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Research on autonomous driving optimization of Intelligent Transportation System (ITS) using Cognitive Internet of Things (CIoT): Survey

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인지사물인터넷(CIoT)을 이용한 지능형 교통 시스템(ITS)의 자율주행 최적화 연구: 서베이

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Abstract This study aims to enhance the efficiency and safety of transportation by developing an intelligent transportation system (ITS) using the Internet of Things (IoT) and artificial intelligence (AI) technologies. The proposed system will enable self-driving and connected vehicles to autonomously collect and analyze information, make decisions, and optimize traffic flow. This will lead to reduced traffic congestion, improved traffic safety, and enhanced user convenience. Additionally, the system will contribute to achieving carbon neutrality and energy efficiency by reducing fuel consumption and emissions. Key contributions of this research include: Development of an optimized cognitive IoT for ITS to enhance road safety and efficiency. Improvement of traffic complexity, resource conservation, and environmental pollution reduction through sustainable urban mobility support. Development of a customized transportation system for self-driving and connected vehicles optimized for ITS-based traffic infrastructure. The proposed research has the potential to revolutionize transportation by making it safer, more efficient, and more sustainable.

Key Words : CIoT, Autonomous, Auto driving, ITS, AI

요 약 본 연구에서는 사물인터넷에 인공지능 기술을 융합하여 사물인 자율주행 자동차와 커넥티드 자동차들이 스스로 정보를 수집하고 분석하여 의사결정을 하도록 돕는 연구이다. 이에 CIoT를 이용한 지능형교통시스템을 연구하여 교통 효율성과 안전성을 향상하고, 교통 상황을 실시간 수집·분석하며, 차량 흐름을 최적화하여 교통사고 예방과 사용자의 편의성을 증대할 수 있다. 제안한 연구결과를 통하여 교통 체증을 완화하고 탄소 중립과 에너지 효율을 높일 수 있는 친환경 연구이다. 본 연구는 지능형교통시스템(ITS)에 최적화된 인지사물인터넷 연구를 통하여 도로 안전을 강화하고, 효율성을 높이는데 기여할 수 있으며, 교통 복잡도를 개선하여, 자원을 절약하고 환경오염을 줄일 수 있는 지속 가능한 도시 모빌리티 지원이 가능하다. 또한, ITS을 적용한 교통 인프라에 최적화된 자율주행 및 커넥티드 차량 맞춤형 교통 시스템 개발에 기여하는 연구이다.

주제어 : 인지사물인터넷, 자동화, 자율주행, 지능형 교통시스템, 인공지능

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1. Introduction

The Internet of Things (IoT) has revolutionized various industries, and the transportation sector is no exception. The integration of artificial intelligence (AI) into IoT, known as the Cognitive Internet of Things (CIoT), has opened up new possibilities for enhancing transportation efficiency and safety. This research proposal aims to develop a CIoT-based intelligent transportation system (ITS) that enables self-driving and connected vehicles to autonomously collect, analyze, and utilize information to optimize traffic flow, prevent accidents, and improve user convenience.

The primary objectives of this research are:

To develop a CIoT framework for ITS, optimizing traffic flow, enhancing road safety, and promoting sustainable urban mobility.

To implement machine learning-based real-time traffic data analysis for dynamic traffic optimization, congestion and accident prediction, and overall system efficiency improvement. To design an ITS optimized for autonomous vehicles, including VANET optimization, city infrastructure integration, communication standardization, and hardware standardization. This research offers significant contributions to the advancement of intelligent transportation systems:

Comprehensive Approach: Unlike existing ITS research that focuses on limited aspects of IoT or AI, this study integrates both technologies for a comprehensive solution.

Intelligent Traffic Management: The proposed system utilizes extensive data collection, AI-powered decision-making, and edge computing to enable real-time traffic management and rapid response to traffic situations. Sustainability and Safety: The research aims to reduce traffic congestion, promote carbon neutrality, and enhance road safety through efficient traffic management and accident prevention. This research proposes a hybrid edge-cloud computing architecture to optimize data processing and decision-making: Edge Computing Layer: Simple data processing tasks will be handled at the edge computing layer, ensuring immediate response to real-time traffic situations. Cloud Computing Layer: Complex data analysis and decision-making processes will be handled at the cloud computing layer, leveraging its powerful computational capabilities.

This research holds immense potential to transform the transportation landscape by introducing a CIoT-based ITS that enhances efficiency, safety, and sustainability. The proposed system, coupled with edge-cloud computing integration, will pave the way for a smarter, safer, and more environmentally friendly transportation future. With these advantages, CIoT-based intelligent transportation systems will greatly improve efficiency, safety, and sustainability, playing an important role in creating a smarter and more environmentally friendly future transportation environment.

2. Research Theory and Related Work

Fig. 1 describe the RNS Montgomery algorithm formula. Fig. 2 shows the flow chart for Fig. 1. The integration of the Cognitive Internet of Things (CIoT) into intelligent transportation systems (ITS) offers several advantages over traditional ITS approaches[1,2]:

2.1. Enhanced Traffic Efficiency, Safety, and User Convenience

- CIoT-based ITS leverages the vast computing power and data collection capabilities of IoT to provide a more comprehensive and accurate understanding of traffic conditions. This enables real-time traffic optimization, dynamic route guidance, and proactive congestion management, leading to improved traffic flow, reduced travel times, and enhanced user satisfaction.

2.2. AI-Powered Decision-Making for Improved Traffic Control

- By harnessing the advanced decision-making capabilities of AI, CIoT-based ITS can analyze vast amounts of data and make complex decisions in real-time. This enables proactive accident prevention, adaptive traffic signal control, and efficient incident management, resulting in a safer and more predictable transportation experience.

2.3. Real-time Response to Traffic Situations with Edge Computing

- Edge computing in CIoT-based ITS enables real-time data processing at the network edge, reducing the need for data transmission to the cloud. This significantly decreases latency and allows for immediate responses to dynamic traffic situations, such as sudden traffic jams or accidents[3-6].

2.4. Hardware Standardization for Accelerated Technology Advancement

- CIoT-based ITS can facilitate the standardization of hardware components for autonomous vehicles, traffic infrastructure, and other ITS elements. This standardization promotes interoperability, reduces development costs, and accelerates the pace of technological innovation [7].

2.5. Superior Performance over Traditional ITS

- The combination of IoT, AI, edge computing, and cloud computing in CIoT-based ITS empowers a new level of performance compared to traditional ITS approaches. This includes:
- More accurate and real-time traffic data
- Intelligent and adaptive traffic management
- Proactive accident prevention and incident response
- Reduced latency and faster response times
- Accelerated technology advancement

2.6. Enhanced Security through RNS Montgomery Algorithm Optimization

- To address security concerns, this research proposes an improved RNS Montgomery algorithm optimization method specifically tailored for ITS applications. This method addresses the computational inefficiency of the original algorithm by pre-computing parameter values, enabling efficient and secure data encryption and decryption[8].

2.7. Development of ITS-Specific Security Optimization Algorithms

- In addition to enhancing the RNS Montgomery algorithm, this research aims to develop novel security optimization algorithms specifically designed for ITS applications. These algorithms will address the unique security challenges posed by CIoT-based ITS, ensuring the confidentiality, integrity, and availability of sensitive data[9-12].

CIoT-based ITS, with its integration of IoT, AI, edge computing, and cloud computing, holds immense potential to revolutionize the transportation landscape. By addressing the limitations of traditional ITS approaches, CIoT-based ITS can deliver enhanced traffic efficiency, safety, user convenience, and environmental benefits, paving the way for a smarter, safer, and more sustainable future of transportation.

$$input : A(a_{s-1}, a_{s-2}, \ldots, a_0), B(b_{s-1}, b_{s-2}, \ldots, b_0), N(n_{s-1}, n_{s-2}, \ldots, n_0),$$
$$R = W^s, R = W^{32}, R \times R^{-1} - N \times N' \equiv 1, N' \equiv N' \bmod W$$
$$output : T = ABW^{-s} \bmod N$$
$$step1 : T \leftarrow 0$$
$$step2 : \text{for } i = 0 \text{ to } s-1$$
$$: m_i \leftarrow (T_0 + a_i b_0) N' \bmod W$$
$$end \text{ for}$$
$$step3 : \text{if } T \geq N \text{ then}$$
$$T \leftarrow T - N$$
$$else$$
$$T \leftarrow T$$
$$return\ T$$

Fig. 1. RNS Montgomery Algorithm

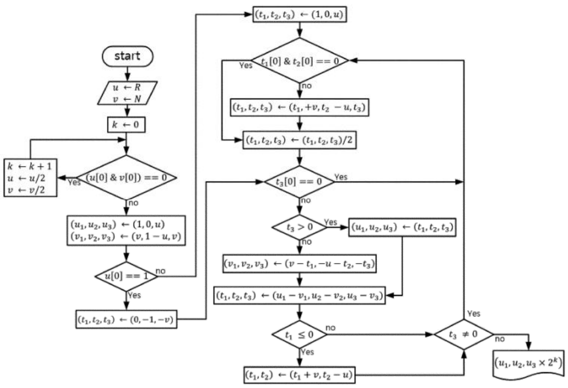

Fig. 2. RNS Montgomery Algorithm Flow Chart

3. Methodology

To complete this research, there are two following research areas.

3.1. CIoT Framework for Intelligent Transportation Systems (ITS)

The CIoT framework for ITS encompasses several key research areas that address various aspects of intelligent transportation systems:

3.1.1. Traffic Management Optimization

- Real-time Data Analysis and Machine Learning: Utilize real-time traffic data and machine learning algorithms to predict traffic patterns, identify congestion hotspots, and optimize traffic signal timing.
- Dynamic Route Guidance: Provide personalized route guidance based on real-time traffic conditions, enabling drivers to avoid congestion and minimize travel times.
- Proactive Congestion Management: Implement proactive congestion management strategies to prevent and mitigate congestion before it occurs, reducing traffic delays and improving overall network efficiency.

Table 1 shows the comparison for related algorithms.

Table 1. Related Algorithm Comparison

Type	Key Points
RNS Montgomery Algorithm Optimization	• Definition: Optimization of Montgomery multiplication in Residue Number System (RNS) for efficient modular arithmetic. • Techniques: Parallel processing, use of reducers, dynamic modular selection.
Enhanced Traffic Efficiency, Safety, and User Convenience	• Definition: Improvements in traffic management systems to ensure smoother traffic flow, increased safety, and user satisfaction. • Methods: Intelligent traffic signal control, real-time traffic monitoring, predictive analytics.
CIoT Framework for Intelligent Transportation Systems	• Definition: Connected Internet of Things (CIoT) framework designed for intelligent transportation systems (ITS). • Components: IoT sensors, V2X communication, cloud computing, edge computing.
Real-time Traffic Data Analysis using Machine Learning	• Definition: Application of machine learning algorithms to analyze and predict traffic patterns in real-time. • Techniques: Supervised learning, unsupervised learning, reinforcement learning, neural networks.

3.1.2. VANET (Vehicle-to-Everything) Communication

- V2X Communication Protocols: Develop and standardize V2X communication protocols that enable seamless communication between vehicles, roadside infrastructure, and other connected devices.
- VANET Infrastructure Deployment: Design and implement a scalable and reliable VANET infrastructure to support the growing demand for data exchange and cooperative decision-making among connected vehicles.

3.1.3. Sustainable and Eco-friendly ITS

- Electric Vehicle Integration: Integrate electric vehicles and charging infrastructure into the CIoT framework, enabling efficient energy management and promoting sustainable transportation practices.
- Renewable Energy Integration: Utilize renewable energy sources to power roadside infrastructure and reduce the environmental impact of ITS operations.
- Eco-friendly Traffic Management: Implement eco-friendly traffic management strategies that minimize emissions and promote sustainable transportation options.

3.1.4. Terminal-level Simulation Research

- Autonomous and Connected Vehicle Simulation: Develop realistic simulations of autonomous and connected vehicle behavior to evaluate the effectiveness of CIoT-based ITS solutions in various traffic scenarios.
- Traffic Infrastructure Simulation: Create simulations of various traffic infrastructure components, such as roads, intersections, and traffic signals, to assess the impact of CIoT-based ITS on traffic flow and safety.

3.1.5. Layered Architecture Research

- IoT Layer: Design and implement an IoT layer that enables real-time monitoring and control of various ITS components, including sensors, actuators, and communication devices.
- Data Layer: Develop a data layer that efficiently manages and processes the vast amounts of data generated by the IoT layer, ensuring data integrity and availability for decision-making algorithms.
- Cognitive Computing Layer: Implement cognitive computing algorithms in the cognitive computing layer to analyze and extract meaningful insights from the data layer, enabling intelligent decision-making and optimization of ITS operations.
- Cloud Computing Layer: Leverage cloud computing resources in the cloud computing layer to handle large-scale data storage, processing, and analysis, providing a scalable and cost-effective solution for managing the ever-growing data volume generated by the CIoT framework.
- Service Layer: Design and develop a service layer that provides a suite of ITS-enabled services, such as traffic information, navigation, and autonomous driving support, to end-users through various applications.

By addressing these research areas, the CIoT framework for ITS has the potential to revolutionize transportation systems, leading to improved efficiency, safety, sustainability, and user experience.

3.2. Real-time Traffic Data Analysis using Machine Learning

The rapid growth of traffic data, coupled with the advancements in machine learning

(ML), presents a unique opportunity to revolutionize traffic management and improve transportation efficiency. Real-time traffic data analysis using machine learning can provide valuable insights into traffic patterns, congestion trends, and accident risks, enabling proactive measures to optimize traffic flow, enhance safety, and reduce environmental impact.

3.2.1. Objectives of Machine Learning-based Traffic Data Analysis

- The primary objectives of machine learning-based traffic data analysis include:
- Traffic Pattern Prediction: Utilize ML algorithms to analyze historical and real-time traffic data to identify patterns, predict traffic flow, and anticipate congestion hotspots.
- Congestion Detection and Prevention: Develop ML models to detect emerging congestion and implement proactive measures to prevent or mitigate traffic jams, reducing travel times and improving overall network efficiency.
- Accident Risk Prediction: Employ ML techniques to analyze traffic data, identify potential accident-prone areas, and implement preventive measures to reduce accident rates and enhance road safety.

3.2.2. Applications of Machine Learning in Traffic Data Analysis

- Machine learning can be applied in various aspects of traffic data analysis:
- Traffic Signal Control Optimization: Optimize traffic signal timing based on real-time traffic conditions, reducing delays and improving traffic flow at intersections.
- Dynamic Route Guidance: Provide personalized route guidance to drivers, considering real-time traffic conditions and predicted congestion patterns, enabling them to choose the most efficient routes.
- Incident Management: Identify and respond to traffic incidents promptly, minimizing disruptions and restoring normal traffic flow as quickly as possible.
- Traffic Demand Forecasting: Forecast future traffic demand to inform transportation planning and infrastructure development decisions.

3.2.3. Challenges and Considerations

- Machine learning-based traffic data analysis faces several challenges:
- Data Quality and Variability: Ensure the quality and consistency of traffic data sources, addressing data gaps and outliers to train and validate ML models effectively.
- Real-time Processing Requirements: Develop efficient ML algorithms that can process and analyze large volumes of real-time traffic data with minimal latency to provide timely insights for decision-making.
- Model Interpretability and Explainability: Build transparent and interpretable ML models to understand the reasoning behind predictions and ensure trust in the decision-making process.

4. Conclusion

This research proposal outlines the development of a CIoT-based intelligent transportation system (ITS) that leverages machine learning and real-time traffic data analysis to optimize traffic flow, enhance safety, and promote sustainability. The proposed CIoT framework integrates various components including VANET communication, edge computing, and cloud computing to enable real-time decision-making and proactive traffic management. Thanks to these advantages, CIoT-based intelligent transportation systems will significantly improve efficiency, safety, and sustainability, and will play an important role in creating a smarter and more environmentally friendly future transportation environment.

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