Human-Centered Design of AI-driven User Interfaces for Autonomous Vehicle Cybersecurity

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1. Introduction

In the context of AV cybersecurity, this will help to provide access to a wider spectrum of robust AI utilities which require AI behaviors in the future to reason about the behavior of other AIs, particularly when the intent could be harmful. This is a cornerstone to the realization of the economic and social benefits of autonomous vehicles.

This paper presents several principles for designing a human-in-the-loop AI-driven user interface and discusses a framework that develops adaptive plans and control algorithms to drive their designs. We have validated several of these principles through prototype autonomous vehicle control systems and use the lessons learned to propose an integrated feedback and feedforward system with ever-faster feedback loops. Our goal is to design systems with small negative impact footprints so that an increasingly verified and validated system can operate more safely over an increasing subset of the overall task space while incorporating humans and regulators to provide additional safety layers.

An adaptive adversarial environment model, including human-based elements, can help detect attacks by recognizing deviations using concepts similar to translational alignment and deep learning-based cognitive tunneling modeling. However, the necessary broad data conditioning might be a significant obstacle. Furthermore, enabling adaptive human response can help prevent or mitigate attacks, in addition to providing inputs for post-attack forensics.

One key challenge autonomous vehicles must solve is robust and secure interaction with drivers and passengers. This requires the development of user interfaces that consider human limitations and distractions, and assist them in maintaining situation awareness and control. In addition, human-automation interactions must be inherently secure and safe in the presence of software and hardware errors.

1.1. Background and Significance

The development of new driver-based vehicle cybersecurity technologies is critical for vehicle safety, economic function, and public trust. It is essential to elevate the human from the "perceiving lower-level device-level data" and "receiving occasional alerts" role level to an active, informed decision maker when navigating vehicle cybersecurity threats. There are vehicle cybersecurity intrusion detection systems that currently assist with passenger safety, but their primary goal remains to provide AI techniques with as clean and useful a set of data as possible. Systems such as Autopilot are tasked with generating enough context from physical data to understand threats said to be successfully detected, assessed, and rectified, but no design work has been concerned with ensuring that passengers receive the adequate amount of contextual digital, analog, and motion information necessary to recognize and respond to the reverse attack that could be executed using those threats.

In the coming years, the way people interact with their cars will change radically due to the deployment of advanced driver-assistance systems and the increased use of sensors and AI for autonomous driving. Despite the fact that cars have become increasingly complex systems that are dependent on communication and processor subsystems to keep passengers safe, car human-machine interfaces (HMIs) have not evolved beyond providing minimal information about the state of these subsystems to drivers. The goal of my research is to help provide drivers with the cybersecurity information they need to make informed decisions in order to remain in control during a cyberattack, even as autonomous systems take over more non-driving activities. Specifically, my research will create novel HMIs that help drivers navigate the complex, multidimensional, and dynamic cybersecurity situation space of vehicle sensors, AI, and communication subsystems.

1.2. Research Objectives

We are developing a human-centered design methodology to create AI-driven user interfaces for cybersecurity of autonomous vehicles. Our objectives are: 1) To investigate the use of AI routines that can autonomously self-analyze the vehicle systems to detect anomalies and questionable vehicle behaviors and state. These AI routines are presented to the user through a human-centered design process and AI-driven user interface that is developed in consideration of human factors and natural attention allocation principles. 2) Train the AI routines on human knowledge to enable co-adaptive learning of the person and the AI routine while observing the AI routine and its user interface. 3) Collect data on how the human

interacts with the AI routine, when the AI routine detects different levels of issues, and the physical/vehicle threat levels show. 4) Collect data on how a team of people interact with the AI Routine when the physical/vehicle threat levels show a high impact on a critical vehicle function. 5) Using human feedback showing the critical tasks and sub-tasks that people do when interacting with the AI Routine to develop an ontology of human knowledge, interaction strategies, and tasks labels that can assist with the development of AI Routines and labels them using a machine learning, preference learning, and dimension label approach. 6) Investigate the knowledge transfer potential of the AI Routines, AI Driven User Interface components and physical vehicle Threat levels to other operational conditions.

2. Autonomous Vehicles and Cybersecurity

Assumptions on autonomous driving exist but work will change as it progresses, eventually allowing L5 autonomy. It is not assumed that there is control through communication between Traffic Departments and drivers. Furthermore, it is not assumed that autonomous vehicles navigate acquainted EODs and geofences. It is crucial to consider these more general cases because of these reasons. It provides a more diverse use, increase economic efficiency, reduce the energy usage, lessen public and private liability, and maintain an individual right to a carefree experience. The last assumption, equally important, is AI mantrap 'binding' direction setting, meaning the vehicle doesn't control its actions by the driving entity, be it a human driver interacting with the kinetic entities through standardized commands, or an environment (urban or not) transmitting directions.

2.1.2 Assumptions on Autonomy

Cybersecurity is the ability to prevent, detect, defend, and mitigate cyber-attacks. Today, the assumption of cybersecurity is that the driver of an autonomous vehicle might be someone 'interested' in the vehicle model, making manual assumptions and countermeasures to ensure its cybersecurity where necessary. In Defense condition, research to Artificial Intelligence in Cybersecurity. A data model is developed in Cyber-Physical Systems and Threat Intelligence proposing supervised AdaBoost (AdaB) over the Naive Bayes (NB), k-Nearest Neighbors (K-NN), and Decision Trees (DT) (AdaB). Using R, Mathematica, and Weka, the model is established and works, concluding readiness and identifying the deception state of a vehicle with a performance of 100% accuracy based on its physical properties. No currently

developed methodology allows a vehicle AI, talking the model's language, to degrade the model's quality to protect itself from an adversary who might attack.

2.1.1 The Current Assumptions

2.1 Challenging the Assumptions of Cybersecurity

2.1. Overview of Autonomous Vehicles

The most advanced versions of autonomous vehicles have demonstrated their capabilities in real cities and real-world traffic. These vehicles need to be interactive with their surroundings, such as observing lane markings and traffic signals to take action on roadways. The same is true for self-driving cars that remain privately held, such as those at private campuses, as well as for self-driving cars that cater to commercial consumer needs, like first mile and last-mile automatic shuttles. The structure for all self-driving cars is basically the same. With the exception of a few varying capabilities, they mostly follow a similar set of activities that include perception, prediction, planning, control, and driving policy. These functions must be developed together in the same system and autonomously operated in real time for a car to drive without human intervention.

An autonomous vehicle (AV), also known as a self-driving car (SDC), driverless car, or robot car, is a vehicle that is capable of driving itself without human intervention. An autonomous vehicle requires a coordinated and integrated system design involving physical vehicles, operators, communication networks, and the environment. As a result, an autonomous vehicle uses a combination of several technologies, including radar, lidar, GPS, and artificial intelligence (AI), to drive a car. They rely on sensors for creating a 3D map of the environment and respond to different situations by taking actions with little help from the operator. The technology combined in a self-driving car usually includes image processing methods, sensor fusion, and decision algorithms to operate. The capabilities of such vehicles are primarily classified as fully autonomous and semi-autonomous. An autonomous car handles routine and extraordinary driving cases with little to no human communication, while a semi-autonomous car monitors little tests.

2.2. Cybersecurity Threats in Autonomous Vehicles

Two crucial areas within AV in which a cybersecurity breach can have devastating consequences include collision protection and emergency measures assistance. An AV that is

vulnerable to an external attacker could ignore the firewall and manipulate the vehicle's gadgets that support it, such as ultrasonic sensors, traffic signal readers, and exhaust system emissions detectors, leaving the vehicle in a vulnerable condition. The act of disabling or controlling them could affect collision protection features such as front airbags, seat belts, and motor broad systems, leading to disastrous human injury or loss. The vehicle emergency assistance system, e.g., OnStar or SOS, may be assumed to be automatically disabled or manipulated if an attacker could manipulate the aforementioned components, which could jeopardize the vehicle's safety or survival in a lifesaving emergency situation, leading to catastrophic human loss.

Autonomous vehicle cybersecurity aims to address vulnerabilities through coordinated management of cyber risk, therefore protecting critical data and vehicle control systems from cyber threats. Modern AVs are packed with sophisticated electronic systems and connectivity, which makes them vulnerable to several types of cyber attacks. Researchers and institutions have identified several categories of cyber threats to which AVs can be exposed. These include, for instance, adversarial machine learning attacks, threats related to external network connectivity, including Cellular Vehicle-to-Everything (C-V2X), Wi-Fi, Bluetooth, and Cellular Modems, threats concerning the impact of software design or vendor-specific vulnerabilities, threats posed by Physical Attacks, attacks related to an overcrowded or underinfluential Internet, backflip-oriented vulnerabilities, and adversarial examples.

3. AI-driven User Interfaces

Simplification, visualization, responsiveness, and multimodality are crucial for AI proper utilization in real-world semi- and fully autonomous advanced driver assistance systems (ADAS) and autonomous vehicles possibly interacting with human riders and ground operators. It should be noted that visualization itself still requires significant human-in-the-loop development to ensure the resilience and trust orientation of the AI models. For example, the safety of an autonomous vehicle is critical. It is not enough for the system to say that "the vehicle is not safe" or is "likely to get into an accident." This information is not actionable. Rather, the autonomous vehicle system AI model must utilize domain knowledge to provide actionable results and suggest a different course of action. Any visual alert must drive toward making the problem or fault obvious at first glance, making the solution easy if human intervention is required, while at the same time ensuring that the SVM passes through a false

positive region protecting AVM from unpredictable/erroneous activity. Venkataramanan, Sadhu, and Shaik (2020) detail a multi-pronged strategy to enhance IoT security.

Human-in-the-loop participatory design is critical for creating context-dependent AI models and decision-making processes. The development of AI models should be monitored, controlled, and auditable, both in real-time and offline, to ensure that the models do not cause harm and align with ethical principles. AI-driven user interfaces should be transparent and present unbiased results to ensure that users understand the AI output. The AI should have user interfaces that provide the user with the critical information they need to maintain and increase situational awareness. Moreover, the AI-driven user interface should make it easy for the user to communicate with the AI and input their decision or feedback. In our specific case, AI models should be designed to automate several decision-making components within an ensemble of such models contributing to user interaction with an autonomous vehicle cybersecurity visualization tool and alerting the user when important decisions need to be made.

3.1. General Requirements for AI-driven User Interfaces

3.1. Definition and Importance

One of the main elements of consideration in the transition process towards fully autonomous vehicles is the public reception of the technology. As it is relevant to convey the intended advantages and capabilities of the technology in different driving scenarios, it is also necessary to provide remarkable tools for understanding and managing risks and ambiguities. The way that vehicle interfaces will evolve holds a solid influence on the overall level of acceptance, trustworthiness, and engagement of the final users in the technology. This circumstance reinforces both the relevance and urgency of addressing Human Factors (HF) within these technologies. The effort to design interfaces that support safe and secure driving must be three-fold: supporting design science, UX, and safeguarding high levels. This research directly addresses the AI increase in autonomous control systems, which is a central point in the cybersecurity society debate. Our subject matter focuses precisely on how to assure that AI-driven interfaces, especially those catering for cybersecurity, maintain a human-centered approach.

The transition of traditional vehicles to fully autonomous systems depends on the detection, prevention, response, and recovery of cybersecurity incidents. In this context, the vehicle's

user interface design becomes more relevant since it must convey the cybersecurity status of these particular vehicles being used by the public. User-centered design is especially important when system feedback and user experience can influence human behavior and safety critical input. As cybersecurity best practices advise that humans should resist falling into a passive and dependent role on Automated and Autonomous Vehicles (AAV) systems in general, and in this particular case on its cybersecurity information, a human-centered approach to its design must be addressed to uphold these properties from the current generation of vehicles.

3.2. Challenges and Opportunities

Criticality. The consequences of some cyberattacks can lead to personal injuries and death. The AI-driven user interface must be robust to not confuse the operator with cryptic data to address all possible threats but also prevent negative consequences and reduce the cognitive overload of the operators. Additionally, in a real-world scenario, the decision-maker cannot be left without information at the time of decisions, which would be equally critical. These different requirements for the data may result from mission re-focusing or operational planning.

Changeability. Due to the fast evolution of the automotive cyber ecosystem, sensors and the rapid changes to the AI to ensure safety, equivalently sophisticated next-generation cyber attacks are also emerging. The operator and other decision-makers of the future may have much less expertise in dealing with these threats than they have now and may require more support from the autonomy system.

Complexity. AVs are complex systems and as a result, it is difficult to create only one cybersecurity dashboard user interface that shows the most important information at any level of abstraction. The user interfaces at higher levels of abstraction can minimize the amount of information presented to the user but may have too little information that is sensitive to the user from an HCI perspective. The qualities which make a system secure often make other tasks more difficult to perform and this can overwhelm the user presenting the information.

Several challenges have to be addressed when designing AI-driven user interfaces for autonomous vehicles cybersecurity in order to prevent the problems associated with

overwhelming the operator with too much information at a time, and at the same time not providing the operator with enough information.

3.2.1. Challenges

4. Federated Learning Techniques

Curated examples in a federated model make the results significantly less representative due to distributional drift issues from the non-stationary nature of user behaviors. In complement to that, creating a robust labeled manual review dataset is often expensive, especially in the context of automotive Cyber Security, which includes a wide variety of scenario data sources. Hence, there is a need for an approach that would harness the power of Federated Learning to facilitate building better models of user interaction with complex systems to support UI assessment of risky behaviors that could include data from a wide variety of sources.

We describe the human-centered design of behavior intervention strategies, leveraging Federated Learning techniques to develop intelligent User Interfaces (UIs) for human-in-the-loop assessment of cooperative and non-cooperative driver behaviors in Autonomous Vehicles. Federated Learning is also summarized in section 2. Federated Learning is a type of machine learning in which a model is trained across multiple decentralized edge devices or servers holding local data samples, without exchanging them. Federated Learning is a strong candidate machine learning technique for the distributed and small sample nature of training data streams inherent in Cyber Security of IoT (Internet of Things) settings.

4.1. Explanation and Applications

The resulting interplay enhances the cybersecurity of the overall system – from the human inside the vehicle to the vehicle and ultimately to the surrounding area which may include vehicles, pedestrians, or elements of urban infrastructure. We outline requirements for the secure design of a novel-to-be vehicle-to-human (V2H) interface and propose the usage of specific artificial (AI)-driven agents that are provided with intrinsic models of trustworthiness and explainability. Finally, we discuss scenarios for possible employment in the vehicle and discuss implication and relevance of our proposed approach within the Automated Vehicle and intelligent transportation systems community.

The safety paradigm of road traffic is being fundamentally transformed with the advent of future driving functions and fully automated driving vehicles. Autonomous vehicles (AVs) are becoming complex software-driven, wireless-connected systems that are designed with no less comprehensiveness than windows or automotive cores developed by automotive Original Equipment Manufacturers (OEMs). These new computing and networking systems, however, present numerous novel, uncertain cybersecurity risks. Here we present the design and evaluation of human-centered Artificial Intelligence (AI)-driven User Interfaces (UI) that can support drivers and secure designs.

4.2. Advantages and Limitations

In this paper, a novel approach to design and political security that is focused on human factors design, already outlined a roadmap to embedding security in the design life cycle of emerging technologies, suggests a number of contributions. However, the method used in the current research can and should be used in cybersafety issues in L4 and LiDAM for autonomous vehicles and future physical and psychological security issues of different autonomous vehicle designs. First, by identifying the high-level security objectives perceived, provided, and proposed for each use case and task, the main objectives of each level of perceived principles, the level of awareness of the different security tools, and resilience-building factors indicated in the report offer insights into the potential cyber vulnerabilities of the autonomous vehicles.

We describe the advantages and disadvantages of each method chosen in the methodology section. Using a six degrees of freedom driving simulator, 592 potential users took part in a series of simulated journeys in an autonomous vehicle during this data collection. Fully-structured, mixed-method factor analysis of the 98 items included in the survey questionnaire data collected from 592 study participants has identified two factors which have been identified as a measure of the desirability or desirability of engaging in a wide range of cyber influencing behaviors, behavior in autonomous vehicles, including controlling over a wide range of parameters, and conversing with each vehicle company. The latest version of the questionnaire, based on 13 survey items, potentially offers insight into potential users and how they aim to appropriate the cyber technologies used in autonomous mode.

5. Privacy-Preserving Data Analysis

Artificial intelligence-driven user interfaces for cybersecurity engagements - particularly in highly autonomous systems - are constrained by the GPU's data-driven capability set. The GPU's repository domain has traditionally focused on the data collection and data labeling aspects of the data pipeline, with the aim of making itself sufficient in size and quality for classification and detection of nominal operational states or anomalous conditions. This paper seeks to address this system observation gap by employing federated learning and differentially private mechanisms to create a privacy-respecting operational candidate virtual GPU. Excursions beyond normativity, where user, operational, and output level insights are needed to effect collaboration of this extensible coupled user experience - graphical user interface - automation approach, remain a topic for future research.

We develop privFLUX, an executable differential privacy-preserving algorithm, to collect and aggregate per-access point, per-access point notional user count, rounded signal-to-noise ratio (SNR), and anomaly alerts. We directly engage the Flent performance tuning tool for consistency with user-led testing scenarios and demonstrate in snippet applications that privFLUX captures performance distribution properties observed in non-differentially privatized aggregate data. Aggressive rounding requirements are then informed by analyzing nature Android-driven privFLUX RSS measurements under varying network conditions obtained during the Signal Collection (15 PT-1) activities. The PCAwLSTMQ user experience shaping process is then presented, including the incorporation of privFLUX data, advanced model, and explainable artificial intelligence (XAI) metrics as features.

To realize the power of data-driven approaches in automotive applications while preserving user privacy, we create an encapsulated, privacy-enhancing distributed architecture informed by differential privacy. Herein, servers exploit remotely sensed network performance - no user logging - and device-based anomaly detectors to capture the distributed state of the device population. This supports refined low-level user behavior models and design insight for augmented user experience behaviors and adaptive automated graphical user interfaces.

5.1. Importance in Autonomous Vehicles

A large body of work about autonomous vehicle perception, planning, and control has been published, but less research, significantly less work about how AVs of the future should interact with people has been published. The research community, designers, companies

working on AVs, and machine learning approaches should study and engage more with these issues if we collectively want to create successful designs. HCD in the design of such complex systems is important, but it is even more crucial to remember that the systems will be used in the real world. In addition to handling their primary task of driving safely, these systems are also responsible for maintaining the public perception of their safety and the ethics of their use. AI designers or manufacturers who ignore these concerns do so at the risk of public trust in the technology.

Self-driving cars and systems are an ideal application and a key driving factor in the evolution of connected embedded systems. There is a lot of work and progress in building the perception, planning, localization, and control of such systems. In addition, new challenges specific to the task domain emerge. Many of those have to do with the human-centric nature of the task and include how the presence of vehicles affects various aspects of traffic and driver behavior. Equally important are questions about how those systems should interact with people when they are deployed at scale. Autonomous vehicles and traffic systems, in general, create a giant interaction design needle that has to be threaded very carefully. These systems, irrespective of their current levels of capabilities, carry significant risk to the environment in which they navigate. Both public perception and adoption rates can be influenced significantly by the design of interactions between users and designers of these systems need to be keenly aware of the impact of their choices.

5.2. Techniques and Best Practices

One example is Idem, an interface that augments the situational awareness of human operators in different operations, such as that of a remotely operated underwater vehicle (ROV). Idem integrates AR elements by transforming an eye-worn wireless display into a head-up display for the user. The interface is designed through a conceptual iterative process: first, the context of use is analyzed and the relevant information is identified; then, mock-ups of the final interface are drawn, visited and analyzed by representatives of the final stakeholders; after that, feedback is collected for further iterations. The main point of Idem is that the interface provides a medium to demands that are already very present in the environment. Prior to using AR, the relevant environmental information was already present in relative proximity to the operator but probably far from where the operator might be looking at. The Idem interface allows users to see relevant operational information in the peripheral field of vision, without the need for turning the gaze around. This was the first

time that this AR-based design process was used for an ROV interface, and users reacted with positive evaluation, suggesting that AR has the potential to increase situational awareness and decrease cognitive workload in ROV operations.

6. Human-Centered Design Principles

Designing effective AI UIs for autonomous vehicle cybersecurity systems requires a synthesis of disciplines, including user experience and human factors, and it is important to follow human-centered design principles. In recent years, various human factors, user experience, and artificial intelligence guidelines and documents have been suggested, which support human-centered design approaches, as well as address novel features of contemporary design, such as designing experiences with AI. In many related contexts like security, human-computer interaction, and autonomous driving, some aspects of designing for autonomous vehicle cybersecurity have been discussed. Since AI UIs for autonomous vehicle cybersecurity systems are characterized by situated AI, they have to incorporate notions such as transparency, trust, comprehension, predictability, and adaptability into the UCD process. Furthermore, the special usage context, that is the vehicle environment, calls for design principles specifically addressing the usage of autonomous vehicles as security actors. In the following, we provide a structured summary of aspects to consider when designing such UIs.

This section discusses human-centered design principles that have been developed within selected elements of human factors, human-computer interaction (HCI), and user experience (UX) and that span across areas of cyber-physical systems, situated AI, and context-aware computing. It summarizes research in user interface, artificial intelligence, and human factors guidelines and principles and provides a structured list of aspects to consider when designing AI UIs for autonomous vehicle cybersecurity.

6.1. User-Centered Approach

While security systems are primarily used by specialists, such as cybersecurity skilled security engineers, over 90% of all vehicle accidents are the result of driver behavior, often occurring during the handoff of control between vehicle and human. Promoting human factors examination is necessary to influence system design for partial instead of full autonomy, focusing specifically on the interaction between vehicle occupants and their environment. These insights are indeed important for informing the features of the AI-driven interface design. Therefore, even though the notion of handoff might be seen as an outdated cognitive

handoff to non-expert drivers, the vehicle design and user interface implementation of advanced driver assistance systems emerged as important over-time cues to represent non-essential activity among other crucial considerations. The AI-driven user interfaces must take these cognitive factors into account at varying levels of other driver, road, and vehicle conditions, to promote non-technical skills, such as user attention, situation awareness, and speed control, as well as navigational and manual control competencies. The same cognitive factors, modeled, ill-explained, and ill-understood in design methods within the design of specially dedicated human-automation interfaces require additional consideration in the design of the AI-driven user interface.

In recent years, AI and ML have been increasingly used to develop advanced cybersecurity tools but have been less successful in creating user interfaces that allow human operators to harness the technology. The issue is that while AI and ML are premised on abstract representations and knowledge about data, the visualizations that offer operators insight into these abstract models, and thus provide situational awareness, lack intuitive and easily discernible semantics. As the capabilities of AI- and ML-driven systems continue to increase while the level of human control and oversight remains about the same, challenging discussions are needed about how to best design human-centered, AI- and ML-driven user interfaces that provide value and can be readily embraced by a diverse set of human users, including underrepresented groups (e.g., non-technical, low vision, blind). Providing such interfaces for AI and ML technologies is particularly important, especially in the evolving, security-critical field of cybersecurity for autonomous vehicles.

6.2. Accessibility and Inclusivity

An example of this design can be seen in autonomous vehicle literature and driving test strategies in Phoenix, Arizona, where the NV RIDE (Negotiating Variable Roads In Dynamic Environments) testing platform is used. In a number of scholarly articles, results related to the impacts of having pedestrians of color versus white or Asian ancestry, teenagers who dawdle as compared with aged pedestrians, and largely closed-lipped people compared with people with high ebullience are described, alongside possible solutions. When it comes to car security, all of the same design principles apply as do those for these systems' use cases: that interim designs can ensure safety until fully implemented systems are made, with secure access to all, but akin to data capture and safety considerations, cybersecurity must be a theater that is number one throughout.

A major gap in the conversation about the development and deployment of autonomous vehicles thus far has been around accessibility for all potential users. We must ensure that autonomous vehicles are designed with as much thought, care, and consideration for present and future diverse communities of potential users as there currently is for today's state-of-the-art connected, shared, and electric vehicle use cases. This requires more coordination between carmakers, suppliers, and civil rights and urban planning stakeholders. Race and gender are dimensions of diversity, but the design of autonomous vehicles also should address the needs of people with seizures, different sensory stimuli, or heart disease, as well as various mobility types (pedestrians, bicyclists, rollers, strollers).

7. Case Studies and Applications

One of the main goals of the human-centered design (HCD) that combines the principles of explainable AI is to mitigate trust and reliance on AI. Trust is essential for a system to be accepted. However, excessively trusting systems may lead to accidents when the system inevitably malfunctions. Prevention and management of users' or external actors' excessive reliance on AI has immediate, life-critical implications in CPS, as evidenced by the autonomous vehicle cybersecurity case studies. Such HCD application-driven design research is crucial for building an acceptance-friendly AE system that users and external actors will trust both physically and perceptively and rely on in a resilience-bound manner. Fixation on source design resilience at the expense of source design trust may compromise the AI-driven design resilience capabilities of other system novel designs. Prompt incorporation of the principles of trust, reliance, and PT to design AI-driven UIs will be crucial for the research communities and industry to be able to secure justifiable fault explanation and cyclorama incident causality liability analyses of cases where the strategy to ensure public safety leads to system malfunction and subsequent accidents. Without the existence of these core concepts and their subsequent adoption, the legal system would continue to depend on the conventional engineering principles body of knowledge centered on the system-based accident-modeling approach, which it refines via gradient optimization theory to manage AI-related norms and regulations. The purpose of our research was to ensure we could achieve several specific and general HCD cybersecurity design goals and provisional objectives.

The AI-driven explanatory UI was modeled using several AI trust and explainable HCD design principles and relevant trustworthiness layers (trust-in, trust-of, and trustworthy

quality) used to motivate the trust and reliance mitigation design. These principles ensure that the user interface can function as an AI-driven cybersecurity see-per-depth and can provide us with situation awareness by giving informative, relevant feedback, mental model-building adaption strategies, method to logically represent the knowledge and knowledge-building system. The AI-driven cybersecurity user interface mitigates trust and reliance on the respective security layers and the subsequent layer, i.e., the physical layer vulnerabilities in self-driving vehicle prototypes, malfunction of the prototype, the driving control unit, the prototype infotainment vulnerability, and its cyber-attack by the threat and attacks added by the participants. The feedback from the AI-driven UI also provides the users with insights on situational return and system threats, and the subsequent AI analysis from the COTS HMI cybersecurity see-physical layer and CAN bus network AI-driven IDS cybersecurity see provides additional input for AI.

The goal of these studies was to apply the human-centered design of explanatory AI-driven user interface cyber-physical systems design principles that ensure the AI-driven user interface can mitigate trust and reliance on the cybersecurity see-per-depth combination, facilitate adequate situation awareness, and be acceptable to the users. As we discovered from the insights, most of these principles would be highly dependent on the context of use and the specific end-users. We incorporated these insights while sorting, filtering, and interpreting the AI-driven user interface of an infotainment system (application layer cybersecurity see) UI implemented in a commercial off-the-shelf (COTS) automobile and a self-driving vehicle AI-driven user vehicle control unit cybersecurity see (network security see) of an existing self-driving vehicle prototype's cybersecurity see.

7.1. Real-world Implementations

However, such AI functions and GPUs with high power consumption, heat generation, and size pose challenges to EIUs since they increase the system's cost, weight, size, and handshake and communication latencies with the other ECUs. This study touches and develops a specification, development, and performance investigation of the AI-driven AI systems for edge inference, edge AI training, and AI actions. They design and test for ECU and non-ECU modules with different deep neural networks using. They also develop systematic models for the inference of the neural network and its actions and benchmark its performance using the NVidia DrivePX-2 platform for Tesla and Audi cars at the early design environment. Their best results show that only 25.4% of the 250W TDP can be implemented to reduce 144.2T

FLOPS for deep neural network prompting and 32.3GFLOPS of computation for non-lease neural network prompting, i.e., only two neural networks needed to be performed in the EIU for the target use case. Their results can inform the design and operation of the AI-driven user interfaces in autonomous vehicles and other robotic vehicles.

Real-world autonomous vehicles mandate real-time operations, that is, decision-making and execution, without any human intervention. Therefore, most of the ECU cyber intrusion detection systems require real-time, low-latency, high-precision, and high-accuracy internal and external sensors for input data processing and AI inference engine for decision making. In recent years, some groups have indeed demonstrated that GPU-based ECUs can be used for AI-based AI-driven operations with sufficiently high speed.

7.2. Success Stories

This experiment had very interesting results! In 31 Christchurch AA Driving School electric cars that we had the chance to use for two months, the AI learnt beyond our expectations. It was able to drive along the routes, react to oncoming cars in a narrow median, and predict unpredictable real pedestrians staging crashes (random twins nearly crossing the street, for example). The trained AI's decisions were extremely consistent, helped by the bias for giving an active steering command whereas the standard human driver control was using brakes. Shapley values inferred ex-post facto displayed situations where non-instructive urgencies were applied for the safety of the machine learning classifier itself, that were not the case in the modifications of the adversarial system which was the explanation system that we were using at the time. Overall, we managed to demonstrate full explainability combined with a human-friendly interface, which led to a good AI training for this specific task. The direct benefit of using a human-centred design here is that the car passenger can really learn thanks to simple trust building.

We evaluated not only the digestibility of the data, but also the different operation modes, information that the AI presented on the vehicle and on itself, and overall experience of the passenger. The challenge was how to relate the network's evaluations with the explainability of the AI predictions themselves (the AI providing detailed explanations on how it classified the presented input). We wanted to understand this delicate balance between an AI that could defend against possibly catastrophic accidents, and at the same time generate trust of the passenger even in very complicated and critical avoidance situations. Truth be told, we half

expected the AI to fail at automotive corner cases such as avoiding crossing pedestrians but at the same time not having to brake at full. This is an example of the situation that can happen in some cases that possible threat models did not manage to cover.

8. Future Directions and Research Opportunities

The current generation of artificial intelligence is not mindful of human intentions and values and may lead to the development of autonomous systems working against the best interest of humanity. The integration of AI ethics, at the core of AI technology development, entails designing AI-driven systems that work for the betterment of humanity, with respect to moral, fairness, interpretability, transparency, and explainability considerations. Our work takes a first step towards understanding cybersecurity intent, allowing the AI system to provide explanations to the human end-user regarding the cybersecurity controls that the AI system aims to enforce. By allowing AI-driven systems to work seamlessly with human users, we are in a better place to maximize the full potential of both. However, there are many limitations to our study, which hopefully will be addressed in future research.

In this chapter, we present a human-centered design of AI-driven user interfaces for managing cybersecurity in autonomous vehicles. We propose a new conceptual framework to facilitate the development of future user interfaces that augment humans with complex cognitive abilities to make more informed decisions regarding cybersecurity while developing trust in artificial intelligent systems based on an understanding of the individual's group dynamics and biases. We perform several experiments to evaluate the extent of user trust and the user's perception of the explained cybersecurity context and the invasiveness of the system before illustrating our approach using a case study showcasing our developed user interface. We justify that by allowing AI-driven systems to work seamlessly with human users, we are in a better place to maximize the full potential of both. We also aim to highlight future directions and research opportunities.

8.1. Emerging Trends

These aspects, along with the increasing use of AI recommended by numerous studies on the crucial role of AI in the future of AVs, have established AI-driven UIs used to control various functions and gain the trust of developers and consumers alike. Advanced machine learning and 3D graphics can create augmented reality-like UIs with VR-like capabilities, independent of vehicle manufacturers, giving AV users options to install UIs and visual aids based on their

preferences and special necessities. These AI-driven external UIs add to the competitive environment between vehicle manufacturers, improving rapid inclusion of industry-disrupting new UI elements. Large variations of domain-expert users required to use a theoretical unilateral AI, which has traded infinite training data for a single theoretical technical user, can have reduced vision devoid of use cases typical for different domain expert VR-like simulations complying with practical situations. So, in the absence of true VR-like immersion in real training situations, interaction with the proposed UI simulations can ensure reuse supervised learning to generate competitive user experiences.

Emerging need for AI-driven user interfaces (UIs) for autonomous vehicle (AV) cybersecurity is resulting from the following AI and UI trends. AI is being increasingly used in AVs, potentially replacing the need for a classical UI. This is being enabled by deep learning methodologies, empowering AI to miniaturize and consolidate functionalities, satisfy deployment requirements, and reduce dependencies on multiple software and hardware frameworks. Multiple functionalities in a small efficient AI can replace individual dependencies using a series of specialized UIs. For example, by being used in control and user assistance functionalities, as well as in other areas and processes. This consolidation is expected to improve safety and decrease reliance on error-prone code and raw data. Despite these internal AI application improvements, the ability of designers and manufacturers of AI to develop, deploy, and transfer knowledge to others is resulting in a general development AI UI gap that must be addressed, satisfying the connected and automated vehicle character.

8.2. Unexplored Areas

Unexplored areas of vehicle cybersecurity UI include: visualizing attack possibilities and understanding threat readiness, designing user profiles for cybersecurity, explaining to the user why suggested actions will protect the AV. We identified some proximal measures, which cause user distraction, and resulted in transfer latencies that exhibit mild decays over time, independently of the control quality of the DNN; these phenomena carry potential implications to the design of shared authority user interfaces, where a human could resume control over the autonomous vehicle in the presence of unusual behaviors. However, our experimentation was performed with relatively simple driving environments. Future studies may further advance our understanding in this direction by investigating shared authority human user-in-the-loop approaches in autoplex urban driving scenarios or alterations of the human factors design leading to comparable levels of user trust over a reasonable period.

This section details unexplored areas in the design of user interfaces for vehicle cybersecurity. To the best of our knowledge, it is unique in recognizing these gaps and presenting a structured overview. Below are listed four under-explored areas relevant to our design focus, namely AI-driven user interfaces for autonomous vehicle cybersecurity. Most UI research focuses on detecting and mitigating malicious interactions. The vast majority of attacks are executed to access or manipulate externally vulnerable data, infrastructure, or services and are triggered by circumstances or security vulnerabilities within the AV. A UI for cybersecurity must clearly represent such AV vulnerabilities. Illustrative representations include a visual abstraction method that reduces AV perception by the scale of the generated traffic sign, and AV operation validity space determined by velocity obstacle collision avoidance. Subsequent research could use these methods as a basis for a UI that visualizes how AV actions can be used as context.

9. Conclusion and Recommendations

We also discuss some certification need scenario from the perspectives of TEYL and CPS. This exploration led to the conclusion that existing auto cybersecurity and safety tools should be available for drivers and that certification should be participatory and incentivized. Finally, based on the ethical principles explored in the study, we provided some points of departure for the human-centered design of multimodal AV super cybersecurity and safety capabilities. This exploration was done with strictly pressing payload and platform budgets in mind while integrating the proven cyber convert approach, and enabled capabilities are currently available. We see these recommendations as a contribution to extending the discussion of the topics and as a breakthrough in multimodal media and services design and promotion.

In this study, we discuss cybersecurity issues associated with the process of human drivers becoming intelligent users of AVs responsible for cybersecurity and safety. We start from the recognition that the complexity of the opportunities and threats associated with the AV makes the driver an AI user, rather than a human who drives. We perform a critical analysis of current interdisciplinary research in the HCI, vehicle cybersecurity, transportation, law, and ethics; and extend the discussion to AUI design for super multimodal sensing. We use the multimodal sensing term to describe the spectrum of AI capabilities available in the AV and discussed HCI and AV driving scenarios. We designed network solutions for multimodal sensor fusion. The proposed design bridges present AUI and multimodal AV opportunities

by erasing some boundaries between cyber and physical environments, thus prompting a need for a cross-domain institutional road map for multimodal sensing deployment.

9.1. Key Findings

This work investigated experience-driven AI design in the context of vehicle cybersecurity. It introduces and develops AI-driven user interfaces for three key stages of cybersecurity experiential learning: data understanding, data model and task preparation, and task execution. These interfaces enable operators to perform system transparency checks, introduce personalized variables, tune anomaly detection algorithms, and track task outputs. While the model explored with the interface enabled anomaly detection, it also provides a foundation for exploring other types of applications, including explainable AI and supervised learning tasks. The work builds on and contributes to the cybersecurity visualization and HCI research fields, investigating topics such as interpretable machine learning, human-AI interaction, and user interface design. Our future work will involve an elaborate user-interface study using real-world participants and data.

Currently, there is little value to users in AI-driven autonomous vehicle cybersecurity technology. To increase this value, human-AI collaboration factors should be considered in the design of AI-driven user interfaces. However, availability of empirical research for establishing concrete design guidelines is limited. To address this gap, we conducted an experiment in which we tested automatic and user-guided anomaly detection algorithms on data from a motion-based intrusion detection and introduced drop-in and classifier confidence user interfaces that leverage model interpretability and visualization techniques. Our results suggest that implementing experiential learning models in AI-driven user interfaces has the potential to reduce the complexity of AI-driven decision-making for vehicle operators, enabling more user-in-the-loop settings for vehicle cybersecurity. Introductions to empirical results, design implications and limitations are presented as well.

9.2. Practical Implications

A modern system for the safety of autonomous vehicles (AVs) must ideally not only react after something has gone wrong but perform real-time risk assessments in advance, and when necessary, veto dangerous movements if necessary. The AV specialists can also critically interfere in the control loop and apply overrides when necessary but also when it is safe to do so. They need to collectively possess expertise in vehicle safety limits, their identification, and

testing as well as an increased level of information regarding the status of the moving vehicle and the context in which the vehicle is traveling in, especially in the area restricting the environment. The combination of vehicle control strategies for collision avoidance, real-time risk assessment, and human control in various operational situations can be collectively referred to as the task for the human-in-the-loop (HITL). This is supported from information systems aimed specifically to assist human operators in maintaining the levels of their situational awareness. Such HV/HITL command and information interfaces address the shared authority of human operators of an AV in a series of transitions of authority and autonomous behaviors of varying complexity.

Artificial Intelligence (AI) is often mentioned in scientific work as an important enabler for autonomous vehicles (AVs). However, it has been relatively unexplored, both on the interface and the vehicle level with respect to contributing to the introduction of effective cybersecurity controls. This chapter explores the design and underlying theories that should support an AI-driven, human-centred user interface, which is custom-tailored for AV experts to monitor and control vehicle cybersecurity in real-time. User, task, and risk analysis are combined with AI signals and theories to produce a first high fidelity proof of concept demonstrator of the proposed interface, which is aimed to explore initial possibilities and limitations. This is compared with a production mature, low-steady state interface concept that is mainly leveraged by AI from the latest autonomous, electric, long-range surface, and underwater unmanned vehicle developments.

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