Top Level Newsletter: Connected Vehicle

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Vol 50: contains a few more viewpoints on autonomous driving technology.

1. When Connected and Autonomous Vehicles Meet Mobile Crowdsensing
2. High-Performance Automotive Radar: A Review of Signal Processing Algorithms and Modulation Schemes,

General Notes

This series of newsletters is intended to provide the IEEE member with a top level briefing of the many different subjects relevant to the research, development and innovation of the connected vehicle.

The objective is to provide a platform for fast learning and quick overview so that the reader may be guided to the next levels of detail and gain insight into correlations between the entries to enable growth of the technology. Intended audiences are those that desire a quick introduction to the subject and who may wish to take it further and deepen their knowledge. This includes those in industry, academia or government and the public at large. Descriptions will include a range of flavors from technical detail to broad industry and administrative issues. A (soft) limit of 300 to 600 words is usually set for each entry, but not rigorously exercised.

As descriptions are not exhaustive, hyperlinks are occasionally provided to give the reader a first means of delving into the next level of detail. The reader is encouraged to develop a first level understanding of the topic in view. The emphasis is on brief, clear and contained text. There will be no diagrams in order to keep the publication concise and podcast - friendly. Related topics in the case of Connected Vehicle technology, such as 5G cellular and the Internet of Things will be included. The terms Connected Vehicle and Automated Driving will be used inter-changeably. Articles from other published sources than IEEE that add to the information value will occasionally be included.

This newsletter forms part of the regional Advanced Technology Initiative (ATI) of which connected vehicles form a constituent part. Technical articles solely from IEEE journals/magazines are referred to by their Digital Object Identifier (DOI) or corresponding https link. The link for each article is provided. Those readers who wish to delve further to the complete paper and have access to IEEE Explore (www.ieeexplore.ieee.org) may download complete articles of interest. Those who subscribe to the relevant IEEE society and receive the journal may already have physical or electronic copies. In case of difficulty please contact the editor at kaydas@mac.com. The objective is to provide top level guidance on the subject of interest. As this is a collection of summaries of already published articles and serves to further widen audiences for the benefit of each publication, no copyright issues are foreseen.

Readers are encouraged to develop their own onward sources of information, discover and draw inferences, join the dots, and further develop the technology. Entries in the newsletter are normally either editorials or summaries or abstracts of articles. Where a deepening of knowledge is desired, reading the full article is recommended.

Article 1. When Connected and Autonomous Vehicles Meet Mobile Crowdsensing Under the Metaverse Framework

Published in: IEEE Vehicular Technology Magazine, December 2023, Vol 18, no 4, Page(s):22 to 34) by Xiao Fei Yu et al.

Abstract: The metaverse employs globally distributed computing and communication infrastructures to construct an immersive digital world. Its continuous synchronization and hyperinteractivity create a dilemma involving tremendous volumes of sensory data and scarce spectrum resources. Connected and automated vehicle (CAV) networks integrate onboard sensing, communication, computation, and storage capabilities to enhance the metaverse. This article introduces an *edge intelligence-based* mobile crowdsensing (MCS) CAV framework, which studies both perception and transmission dimensions. The metaverse's cornerstone is high-quality edge sensory data delivery across a geographical distribution. Thus, we construct a CAV crowdsensing-based traffic coverage model. Furthermore, we provide information silos in urban transportation networks as a use case. Simulation results validate the proposed framework's superiority in improving MCS coverage and perceptual data offloading efficiency. With edge intelligence, such a framework can illuminate the prospect of the convergence between CAV applications and the metaverse.

Introduction: The science fiction novel *Snow Crash* first coined the metaverse concept, which has recently regained popularity. Regarded as the *"next-generation Internet,"* the metaverse allows people to interact in real time via digital avatars in a 3D Internet world. By contrast, in the current mobile Internet era, we utilize a web browser or software via a cursor to navigate the Internet. Indeed, emerging technologies, such as virtual reality/augmented reality (AR)/extended reality (XR), artificial intelligence (AI), and 6G networks, play a crucial role. They enable the construction of a panoramic, immersive, embodied, and interoperable metaverse. Nonetheless, the existing lightweight metaverse does not enable the entire vision of a synchronized virtual world seamlessly connected to the physical world, especially considering the accessibility of worldwide users. Driven by the paradigm shift from "content inside the screen" to "users inside the content," the metaverse's performance relies heavily on collecting and processing data that capture or describe surrounding changes. Such data can enhance renderings and further blur the boundaries between the physical world and digital entities. Specifically, further integration of sensing and communication is critical to guarantee the stable bidirectional data mapping between physical and virtual worlds. As multifaceted Internet of Things objects, CAVs are not only equipped with onboard sensors (radar, cameras, and location receivers) but also with storage, computing, and communication abilities. These sensors and capabilities can help support and enhance fine-grained metaverse applications. Examples include real-time 3D object (e.g., pedestrians, vehicles, and landmarks) detection in AR-based scene sensing for urban driving, which has already been applied in reality. The Internet of Vehicles (IoV) consists of CAVs and roadside infrastructure. By tracking and perceiving environmental information, it can achieve intelligent decision making based on context awareness. Therefore, as shown in Figure 1, the convergence of the metaverse and CAVs enables efficient edge resource management and guarantees the quality of service (QoS) for diverse applications in the metaverse.

As a data perception network, MCS involves utilizing sensors on mobile units to perform large-scale sensing tasks. MCS has three main characteristics: 1) a random distribution of sensing nodes and wide sensing area; 2) a high robustness of the sensing network; and 3) a human-centric nature, with humans acting as sensing objects, device managers, data sources, and service recipients. Such characteristics coincide with the metaverse's features, which include distributed computing and communication infrastructures and humans as the primary players. Thus, such a metaverse context allows MCS to monitor and gather bidirectional mapping information. This information consists of the surrounding information in the physical world. It also includes data about user interactions and experiences in the virtual environment. The above perception data can optimize metaverse network settings and resource allocation in a multidimensional and fine-grained manner. In addition, the CAV network's scalability, distributed mobile nature, and reliable wireless transmission capability make it the preferred sensing participant for MCS

The remainder of the article is structured as follows. We first introduce the MCS CAV framework hierarchy and its corresponding architecture functions. Then, we present a CAV crowdsensing-based traffic coverage model. We also go through a case study of solving the information silos problem in urban transportation networks via the proposed MCS CAV framework and model. Extensive simulations are performed to investigate the approach's superiority. Finally, we conclude the article, followed by a discussion of future directions. (606 words)

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Article 2. High-Performance Automotive Radar: A Review of Signal Processing Algorithms and Modulation Schemes, (by Gor Hakobyan et al)

Published in: IEEE Signal Processing Magazine (Volume: 36, Issue: 5, September 2019) Page(s): 32 – 44

Abstract: The ongoing automation of driving functions in cars results in the evolution of advanced driver assistance systems (ADAS) into ones capable of highly automated driving, which will in turn progress into fully autonomous, self-driving cars. To work properly, these functions first must be able to perceive the car's surroundings by such means as radar, lidar, camera, and ultrasound sensors. As the complexity of such systems increases along with the level of automation, the demands on environment sensors, including radar, grow as well. For radar performance to meet the requirements of self-driving cars, straightforward scaling of the radar parameters is not sufficient. To refine radar capabilities to meet more stringent requirements, fundamentally different approaches may be required, including the use of more sophisticated signal processing algorithms as well as alternative radar waveforms and modulation schemes. In addition, since radar is an active sensor (i.e., it operates by transmitting signals and evaluating their reflections) interference becomes a crucial issue as the number of automotive radar sensors increases. This article gives an overview of the challenges that arise for automotive radar from its development as a sensor for ADAS to a core component of self-driving cars. It summarizes the relevant research and discusses the following topics related to high performance automotive radar systems: 1) shortcomings of the classical signal processing algorithms due to underlying fundamental assumptions and a signal processing framework that overcomes these limitations, 2) use of digital modulations for automotive radar, and 3) interference-mitigation methods that enable multiple radar sensors to coexist in conditions of increasing market penetration. The overview presented in this article shows that new paradigms arise as automotive radar transitions into a more powerful vehicular sensor, which provides a fertile research ground for further investigation.

Introduction: When the idea of radar was first explored back in the late-19th and early-20th centuries, it was primarily seen as a technology for military applications. Other applications gradually emerged, however, and in the last four decades, radar has been studied for use in the automotive sector for such applications as predictive crash sensing, obstacle detection, and braking. The term *radar* is short for *radio detection and ranging*, an

indication that radar is used to detect objects (obstacles and other road users) near the vehicle and to estimate their range as well as velocity and angle relative to the radar. For many years, production cars have made use of these capabilities to facilitate various driver-assistance functions, such as emergency brake assist and adaptive cruise control. More complex functions, such as fully autonomous driving, also rely heavily on radar as an environmental sensor , as it is capable of direct range and velocity measurements, can sense long distances ahead, is robust to bad weather and poor light conditions, and can be hidden behind a bumper.
A detailed overview of the status of automotive radar during its first several years is presented. The evolution of automotive radar is discussed. Other review articles provide overviews of the signal processing architecture and of the millimeter-wave technology for automotive radar. A more recent review article discusses the state-of-the-art signal processing algorithms for automotive radar and gives a bird's-eye view of estimation techniques, radar waveforms, and higher-level processing steps, such as tracking and classification.

This article gives an overview of the signal processing and modulation aspects of high-end automotive radar systems and discusses recent advances in these fields. We address the use of digital modulations, such as orthogonal frequency-division multiplexing (OFDM) and phase modulated continuous wave (PMCW) waveforms, for automotive radar and multiple-input, multiple-output (MIMO) radar in particular; discuss their potential benefits and challenges due to increased complexity; and survey recent research in this area. We also point out that classical automotive radar signal processing does not fully accommodate performance improvement through simple upscaling of the radar parameters (e.g., bandwidth, measurement time, antenna aperture) due to underlying fundamental assumptions. We provide a signal processing framework based on a more advanced signal model that surpasses these limits at a feasible computational cost. Next we explore the reliable operation of future automotive radar systems for which interference mitigation is vital and complete the discussion with a survey of interference-mitigation methods. These include some promising paradigms, such as interference-aware cognitive radar, and centralized coordination for interference avoidance.(706 words, excerpt repeated from vol 50.0).

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