations for automated vehicle level 4 and 5 deployments.

6. Case Studies and Examples

An infrastructure that could allow driverless vehicles to gain rapid traction relies on extensive deployment of network-centric (IoT) sensors in the infrastructure that could allow driverless vehicles to be monitored and guided. The IoT driverless vehicle research focus has primarily relied on the technology of the 'things' - sensors, communication and computing infrastructure, machine learning, and artificial intelligence that are the foundation layer of IoTs. However, given widespread adoption, the deployment aspect of the "things" is expected to be performed by a diverse set of actors and authorities that could also bring in a diverse set of ethical considerations.

This section discusses the deployment of various sensor technologies in IoT for driverless vehicle safety and discusses potential ethical implications during the design and deployment of the IoT infrastructure for the driverless operation of vehicles. They are intended to serve as a food-for-thought document that stimulates a structured dialogue for the practical design and deployment of the IoT infrastructure for fully automated driverless vehicles. The examples aim to provide technology designers with a practical reference guide for maintaining ethical principles in the development and deployment of IoT driverless vehicles. They are not intended to be an exhaustive study of the design and deployment of possible IoT sensing implementations of driverless vehicles. Their goal is to suggest a practical approach for identifying and addressing key ethical dilemmas that may arise during the deployment of IoT sensor infrastructure for driverless vehicles.

6.1. Real-world Applications of IoT Sensors in Autonomous Vehicles

A self-driving car, also known as an autonomous vehicle (AV), driverless car, or robotic car, is a car that can travel without human effort. These vehicles sense the environment by employing IoT technologies such as radar, laser light, GPS, odometry, and computer vision. Advanced control systems see to the functional planning and they can control steering, braking, and propulsion as a result of a digital map. Since these sensors implemented in an autonomous vehicle aim to provide the driver with a safer experience for travel and make it adaptable to any attending needs, ethical conceptions when considering the inaccurate data and errors this application could provide is very relevant. Thus, as these sensors use AI to understand the environment, this requires constant updates of the rules and outcomes the AI current algorithm could provide.

7. Future Directions and Recommendations

Moreover, alternative sensing systems are substantially less reliable than the library of algorithms that currently run in graphics processing units when they track pedestrians or bicycles. Higher-resolution images and more usable processing power will provide greater situational awareness and better object classification. One safeguard against privacy invasion concerning any visual sensor-based deployments would be to store images and then process them only following an accident or other triggering event. Another possibility that could be implemented is to establish a point at which the onboard computer can be disconnected from the power source and then lock the images from sensor use—rather like transportation of gold versus currency domestically and internationally. These are at best partial protections as severing the onboard processor for a given duration could be determined by an accident in which the vehicle is not involved; on the plus side, total reliance on machine-driven algorithms has the huge advantage that automatic surveillance will not be subject to individual ethnic discrimination.

Clearly, the use of cameras, especially rearview ones, will continue to raise concerns for intrusion into individual privacy. Our goal here is neither to downplay nor to criticize these issues but rather to provide solutions that allow support for the social rather than the personal good to be deployed. The areas in which remote sensing raises social concerns include protection of intellectual property, preventing fraud, theft and vandalism, and enabling remote supervision or surveillance by a variety of authorities. Consequently, our approach is very conservative. Since remote sensing includes the potential for abuse, the process and

content of the business model, including the types of alarms, situational awareness, and the location that benefits from the use of each sensor, will be subject to oversight by public interest organizations. To fortify the argument that we are not reinforcing the current limitations but rather expanding the ability of a machine to offer enhanced safety, let us compare with today's technology, which mandates that each driver employ visual sensing to augment their actions, yet that is totally the purview of individual judgement.

7.1. Potential Innovations in IoT Sensors for Safety

Specifically, in the field of autonomous vehicle safety, automotive manufacturers have a lot of leeway in customizing sensor deployment due to the lack of standardization in both in-vehicle and infrastructure hardware. As mentioned in Chapter 2, manufacturers at present do not collect standard, comprehensive, global datasets to verify their safety claims. Federal oversight in the United States is not yet systematic, despite the voluntary self-assessment reports issued under the CIS 'Seven Guiding Principles'. In the realm of commuter safety, as identified by Foxx, numerous issues have been raised about the possibility of accidents with vulnerable populations, malfunctioning sensors, data hacking and other issues. Much less is known about the technologies the government believes are fundamental to mitigating the safety problems. Currently, these sensors are tested by the manufacturers themselves, as the federal 'Guidance' has not yet led to the issuance of specific, enforceable legal regulations for the sake of verification. For example, while there are tests for auto-brakes and crash avoidance systems developed by the Insurance Institute of Highway Safety and the National Highway Traffic Safety Administration under its New Car Assessment Program, they are voluntary, and it is unclear how devices behave under real-world conditions. This chapter argues that no matter how straightforward and necessary IoT hardware appears to be, governments should promulgate mandates or standards for the development and use of IoT sensor data in safety-critical applications. They should also conduct oversight to verify veracity since humans will continue to provide a backstop or act as injured parties.

8. Conclusion

Sensorised autonomous vehicle fleet data can remain useful for long periods of time, up to a consortium's lived ethical framework. Tools exist to restrict what can be done to the data as modifications to the AGPL carry forward, its functions and requirements for all derivatives. istros.isory.data package, augmented by enforcements of these functions, hard or soft

instructions to only enable actions by those able to demonstrate a focus for datasets over long periods of time.

This chapter highlights the potential of collective autonomous vehicle data on sensor location to improve the quality of these data over time and at scale. To editors of mapping platforms and others placing IoT sensors into cities, it suggests arguments that can be used to encourage and maintain long-term sensor deployment. There are, however, ethical considerations of exposing location data to senders and beneficiaries of privacy that must be observed. The design and reporting of sensor deployments need for this reason to safeguard legitimate privacy needs through community involvement in the design of sensor deployments, system designs not to worsen inequalities in agency, more than technical general-practice support for what individual security looks like and limited lifespan's engagement.

8.1. Summary of Key Findings

The ethical considerations built into the deployment and regulation of IoT sensor networks have important ramifications not just in complex, shared, and increasingly autonomous modes of transportation, but in the wider effort to deploy AI technologies across areas of life with public good endpoints. The challenges inhabit multiple stakeholder levels. City and regional transportation officials and planners have a complex task in guiding the transition of a transportation sector dominated by private cars to a mix of transit and shared high-assurance vehicles.

This paper has reviewed ethical considerations in the deployment of IoT sensor networks used in the context of autonomous vehicles. In the process, we have provided a model for synthesizing machine learning-based high-dimensional sensor data from a variety of sources from other ITS and IoT systems in a privacy-sensitive secure manner. This includes enriching sensor data at "sensor fusion" layers. We review ethical considerations at sensor design and deployment, as well as issues unique to the capture of camera and similar sensor data. We also consider how the data engineering solution affects the ergonomics and acceptability of the end product, and ethical concerns relating to mental and emotional states of drivers and passengers. We conclude by discussing how future deployments can use a comprehensive set of ethical and privacy considerations in guiding individual company practices in developing powerful yet ethically sensitive vehicle IoT architectures.

8.2. Implications for Policy and Practice

However, it would be simplistic to suggest that an approach which seeks to address the ethical implications would on its own remove significant concerns, particularly about data privacy and security, or the assertion of political power or social justice, still less those associated with instances of the technological affordances potentially raising dilemmas between moral and non-moral policies. Ethical development needs to be energy efficient in achieving acceptable risk design and regulation, so the ethical reflection requires to be part and parcel of technology development and regulation. Such engagement brings with it the possibility of identifying ethical barriers to progress and innovation.

Given that the promotion of the public good for safety requires the large-scale distribution of sensor-based data to enable innovation, ethical considerations suggest that automated transport and IoT developments should be underpinned by a robust ethical framework enabling scrutiny while remaining true to the democratic commitment to open innovation and public welfare. Involving a wide range of stakeholders in policy and standard-making processes would enrich the normative ethics approach in facilitating the improvements required in the technology while providing reassurance. This would help to build public trust as regulation that is based upon such a genuine ethical commitment can reassure individuals and wider society that the developers of IoT-AV technology are indeed working to promote public welfare.

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