거대언어모델 기반 LIME 분석을 통한 설명가능한 전기자동차 에너지 사용량 예측 기법

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Explainable Electric Vehicle Energy Consumption Prediction Scheme Using Large Language Model-Based LIME Analysis

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Key Words : Large language model(거대언어모델), Electric vehicle(전기자동차), Local interpretable model-agnostic explanations(LIME 분석), Explainable artificial intelligence(설명가능한 인공지능), Energy consumption prediction(에너지 사용량 예측)

ABSTRACT

As electric vehicles (EVs) become increasingly widespread, accurately predicting their energy consumption during charging is critical for improving charging infrastructure efficiency and supporting effective energy management. However, machine learning (ML) models for energy consumption often function as black boxes due to complex interactions among diverse variables, making their predictions difficult to interpret and trust. This study proposes an integrated framework that combines an ML model, explainable artificial intelligence, and large language model (LLM) to address this challenge. Using real-world charging data collected from EV charging stations, we built a predictive model and applied local interpretable model-agnostic explanations (LIME) to analyze the contribution of each variable. Furthermore, we leveraged an LLM to transform the LIME results into human-friendly natural language explanations. The proposed approach enhances the interpretability and usability of the prediction results, supporting EV charging station operators and policy makers in understanding and applying the model outputs more intuitively. This framework is expected to contribute to optimizing EV charging strategies while ensuring transparency and trust in future energy management systems.

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직병렬형 신구조 하이브리드 시스템의 MATLAB/Simulink 기반 시뮬레이션 모델 개발 및 분석

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Development and Analysis of MATLAB/Simulink-Based Simulation Model for a Novel Series-Parallel Hybrid System

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Key Words : Electric Vehicle(전기자동차), Hybrid electric vehicle(하이브리드 전기자동차), Series-Parallel Hybrid System(직병렬형 하이브리드), Forward simulation(전방향 시뮬레이션), MATLAB/Simulink

ABSTRACT

As the adoption of battery electric vehicles (EVs) and fuel cell electric vehicles (FCEVs) has not progressed as rapidly as anticipated, hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) are emerging as key alternatives in the global automotive industry. This shift is driven by high battery costs, delays in charging infrastructure expansion, and uncertainties in raw material supply chains, prompting automakers to revise their strategies away from pure electrification and to regard hybrid systems as a pragmatic solution for reducing carbon emissions.

In this study, we propose a novel power-split hybrid system architecture consisting of an internal combustion engine, two electric motors, and a dog-clutch-based two-speed transmission. The proposed system is capable of operating in multiple modes—EV, Series, Parallel (1st/2nd gear), and regenerative braking—while targeting performance equal to or exceeding that of representative hybrid systems such as TMED and i-MMD, thereby ensuring competitiveness in future markets. However, the ability to realize diverse operating modes introduces high complexity in mode selection, power distribution between the engine and motors, and transmission control.

To verify the feasibility of this architecture and address its design complexity, a forward-facing simulation model was developed in MATLAB/Simulink. The model enables analysis of key performance indicators, including vehicle dynamics, fuel economy, energy efficiency, and battery state of charge (SOC) behavior. It also provides a robust evaluation framework for mode-specific performance assessment and control strategy development under various driving scenarios. Furthermore, the simulation model facilitates systematic examination of mode advantages and disadvantages, supports the derivation of mode transition conditions, and assists in formulating energy management strategies through pre-structural analysis.

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고압수소에너지를 이용한 차량용 에너지회수 시스템 개발

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Development of Energy Recovery System for Vehicles Using High-Preussre Hydrogen Energy

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Key Words : High-Pressure hydrogen energy, Vehicles, Recovery system, CFD analysis

ABSTRACT

수소 전기차는 크게 배터리, 수소압력용기, 모터 등으로 구성되며, 이 중 수소압력용기는 700 bar의 고압으로 충전되어 수소연료전지에 수소를 공급하는 역할을 한다. 700 bar로 압축된 수소는 고압 레귤레이터를 통해 중간압력단계 (10 ~ 20 bar)로 1차 감압되며, 저압 레귤레이터를 통해 최종적으로 1.5 ~ 3 bar로 감압되어 연료전지에 공급된다. 차량용 수소압력용기에 700 bar의 수소를 충전하기 위해서는 피스톤이나 다이아프램 방식 수소압축기에 의해 900 bar로 압축된 고압 수소가 필요하다. 900 bar로 저장된 수소는 수소충전소 디스펜서를 통해 차압방식으로 차량용 수소압력용기에 700 bar로 충전된다. 이 때, SAE J2601충전 프로토콜에 따라 차량 수소압력용기 내부 온도는 85℃ 를 넘지 않아야 되며, 따라서 충전 중 상승하는 온도를 감안하여 -40℃ 이하로 수소를 냉각한 후 충전을 진행해야 한다. 수소를 튜브트레일러 (200 bar)에서 900 bar로 압축한 뒤 차량의 수소고압용기 (700 bar)에 저장하기 위해서 약 100KW의 에너지가 필요하다. 대부분은 수소의 압축, 냉각 과정에서 소모되는 에너지이며, 전기차 완충기준으로 약 400 km ~ 600 km를 주행할 수 있는 에너지이다. 700 bar로 저장된 고압수소는 연료전지에 공급되는 과정에서 레귤레이터를 통해 1.5 ~ 3 bar로 감압되며, 감압과정에서 발생하는 잠재적인 에너지 (△P)의 대부분은 열, 진동, 충격 등에 의해 손실된다. 수소 충전에 필요한 에너지 (100 kW) 중 20%만 확보하여도 80 ~ 120 km의 추가 주행거리를 확보할 수 있으므로, 수소전기차의 연비 향상에 크게 기여할 수 있을 것으로 기대된다. 본 연구에서는 고압 수소에너지 회수를 위한 차량용 에너지 회수 시스템 개발 방안에 대하여 검토하였다. 시스템 구성에 따른 에너지 회수량을 계산할 수 있는 설계 프로그램 개발안과 에너지 회수 모사장치 제작 및 시험데이터 도출, CFD 해석을 통한 개발된 프로그램의 타당성 검증 방법을 제시하였다. 개발된 프로그램을 통해 시스템 구성, 제어 로직 설계 및 에너지 회수량을 계산할 수 있으며, 도출된 설계안을 토대로 Full model 에너지 회수 장치의 제작 및 성능검증을 수행할 예정이다. 최종적으로 실험을 통해 얻어진 성능검증 데이터를 기반으로 차량용 에너지 회수 시스템의 최적설계안을 도출할 수 있을 것으로 기대된다.

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Euro-7을 고려한 전기차 · 내연기관차의 비배기 미세먼지 경향성 분석

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Analysis of Non-Exhaust Particulate Matter Trends in EV and Engine Vehicles considering Euro-7

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Key Words : Non-Exhaust Particulate Matter(NEPM, 비배기 미세먼지), KADAS(자율주행검사시스템), AEB(자동 긴급제동), Brake Wear(브레이크 마모), PM(미세먼지)

ABSTRACT

With the introduction of Euro-7 emission regulations, the significance of Non-Exhaust Particulate Matter(NEPM) from vehicles has greatly increased. Despite its substantial contribution to overall vehicle particulate emissions, standardized test methodologies and inspection regulations for NEPM remain underdeveloped.

This study proposes an innovative test environment to address this regulatory gap and minimize uncontrollable variables inherent in real-world driving. We establish a Vehicle-in-the-Loop Simulation(VILS) system integrated with KADAS(Korea Automated Driving Vehicle Assessment System), enabling dynamic driving and braking scenarios, such as Autonomous Emergency Braking(AEB), to be freely executed on a dynamometer. Preliminary observations during harsh braking events, like AEB activation, distinctly showed visible tire particulate generation, highlighting the urgent need for NEPM analysis.

The research aims to systematically analyze NEPM emission trends under various conditions: Normal driving, severe braking(AEB), and regenerative braking for EV. A low-cost, optical particulate matter measurement system, developed using an Arduino UNO and PMS7003 sensor, will be employed to capture these trends. The controlled VILS environment effectively isolates NEPM generation mechanisms without real-road disturbances. This study is expected to provide fundamental data for developing future Eure-7 compliant NEPM inspection methodologies, offering significant academic and practical implications for evaluating the environmental performance of both electric and internal combustion engine vehicles.

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친환경차 주행경고음 발생장치의 측정 간소화를 위한 ROS 기반 분산시스템

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ROS-Based Distributed Architecture for Simplifying the Acoustic Vehicle Alerting System Measurement Procedure in Eco-Friendly Vehicles

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Key Words : Acoustic Vehicle Alerting System(주행경고음발생장치), Robot Operating System(로봇운영체제), Distributed System(분산 시스템), Actuator(엑츄에이터), Microphone(마이크로폰)

ABSTRACT

This study proposes a ROS-based distributed system to enhance the field applicability of the Acoustic Vehicle Alerting System (AVAS) for eco-friendly vehicles by simplifying conventional microphone placement and distance measurement procedures. Traditional measurement methods rely heavily on manual operations, such as measuring distances between the vehicle and microphones and determining front and bottom positions of vehicle. These approaches result in low reproducibility and significant time consumption, particularly when testing multiple vehicles. To address this issue, a distributed system was designed to standardize microphone placement and distance input based on user-provided front and bottom position data, thereby reducing variability across different test vehicles. The proposed method enables operators to confirm vehicle-to-microphone distances, input positional information into a laptop, and automatically place microphones at the desired locations through a connected placement module.

The distributed system employs topic-based node communication between a laptop (ROS Master) and a Raspberry Pi (SBC) to control actuators and encoder sensors, ensuring accurate microphone positioning according to target location inputs. Through field validation, the proposed ROS-based system and supporting measurement module demonstrated the feasibility of simplifying test procedures. Furthermore, it reduced repetitive workload and contributed to establishing a more efficient measurement process pipeline. This research suggests that the proposed approach can significantly streamline test operations, enhance reproducibility, and support broader adoption of AVAS in real-world automotive testing environments.

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