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Guest Editorial

Special Section on Risk, Resilience, and Reliability for Autonomous Vehicle Technologies: Trend, Techniques, and Challenges

Mechanical engineering continues to dominate the design, development, and advancement of autonomous vehicle technologies, and throughout this process is likely to evolve through several risks and uncertainties. Self-driving cars are making strides in technical advancement and are maneuvering barriers through testing, regulations, and societal integration. User acceptance is put to test in the adoption of fully autonomous public transit systems. Autonomous systems, in general, must harmoniously integrate hardware, software, and humans while conforming to principles of safety, security, and reliability. The challenges range from identification of failure modes, determination of imprecise probabilities, and development of use case scenarios to integration analysis and interpretation of observations, to name a few.

In April 2019, a joint American Society of Mechanical Engineers (ASME)-University of Maryland (UMD) was convened on "Risk Analysis for Autonomous Vehicles: Issues and Future Directions," and identified the following needs to: (1) develop more case studies on the topic, (2) develop clear top-down safety requirements, (3) use modern safety and risk-based analysis methods and simulations, (4) investigate and optimize the use of more redundancies in the safety equipment of driverless vehicles, (5) develop approaches for better safety enforcement, and (6) understand, study and model the role of human behavior and intensions in fully autonomous vehicles. Workshop participants working on those areas were invited to submit their research findings on the topics of this special issue. This special issue is aimed at gathering contributions that discuss new theoretical developments and advanced applications of risk, reliability, and uncertainty assessment toward the management of autonomous vehicle technologies. Interpretation of and insights gained from the implementation of risk-informed frameworks are also encouraged at various levels of maturity and discussion from a philosophical and ethical standpoint. An account of data needs and uncertainties around the collection of such data required for successful assessments along with novel solutions to encounter such challenges is welcome. Predictive analytics toward prognostic health management, techno-economic analysis, and loss prevention of autonomously engineered systems were also of interest.

This Special Section on risk, resilience, and reliability for autonomous vehicle technologies: trends, techniques, and challenges contain a collection of six research papers and two technical briefs. The Issue reflects the need to rethink system representation techniques (e.g., fault tree analysis (FTA), systems theoretic process analysis (STPA), unified modeling language (UML), and systems modeling language (SYSML)) and system risk assessment techniques (e.g., hazard and operability analysis (HAZOP), failure modes and effects analysis (FMEA), and functional resonance analysis method (FRAM)). The focus is also on safety performance in hazardous conditions and cybersecurity. The technical briefs look forward and emphasize risk communication between humans and autonomous vehicles as well as look back into statistics of past collision incidents.

The paper by J. Duan focuses on the STPA compensating for limitations in modeling system failures using traditional failure analysis methods like FMEA and FTA in the presence of a complex human, vehicle interactions. The method leverages control system interaction representation using the SYSML structure. These advanced methodologies were applied to vehicles with autonomous emergency braking systems.

Morozov et al. state that while UML/SYSML has been successful in representing complex autonomous system interactions, the essential mechanism to augment and transform such representations to include error propagation characteristics has been captured. The transformation technique has been demonstrated on autonomous medical patient tables. There also have been attempts to transform SYSML models into Bayesian networks by Melani et al. [1].

The research by Abdo et al. studies the response of LIDAR imaging systems for autonomous vehicles under nominal weather conditions. Their performance under adverse weather systems is investigated in with insights leading to believe that rain and fog conditions have performance implications unlike under snow conditions.

The author's Sun et al. focuses on the requirement to revisit system failure analysis methodologies for autonomous vehicle technologies. The traditional HAZOP and FMEA methodologies are compared to contemporary hazard assessment techniques such as the functional resonance analysis method (FRAM) and system-theoretic process analysis (STPA) in the failure analysis of automatic emergency braking systems. Similarly, hybrid causal frameworks for autonomous systems were explored by Thomas and Groth [2].

Lombardi et al. state that the connected autonomous systems could have unresolved vulnerabilities that open them to cyberattacks by adversaries. A two-step Bayesian network algorithm is proposed to detect cyber intrusion in-vehicle electronic control unit circuits is presented.

The research by Ferenchak and Shafique discusses that risk communication is an integral part of human interaction with autonomous vehicles. This has been at the core of a technical brief studying the usefulness of external human-machine textual and nontextual interfaces in communicating the presence of autonomous vehicles in the vicinity of humans. Similarly, the interaction between humans and autonomous marine systems was studied by Thieme and Utne [3].

McCarthy states that while autonomous vehicles climb the learning curve, the few collisions and crashes in the California jurisdiction are statistically analyzed with the conclusion that there could be a slight uptick in vehicle crash frequency before providing the full benefits of accident-free autonomous driving. Road safety has also been explored from a risk management perspective by Nicholson [4].

The paper by Farnaz and Zhimin addresses the research gap for autonomous navigation reliability analysis by further conducting design improvement and characterizes systems operation conditions for meeting the collision avoidance reliability using the dynamic window approach. To address the technical challenges associated with a limited number of simulations or experiments, reliability analysis is conducted using Bayesian statistics combined with the Monte Carlo simulation. Design improvement and reliable operation conditions can then be conducted based on the reliability analysis. Braking systems have also been explored in the context of collision avoidance reliability analysis by Liu et al. [5] while the emphasis on risk, reliability, and uncertainty quantification of automotive systems was studied by Hu et al. and Wang et al. [6,7].

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