Scanning the Issue

5G Key Technologies for Smart Railways

by B. Ai, A. F. Molisch, M. Rupp, and Z.-D. Zhong

Rail traffic systems are widely acknowledged to be an alternative green transportation for goods and people due to their higher mobility, energy efficiency (EE), and/or substantially lower environmental impact than conventional transportation systems. Railway communications have attracted significant attention due to its potential for not only improving operational mobility, safety, and reliability but also improving quality-of-service, eco-friendliness, comfort, and cost efficiency.

This month's regular papers focus on communication technologies for future smart railroad, robust pattern recognition, indoor millimeter-wave systems, and information transmission of haptic devices.

Future smart railways are expected to include services such as real-time 4K/8K ultrahigh definition (UHD) video transmissions, security closed circuit television (CCTV) in the train cabin, remote maintenance of trains, and high-data-rate wireless offloading at railway stations. Moreover, there is a need for a dedicated wireless communication system that can support a massive number of sensors, ms-level delay, ultrareliability, and/or Gb/s transmission rate at over 500-km/h train speed for rail traffic management. Until recently, it has been challenging to reach the required Gb/s-level data rate as LTE-R was not able to deliver it; however, the arrival of 5G key technologies has been a game changer in this regard.

In this article, the authors analyze smart rail traffic services and communication scenarios and propose a network slicing architecture for a 5G-based HSR system that can help achieve the desired goals for future smart railways. With a ray-tracing-based analysis of radio wave propagation characteristics and channel models for millimeter-wave (mmWave) bands in railway scenarios, this article draws important conclusions with regard to appropriate operating frequency bands for HSRs. Specifically, this article identifies significant 5G-based key technologies for HSRs, such as spatial modulation, fast channel estimation, cell-free massive multiple-input–multiple-output (MIMO), mmWave, efficient beamforming, wireless backhaul, ultrareliable low-latency communications, and enhanced handover strategies. Based on these technologies, this article presents a complete framework of 5G technologies for smart railways along with exciting future research directions.

Towards Robust Pattern Recognition: A Review

by X.-Y. Zhang, C.-L. Liu, and C. Y. Suen

In human intelligence, the ability of recognizing patterns is the most fundamental cognitive skill in the brain and serves as the building block for other high-level decision making. Historically, this ability has been crucial for our survival and evolution in complex environments. In terms of machine intelligence, pattern recognition is also an essential goal for both machine learning and artificial intelligence, where solving many high-level intelligent problems relies heavily on the success of automatic and accurate pattern recognition. There have been many exciting achievements in pattern recognition in the last few decades, including various successful approaches such as Bayes decision rules, support vector machines, boosting algorithms, and more. To guarantee high accuracy, models based on these approaches are usually built using some well-designed handcrafted features since the choice of the feature representation strongly influences the classification performance. Since 2006, however, the end-to-end approach of deep learning, which simultaneously learns the feature and classifier directly from the raw data, has become the new cutting-edge solution for many pattern recognition tasks.

The accuracy of many pattern recognition tasks has increased significantly year by year, achieving or even outperforming human performance in some cases. From the perspective of accuracy, pattern recognition seems to be a nearly solved problem. However, once launched in real applications, high-accuracy pattern recognition systems may become unstable and unreliable due to the lack of robustness in open and changing environments. This article provides a comprehensive review of robustness in pattern recognition from

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the perspective of breaking three basic and implicit assumptions: closed-world assumption, independent, and identically distributed assumption, and clean and big data assumption, which form the foundation of most pattern recognition models. The major difference between our brain and machine intelligence right now is that our brain is robust at learning concepts continually and incrementally, in complex, open and changing environments, with different contexts, modalities and tasks, by showing only a few examples, under weak or noisy supervision. To help build upon the significant improvement in accuracy achieved nowadays, this article aims to provide a framework for analyzing the shortcomings and limitations of current methods and identifying future research directions for robust pattern recognition.

Indoor Millimeter-Wave Systems: Design and Performance Evaluation
by J. Kibiłda, A. B. MacKenzie, M. J. Abdel-Rahman, S. K. Yoo, L. Galati Giordano, S. L. Cotton, N. Marchetti, W. Saad, W. G. Scanlon, A. Garcia-Rodriguez, D. López-Pérez, H. Claussen, and L. A. DaSilva

Millimeter wave (mmWave) is a natural choice for indoor deployments due to the much larger available bandwidths and the much shorter link distances with weak penetration through walls. The concept of using mmWave to provision multi-Gb/s speeds over indoor areas dates back to works published in the late 1990s. A suite of standards introduced later offered the possibility of mmWave *ad hoc* networking and increased the importance of mmWave further. Today, mmWave is considered one of the key features of fifth generation (5G) broadband wireless networks.

It is a well-known fact that many aspects of wireless communications, for example, system design and network deployment and its performance are dependent upon an accurate understanding of the channel characteristics. Therefore, a comprehensive study of channel characteristics at mmWave is required for developing detailed channel models. Many ongoing measurement campaigns are being conducted around the globe with the aim of characterizing and modeling the mmWave propagation channel. By nature, all these measurements are context specific (as any experimental work), and, depending on the modeling technique used, apply to different types of system-level evaluations. The key is to capture the relevant propagation-related effects in a model that is both accurate and amenable to the analysis at a specific system level.

This article brings together multiple strands of research to provide a comprehensive and integrated framework for the design and performance evaluation of indoor mmWave systems. It introduces the framework and provides an update on mmWave technology, including ongoing 5G wireless standardization efforts, and elaborates further on experimentally validated channel models. Finally, it provides details on the informed performance evaluation and subsequent deployment planning, that a service provider may perform prior to deployment.

Methodology for Maximizing Information Transmission of Haptic Devices: A Survey
by H. Z. Tan, S. Choi, F. W. Y. Lau, and F. Abnousi

The word haptics refers to sensing and manipulation through the sense of touch. Modern haptics is concerned with the science, technology, and applications associated with information acquisition and object manipulation through touch, including all aspects of manual exploration and manipulation by humans, machines, and the interactions between the two, performed in real, virtual, teleoperated, or networked environments. With the ongoing and increasing interest in haptic (touch-based) interfaces for virtual and augmented reality, human–robot interaction, gaming and just about any human–machine system, the question arises as to how much information can be transmitted effectively through the sense of touch. Estimates vary widely, with the highest reported upper bound being 56 b/s using simple binary signals at the fingertip. A more conservative and perhaps more realistic estimate of haptic communication capacity is 12 b/s for a natural speech communication method, called the Tadoma method, used by individuals who are both deaf and blind.

This article surveys the information transmission capability of haptic devices and ways of maximizing it. It is intended for readers who are engineering professionals interested in developing novel haptic interfaces for a variety of applications but are not necessarily trained in haptic science or human user research. This article begins with a concise yet comprehensive tutorial on information theory as applied to human performance studies and the corresponding psychophysical methodology. Methods and findings of the survey study on the typical information transfer achievable with haptic devices, and guidelines for maximizing information transmission with any human–machine interfaces are presented next. The results help uncover new ways to effectively increase information transmission and point to the need for broader dissemination of proper experimental methodology. ■