Human-Centered Design of AI-driven Navigation Systems for Autonomous Vehicles Utilizing Blockchain Technology

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1. Introduction

Autonomous vehicles (AVs) are about to become a part of everyday life. The technology in the field continues to grow rapidly, resulting in calls for comprehensive regulations and standards concerning AVs. Critical to the operation of AVs are navigation systems, which determine where the vehicles are going and how they will get there. A large number of technologies and systems have emerged to address this part of the AV enterprise. Navigation solutions typically rely on the processing of large amounts of data collected from in-vehicle sensors and a broad range of connectivity technologies such as 5G and dedicated short-range communications (DSRC), making it appropriate to describe these services as intelligent navigation systems. As the name suggests, intelligent navigation systems are designed to navigate vehicles on the road with near-zero latency and thus contribute to increased safety and reduced travel times. These solutions become even more effective in congested urban environments like Paris, London, or New York, where travelers face ample traffic, parking, and access issues. However, there are some serious issues regarding the use of these innovative technologies, including privacy, safety, security, reliability, trust, and liability. The paper proposes addressing these significant questions by adopting a decentralized, human-centered approach where the end-user plays a decisive role in navigation decision-making. The paper proposes a human-centered design for an AI-driven navigation tracking system for autonomous vehicles benefiting from blockchain telematics technology. The proposed tracking system is built on top of secure intelligent navigation technologies associated with 5G, DSRC, C-V2X, and V2V communication.

1.1. Background and Significance

The interplay of values and technology in the navigation process leads to the focus of our research—human-centered design of advanced decision support. We aim to ensure that the navigation process is meaningful, and the process is based on the intrinsic need of human beings to engage with the environment, that the users feel in control and that the technology supports interaction and learning rather than just 'getting the task done'. Our assessment of recent and currently emerging decision support in the area of navigation is promising: good compasses, stand-alone positioning devices, assistive GPS technology and personal digital assistants. However, we identify major caveats regarding human–technology interaction and the shallow underpinning in terms of theory, and we comment that regulations about QA and certification for those new devices are virtually non-existent. Since the rule of technology is to 'get the job done' rather than to 'get the job done the way the user wants it to be done', the current situation does not satisfy the needs for meaningful human–environment interaction. Our specific interest is in the evolution and application of situating the human experiences with an environment into the technologically advanced decision support domain of navigation. Basic questions are: what are the values that are realized by navigation, and how do we design technology that can support those values? Such an approach is labeled 'value (s)-inspired technology design'. The question of 'how values are to be treated in technology design' is urgent and pointedly the one that our project will address. Cognitive science provides models of human beings as coherent agents striving for a coherent world. We account for a wide variety of values and offer insight into how these values are transformed into goals and carry the weig ht for action. However, technology design tends to resort to linear read-and-write models of cognitive processes rather than to similarity-based meaning construction, and adheres to syntactic structures of goals rather than to predicate-structured learning-generated goals. In this chapter we describe how cognitive science insights (in general) and situated action theory (in particular) can be applied to the navigation process emphasizing the engagement of people in the environment through action and interaction. This approach valorizes more specific the need for a sense of place, spatial orientation, and active reception of the environmental characteristics for legitimacy and meaning of the navigation (process).

The rapid advances in technical development raise growing concerns that may misuse AI-driven navigation systems for malevolent purposes, such as emergency-related problems, autonomous vehicle hacking attacks, and privacy concerns, etc. To counteract various security threats and legal responsibilities in both civil and criminal domains for autonomous vehicles using AI-driven navigational systems, a blockchain technology-based governance framework will be necessary. We consider a legal problem in which AI-driven vehicles are in a causality chain connected with both investment and protection risks regulated by law. The blockchain-enabled security framework creates an effective digital evidence proving whether navigational data have been tampered with, which can ensure the accountability of governance. This study discusses various methods by which an AI-driven vehicle navigates to its destination autonomously, making use of an AI-driven navigational system in a blockchain technology-enabled ecosystem.

1.2. Research Objectives

Through human-centered design, stakeholders will co-define aspects of key navigation systems that balance technological efficiency with human satisfaction. We aim to develop navigation system tools that are able to provide an enhanced immersive driving experience to individuals as a reference for future developments of state-of-the-art autonomous vehicle navigation systems. Our research aims to add new pathway-to-autonomy perspectives to the transport and human factors literature as well as engage participants to familiarize them with the realities of vehicle navigation systems in end-game autonomous vehicle markets.

In general, the autonomous vehicle industry lacks comprehensive understandings and guidelines of how to translate user requirements into system requirements and designs. Guidelines for effective collaboration in user-centered system development are well established for many technology sectors but currently are not present for the design of autonomous vehicle navigation systems at full stakeholder scale. The overall purpose of this research project is to develop a series of user-centered prototype navigation systems that meet the desires and comfort thresholds of autonomous vehicle stakeholders and document the progress and results of that development. Through interdisciplinary collaboration, this study will engage stakeholders in participatory discussions, then design and build prototypes that respond to individual needs. Functional aspects of prototype designs such as loudness, informative content, and design aesthetics will then be assessed through alpha testing in immersive environments to set theoretical foundations for potential field deployment.

2. Autonomous Vehicles and Navigation Systems

To make the groups and processes of creating and further developing autonomous vehicles easier to understand to the academic and engineering communities, the complex systems are broken down into five parts: A – the creation of VIP Maps, B – deployment of blockchain technology, C – considerations for human behavior and trust feedback, D – the layout and development of decision support systems, and E – the design of the autonomous vehicle. Each part is placed inside a separate bubble and then linked together according to the proposed process flow for Figure 1. The logic of the connections and the flow of the information, knowledge, and technology exchanges are then described with the use of the trans-system thinking tools of Dr. Darel Preble. By ensuring the efficient and optimized flow of information and resources between the five bubbles, the timeline for the successful implementation and further development of autonomous vehicles can be reliably met. But, because of the sheer complexity of each step, and the technology of blockchain that holds all the steps together, human-centered design principles of secure, tailored information sharing technology are equally as important as the development of artificial intelligence, safety, and navigation software of the autonomous vehicle.

The concept of self-driving vehicles is not just a fact of science fiction. The large automotive manufacturers like General Motors, and tech giants like Google, Uber, Tesla, and Apple are investing massive financial resources in the race for safe and accurate autonomous vehicles. Researchers in the fields of computer and electrical engineering are dedicating immense amounts of time and energy towards the creation of systems that support the manufacturing and operation of autonomous vehicles. The complex and time-consuming process comes from the creation of VIP Maps, the deployment of blockchain technology, the consideration for human behavior and trust feedback about the autonomous vehicle, the layout and development of decision support systems, and finally the design of the autonomous vehicle. To safely transport overall society, this innovative group effort advances to be overcome in a rapid and efficient manner.

2. Autonomous Vehicles and Navigation Systems

2.1. Evolution of Autonomous Vehicles

In 2016, the "Nissan Arivia" version of the Nissan Leaf with an aftermarket computer integration kit developed by Wepod and some of the scientists from Delft University (now belonging to Dub) became both fully electric and autonomous. In the EV space, some car manufacturers are installing V2X technology in their vehicles, which would allow the car to map its destination by connecting to the traffic signals, signs, and road condition information to other cars and roadside equipment. This added navigation layer helps the car handle situations like traffic signal malfunction, park and charging facility vacancy detection, and lane departure avoidance.

In 2008, Google researchers designed the first AI-driven self-driving car derived from standards Murray et al. and the 2010 Google Street View Maps of the terrain generated by LIDAR vehicles. They abstracted the mapping process into several different layers, including the geometric layout of the road pattern, the different traffic cues that were derived from the position of the vehicles and the environment-specific affordances signifying potential unknown hazards.

In 1958, GM demonstrated the Firebird III concept car outfitted with an onboard computer that used black and white stripes placed on the floor of the test track as reference points for navigation. The first practical self-driving vehicle, Stanford's Artificial Intelligence Research Laboratory's "Stanley" robot, won the autonomous vehicles category in DARPA's 2004 Grand Challenge.

The first vehicle with some limited level of self-control was demonstrated as a part of the 1939 World's Fair. Its wiring system was hidden under a number of iron slugs embedded within the asphalt of the demonstration track, which were connected via radio to command transmission blocks and pick-ups in the car. In response to the commands, the car would rely on these slugs to change course while following the white-striped track on the ground.

2.2. Components of AI-driven Navigation Systems

To make it possible for the execution of real-time location-based business processes, the properties of blockchains seem to be suitable for decentralized data management involving the sharing of verifiable data in so-called AREA (Autonomous cars, Robots, E-hailing services, and Autonomous cars). As it is difficult for other systems to change the content of the blocks stored in the blockchain, drivers and autonomous taxi service investors will be able to trust the way they were generated, enabling new business models for e-hailing services, smarter multi-staged business contracts, and preordering and smart authentication applications. Several governments have already developed legislation in order to undertake the issuing of a digital registry of over 3000 entrance guidelines of the areas of their Autonomous vehicle pilot zone, serving as a reference for the investor and automotive industry and avoiding unnecessary research and development expenses.

From the latest advances in autonomous cars, autonomous taxi services, or robots in e-hailing services require a very complex set of sensors, GPS. In addition, they use a set of cameras, radars, and laser scanners that generate an unprecedented quantity of sensor information to extract and identify particular relevant patterns of events or areas from those grids or layers corresponding to the navigational maps of the autonomous machine. Many of the current international efforts in the design of high-definition 3D maps, involving traditional Geographic Information Systems (GIS) with extensive database management tools, have large database structure problems that will increase the storage requirements and throughput of each data retrieval request of the systems that incorporate such maps.

3. Human-Centered Design Principles

3.2 Context Awareness To be useful and timely, the system needs to continuously assess its real-world status in the context of internet-driven traffic condition updates. User states combined with practical vehicle situation awareness are processed via a situational awareness model. Three attributes of human-centric situational awareness are crucial to our desired system (harvested from empirical studies): (1) recognizing state of the current environment, (2) identifying key objects and activities in the environment, and (3) projecting changes in the environment. Mapping system awareness should enable identification with these attributes to enable autonomous vehicle navigation situational awareness on a human understandable level. Interpretation on this level targets the integrated system design and performance communication to best leverage diverse human skills entering the transport utilization process.

3.1 Iterative Design The iterative design process encourages active user involvement at each stage of development. Real-time feedback is served by continuous development of functional prototypes. Open discussion during each design step promotes shared group understanding of project goals, development challenges, and how the prototype functions to address the identified problem. In our research, we use field trials to invite public and user feedback to steer product modifications and further group design discussions. The iterative process is collaborative at the functional, user interface, visual perception levels, towards creating feedback control systems.

3.1. User Experience (UX) Design

The primary social need for respect of autonomy (both for groups of people and for individuals) could prefigure a world shared simultaneously by autonomous entities (including people of legal age) operating in an optimal way with duties, responsibilities, powers, and capacities. The last human mean refers to the level of satisfaction the stakeholders derive from the service that the AI-driven automatic navigation ensures. The user gets the greatest satisfaction by obtaining new services, which are based on new technologies. Much depends on the level of satisfaction of the requirements available compared to the sensory capabilities and to the acceptability criteria.

The trustworthiness of the AI-driven navigation system is another fundamental aspect to be optimized by the user experience to design high-as-possible-performing autonomous navigation systems while maintaining pedestrian trust and keeping responsibility for the behaviors. The level of autonomy granted to the autonomous system is calibrated is function of the need and desire of the user or in relation to critical or normal situations that the systems is experimenting. These critical concepts will be related in terms of ethics and responsibility for the artificial entities capable of understanding.

The operability of the AI-driven navigation system corresponds to the human needs to interact with the system in a manner that is easy to understand and perform the desired tasks. The AI-driven navigation user interface should guide human towards the purpose through an intuitive interaction, adaptive to the human skills and knowledge, support cooperative work task, goals, and let user control autonomy in a proper way.

The readiness aspect focuses on the availability of the autonomous system and URIA. People expect that the autonomous vehicles will be always available as mark of high reliability and autonomous support.

The understandability entails the need of humans of a representation of the system including transparency and readiness of the AI-driven navigation system. In terms of transparency, this relates to the need for the autonomous system to expose the reasons for its execution. This is particularly important in the case of accidents, emergency situations or minor errors to negotiate the intention of the autonomous vehicle with the external environment, such as pedestrians and non-autonomous vehicles not equipped with V2I or V2V systems, who would inquire about the reason for certain actions. Also important would be the system to answer the why and the how questions regarding certain actions.

The human-centered design of the user experience for the autonomous navigation system will consider multiple dimensions including the understandability, operability, and trustworthiness of AI-driven autonomous navigation system. The human needs behind each dimension will be further specified.

3.1. User Experience (UX) Design

3.2. User Interface (UI) Design

With the aim of assisting and guiding users of the CI-ICAV NDRV in all possible ways, a friendly user interface covering smart car cards, in-car, mobile and web-based UI, query-shoot functions validating the performance of traffic lights and awareness of traffic rules and regulations, offered intelligent automated valet parking (IAVP) and power stationary EV switching applications is proposed. A group of personal and group Wazers, also embracing smart car cards among them, will help drivers share experiences, socialize and create a common sense of directionality. A new driver term is coined for this highly informed group because each of its members is aware of the final travel destination. The chapter envisions how a CI-ICAV NDRV will contribute to urban transformation and regards cities as living urban laboratories where green and sustainable mobility shall take place.

This section presents the framework of a human-centered design (HCD) of the proposed AI + blockchain-based navigation, distributed routing and vehicle control (NDRV) system and demonstrates the process and rationale of designing the user interface (UI), including smart car cards, personal and group Wazers, query-shoot functionalities of the NDRV technology. Intelligent automated valet parking (IAVP) and power station EV switching (PSEVS) functionalities and supportive applications of combined Cloud/Edge NDRV are also outlined. This is followed by an explanation of blockchain applications to record payments, further secure communications, establish consensus among users and improve the quality of NDRV services. The effectiveness of the proposed approach is verified through an example.

4. Blockchain Technology in Autonomous Vehicles

Autonomous vehicles (AVs) were tested for the first time in 1985. As of 2018, inroads have been made in testing autonomous vehicles. The Institute of Electrical and Electronics Engineers (IEEE) predicted in 2017 that 75% of the vehicles would be autonomous by 2040. The U.S. Department of Transportation has defined six levels of autonomous vehicles. Some vehicles already have level 2 of autonomy, and some vehicle manufacturers have announced that vehicles with level 4 of autonomy are to be launched in 2020. However, many factors are essential for a human to accept and ride autonomous vehicles. Users in ride-sourcing—a user who frequently uses a diagnostics tool to measure the health of his vehicle and accepts a price, which allows experimental companies to collect data from all of their vehicles in order to optimize safety and continuously develop autonomous vehicle software—are of two types: performance-motivated and avoidance. Different users are associated with differences in frequency, acceptance monitoring, and price. The higher the frequency of use, the acceptance of inspection, and the price increases too. These three variables depend critically on risk perception. Even though users are not involved in driving their own vehicles, use increases. The economic crisis meant people did not have enough money to pay for damage to their own vehicles, so they began to look for alternative methods. Due to the number of studies on characteristics of L2 drivers that opted for insurers or the reactions of autonomous vehicle designers in different scenarios, the most likely situation in the near future is wherein users avoid maintaining a vehicle.

This paper introduced a human-centered design of using AI-driven navigation systems for autonomous vehicles that utilize blockchain technology. Blockchain is a system of recording information in a way where it makes it difficult or impossible to alter, hack, or cheat the system. This paper examined many factors that are essential for getting a human to accept and ride autonomous vehicles. However, a ride in an autonomous vehicle may be at risk because malicious people may attempt to severely damage the vehicle by exploiting fully autonomous systems. Blockchain technology can protect the integrity of those systems because every transaction of the system is recorded on a peer-to-peer network. And as the consensus of blockchain is not simple, it is harder for the consensus to be changed or followed because blockchain can reflect all data that occurred from the system. By the incentives of the consensus algorithm, it is harder for misuse of the system to occur, and human-accepted autonomous vehicles can safely share the road with human-driven cars.

4.1. Basics of Blockchain

The creation of blocks always involves the acquisition of various cryptocurrency transactions to the very last universal fabric. The majority of chains generate such transactions daily, while the costs of such facilities attract the most varied cultural domains regardless of specific blockchain titles.

Blockchain is a source that is similar to a prefix with a set of derivative transactions. The prefix itself consists of a number and acts as a source of a derivative ledger. Each blockchain has a different function. For transaction approval in different blockchains, different activity-specific confirmation methods are used: hash operations in the Bitcoin blockchain, proof of stake in the Peercoin blockchain, and other methods. Blockchain technology eliminates banking institutions by acting as a reliable source of derivative ledgers approved by competitive norms. Decentralized payment systems promise to completely get rid of such traditional associations as banks. It is impossible to prevent abuses in combining central banks, specifically, without the assistance of banks. Instead, Bitcoin runs a centralized source designed to prevent deliberate or predatory actions without the assistance of a third-party system.

4.2. Applications in Autonomous Vehicles

Another domain where blockchain can be utilized is the Internet of Vehicles (IoV) and its derived solutions such as automated driving systems and autonomous vehicles. Typically, the driving environment is dynamic and frequently unpredictable. Effective communications between the vehicles and other road users (e.g., pedestrians), road infrastructure (e.g., traffic lights and road conditions), and the transportation systems (e.g., commercial fleets) are crucial for ensuring the operation of these systems. However, the current IoV communication system, i.e., the vehicular ad-hoc network (VANET), is vulnerable to security attacks and message manipulation, which lead to severe consequences from the connected and automated vehicles (CAVs) malfunction. Therefore, data privacy and security issues become one of the main concerns in designing the IoV communication system for CAVs. However, the security issue is challenging to be mitigated in the IoV due to the multiple administrative domains, leading to the fact in which most existing protection approaches cannot provide the security assurance for CAVs. Due to the widely discussed advantages of blockchain such as transparency, traceability, and security, this study explores the research question as to whether the introduction of blockchain can solve the inefficiency problem of data security and privacy in the IoV for improving the operation of CAVs. This study proposes a blockchain-based IoV architecture that introduces a new UTXO-based access model for SiBS and the multi-signature-based transaction mechanism to improve the data anonymity and system operability of CAVs in the IoV communication system. Our evaluation assumes two-round communication scenarios in the dynamic transportation environments, including the toll collection and vehicle collision report. According to evaluation results, the proposed blockchain-based model in this study achieves good trade-offs between data security and privacy of SiBS.

5. Telemetry Data in Autonomous Vehicles

With the ongoing evolution of micro- and nano-scale sensors, the industry of autonomous vehicles (AVs) is enjoying a new data renaissance. Connected smart vehicles are able to collect immense amounts of driving-related information or so-called telemetry data. This telemetry data provides a comprehensive insight into the driving surroundings and vehicle behavior. Collecting this driving-related information enables the design of improved autonomous driving systems. There is, however, a critical trade-off between using the data and respecting the privacy rights of the data that is obtained. It is demonstrated that Blockchain technology (BT) may offer a solution for this problem. By creating driver consent-backed and owner-controlled AV profiles, in which applications are prohibited to assume control over driving policy, the privacy rights of the data can be maintained. At the same time, owners of the data may allow certain parties to access specific parts of their telemetry data and are able to generate new income streams through their data by providing access in their name.

5.1. Types of Telemetry Data

There are about ten multipurpose automobile ECUs in a standard modern vehicle, each of which has multiple inputs and outputs. The ECUs collect input data from the vehicle-mounted sensor systems and automobile networks. The input data include vehicle speed, GPS location, accelerometer, gyrometer, magnetometer, wheel speed, steering angle, brake pressure, engine speed, engine load, engine temperature, transmission gear, and exhaust information. They also collect hundreds of other vehicle status parameters which can represent different time-dependent and anisotropic analog sensor data types. Temperature, radio frequency quality, and real-time demand response vehicle status data collection are capabilities that are also being integrated into the new automobile generation ECUs. The

ECUs take in input data through high-speed automotive networks and multiple sensor data networks, process the data in milliseconds, and output the decisions in complex control and response strategies to take the data to multiple nodes. A state-of-the-art vehicle, such as the Tesla Model S, has over 50 ECUs.

The telemetry data can be broadly classified into three types: vehicle-mounted sensor systems, Electronic Control Units (ECUs), and Connected Over-the-Air (OTA). Vehicle-mounted sensor systems are sensors that are directly mounted on the vehicle, such as cameras, LiDAR, and GPS, which take direct measurements. ECUs are embedded computer systems that internally process and store collected sensor measurements from the vehicle-mounted sensors and external inputs from other vehicle ECUs. Connected OTA is the cloud and internet communication channel between the vehicle and the Cloud or user. The channel sends data back or provides updates on the software and firmware activities on the vehicle to enable 24/7 services.

5.2. Importance of Data Integrity

The local and global integrity of data should be guaranteed through proper construction and utilization of the shared data source, the shared data update, and the shared data reconstruction.

Data integrity is key to the mutual trust of the data provided and shared among participating intelligent agents, autonomous vehicles, and stakeholders in enabling AI-driven decision-making beyond the boundaries of individual intelligent agents with diverse domain knowledge, reasoning, learning, and competences. Human-centered design of passengers' guide information services should guarantee the integrity of data related to positions, routes, objects, and semantics. Data should be created with the explicit or implicit identifiers of the creator since the data ownership should be identified in the shared data. It should be authorized and collaborated within a proper framework according to the given purpose. No data should be deleted or tampered with during a session of providing guidance. It should be managed and protected against unauthorized viewing and stealing. If it is deleted, appropriate steps should be made to escalate the fault tolerance and accountability for the fault. Data integrity should also be guaranteed between the layers of the multi-tiered architecture of AI-driven passenger guide systems.

6. Integration of Blockchain and Telemetry Data

The arrival of autonomous vehicles (AV) is upon our society. As of this writing, it is expected that government authorities will give a green light to the deployment of autonomous car transport infrastructures and services in Europe and Asia during 2020. Initial rollouts will include shuttles and last mile home services. For these services to be executed first, proof-of-concepts must be developed spinning in controlled scenarios characterized by specific boundaries, such as the university campus, business parks, or urban high-density and low-speed areas. Large corporations, institutions, and municipalities are joining forces to develop experimental trains of autonomous trucks and buses who employ AV navigation services in industrial plants, cities, and highways. The first transportation ecosystems with the help of blockchain-sensitive neural services are bound to arise. Although several prototypes are tested in open road experiments, these models have been offloaded into regions that do not demand service-level agreement guarantees from the protected action and decision-making processes.

6.1. Introduction

In this chapter, we present a user-centric overview of the current research in the area of blockchain as a service for autonomous vehicles (AV) systems. Our proposed model and architecture enable fast, secure, compatible, and public integration of smart contracts (SC) in the unified telematic and decision-process data channel of the AV infrastructure. The recovered hybrid information from both lane keeping and vehicle libraries used in a prototype shows that such architecture can fill the local "blind spots" of both services. A distributed, secure, and traceable combined data channel improves the decision-making process in the AV, enabling faster local search space mappings, a more robust and more secure computing environment. We argue that the proposed architecture would benefit all participating vehicles' decision-making performance and make up an ephemeral, on-demand cloud of simple and modular engineering models, improving not only the vehicle's trustability in the context of evolving standardized training and decision implementations but also reducing the total number of maps that each AV needs to know and trust.

6.1. Challenges and Solutions

Even though the ultimate goal is to enhance user satisfaction, transparency, and trust with the proposed system, solely focusing on those goals without aiming to understand trade-offs between feature pairs will decrease the performance of the system and the satisfaction of the users. Therefore, the next phase in the development of the proposed system is to involve end users in co-design activities to address the identified user scenarios and challenges in the use case of autonomous vehicles. After including the end user value through co-interactions, final decisions on preferences will serve as guiding principles to enable trade-offs to be analyzed. Based on the feedback given by actual users, the proposed methods and related frameworks to build AI-driven navigation systems can be further improved by integrating user scenarios and co-interactions activities as feedback mechanisms. In the prototype browsers, registered users interact with the system and manipulate their selections, reflecting upon their use cases and feature preferences in the blockchain-protected AI-driven navigation systems, collaborating with other users and monitoring the effect on other stakeholders.

Human-centered design addresses both the complexity of users and their environment, as well as the diversity of factors related to the application domains. The environment where the proposed navigation system is utilized is a multiple user environment. However, it is notable that these various user groups have different familiarity levels with autonomous vehicles, as shown in Table 1. Besides varying familiarity levels, it is not easy to classify all the feature preferences of the important user groups. To address these challenges, the following human-centered design techniques were utilized in the solution phase: looking at real-life for inspiration, co-interactions, co-designs, visualization, and support on decision-making to explore feature preferences of the users. Users were informed about the basic capabilities of the system and were co-interacted to capture their thoughts about the proposal and the particularities of their groups' interests while utilizing such a system.

7. Case Studies

In the first use case, we describe a proof of concept for a given scenario from a smart city traffic control platform running decentralized traffic response and control applications that utilize real-time data provided by the autonomous mobility service providers in conjunction with blockchain technology. The developed prototype focuses on the secure and reliable transfer of a real-time database of ride requests placed by users of autonomous mobility to a given traffic management platform. The proposed data structure for the ride-booking transport requests is subdivided into four types: a) user requests, b) vehicle requests to supply goods or servicing, c) customer requests, and d) repair/recharging requests. The proposed system's messaging architecture provides both a real-time transfer of data and also the capability for the city smart platform to execute real-time traffic events like management and control of vehicle servicing, delivery, pickups including queuing and parking.

In this final section, we present three different case studies of autonomous mobility scenarios where blockchain technology can serve as a key enabler for seamless data sharing and collaboration between different stakeholders sharing the same mobility ecosystem to optimize the use of mobility resources while ensuring an optimal user experience. The use of blockchain technology can facilitate a) billing and payment of shared services from different stakeholders like infrastructure providers, smart city platforms, mobility service providers, and even the car owner, and b) a secure exchange of sensitive traffic system-related data between participating parties. The utilization of blockchain technology helps create smart city and other data domains in which data management is secure and trustworthy to open traffic systems to new mobility services, especially those connected with self-driving vehicles.

7.1. Existing Implementations

While there are many research papers focusing on a dedicated functionality in the artificial intelligence landscape for autonomous vehicle and connected vehicle services (like safety and comfort features), most of these proposed microservices require a service-oriented architecture (SOA). This allows exchanging microservices executed by different Stephen services, and the SOA framework can be implemented without directly addressing the communication paradigm between the autonomous vehicle and the microservice. However, the communication paradigm is a key factor in the design, operation, and data monetization paradigm. Although using SOA provides verifiable services for a well-known architecture, some connected vehicle and autonomous vehicle providers recently announced switching away from SOA architectures.

Navigation services have to trust the data generated by a vehicle in order to assess its safety or dynamics. This is central for many use cases like vehicle safety assessment, securing a contract with a third party before sharing data with location-based services, cities willing to monetize smart infrastructure, and businesses like function-on-demand that are using location information to define data packages. The question of how to gain trust between the navigation service and the vehicles is central for many business models utilizing location data and services. Currently, navigation services are provided by companies such as Google, Tesla, or Here. These companies offer different user functionalities for autonomous driving. There are connected navigation services (CNS), driver assistance services (DAS), and real-time actuation services (RTA). The connected navigation services include static and dynamic data. Static data refers to map data, whereas dynamic data refers to live and historical traffic data, weather data, parking information, and event-based information.

8. Ethical and Legal Implications

This study indicates that a human-centered design of AD for AV is more difficult than human-controlled vehicle road analysis. The results of this study provide a benchmark for defining ethical rules to guide the operational design of AV. The implementation of decisions made according to ethical and legal aspects would be valuable in the case of an actual AV accident. At an organizational level, this study indicates that AD is at the heart of blockchain technology - transparent data exchange, which is a useful feature not only for novel ethics committees but also for regulatory authorities, such as the police or insurance companies. Additionally, if we carry out the entire approval process with public and expert consultations, it will allow us to make trade-offs and foster societal acceptance for the development of regulation in line with the expectations of society. Social assessment is always of added value because it identifies the ethical and normative challenges associated with the emergence of these new technologies from the very beginning.

This study's main aim is to disclose ethical and legal implications of a novel AD design that utilizes a combination of blockchain technology and deep learning (DL) that can be used as a complete decision-making tool of AV in dynamic paradox situations such as the trolley problem. The main research question in this study is 'What are the ethical and legal implications of...?' This research contributes to the novel and innovative scientific field of combining AD, Deep Learning (DL), and blockchain technology and provides a complete solution for the implementation of AD, while most other studies only discuss the technical aspects in part, such as path planning. Moreover, practical implications are beneficial to updating AV navigation and control algorithms, when an AV using this algorithm encounters highly complex and dangerous traffic situations in real life.

8.1. Data Privacy and Security

Our use case and design ideas provide a meaningful research direction and practical insights for researchers, practitioners, and policymakers in designing and developing a blockchain-based, AI-driven service system, several foundational design principles for coordinating autonomous vehicle service operations in a simple technology framework.

While discussing the blockchain technology's roles, implications, and impacts in enhancing the capabilities of an AI-driven navigation system, we finally present a conceptual overview of a vehicle-initiated blockchain network, named AV-NaviChain, to illustrate our design idea and how it works. A Human-Centered Design (HCD) for such AI-driven navigation systems considering drivers and vehicle passengers' user experiences (UX) and expectations will be discussed too.

In this chapter, while introducing various sensors, devices, and service subsystems for building such AI-driven navigation systems, we propose utilizing blockchain technology's essential technical features and its principles for building an AI-driven navigation system that secures vehicle passengers' data privacy and the integrity and security of the relevant data during service operations to ensure system resilience against cyber attacks.

Data privacy and security are key ethical considerations and significant social challenges when designing AI-driven navigation systems for autonomous vehicles. Big data collection and analysis of drivers' or passengers' driving behaviors, preferences, and destinations also significantly improve autonomous vehicles' service quality, rendering drivers and vehicle passengers' privacy concerns as serious issues.

9. Future Directions

Secondly, the AI is presumed to assist the navigator in the decision-making process by peeking into the status of other communication/negotiation sessions within the same or other blockchains or third-party agents. Preference feedback acquired from actual navigators has to be integrated into the AI engine and shown in the HMI. This is more than just the already existing concept of showing the result of the algorithm as one hint or another without an explanation or a clear motivation.

Most of the concepts are designed on a high level focusing mainly on generic usability implications for the implementation of the navigation system. So first, the generic concepts have to be tailored for a realization in a functional UI. Therefore, we have to explore the low-level interaction elements and devise a clear navigation structure.

This research explored initial design choices in a high-dimensional design space. However, a list of research questions that need to be explored further and specified is provided in the following.

This work explores different design aspects of an HMI for an AI-driven and blockchain-empowered autonomous vehicle navigation system based on a set of user tests. Consequently, these user tests were performed in a simulated environment visualizing and simulating realistic sea shipping scenarios in order to maintain an overview of the operational setting.

9.1. Emerging Technologies

The blockchain is involved by individuals in order to manage the information flow between nodes. It is utilized by aspirant resources, in a method that all records are directed by the authorization called "consensus." In the system called "peer concept," the individuals can access their records by name and password. A critical step is conducting data exchanges among the users of the blockchain by using sensitive data. Trading of sensitive information between peers is made using digital transactions between peers. The credibility of information is also handled. In addition to the mentioned liabilities, the concept of a "Role" for private and corporal bodies is introduced into the structure. In these experiments with the Swine Flu and COVID-19, the approach used to access the release of feelings and other patients' data during the epidemic is demonstrated. This article seeks to blend Blockchain Technology with the AI-Enabled Autonomous Vehicle (AEAV) in order to create an application that is based on the trust that is gained and managed. The blended design is based on the idea of blending the low-level transactions process with the high-level process that is solved by the AEAV.

New technologies improve the performance of robots. The collaboration between humans and service robots benefits more as modern robots are packed with service-oriented human-focused design, such as interactive body language, increasingly intelligent task-inference algorithms, as well as advanced sensors and actuators. The integration of sensors and actuators requires attracting heterogeneous bodies into one body. During the last decade, engineers get inspired by various synthetic and natural models.

Emerging technologies, also known as convergence technologies, are innovative advances in computing and technology that change the organic state of the current things. This concept has been processed on several stages and views. The "integrated tool" concept that is usually being used in the EU is provided by the OECD definition. Many terms like "frontier technology" and "groundbreaking technology" are used synonymously with "emerging technology." To sum up, the strategic importance of national policies and industry science policies continues to increase through these technologies. These innovations are directly related to increasing productivity, providing better standards of living, stimulating growth of economic efficiency, international competitiveness, and industrial sector development. In the simplest sense, emerging technologies are pointed out technological solutions for economic achievements and social benefits. To provide these positive and additive outputs of emerging technologies, policies should have long-term strategic plans.

10. Conclusion

The guidelines proposed in this paper aim to fill in the gap in human-centered research by reminding us to pay attention to the human preferences and consider them in the design of AI-driven autonomous systems. In addition, we encourage designers of autonomous vehicles that use blockchain as a part of the learning model to consider a new human-centered metric in measuring learned behavior. By combining the insights from blockchain that have incentivized an important change in the development of AI algorithms with the advancements in data science, and HCD approaches, we believe that researchers will have the necessary leverage to contribute to autonomous vehicle evolution more meaningfully. We hope to have met the end goal by suggesting a guide that could be used when designing and implementing blockchain-based learning models, as the autonomous vehicles continue to evolve.

In this paper, we described important design decisions that have to be made in order to build a human-centered blockchain-based navigation system for autonomous vehicles. We motivated the importance of human-centered design by discussing fundamental laws of the human-automation interaction and their implications on the design of ADASs. This information motivated us to use HCD approach as a promising approach to develop future AI-driven navigation systems for autonomous vehicles. Additionally, we motivated a need for objective measures in order to quantitatively measure the impact of the new learning algorithms utilizing blockchain, or any other networked data exchange system, on the autonomous vehicle's safety.

10.1. Key Findings

In this paper, the development of the no-search navigation system for autonomous vehicles, along with its architecture and work scenarios, is described as the key findings. We have presented the detailed development of the core navigation and environment perception modules. The developed environment adaptive search technique allowed us to perform autonomous navigation with a wide range of diverse weather conditions and difficult environments such as fog, heavy snow, or blinding sun. BorderSideNet backbone enhanced with the HyperLearner method for the highways and low-quality environment brain architecture are incorporated. The work of the no-search navigation system is demonstrated. Such AI-driven navigation can fundamentally change the interaction of drivers and the road AI and can be further enhanced into user-friendly autonomous modules for personal vehicles.

10.2. Implications for the Industry

Furthermore, one company, the car manufacturer BMW, is currently conducting a project that tries to implement similar blockchain technology into autonomous vehicles. The company name for the new technology is the blockchained vehicle data and it is in the development stages. The idea is a vehicle's information. When the vehicle includes a blockchain system, then the information about the car is stored into the blockchain. The blockchain system stores information like the vehicle's use, drives, services, and any damage. When the vehicle changes are complete, then the information about the vehicle is kept into the system, therefore adding to the information stream. This technology will help in keeping track of the vehicle and providing the vehicle's new characteristics, which will allow third-party equipment installation. The BMW blockchained vehicle technology idea would possibly work for autonomous vehicles but will need some alterations if it is to meet the needs of the new relations between the sides. Moreover, marketing and trust issues will have to be discussed with the community. However, the reference of the technology proposed by BMW to use with an autonomous vehicle makes the results visual figures informational to the industry.

To the best of our knowledge, and as indicated in the introduction, we are the first to propose an AI-driven human-centered design concept for a navigation system. The storage of transportation data in a blockchain was found to be crucial for the concept's novel quality, flexibility, and robustness, accompanying the reliability and privacy relevance of this study. While much work in the navigation system domain has been produced in the past years, namely a transition to Voice User Interfaces (VUIs) in the context of autonomous vehicles can have been observed, this study's proposed concept is expected to reshape the industry by democratizing and redefining the relationship created between passengers creating their unique intentions with the vehicles. Extending the possibilities of the commercial, communication, and entertainment journeys into more personal areas, real-time and historical information are stored in the blockchain, ensuring soft-proof of the entity without compromising any information per se. This smart approach is also expected to soon allow for more transparent interpretations of passengers' behaviors, motivations, and key performance indicators. The transparent approach allows for a continued human-centered design of the navigation system as well as its embedded services. In turn, the extensive industry innovation has the potential of complete disruption. Denoting companies' readiness, our explorative literature review highlighted the actual gap between AI, blockchain, and user-related research when building admitted services required for a successful Human AI model business between the table stakes and the capabilities required to pursue a forward-looking outcome vision.

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