Adaptive Human-Computer Interfaces for Cybersecurity Situational Awareness in Autonomous Vehicles

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1. Introduction

Such human factors research on AHCIs depends very much on the context of use, including organizational cultures such as risk tolerances and communication patterns. This paper considers both, of particular importance for stakeholders from critical infrastructure sectors. Its chapter 1 is an introduction that includes a description of the CSA challenge and its importance in the topic of AHCIs and CSA for autonomous vehicles. Autonomous vehicles are designed to operate while interacting with physical environments and human passengers without direct human intervention. Control of a level 5 vehicle is typically achieved without such vehicle human intervention. However, a computer and any connected networks may be subject to hostile act threats leading to a risk of severe CCS breach.

The core objective of the Daschem project is to identify the extent to which user-centered design methods for tailoring adaptive human-computer interfaces (AHCIs) can significantly improve cybersecurity situational awareness (CSA) in autonomous vehicles for laypersons. To reach that objective, the project will co-create AHCIs with stakeholders, using advanced digital technologies in a mixed-reality environment powered by artificial intelligence for data enrichment, scenario generation, and real-time semi-supervised learning testing. The project will conduct empirical, exploratory human factors research on real user reactions to simulated cyber-attacks and AHCIs, as well as real scenarios of interest, and evaluate the results. The project will apply qualitative and quantitative research methods to evaluate if AHCIs induce laypersons to engage in cyber-hazard risk mitigation behaviors, better CSA, and ability to spot manipulative social engineering attack indicators, and provide responses in case of a threat.

1.1. Background and Significance

Strong forward progress is likely to be seen only if adaptive human-AI interfaces designed to augment human abilities in understanding and making decisions in critical environments are put in place. Cyber-physical systems require cyber defense mechanisms that are highly adaptable, on par with the shapes, sizes, and complexities of the controlled physical systems. Developing user interfaces that provide continuously updated insights and assistance to users in the face of dynamically changing cybersecurity threats is particularly challenging, as the well-known situation awareness (SA) research has shown that humans experience SA breakdowns when faced with novelty or low probability threats or unforeseen/forgotten rare long-duration events. These SA gaps can be particularly severe in ethically sensitive environments such as battlefield settings, and must be filled with effective decision aids. However, the development of such intuition-preserving adaptive interfaces is especially challenging in dynamic, challenging, and capacity-constrained real-world scenarios, such as vehicle driving.

The widespread adoption of autonomous vehicles (AVs) has the potential to revolutionize many aspects of our lives, including saving lives on the roads, reducing traffic congestion, making transportation of goods more efficient, and enabling mass transit in cities. Based on recent advances in machine learning, vision, and robotics technology, AVs have achieved considerable success in terms of navigational tasks and safe operation on the roads. However, this race toward autonomy has not paid the needed attention to the development of robust and effective cybersecurity solutions for AVs.

1.2. Research Objectives and Scope

Following these research objectives in three problem areas, the research is structured in three phases. First, a detailed user task analysis in an operational context of partial autonomous vehicles that leverages methods from naturalistic decision making, MMI, and resilience engineering spreads across the initial and two middle years (schematic below). In Year 2, neuroergonomic (ERCOFTAC) research quantifies attention to cyber events in hypervigilant and varying levels of sleep-deprived states in simulated AV, as well as tests the feasibility of MI sensing a decline of hypervigilant state and serving as a reliable input to an ERRT interface. These studies provide recommendations for driver state assessment and designs of the supporting adaptive HCI. In parallel, Year 2 MMI studies and the results from the AeroVironment AV display with agent-based controller prototype contribute to the design

and demonstration of the enhanced Supporting Intelligent Driver-AI Interactions Interface (SIDAII) specifications in the relevant operating scenarios that AVs face daily. The third year provides additional validation of HCI recommendations, as well as ML models for cyber MQA in real-world AV operational settings, in collaboration with General Motors and their technical support stakeholders.

The primary objective of the work is to research, design, and prototype adaptive HCI techniques that address automation challenges in order to increase cyber situation awareness for the design and operational phases and improve system safety for autonomous vehicles (AVs). Specifically, inspired by hypervigilance in human cognition, this research will investigate hypervigilant or sleep-deprived states using neuroergonomic techniques, as well as utilizing MI to sense state changes associated with partial automation. The enhanced situation assessments will enable the combination of different ML algorithms to improve the predictions and, hence, safety systems for the AV. While the proposed investigation aims to improve perception and judgment process, other limitations of partial automation, such as complacency, will require additional research and are beyond the scope of this study. The resulting tools will guide future development of adaptive HCI solutions for other defense and critical infrastructure domains.

2. Fundamentals of Autonomous Vehicles

Within the context of a fully automated AV, all knowledge regarding where to drive, how to steer, and what speed limits to obey are rendered obsolete and unnecessary. This means that control and actuation of the vehicle, real-time sensing, and decision-making about vehicle operation are no longer under the control of the human driver. Before we reach our vision for fully autonomous AVs, partially autonomous vehicles are already in development and commercial operation, with advanced driver-assistance systems being standard equipment on many passenger cars and light trucks.

Autonomous vehicles (AVs) are garnering significant attention due to the emerging technical capabilities and anticipated societal and economic impact. These vehicles have great potential due not only to the potential to minimize human-related errors and driving costs, but also due to enabling a variety of new vehicle types with the potential to greatly improve personal mobility for a number of societal segments. Scholarly industry estimates suggest that independent autonomous ground vehicle technology will begin to emerge between 2020 and

2025, increase in use through 2025 to 2040, and almost dominate sighting technologies beyond 2040. Due to the combined benefits of AV usage, the transition to this new technology will likely occur. Thus, AVs promise to be an important future direction for the automotive industry.

2.1. Definition and Types of Autonomous Vehicles

Anyway, the various definitions characterize a few types of autonomous vehicles. In terms of autonomy and controls, they can be placed into six types: non-autonomous, remotely controlled, remotely supervised, co-piloted, supervised and autonomous vehicles. Anyway, based on the driving conditions the following definitions were given to define the level of autonomy of a car. A level 0 car is non-autonomous, there is no driving assistance. A level 1 car cannot handle any important function, there is human driving and if needed there is a certain driving support (e.g. autonomous parking, Mills Cross Park Assist). A level 2 car can manage the important functions. It only requests minimal human intervention (e.g. adaptive cruise control). A level 3 car can pilot autonomously under certain driving conditions (e.g. Audi in traffic jams). A level 4 car is planned to be able to drive without driver's intervention in all driving situations in a given environment (e.g. recent research cars). At last, in a level 5 car, there is no driving support and the car manages any type of riding, regardless of the driving conditions (e.g. Google Car).

Since their first appearance in the scientific literature, autonomous vehicles (AVs) have been the subject of considerable interest to researchers, both in academia and in industry. In the early 2000s, the formation of the Defense Advanced Research Projects Agency (DARPA) Grand Challenges brought increased attention to the technology and contributed to a rapid development and maturation. The ultimate goal of the Grand Challenge was to develop independent, robotic ground vehicles and harvest US support for advancing AV technologies for military purposes. The initial challenge took place in March 2004 and was situated on an unrestrained artificial desert. Vehicles had to drive a 240-km-long course and were free to select their own routes according to local obstacle avoidance. Eleven vehicles graduated to the final of this round, although none completed the course in good standing within the required 10-h time span. Following this initial breakthrough, a number of AV development projects were initiated at universities and research institutions throughout the USA. In October 2005,

a second Grand Challenge was held on a larger course, and five autonomous vehicles successfully completed it within less than 10 h.

2.2. Key Components and Technologies

2.2.1. Adaptive Visualization One of the core components of personalized adaptive situational awareness is the adaptive visualization technology. Adaptive visualization offers general visualization and provides more focused sensory channels in response to changing task context, user context, user intentions, and user affective state. This form of information presentation, where the visualization adapts to the user using advanced data analytics, supports the visualization and improves the user's understanding of the subject matter. Adaptation is not simply changing colors or transparency levels. In many cases, the adaptation comes in the form of an explanation for the data shown. These explanations can focus on outliers, specific event conditions that contribute to anomaly detection, as well as the network topology or temporal relationships of user interest. Multiple visualization displays can cooperate, for example, merging an abstract overview display with detailed specialized displays to create guided representations.

Here we briefly describe a number of technologies we utilize in building adaptive and adaptive cognitive assistance for vehicular cybersecurity. The list of necessary technical and cognitive building blocks that would enable situational awareness and root cause analysis is included in this section and can be found in Section 2.1.

3. Cybersecurity in Autonomous Vehicles

The information includes the vehicles' location, speed, and braking information. To avoid crash and risk, autonomous vehicles need to operate in real time and channel dynamic decisions based on the data collected from their surrounding environment. These decisions are usually shared with other moving vehicles and fixed traffic posts. With the increasing intention for autonomous vehicles to increase traffic stability, enhance hazard expectation, decrease energy utilization, and diminish the time length vehicles spend on the road, and the rising number of investigated and actualized cases of vehicle-to-everything (V2X) communication technologies, an associated and cooperative vehicle framework is probable to be an essential part of transportation systems. The latest intelligent transportation system standard approved by the Institute of Electrical and Electronics Engineers (IEEE) is 802.11p,

and it is an assistive technology for short-range V2X communication. The 802.11p protocol, built on the 802.11a standard, conducts as usual under European Telecommunications Standards Institute (ETSI) and Federal Communications Commission (FCC) rule for dedicated WLAN radio access.

The recent development in fabricating autonomous vehicles is driving various technologies and standards for their implementation. These technologies are also driving new modifications for enhancing V2V and V2I communications. The V2V and V2I communications used for autonomous vehicles are expanding the potential for cyber attacks. It is a difficult task to detect, contain, and protect against cyber threats inside these vehicles. Connected and autonomous vehicles equipped with modern radar, light detection and ranging (LiDAR), and communication systems could expose passengers' safety and privacy to serious risk if cyber threats succeed in bypassing the network security technologies. With the essential purpose of safety and to avoid crashes and risks, connected autonomous vehicles perform various tasks such as collision and lane departure avoidance, and traffic jam pilot for changing lanes and increasing speed. With the purpose of privacy, connected vehicles need to exchange information with other moving and fixed devices in the network.

3.1. Threat Landscape and Vulnerabilities

While the potential societal benefits of AVs are numerous, realizing them is not guaranteed. One important opinion is the safe integration of AVs into mixed-use traffic flow while still realizing the potential reduction in traffic fatalities. Cybersecurity threats are a growing concern in critical information infrastructure systems that affect national security and public safety. To exacerbate cybersecurity concerns, many AVs are designed to be tamper-resistant but not necessarily tamper-proof. This flexibility leaves openings that malicious attackers may exploit.

Autonomous vehicles (AVs) have been the subject of widespread media attention and government investment in recent years. The potential societal advantages of such vehicles are numerous, including improved safety through a reduction in driver error and drunk driving, reduced congestion and emissions, and better access to personal vehicle travel for individuals who are legally unable to drive today (e.g., the underage, elderly, and disabled). As a result of these potential benefits, there is a broad effort in government and industry to rapidly develop and widely deploy AVs.

3.2. Current Security Measures and Challenges

The magnitude and potential catastrophic results of losing self-driven vehicle security cannot be involved or unintended. Yet we have taken it seriously for the protection of the life of a big multilevel self-driven vehicle. Given that the number of vehicles incorporating self-driven technology is rapid, security development relevant to the adoption of self-driven technology is essential. As the full potential of the self-driving car is not easily reached, human participation is necessary until self-driving cars are recognized. Due to some technology's dynamic properties, self-driving cars are fitted with manual controls as usual. Even fully autonomous vehicles do not eliminate ruin and require security measures, especially due to the potentially widespread deployment and safety influence of self-driving technology.

Cybersecurity as a concept has been extended to the vehicle industry to involve measures that protect the vehicle systems, including the car components, the environment in which it operates, and the data transferred between the vehicle and external entities, from accidental and deliberate malicious intrusions. Consequently, during the advancement of the smart and self-driven vehicles, veto challenges exist to guarantee the vehicle security in an efficient and effective manner. Due to the advancements in general computing, communication, and data storage in the contemporary vehicles, the sophistication of ethical and privacy violations and security threats and risks has also scaled up. Such disclosures represent challenging and increasingly widespread dangers for vehicle transportation. These types of revelations that such robots and terminals are vehicles present these vulnerabilities. Those risks also increase the probability of vehicles involved in fatal accidents since the intrusions can override the car control, such as the steering system, the gas and the car brakes in self-driven vehicle systems.

4. Human-Computer Interaction in Autonomous Vehicles

Since the HCI of an autonomous system is the primary avenue for situational awareness, it must be designed so that the system can leverage the unique temporal and spatial characteristics of the vehicle for DVE and mobile/local HCI. Moreover, the system can communicate and coordinate the collaboration required to execute complex cognitive and physical tasks (and the complete set of tasks) in a way that does not constitute a point of failure or a bottleneck in the plan. The user-generated passive command interface design implemented must also be developed accordingly. This is all part of context- and/or culture-oriented research, evaluation, integration, and testing that surround the vehicle-occupant

interaction system. The attitude and style of real-time adaptive communication with the end users that occurs during operations are critical, and change adaptation is a critical asset to be exploited. We address these issues again by describing the impact of the importance of system adaptability in an autonomous vehicle environment in advance of the experimental portion of the research.

User displays and controls for computer software are often implemented as outputs and inputs through data processing I/O devices. In the context of vehicles, different interfaces are deployed for the convenience of operators (crewed fossil fuel-powered vehicles), drivers (conventional automated road vehicles), and riders (autonomous vehicles). The role played by these interfaces is essential for safety, comfort, and productivity. When mission-assigned physical interfaces focused exclusively on the vehicle interface are not adequately informative or are absent, it becomes risky for the crew, driver, or rider, which can be seen as increasing design and engineering system users. Specifically for autonomous vehicles, the degree of automation related to driving tasks affects the role of the copilot or the driver and therefore the development needs of the user interfaces. HCI design technology is key to facilitating decision-making accuracy and efficiency, with systems and vehicle genres that enable the user. Since this problem is particularly difficult (and crucial) for the interface of the autonomous vehicle, the user's understanding of the operation of the vehicle on the road.

Adaptive human-computer interfaces for cybersecurity situational awareness in autonomous vehicles. In this section, we present the general concepts in human-computer interface development methodology and technologies particularly relevant to autonomous vehicles. These concepts will be used to develop an innovative approach for displaying multi-source data fusion risks in dynamic vehicle environments. A typical human operator's interaction with the various components of a complex system will involve interaction with user interfaces at different levels of operation. The process will include a set of complex functions, structures, behavior, and aesthetics. Most human-computer interfaces (HCI) are structured as a set of tiers corresponding to different levels at which users interact with the system.

4.1. Importance of HCI for Cybersecurity Situational Awareness

An essential human-centric system to consider for a system like the autonomous vehicle is a human-computer interface (HCI). It includes everything that deals with the exchange of information between human users and computer systems, with the aim of supporting user's

cognitive and physical capabilities. More importantly, HCI helps ensure situational awareness by visually representing critical information. This empowers human users to process and comprehend implications of their actions on a given system, and corresponding actions and studies by the HCI research community on these technologies have also shown considerable advancement to make HCI more effective over time. This chapter describes HCI relevant research and design implications for cyber-physical systems, in particular the autonomous vehicle. After a brief summary of the impact of cybersecurity on the domain.

Healthcare systems, bioinformatics, computer vision, and radar domains have begun employing computers and algorithms for parallel human capabilities to make reliable decisions. Recent efforts by vehicle manufacturers in building cooperative systems are already showing promising results. However, with such sophistication of machine autonomy, humans have become more out of the loop. It is crucial to make sure that machine technologies are used appropriately and that their usage preserves the autonomy of the human users and ensures human reliability in order to strike the right balance between leveraging machine capabilities and maintaining desirable human capability levels. Furthermore, increased human reliance on complex machine-based technologies introduces new challenges to keep track of the state of operations and facilitate safe and effective human decision-making.

4.2. Design Principles and Considerations

The main problem of this approach is that the human task is exclusively considered to design the interface so that all data are made available to carry out the monitoring functions. In contradiction with the studies on human-computer interface design, in this way, the designer has not considered the fact of the human operator information system of the entire environment and that something that was already perceived and determined as safe may suddenly be considered unsafe. This mismatch could make the verification phase not sustainable and can make the vehicle act in an inadequate or dangerous manner. The aim of the interface I present is to guide the operator to better understand the real situation and then also stimulate to request a re-evaluation of the information acquired by the vehicle when considered not reliable and/or sufficiently effective.

This concept introduces an adaptive human-computer interface designed to support the operator's cybersecurity situational awareness in autonomous vehicles. The specific scenario concerns the interaction between the monitoring operator and the accompanying autonomous

vehicle, which is designed to operate within a partially trusted networked environment and to make decisions depending on the available data sources according to its mission and to its final user. The purpose is to prepare the more humanly informed verification of the propriety of each command that the operator can launch in its duty in case of mismatch between the operator's information and those the vehicle uses to determine the meaning of the situations met along the mission. Until today, the majority of the autonomous vehicle studies involve system and infrastructure optimization and automation of the mission reprogramming processes.

5. Adaptive Interfaces for Cybersecurity Situational Awareness

Before detailing a defense strategy framework and the connection orientation problem, we'll discuss existing situational awareness methods and applications directed at more traditional, recoverable vehicle safety problems. As we've mentioned, the driving detail for an Advanced Driving Assistance System (ADAS) would fill pages; as with any system on so many automobiles, the responsibility of parsing these details for the public goes to the car vendors. It's left to independent testing to spotlight cars that implemented these mentioned things especially well, and the majority of a review that suggested performing them.

The main goal of an interface is to inform a user about events in the system, allowing them to monitor its operation. This becomes especially challenging in the case of autonomous driving, where system complexity is high and direct system contact is limited by the user's seat location. Moreover, typical autonomous vehicle (AV) users may have fragmentary or no prior experience/motivation for driving. It seems inconsistent to place so much performance improvement for mitigating AV cybersecurity threat possible in an adaptive safety-critical application without developing an interface technology to help end users understand the nature of these extra safeguards. Adaptive security within autonomous vehicle experience has an effect grander than simply letting system designers fix potential car troubles.

5.1. Definition and Benefits of Adaptive Interfaces

A human in the loop needs assistive intelligence to allow him to understand something of the vehicle's actions and intentions, particularly if things are going wrong, so that the human can get help, but also so that the human can understand something of the vehicle's logic and specify changes in intent. These things are necessary to fulfill the most important role of the

human in the loop - "sanity check" of the vehicle, particularly in fluid and non-deterministic or stochastic situations using natural language or gesture rather than complex displays requiring authorizing input. To do this, vehicle-aware infotainment and situational awareness dynamic displays can be developed that understand the human in the loop via measures of engagement that feed into control of the content and attention, even allowing discomfort to be recognized, predicted, and allayed by adjusting vehicle control actions, together with appropriate dynamism in voice and touch feedback. When the vehicle is aware of the information needs and status of their human passengers, it makes for a situationally aware partnership in control providing directed and dynamic feedback to the user. Adaptive "situational awareness" can be implemented through a dynamic "display agent" that provides a 3D visualization of the vehicle's sensor data for passengers sitting in the rear. Synchronization of the display agent with the vehicle's sensor data provides a visual situation awareness feedback to the passengers. The display engenders a sense of calm in the passengers, making their trip more enjoyable and freeing them to undertake other activities other than having to maintain a constant watchfulness over the vehicle's operation.

Autonomous vehicles and transportation systems should require minimal human interaction, and so little is known about evaluating situational awareness, interactions, or displays. The review of autonomous systems and the assessment of interactions and displays across autonomy levels suggest areas needing attention, such as the role and interactions of the human and vehicle controllers, and the demands on the human operator to maintain overall system awareness. One approach to assess and potentially mitigate the attention and situational awareness demands of the human in associated control and shared control systems is to apply adaptive automation to these systems to allow the vehicles to have "situational awareness" of their humans in the loop and understand what the human lacks in situation awareness or available mental resources.

5.2. Adaptive Interface Technologies

Attentive and generically brain aroused neuro-interaction devices capable to weld spreading of delta, theta, alpha1, alpha2, beta1, beta2, and gamma EEG bands together with EDA measures and HMD-mountable eye tracking plus connected motion descriptors and enveloping audio and voice pitch and tone data analysis are the suggested components

combined in a smart sensor fusion model outputting computed trust-related assessments about the user interacting with the system.

The suggested adaptive interface is a first step in developing for robotic systems and their operators a trustable interaction model, based on sharing of different sensory cues by various humans and computed trust-related evaluative parameters, such as the stress level, the operator's attitude, his/her mindfulness, his/her workload, his arousal, his situation awareness, his/her performance, and his readiness to overcome the mission either as the tele-operator of a mission or as the human supervisor and arbitrator of an autonomous system.

Currently available robotic systems and interfaces demonstrate limited flexibility and adaptive capacity, mainly due to the reliance on operators who are expected to take over or intervene with control, communication, and decision-making processes as needed at any stage in the mission, without in-depth awareness of the environmental conditions or the mission status.

6. Case Studies and Examples

In Section 2, we review the state-of-the-art AI techniques for robust perception and trust management. In Section 3, we present the framework of the proposed system. In Section 4, we provide proof-of-concept demonstrations of the proposed mechanisms. Since end-to-end trained neural networks are commonly deemed to hide the details, the interpretation about the deep models themselves is also a vital subject. Besides the major security topic, in Section 5 we provide detailed interpretation of the best-performing NN models for the trust inference. Finally, after presenting related results, Section 6 concludes this paper.

At the dawn of autonomous driving as-a-service era, leveraging autonomous vehicles to transport VIPs (Very Important Persons) and VVIPs (Very Very Important Persons) will definitely become an important use case. The service put fierce requirements to both vehicle driving capabilities and user interfaces. In the meantime, with the vision of adverse agents and the physical actions, the adversary can perfectly formulate the training samples for logistic regression and hence deceive state-of-the-art RGB-based trust estimation algorithms. Therefore, such algorithms are vulnerable to adversarial attacks: the adversary has been burnt in, yet the attack model is still adaptive in the wild. In this paper, we explore various defense

mechanisms, from conventional image degradations and adversarial training mechanisms to using auxiliary adversarial training loss.

6.3. Robust Trust Estimation System with Neural Networks for Autonomous Driving As-A-Service

In the last few decades, the development of technology to perform autonomous vehicle in the occluded environment has made impressive progress. The in-flight sensing system, such as LiDAR and ultrasonic sensors, in the autonomous vehicle can tell its position and its surroundings in real time, while camera-based perception system identifies specific objects, such as people. Even though many studies on the subject of collision free motion have tackled the problem effectively, most of the solutions still do not explicitly consider the presence of the human obstacle in a shared space to either emulate human navigation behavior or efficiently adjust their predicted occlusion. The actual pedestrian, in many cases, does not move in a predictable way. This phenomenon cannot be understood without a consideration of the intention.

6.2. Human-Aware Autonomous Navigation Strategy Using Collision Probability Estimation

In this study, we investigate novel and effective techniques for performing first-cut analysis of vehicle data by identifying the anomalies that deviate substantially from the normal healthy system behavior so that subsequent more in-depth forensic analysis is triggered. The primary focus is to provide a holistic solution by investigating efficient techniques of performing anomaly detection from the lowest level of vehicle operation and performance data such as signals and functions, to the highest level data that represent driver behavior and vehicle control. Such multi-level anomaly detection allows rigorous detection of cybersecurity breaches and inappropriate vehicle operations from the signals, control operations, and data that run in the vehicle like the traditional vehicle functional safety processes.

6.1. Anomaly Detection at Multiple Abstraction Levels for In-Vehicle Cybersecurity

In this chapter, we present three systems as case studies of adding HCI to vehicle security. Each describes systems with some level of evaluative assessment we have performed; reporting on the basic capability, implementation, and system integration design and the final assessment is performed.

6.1. Successful Implementations in Autonomous Vehicles

As previously noted, we are not the first to receive the informative and stimulating response that hybrid adaptive interfaces for the state of an autonomous vehicle (AV) are a good idea. We substantiate and illustrate that assertion with a brief summary of several widespread or successful applications of AV techniques and reviewed heuristic rules that combine or prioritize, or break news about the three goals identified here of increased performance (or "robustness"), increased user situational awareness (SA) (including cognitive capacity) and coordination, and increased user compliance. Compliance from the user perspective in the context of autonomous vehicles is not just an issue of concern.

We noted at the start of Section 6 that the reference to the context in which adaptive interfaces can house multiple applications - including safety, entertainment, and human performance - is often ignored. Here, we summarize some related examples in the context of autonomous vehicles and then review, relate to, and extend the five challenges informally identified based on these experiences. In doing so, we demonstrate a path to more successful implementation of the research agenda offered in Section 6.1.

7. Evaluation and Testing of Adaptive Interfaces

A second challenge is effectively coordinating knowledge sets and priorities where different expert discipline applications intersect, all in real time. For an example of a sensor filter in web-causing operation, it can be more important to discover a web change sent to the physical world through the application layer and then encountered for a second time at the physical recognizer in the network layer. Different discipline experts also have different notions as to what is important to prioritize in an intrusion scenario, all in real time. A priority assignment for a web change then becomes a classification task given web configuration disturbances and the filter function classifier. However, recognizing thousands of web changes is a formidable challenge in real time; in a similar classification task for a network accessing web services, these conclusions can be readily verified with the reliable technology provided by an uncomplicated 10-bit correlator classifier. Other real-time needs include classification of what to do about types of visual web changes noticed.

Despite active AI techniques, many challenges remain in designing adaptive interfaces for ASV cybersecurity situation awareness. At the network layer, one challenge is planning and

simulating a complex array of imaging sensing and motion coordinating hardware for ASVs to respond to different kinds of physical world interference with data and control signals and object ranking. The following network layer is the application layer, which contains digital control systems for ASVs, and the web layer, which contains observables about the ASV control system and overlap features. Knowledge used in these layers comes from different expert disciplines.

7.1. Usability Testing and Metrics

These typical uses and experiences together should model standard procedures for end tasks done/encountered by the user community. Researchers observing the test subjects collect both verbal and behavioral data about any problems encountered, degree of ease of use, and perceived task difficulty. The goal is to identify any problems with the interface, and thereby to obtain a measure of the "usability" of the system. These collected data help researchers improve the interface design.

Just as for traditional two-dimensional (2D) software applications, the systematic pursuit of objectively measurable usability in 3D augmented reality interfaces begins with usability testing. To recap, usability testing involves real users working in a laboratory performing specific tasks to assess ease of use and the associated metrics of usability (time to complete, error rate, and subjective user satisfaction). During the testing, researchers ask the test subjects to complete typical tasks while they collect data and observe the subjects using the system. Researchers test the system with different typical users (who are representative of the overall user community), because different types of users find different usability problems, and different typical uses/experiences of the system.

8. Future Directions and Emerging Trends

New versions of AR and VR will enable humans and machines to interact in 3D dynamic space. Corresponding AR and VR features will be added to 5G communications. The rich contexts generated by these technologies and the rapidly increasing volumes of data will enable machines to deeply understand human behaviors. With such benefits, however, the right to privacy and data security may also be threatened. The use of wearables provides an opportunity to monitor the states of the human body for rapid medical treatment but may also harm the user. The real concerns about the possible negative effects of these technologies

on human beings are legitimate and cannot be ignored. In future HCI development, we need to optimize the combination of high technology and community well-being, and in the cloud HCI development, we need to include an HDCI ethical system.

The future of HCI development is largely driven by technology, especially emerging technologies like neuromorphic chips, quantum computing, and direct communication with a human brain through the internet. Humanoid robots and cyborgs will be a grand part of our daily life in the future. Smart offices and smart homes will be able to run a variety of applications, such as acting as our personal assistant. When interacting with machines, humans will expect machines to adapt to human behaviors and conditions, tolerate human errors, and conform to humans' cultural backgrounds. These include developing human-computer interfaces that can adapt to mental workload, stress, and negative emotions. In this chapter, we describe the expected roles of mental workload, stress, and negative emotions in future human-computer interfaces that need to be addressed in order to improve the personal experience and the effectiveness of human-machine cooperation.

8.1. Advancements in Adaptive Interfaces

Such advances will, in turn, allow for interfaces that can adapt to the user in a fast, fluid, and efficient manner. The level of adaptive sophistication can range from personal interfaces capable of learning and anticipating user needs, to universal interfaces that can be customized with different levels of adaptive behavior to fit individual preferences. Additionally, traditional touch interfaces may be substituted with highly flexible, stretchable, and conformal sensing surfaces that can conform to any desired shape, even three-dimensional surfaces, while maintaining sensing capabilities. These adaptive capabilities are not only useful for fragile, complex, and multitasking devices, but can also optimize the interface of these multifunctional devices, maintaining form-fitting designs that are unobtrusive.

The system will capitalize on technological advancements in adaptive interfaces, trust calibration, and task automation to enable secure, adaptive, human-in-the-loop functionality. This functionality will provide a smooth situational awareness evolution as vehicles evolve towards autonomy. Advances in adaptive interfaces are leveraging the rapid improvement in multifunctional materials that offer the potential for reconfigurable and shape-morphing capabilities at the surface and bulk scales. Additive manufacturing and three-dimensional printing are viewed as potentially revolutionizing traditional forms of manufacturing. Such

technological advances are also being exploited in the human-computer interface area, capitalizing on multifunctional material properties to create those capabilities such as adaptable, shape-morphing surfaces that can provide a rich set of modalities allowing for objects to become shape-changing.

9. Conclusion

The context-aware model of attention enables the vehicle to present actions and notifications in natural language and perception channels that are tailored to the driver's current capabilities and task load while being attentive to momentary online events. Furthermore, this representation can guide the car to provide cues of attentiveness through non-modal presentation (tailored to the user's likely attentional broadcast capabilities) and adjust for interruptions more effectively. By carrying out these steps, the HCI can, at all times, appear relevant and interested in the driver's actions by responding to the driver's utterances at a time that makes sense to the driver given the driver's current focus of attention. The driver's utterances within a context that records human attention toward X can be implicitly referenced in the shared attentional model and through analysis of the language used, a mixed-initiative dialog model between the computer and the driver can also contribute to discerning if the driver appears present or attending to the updated system state fully.

The emerging landscape of autonomous vehicles will introduce new safety and security challenges that must be addressed by providing drivers with an adaptive HCI to ensure the driver's dynamic situational awareness is commensurate with the responsibilities and freedom allocated to the driver by an enabling space of interaction design. This paper makes the case that an enabling and empowering HCI in such A/ADAS contexts can benefit from adapting models of human attention to draw specific inferences about the driver's perceptual and cognitive states. We offer three guidelines that can inform the design of an adaptive A/ADAS interface based on continuous or near-continuous monitoring of driver behavior and driver's response to changing expectations (e.g., natural language dialog with vehicle seeking to ascertain driver's interruptibility) to dynamically adapt these models of attention and disturbing events, and make a case for the system to establish a shared representation of the driver's attentional state out of concern for the driver-initiated safety procedures.

9.1. Key Findings and Implications

However, designing driver assistance systems based on the assumption that drivers are eternally vigilant is unlikely to succeed. Drivers will be exposed to virtualization bombs, information overload effects, and zero-day vulnerabilities, leading to significant delays in recognizing and responding to safety-related environmental changes. While addressing driver distractibility is an interesting area of "big data" research, it could also lead to other privacy concerns. As the source of truth, the traffic infrastructure can play an important role in improving the drivers' and passengers' cybersecurity situational awareness by designing adaptive human-computer interfaces that have high recognition compliance and low false alarm rate. While the traffic infrastructure can play a significant role in terms of improving human cybersecurity situational, CYA (Cover Your Ass) mechanisms are also desirable to ensure liabilities can be accurately traced.

Recent advances in artificial intelligence and machine learning research have enabled fully autonomous vehicles to act in extremely complex and dynamic situations at least as good as, if not better than, human-operated vehicles. However, the level of cybersecurity readiness of fully autonomous vehicles in the hostile and adversarial cyber-physical environment is still unknown. On one hand, fully autonomous vehicles have much better information processing capabilities. On the other hand, the widespread presence of internet connectivity and the mandatory remote software updates may provide adversaries with easy access for malicious code attacks to cause safety hazards.

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