Analyses of Researches on Edge-AI for Cooperative-ITS Applications

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C-ITS 응용을 위한 Edge-AI 연구 동향 분석

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Abstract

This paper briefly explores the integration of Edge-AI into C-ITS applications, emphasizing its role in empowering C-ITS operations. The paper reviews recent literature on various C-ITS operations, highlighting the significance of Edge-AI in smart transportation infrastructure. The paper investigates solutions from existing literature while highlighting the challenges in this evolving field.

Ⅰ. Introduction

Intelligent Transportation Systems (ITS) offer potential remedies for enhancing commuter safety and optimizing traffic flow. By doing so, they contribute to the reduction of traffic congestion and reliability of public transportation. The advancement of ITS is sustained by both industrial and academic resources, propelling it into a highly researched domain. Notably, recent years have seen significant progress in Artificial Intelligence (AI), wireless sensor technology, advanced wireless applications, etc. This progress is leading to a notable increase in AI-driven Cooperative-Intelligent Transport Systems (C-ITS) applications [1].

C-ITS denote transportation systems in which collaboration among two or more ITS sub-systems such as personal, vehicle, roadside, and central—facilitates and delivers an ITS service of superior quality and an elevated service level. C-ITS applications include safety features like collision avoidance, efficiency tools such as dynamic route planning, and cooperative maneuvers like platooning. Infrastructure-to-vehicle communication enhances hazard warnings, while parking assistance and real-time updates contribute to a connected transportation system [2].

Edge AI involves running artificial intelligence algorithms directly on edge devices like Mobile Edge Computing (MEC) servers, smartphones, and IoT devices, eliminating the need for centralized cloud processing. This approach reduces latency, enhances privacy and security, and allows for offline functionality, making it suitable for real-time applications such as image recognition and predictive maintenance. Edge AI optimizes bandwidth, saves energy, and enables efficient processing at the edge of the network [3]. Edge AI proves invaluable in C-ITS by empowering vehicles to make real-time decisions locally. This reduces latency, ensuring swift responses for critical features like collision avoidance and traffic optimization. Fig. 1 represents the role of Edge-AI terminals in C-ITS environment.

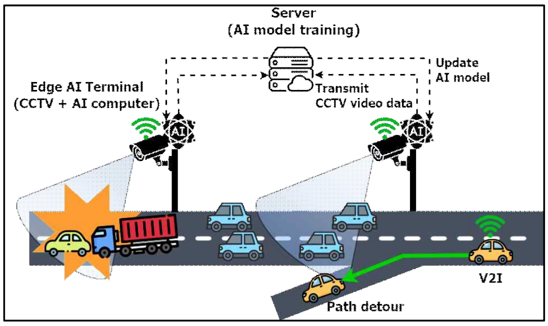

Fig 1. Role of Edge-AI terminals in C-ITS environment

This paper succinctly examines the incorporation of Edge-AI in C-ITS applications, underscoring its empowerment of C-ITS operations. Recent literature on diverse C-ITS operations is reviewed, emphasizing Edge-AI's importance in smart transportation infrastructure. The paper explores existing literature solutions and addresses challenges within this dynamic field.

Ⅱ. Edge-AI For V2V C-ITS Applications

In this section, the importance of Edge-AI infrastructure in supporting smart transportation through C-ITS applications is discussed while reviewing the recent literature in the field.

A. Edge-AI Infrastructure for C-ITS Operations

Smart city transportation systems optimize ITS with advanced C-ITS technologies. AI, particularly Edge-AI, addresses challenges like parking allocation, traffic congestion, proactive traffic prediction, and efficient Vehicle Routing Problems (VRP) in C-ITS.

Edge AI technologies, exemplified by devices like Nvidia's Jetson AGX Orin and Jetson Orin Nano, enable parallel execution of multiple neural networks, transforming transportation solutions. These AI-powered terminals combine high-performance computing with energy-efficie nt design [4]. Subsequent exploration delves into AI-based solutions for C-ITS challenges, emphasizing the transformative impact of cutting-edge technology on urban transportation systems.

In [5], a neural network-based scheme is introduced to enhance intelligent parking guidance systems in urban areas equipped with the Internet of Things (IoT) technology. This approach optimizes the management of public and private parking spaces by utilizing real-time vehicle positions and a centralized parking lot database. By leveraging these data sources, the system improves overall efficiency and user experience in urban scenarios. Moving on to [6], a novel intelligent parking system is proposed, integrating a Convolutional Neural Network (CNN) to determine the most suitable parking area based on vehicle size. The CNN, employed for image processing, accurately extracts vehicle dimensions with an impressive 85% accuracy rate. This contributes to the development of efficient parking solutions that are tailored to individual vehicle sizes, showcasing the potential of advanced technologies, particularly neural networks, in addressing the intricacies of parking management and optimization.

The recognition and prediction of traffic congestion are addressed through the integration of various data sources, with a particular focus on computer vision and image processing methods for congestion detection. In the study presented in [7], researchers leverage Unmanned Aerial Vehicle (UAV) recordings as "Electronic Eyes in the Skies" to effectively detect roadway congestion. Their scheme employs CNN to extract information from images captured by UAVs, achieving an impressive 93.5% accuracy on a dataset comprising 8000 images. Additionally, Bisio et al. [8] offer a comprehensive review of drone-based traffic monitoring systems, providing insights into the advancements and applications of this technology in the context of traffic management and congestion analysis.

Anticipating traffic patterns is crucial for proactive hazard identification and response in infrastructure. Zhao et al.'s [9] widely cited paper demonstrates real-time traffic forecasting through Temporal Graph Convolution Networks (T-GCN) and Graph Convolutional Network(GCN). While Random Forest(RF) and Autoregressive Integrate Moving Average Model(ARIMA), traditional statistical methods, are common for traffic prediction, more advanced models like GCN tend to outperform them [10]. In recent publications over the past five years, Long Short-Term Memory(LSTM) and CNN are frequently employed for traffic prediction.

The VRP is a prominent optimization challenge, extensively studied for its applications in route optimization. Smart Routing Systems (SRS) play a pivotal role in minimizing travel time for emergency vehicles and optimizing routes, ultimately reducing hospitalization durations. Bai et al. [11] contribute to this field by exploring how machine learning can enhance VRP. Their research provides a survey of novel machine learning-based methodologies, shedding light on innovative approaches to address VRP complexities. In a related work [12], Bai et al. introduce a Bat Algorithm-Based Convolutional Neural Network (BA-CNN), combining the powerful Bat Algorithm inspired by bats' echolocation behavior with CNN. The BA-CNN exhibits high efficacy, surpassing the performance of existing methodologies. This innovative integration of nature-inspired optimization algorithms with machine learning frameworks showcases a promising direction for addressing complex optimization challenges, particularly in the domain of vehicle routing and emergency response systems.

Ⅲ. Conclusion and Challenges

Minimizing computation time is a major challenge in optimizing AI-based C-ITS applications. Complex neural network assessment and high-dimensional state space representation in problem-solving often prove time-intensive. In the dynamic traffic landscape, the focus is on reducing response times. Trust among users is vital, tied to safety assurance and user acceptance. Reliability perception impacts demand, contingent on accurate, quality input data. Obtaining such data poses challenges, with scalability being a significant concern, especially in complex city architectures.

These challenges prompt researchers to utilize Edge-AI, creating effective frameworks for successful C-ITS application implementation.

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