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충돌안전 & 승객보호

모듈러 아키텍쳐 기반의 전동화 모듈 충돌 평가 방법 개발

이혁재* · 박재우* · 송주현* · 정상섭*

Development of Collision/Safety Evaluation Methodology for System Level of Electrified Module Based on Modular Architecture

Hyuck Jae Lee*, Jae Woo Park*, Ju Hyun Song*, Sang Seop Jeong*

Key Words : Full cell electric vehicle(수소연료전지차), Protocol(프로토콜), Modular architecture(모듈러 아키텍쳐)

ABSTRACT

Today, collision/safety assessment standards of commercial electrified vehicle is not setup. Automotive makers have developing design methods using modular architecture method to solve design complexity.

Throughout this study, commercial FCEV vehicle collision/safety assessment process is established and hope to has been demonstrated to be useful to develop a more optimized design in consideration of Fire/High-voltage safety. We get the information where is the most sensitive evaluation criteria in using the process to raise the safety. Existing crash safety development methodology has limitations and may have changed to a difficult environment where the safety of the vehicle is to be guaranteed by the manufacturer in an unformatted crash condition. It takes a lot of time and effort to test vehicle with full system again and again. A second-best solution is to make use of component system level testing. This solution is collision/safety assessment test methodology for module unit based on modular architecture.

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Far-side 충돌 시 안전벨트 설계 변수의 승객 상해 민감도 분석

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Sensitivity Analysis of Seatbelt Design Parameters Affecting Occupant Injury in Far-side Impacts

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Key Words : Far-side impact(Far-side 충돌), Three-point seatbelt(3점식 안전벨트), Occupant safety(승객 안전), Human body model(인체모델), Injury risk(상해 위험도)

ABSTRACT

Far-side impacts have only recently been addressed by safety regulations and assessment protocols, such as those of NHTSA and the Korean NCAP, in contrast to other well-established impact conditions (e.g., frontal or side impacts). Despite this late inclusion, far-side impacts account for a significant proportion of severe and fatal injuries. Real-world crash investigations consistently highlight the vulnerability of occupants—particularly the head and thorax regions—under far-side impacts. In response, Euro NCAP introduced a dedicated far-side impact assessment protocol in 2020 to better evaluate occupant protection.

This study investigates the influence of three-point seatbelt design parameters on occupant kinematics during far-side impacts. Using the Euro NCAP far-side sled model with the GHBMC M50-OS human body model, we validated simulation results against Post-Mortem Human Subject (PMHS) data under identical conditions. The analysis varied the Z-axis positions of the D-ring and buckle, and the X-axis positions of the buckle and lap belt anchor, producing 81 simulation cases. Injury risks were quantified across these cases, and sensitivity analyses identified which parameters most significantly affected occupant injury outcomes. These findings allow for effective restraint system optimization to reduce injury risk in far-side impacts.

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정면 충돌 시 차량의 연식에 따른 승용차량 탑승자 손상 중증도 비교

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Comparison of Injury Severity of Passenger car Occupants According to Car years in Frontal collisions

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Key Words : Car years(차량연식), Frontal collision(정면충돌), Passenger car(승용차), Injury Serverity(손상중증도)

ABSTRACT

The purpose of this study was to investigate the association between car years and injury severity among passenger car occupants in frontal collision. It also examined whether older vehicles are associated with an increased risk of severe injuries.

Passenger car were categorized into two groups according to model year: vehicres manufactured in 2010 or earlier and those manufactured in 2011 or later. In frontal collisions, occupants were further classified based on seat belt use (Yes, No, Unknown). Injury severity was evaluated using the Injury Severity Score(ISS) and the Maximum Abbreviated Injury Scale(MAIS). Independent samples t-tests were conducted to examin whether there were significant differences in injury severity betwwn the grops, in order to clarify the association between car years, seat belt use, and injury outcomes

The analysis revealed that occupants in vehicles manufactured before 2010 sustained significantly higher injury severity compared with those in vehicles manufatured after 2011. This difference was most pronounced in frontal collisions without seat belt use, where both ISS and MAIS were markedly elevated. Among belted occupants, the protective effect of seat belts was ovserved regardless of car years, although older car still sdhowed slightly higher injury severity.

In addition, CDC codes reflecting greater deformation extent and intrusion were strongly associated with higher ISS and MAIS. These findings suggest that both car years and crash characteristics in fluence injury severity, and that the combination of seat belt non-use and older vehicle models substantially increases the risk of severe trauma

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실사고 기반 충돌 안전성 평가를 위한 시뮬레이션 기법 개발

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Development of Simulation Techniques for Real Field Accident-Based Crash Safety Evaluation

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Key Words : Integrated safety(통합안전), Madymo(마디모), Ls-dyna(엘에스다이나), Equivalent crash model(등가충돌모형), Crash event scenario(충돌사고 시나리오), Car-to-Car crash(차대차 충돌), Virtual vehicle development (버추얼차량개발), Roll over(전복사고), Human body dummy(인체모형더미).

ABSTRACT

This paper introduces a collision simulation methodology that describes a real-filed complex collision scenario and introduces the results of research on injury patterns in complex collisions using full size human body dummy for crash simulation.

실사고 시나리오 기반의 복합충돌 사고 시뮬레이션은 기존의 정형화된 NCAP 이나 법규 시험모드와는 다르게 시나리오 자체가 매우 길다. 예를 들면 고속 정면 고정벽 충돌 시험의 경우 시뮬레이션 시간이 짧게는 100ms 길게는 300ms 정도면 모든 이벤트가 끝이 나지만 정면 폴 충돌 등의 1차 충돌에 이은 2차 전복 까지의 시나리오라면 짧게는 2,000ms에서 길게는 4,000ms까지 진행되므로 슈퍼 컴퓨터 연산 시간이 그만큼 기하급수적으로 늘어날 수 밖에 없다. 때문에 충돌 해석 시뮬레이션을 계획할 때 좀 더 효율적인 방법론이 필요하다. 더불어 정면충돌, 측면 충돌 하는 식으로 충돌의 방향이 정해져 있다면 정면용 더미, 측면용 더미를 그때 그때 맞춰서 사용하면 되지만 충돌 방향이 정해져 있지 않은 실사고 충돌 시나리오에 더해 전복 현상까지 진행이 된다면 사용해야 되는 더미 선택에 대한 이슈도 있다. 본 논문에서는 이러한 문제점 해결을 위해 실사고 복합 충돌 시나리오에 걸맞는 효율적인 충돌 시뮬레이션 방법론 소개와 함께 일반적인 충돌용 더미가 아닌 인체를 그대로 묘사한 휴먼 바디 인체더미를 사용하여 복합충돌시 발생하는 상해 패턴에 대한 연구 결과 소개 및 이러한 기법을 실제 차량 개발에 어떠한 방식으로 적용하여 차량의 안전성을 높이고 있는지 간략히 소개해 보고자 한다.

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수납형 스티어링휠 조건 안전장치 시나리오 연구

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A Study on Safety Device Scenarios for Retractable Steering Wheel Conditions

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Key Words : Retractable steering wheel(수납형 스티어링휠), Autonomous driving(자율주행), Driver airbag(운전석 에어백)

ABSTRACT

With the commercialization of Level 4 and higher autonomous driving systems, steering wheels may be retractable during driving to enhance occupant comfort. However, when the steering wheel is stowed, the distance between the driver and the wheel increases by approximately 200 mm, potentially compromising occupant protection performance in the event of a collision.

This study investigates safety device solutions applicable to scenarios where the steering wheel is retracted and aims to identify the optimal alternative. Three feasible scenarios were first derived, followed by the design and evaluation of a novel airbag system tailored to each. Based on these evaluations, a new concept for a driver airbag mounted on the dashboard was proposed. Deployment tests confirmed that this airbag provides a protection area equivalent to that of conventional driver airbags within the same deployment time.

Furthermore, in the stowed steering wheel condition, the proposed airbag can be deployed simultaneously with the conventional driver airbag, effectively filling the additional space between the occupant and the airbag. This suggests that the proposed system can maintain equivalent protection performance even in future autonomous vehicle layouts.

Through this research, a foundational direction for designing safety devices in future vehicle interiors with retractable steering wheels is presented. Further studies will evaluate the applicability of the proposed system across various crash modes.

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Efficient Prediction of Passenger Chest Injury Distributions Using Surrogate Modeling Under Uncertainty Variables

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Key Words : Finite element analysis(유한요소해석), Surrogate model(서로게이트 모델), Gaussian proess(가우시안 프로세스), GHBMC(Global Human Body Model Consortium), Uncertainty Quantification(불확실성 정량화)

ABSTRACT

Real world crashes involve a range of uncertain factors such as occupant posture and restraint-system configuration. With emerging technologies such as autonomous driving enable more flexible passenger postures, addressing the increased variability and uncertainty in posture and restraint conditions becomes critical. For injury assessment in real-world crashes, we need to use a human body model (HBM) due to its higher biofidelity than anthropomorphic test devices. HBM based crash simulations are yet highly computationally expensive, which makes extensive parametric exploration and continuous injury quantification across crash scenarios difficult. To address this, we employ surrogate modeling to quantify occupant injury across diverse crash conditions. First, we build a frontal sled model using the GHBMC M50-OS model. We then generate 25 parametric models by varying two design variables: occupant posture and D-ring Z position at five levels each, and simulate them to obtain chest deflection as the output. Using these cases and their corresponding outputs, we train a Gaussian Process surrogate model to predict chest deflection and use an adaptive sampling scheme to improve accuracy. The proposed method performs continuous injury prediction across diverse crash scenarios using only a finite set of simulation runs. Consequently, we quantitatively characterize continuous injury responses over a diverse set of cases.

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근접 측면 충돌 조건에서 여성 인체모형의 생체모방성을 고령자 기증자와 비교 평가

강윤석* · Amanda M. Agnew* · John H. Bolte, IV*

Assessing the Biofidelity of 5th Percentile Female ATDs Against Elderly PMHS in Near-Side Impacts

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Key Words : Elderly PMHS(고령기증자), Thoracic injury(흉부상해), Near-side impact(근측면), ATDs(인체모형더미).

ABSTRACT

Small, elderly females have been identified as a highly vulnerable demographic in motor vehicle crashes and are particularly susceptible to severe thoracic injuries in near-side impacts. For decades, the biomechanical data used to develop safety standards has often been derived from unrealistic test conditions that fail to capture real-world crashes, or from data scaled down from mid-size males using an approach that overlooks key sex differences. This study evaluates whether current 5th percentile female side impact ATDs can accurately replicate Post Mortem Human Subject (PMHS) responses and predict injury in a realistic near-side impact scenario. The biomechanical responses of five small, elderly female PMHS were compared to those of the SID-IIs and WorldSID-05F in a realistic 50 kph near-side impact test. The experimental setup recreated the occupant environment, including a mass-production vehicle seat, a side-impact airbag, a standard three-point restraint with a pretensioner, and simulated door intrusion. Both PMHS and ATD were extensively instrumented with chestbands to quantify chest deflection. Spinal kinematics were recorded and ranked using the Biofidelity Ranking System (BioRank) to assess biofidelity of the ATDs during the event. The ATDs demonstrated biofidelic spinal kinematics (BioRank < 2.0). However, significant differences were found in thoracic response. While anterior-posterior chest deflection was similar, the ATDs failed to match the lateral chest deflection of the PMHS (e.g., PMHS:24.4±10.6mm vs. SID-IIs:56.3mm and WorldSID-05F:5.2mm), leading to an inaccurate prediction of thoracic injury risk by the ATDs. The discrepancy in thoracic response suggests that current injury metrics for side-impact ATDs are insufficient for realistic near-side impact scenarios involving combined loading from modern restraint systems. Updated Injury Assessment Reference Values (IARVs) are necessary to accurately predict injury risk for small female occupants.

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Designing Trust: SDV 시대의 법, 인증 그리고 신뢰

화물자동차 규모별 세부 분류기준 적용에 관한 연구

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A Study on the Application of Detailed Classification Criteria Based on Cargo Truck Size

Hyuk Jung*, Sangryul Lee**, Byoungmoo Kim***, Jaehun Kim****

Key Words : Cargo Truck(화물자동차), Limit of Dimension(크기), Classification of Vehicle(차량분류), Safety Standard (안전기준), Regulation on the Performance and Standards of Motor Vehicles and Motor Vehicle Parts (자동차 및 자동차부품의 성능과 기준에 관한 규칙)

ABSTRACT

Article 4 of the current Regulation on the Performance and Standards of Motor Vehicles and Motor Vehicle Parts restricts the length, width, and height of vehicles according to road facility standards defined by the Road Act. In addition, Annex 1 of the Enforcement Rule of the Motor Vehicle Management Act further classifies vehicle types by category and size, setting detailed criteria. Under these rules, vehicles are categorized into mini, small, medium, and large according to their size. However, unlike passenger cars or vans, cargo trucks—excluding mini trucks—are classified only by maximum payload and gross vehicle weight (GVW), without size-based standards for length, width, or height.

Therefore, even small cargo trucks can be legally manufactured up to 13 m in length and 4 m in height if they meet the general standards outlined in Article 4. There is no regulatory basis to restrict such production. As a result, manufacturers may produce similar vehicle types in response to market demand without sufficient validation of driving stability, which can lead to serious safety concerns.

For example, small cargo trucks with excessively tall cargo beds relative to their body structure are vulnerable to crosswinds at high speeds, reducing driving stability. These designs also facilitate overloading, shifting the center of gravity upward and increasing the risk of rollover accidents. Additionally, when such vehicles operate in narrow urban areas or alleys, they may obstruct the visibility of pedestrians and other drivers, increasing the risk of accidents and related social costs.

This study presents actual examples of these issues and examines classification and dimensional standards in major countries, including those in Europe. Based on Korea’s cargo truck operation practices, it proposes applying detailed length and height standards by size, in addition to current payload and GVW criteria.

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가변축 시스템 성능평가 및 현가장치 구조에 따른 특성 연구

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Evaluation of lift Axle Systems and Characteristics According to Suspension Structure

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Key Words : Left axle(가변축), Lift axle test(가변축시험), Suspension(현가장치), Korean Motor Vehicle safety Standards(자동차 안전기준)

ABSTRACT

This study was conducted to evaluate the performance of left axle systems applicable to commercial and special-purpose vehicles and to verify their compliance with Article 13 (7) and (8) of the Korean Motor Vehicle safety Standards(KMVSS). Tests were performed on general cargo vehicles to assess major performance parameters such as load distribution ratio and automatic lowering function through lift axle operation and manual control tests. In particular, this study compared the sensing characteristics of left axle systems according to the structural differences of fixed-axle suspensions. For spring-type suspensions, a deformation-based mechanical load-sensing method using angle sensors was applied to directly measure changes in axle load. For air suspension systems, an electronic sensing method was employed to detect airbag pressure variations. Both sensing methods reliably detected load variations for axle control. however, the air suspension type demonstrated superior responsiveness and higher precision in controlling small load fluctuations, as each airbag could independently sense pressure changes. The results indicate that the tested left axle systems maintain stable load distribution and control performance regardless of suspension structure. Moreover, the application of air-suspension-based sensing systems is expected to enhance the accuracy of load control and improve road load management efficiency for heavy commercial vehicles in future implementations.

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서비스디자인 기반 대량맞춤형 프레임워크를 활용한 픽업트럭 사용자 경험(UX) 향상에 대한 연구

박성흠*

A Study on the Improvement of Pickup Truck User Experience (UX) Using a Mass Customized Framework Based on Service Design

Sung Hum Park*

Key Words : Pickup Truck(픽업트럭), User Exprience(사용자 경험), Service Design(서비스 디자인), Mass Custumazation (대량 맞춤), Modulization(모듈화)

ABSTRACT

Recently, the Korean pickup truck market has become increasingly diversified. The strength of pickup trucks lies in their versatility—they can be adapted to various purposes and usage styles depending on user needs. In this context, user experience (UX) plays a critical role. This study proposes a service design–centered mass customization framework aimed at improving the UX of pickup truck users from the perspective of a special-purpose vehicle manufacturer.The research adopted the Double Diamond model, which is widely applied in service design. In the Discover stage, different types of pickup truck users were categorized according to their usage characteristics and the specialized features they required. In the Define stage, the core needs of each user cluster were identified and clearly articulated. During the Develop stage, the pickup truck's specialized features were structured into modular components, divided into internal and external factors. These modules were developed to reflect the essential needs of each user cluster. In the Deliver stage, real users participated in experience-based evaluations of the developed modules. Through this framework, special-purpose vehicle manufacturers gained advantages in production and inventory efficiency, as they could flexibly respond to new user demands by recombining existing modules. User feedback indicated that the proposed modular features offered consistent quality, ease of use, and expandability to other modules. However, they also revealed limitations in meeting highly individualized aesthetic preferences and diverse functional requirements. Future research should explore platform-based modular design strategies that expand the performance and functional aspects of modular products, while simultaneously enhancing personalization. This approach is expected to further improve both manufacturer efficiency and user satisfaction, creating a more adaptive and user-responsive pickup truck ecosystem in Korea.

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삼륜형·사륜형 이륜자동차 안전기준 개선에 관한 연구

김도완* · 이재광** · 최동석*** · 이현우****

A Study on Improving Safety Regulations for Three- and Four-Wheeled Motorcycles

Dowan Kim*, Jae-Gwang Lee**, Dongseok Choi***, Hyune Woo Lee****

Key Words : Motor vehicle management act(자동차관리법), Three-wheeled motorcycles(삼륜형 이륜자동차), Four-wheeled motorcycles(사륜형 이륜자동차), Vehicle regulations(자동차 제작기준)

ABSTRACT

Under the Motor Vehicle Management Act, motor vehicles are classified into passenger cars, buses, trucks, special-purpose vehicles, and motorcycles. These motorcycles are further divided into two-wheeled, three-wheeled, and four-wheeled types according to the number of wheels. Consequently, issues have been raised regarding the boundary between four-wheeled motorcycles and ultra-compact vehicles, as well as fairness concerns between three-wheeled and four-wheeled motorcycles. In particular, with the approval of a cargo compartment for four-wheeled motorcycles, deficiencies have emerged in the classification of steering systems and other regulations for vehicles in the light or sub-compact categories. This study reviews regulations such as steering systems, seat arrangements, windshields, and passenger compartments of these motorcycles, with the aim of minimizing confusion in the industry and proposing rational improvements to manufacturing regulations.

자동차관리법에서 규정하는 자동차의 차종은 승용, 승합, 화물, 특수, 이륜 자동차로 구분된다. 이 중 이륜자동차는 다시 바퀴의 개수에 따라 이륜형, 삼륜형, 사륜형으로 분류할 수 있다. 따라서 사륜형 이륜자동차와 초소형자동차와의 경계, 삼륜형 이륜자동차와 사륜형 이륜자동차와의 형평성 문제 등이 제기되고 있다. 특히 사륜형 이륜자동차의 물품적재장치가 허용됨에 따라 조향장치 등 경형 이하의 자동차 구분에 미비점이 발생되고 있다. 본 연구에서는 이륜자동차의 조향방식, 좌석배치, 방풍장치, 차실 등의 기준을 검토하여 산업계의 혼란을 최소화하고 합리적인 제작기준 개선안을 제시하고자 한다.

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첨단특장차 전문인력양성 교육사업의 효과분석

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Effectiveness Analysis of the Advanced Special-Purpose Vehicle Workforce Training Program

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Key Words : Educational effectiveness(교육효과분석), Cost-benefit analysis(비용편익분석), Workforce development (전문인력양성), Special-purpose vehicle(특장차), Electric vehicle(전기차), Artificial intelligence(인공지능), Regional economic impact(지역경제효과)

ABSTRACT

This study aims to empirically analyze the economic feasibility and educational effectiveness of the Advanced Special-Purpose Vehicle Workforce Training Program implemented in 2025, in order to verify the necessity of vocational education during the ongoing industrial transition. The program, initiated and supported by the government, was designed to respond to the eco-friendly and digital transformation of the mobility industry by promoting the professionalization of the vehicle certification system, strengthening the safety competence for high-voltage electric vehicle components, and enhancing artificial intelligence (AI) and software utilization skills.

The curriculum comprised four major areas: (1) Certified Safety Inspection Training for manufacturers, (2) Certification Process Manager Training, (3) Electric Vehicle High-Voltage Safety Training, and (4) AI and Software Utilization Training. The program targeted approximately 4,600 manufacturers nationwide, requesting at least one participant per company. As a result, a total of 399 individuals participated, achieving a participation rate of 8.67%. The survey results showed an average satisfaction rate of 96.8%, and between 93% and 100% of respondents indicated that “institutionalization of the education program is necessary.” A regression-based summary revealed that perceived institutional necessity ($\beta_1>0$), professional competence ($\beta_2>0$), and adequacy of training time ($\beta_3>0$) had significant positive effects on overall satisfaction, while external economic conditions ($\beta_4<0$) had a negative effect ($R^2\approx0.75$). These findings suggest that the intrinsic quality factors of the training are key determinants of participants’ perception and satisfaction.

From an economic perspective, the total investment of 215 million KRW generated a cumulative economic ripple effect of 1.799 billion KRW. The benefit-cost ratio (B/C) was calculated as 3.7 for the single year and 4.5 cumulatively over three years, indicating that each 1 KRW of local government funding created approximately 4.5 KRW in economic value. This confirms the high economic feasibility and efficiency of the public educational investment.

Overall, this study empirically demonstrates that the training program effectively enhanced practical capabilities in the industrial field and contributed to regional industrial revitalization. It also emphasizes the necessity of establishing a legalized and standardized certification-based education system. These findings provide a substantive foundation for developing sustainable growth strategies and regional workforce development policies within the advanced mobility industry.

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Transportation Innovation:
도시교통 혁신, 무궤도 시스템
(신교통수단 TRT)
단계적 도입 방안

건설 · 운영비 관점에서 볼 때 트램&TRT 도입의 타당성 및 정책 제언

서정미*, 이정배**

ABSTRACT

대전시는 도시철도 2호선 트램과는 별개로, 건설 및 운영 비용의 효율성을 높이기 위해 3칸 굴절차량(TRT, 무궤도 굴절 전기버스) 도입 시범사업을 전국 최초로 추진 중입니다. 이 차량은 트램의 약 40% 수준의 낮은 건설비로 대규모 수송력(230명~270명)을 확보하여 경제적 타당성이 높지만, 현행 국내 법규상 정식 운행 및 차량 기준이 없어 규제 실증 특례를 적용받아 추진하고 있습니다. 주요 노선은 도안동로 중앙버스전용차로 일원으로, 2026년 상반기 시범 운행을 목표로 하고 있으나, 향후 차량 구입에 대한 국비 지원 미비 등의 과제가 남아 있습니다.

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** 대전시 철도정책과/주무관

신교통수단 TRT 운영사례 분석을 통한 이용자 선호도 연구

이창운*

ABSTRACT

본 연구는 신교통수단인 TRT(무궤도 굴절차량, 3칸 굴절버스)의 운영사례 중 하나인 중국 이빈시 사례를 분석하여 이용자의 선호도를 도출했습니다. 이빈시의 TRT는 트램과 유사한 대용량 수송 능력을 가지면서도 궤도 설치가 필요 없어 트램 대비 건설비가 저렴하고 공사 기간이 짧다는 특징을 바탕으로 도시 교통난 해소에 기여했습니다. 이용자 선호도 분석 결과, 이용자들은 TRT의 높은 수송 능력과 이로 인한 혼잡도 감소, 쾌적한 차량 환경(정숙성, 친환경성), 그리고 기존 버스보다 정시성이 확보된 운행 측면에서 높은 만족도와 선호도를 보였습니다. 이는 TRT가 대용량 수송이 필요하지만 트램 도입의 높은 건설비와 긴 공사 기간이 부담되는 도시에서 합리적인 대안이 될 수 있으며, 이용자 선호도를 높이는 핵심 요소는 수송 효율성과 서비스 품질임을 시사합니다.

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실증특례 활용한 모빌리티 인증제도 개선 방향

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ABSTRACT

실증특례는 현행 법령이나 기준이 없어 시장 출시가 불가능하거나 부적합한 새로운 모빌리티 수단 및 서비스에 대해, 제한된 조건(기간, 지역, 규모 등) 하에서 규제의 전부 또는 일부를 면제하고 실제 시장에서 안전성과 유효성을 시험하고 검증할 수 있도록 허용하는 제도입니다. 따라서 모빌리티 인증제도는 실증특례를 통해 얻은 현장의 데이터와 검증 결과를 바탕으로, 불필요하거나 현재 인증제도에 맞지 않는 부분은 연구하고, 혁신 기술의 발전을 도모하도록 하는 '선 사업 허용, 후 규제 정비'입니다. 따라서, 이번 실증특례의 내용을 바탕으로 TRT와 관련된 정비되어야하는 규제들을 정리했습니다.

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신교통수단(TRT) 활성화를 위한 재정 · 정책 지원방안

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ABSTRACT

신교통수단인 3칸 굴절버스(TRT)가 국내에 성공적으로 활성화되기 위해서는 현재 규제 실증 특례로 추진되는 시범사업을 넘어선 전향적인 재정 및 정책적 지원이 필수적입니다. 특히, TRT는 트램 대비 건설비는 낮으나 차량 가격이 고가이고 현행법상 '버스'로 분류되어 차량 구매 시 도시철도나 경전철처럼 국비 지원(보조금)을 받지 못하는 재정적 한계가 명확합니다. 따라서 정부는 TRT를 도시철도의 경제적 대안으로 인정하고, 차량 구매 및 기반시설 구축에 대한 국가 보조금 지원 근거를 조속히 마련해야 합니다. 아울러, 현재의 규제 실증 특례 결과를 바탕으로 차량 규격, 안전기준, 운수사업법 등 관련 법령을 정비하여 TRT를 독립적인 대중교통 수단으로 공식 제도화하고, 지자체가 재정적 부담 없이 안정적으로 도입할 수 있는 정책 환경을 구축해야 합니다.

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트램 건설계획의 한계와 신교통수단(TRT) 전환의 필요성

박준식*

ABSTRACT

트램 건설 계획의 가장 큰 한계는 도시 교통 혼잡 유발 가능성과 이로 인한 사업 지연 및 비용 증가 문제에 있습니다. 트램은 기존 도로의 차로를 전용차로로 사용하면서 도로 용량을 축소시켜 교통 혼잡을 야기할 수 있다는 지적이 끊이지 않았으며, 이 때문에 일부 구간 지하화 등 대안이 반영되면서 초기 사업비가 크게 증액되고 사업 추진 시기가 수년씩 늦춰지는 악순환을 겪었습니다. 이러한 한계를 극복하고 신속하게 교통 대책을 마련하기 위해, 신교통수단인 3칸 굴절차량(TRT)으로의 전환 필요성이 부각됩니다. TRT는 트램과 유사한 대규모 수송 능력을 가지면서도 궤도 설치가 불필요하여 건설비가 트램 대비 상대적으로 훨씬 저렴하고, 기존 도로 인프라(BRT 등)를 활용하여 사업 기간을 단축할 수 있으며, 실제 경제성 분석에서도 트램보다 높은 사업 타당성(B/C)을 확보할 수 있다는 것이 TRT 전환의 핵심적인 필요성입니다.

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Containing the Future:
수소저장 안전기준 기술적 한계와 도전

수소자동차 국제기준 개발 및 국내 도입 현황

김형구*

The Status of International Vehicle Regulations on Hydrogen Fuel Cell Vehicles and Its Implementation in Korea

Hyoung Gu Kim*

Key Words : UN ECE WP.29(유엔 유럽경제이사회 자동차국제기준 조화기구), UN Regulations(UN 기준), UN GTR (UN 세계기술기준), HCFV(Hydrogen Fuel Cell Vehicles, 수소연료전기자동차), Liquified Hydrogen Engine Vehicles(액화수소엔진자동차)

ABSTRACT

Since the establishment of the UN GTR No.13(Global Technical Regulation) for Hydrogen Fuel Cell Vehicles for passenger vehicles in June. 2013 in UNECE WP.29, the UN R134 for HFCV has also been established in accordance with UN GTR No.13 in 2014, and the phase 2 activities for amending of UN GTR No.13 has been started to expand applicable to large vehicles and improve performance requirements in 2020, and this activities were completed in June 2023, and now, the development of liquefied hydrogen engine vehicle requirements have begun after finishing phase 2 and is currently in the final stage. for reflecting all requirements of UN GTR No.13 phase 2, MoLIT are now proceeding to amend ‘Notice for the Safety of Pressure Containers for Vehicles’ with the goal of complete the promulgation of this notice within this year.

Therefore, the major recently established UN GTR No.13 Phase 2 and the current activities for introducing requirements for liquified hydrogen engine vehicles in WP.29 and its implementation in Korea will be introduced.

2013년 6월, UN ECE WP.29에서 수소승용자동차에 대한 UN 세계기술기준(UN GTR No.13)이 제정된 이후, 2014년에 UN 세계기술기준을 반영한 UN 기준 No.134도 마련되었으며, 2020년부터 대형자동차로의 적용 대상 차종 확대 및 성능기준 개선을 위한 2단계 국제기준 개정작업이 시작되어 ‘23년 6월 개정을 완료하였다. 현재는 액화수소엔진 자동차 기준 개발활동을 시작하여 현재 마무리 단계에 있다. 국토교통부는 올해 안에 국토교통부 고시인 “자동차용 내압용기 안전에 관한 규정”의 개정 공포를 목표로 절차를 진행하고 있다.

이에 최근 WP.29에서 마련된 UN 세계기술기준 No.13의 2단계 기준 및 액화수소엔진자동차 기준 개발현황과 국내 도입 현황을 소개하고자 한다.

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나노클레이 혼합비에 따른 수소저장용기 라이너의 기계적 물성 연구

조재동* · 남칠진* · 허녕도* · 신석철** · 김성현*** · 서종덕*

Effect of Nanoclay Mixing Ratio on the Mechanical Properties of Hydrogen Tank Liners

Jaedong Cho*, Chiljin Nam*, Nyeongdo Heo*, Seokchul Shin**, Sunghyun Kim***, Jongdock Seo*

Key Words : Hydrogen tank(수소저장용기), Nanoclay(나노클레이), Gas permeation(가스 투과도), Hydrogen barrier property(수소 차단 성능), Mechanical properties(기계적 물성)

ABSTRACT

This study investigates the effect of varying nanoclay mixing ratios on the mechanical properties of polyamide 6 (PA6), a widely used liner material for Type IV composite pressure vessels in high-pressure hydrogen storage systems. Nanoclay, a layered silicate with a plate-like morphology, enhances the polymer's structural integrity by strengthening intermolecular interactions and introducing a microstructural barrier effect when well dispersed within the matrix. PA6 nanocomposites with different nanoclay contents were prepared using a masterbatch process and subsequently molded into specimens through injection molding. Tensile tests demonstrated that the addition of nanoclay improved tensile strength and modulus compared to neat PA6, particularly at optimal mixing ratios. This improvement is attributed to the plate-like nanoclay structure, which enhances stress transfer and stabilizes crystalline morphology. However, excessive nanoclay loading led to particle agglomeration, reducing dispersion uniformity and increasing property variation. The results confirm that precise control of nanoclay content is a key factor in improving both the mechanical performance and hydrogen barrier characteristics of PA6 liners, contributing to enhanced durability and safety of high-pressure hydrogen storage systems.

본 연구는 산업통상자원부(MOTIE)와 한국산업기술기획평가원(KEIT)의 "자동차산업기술개발"의 지원을 받아 연구한 과제입니다. (No. RS-2024-00507688)

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Type Ⅳ 수소저장용기의 필라멘트 와인딩 장력에 의한 공압 인가 시점 분석에 관한 연구

김건우* · 김혜원** · 박한민** · 박규환*** · 김한상†

A Study on the Analysis of Pneumatic Pressurization Timing Induced by Filament Winding Tension in Type IV Hydrogen Storage Vessel

Gunwoo Kim*, Hyewon Kim**, Hanmin Park**, Gyuhwan Park***, Hansang Kim†

Key Words : Hydrogen storage vessel(수소저장용기), Filament winding(필라멘트 와인딩), Tension(장력), Compressive load(압축 하중), Pneumatic(공압)

ABSTRACT

In filament winding, a key process in fabricating composite hydrogen storage vessels, fiber tension strongly influences laminate quality and mandrel stability. Direct evaluation of tension variation is costly and time-consuming due to complex fiber paths and contact conditions. To address this, an integrated process combining analysis and experiments was developed to quantitatively assess tension effects. The fiber path through the tensioner, resin bath, machine eye, and mandrel were modeled using geometric coordinates, and cumulative tension loss was calculated with the Capstan equation and effective friction coefficients. The model was validated by comparing predictions with pressure sensor measurements. A tension to compressive load conversion model was then applied to hoop and helical layers, while mandrel buckling limits were examined using theoretical equations and finite element analysis. From these results, pneumatic pressurization timing was determined based on cumulative compressive pressure. The proposed process and results enable optimized design of fiber tension, winding patterns, and pressurization timing, contributing to improved process reliability and development efficiency.

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고압수소에너지를 이용한 차량용 에너지회수 시스템 개발

박건영* · Brilianto Rivaldo Mersis** · 안용수** · 이호길***

Development of an Energy Recovery System for Vehicles Using High-Pressure Hydrogen Energy

Gunyoung Park*, Rivaldo Mersis Brilianto**, Yongsoo An** Hokil Lee***

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

ABSTRACT

A hydrogen fuel cell vehicle consists mainly of a battery, a high-pressure hydrogen storage vessel, and an electric motor. The storage vessel is charged to 700 bar and supplies hydrogen to the fuel cell. Hydrogen compressed to 700 bar is reduced to 10–20 bar through a high-pressure regulator, and then to 1.5–3 bar through a low-pressure regulator before entering the fuel cell stack. To achieve 700 bar charging, hydrogen is compressed to 900 bar using a piston-type or diaphragm-type compressor and supplied to the vehicle tank via a dispenser at the refueling station. According to the SAE J2601 protocol, the tank temperature must remain below 85 °C; therefore, hydrogen is pre-cooled to below −40 °C to account for temperature rise during refueling. Compressing hydrogen from 200 bar (tube trailer) to 900 bar requires about 100 kW of energy, most of which is consumed in compression and cooling, equivalent to the energy needed for an electric vehicle to travel 400–600 km. During fuel supply, hydrogen pressure decreases from 700 bar to 1.5–3 bar, and most of the potential energy (ΔP) is lost as heat, vibration, and impact. Recovering only 20 percent of this o100 kW energy could extend the driving range by 80–120 km, significantly improving fuel efficiency. This study proposes an on-board hydrogen energy recovery system that reuses high-pressure energy released during decompression. A design and analysis program was developed to estimate recoverable energy according to system configuration, supported by a test apparatus and CFD-based validation. The developed program enables system design, control logic development, and energy recovery estimation. Based on the design results, a full-scale prototype will be fabricated and experimentally validated to establish an optimal configuration for a vehicle-integrated hydrogen energy recovery system.

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타입4 수소저장용기 PA6 라이너의 융착 공정 최적화를 위한 CT 분석

동권휘* · 정근성**

CT-Based Butt-Fusion Quality Analysis for PA6 Liners in Type 4 Hydrogen Pressure Vessels

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Key Words : Hydrogen Pressure Vessel,(수소저장용기), Liner(라이너), Butt-Fusion(열융착), Computed Tomography (컴퓨터 단층촬영)

ABSTRACT

The liner of Type 4 hydrogen storage vessels is manufactured by insert injection molding of polyamide 6 (PA6), a material with verified hydrogen impermeability, followed by thermal butt-fusion. In the thermal fusion process, key parameters such as heating time, temperature, and pressure, as well as preprocessing factors like the moisture content and surface roughness of hygroscopic PA6, significantly influence weld quality. This study establishes a non-destructive quality analysis process for PA6 liner welds using industrial computed tomography (CT). By comparing and analyzing weld imperfections and mechanical properties of prototype liners under varying fusion conditions, optimal process parameters were derived. This research is expected to contribute to enhancing the safety and reliability of Type 4 hydrogen storage vessels.

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상용차용 고압수소저장용기의 수소 충전 조건에 따른 열유동 해석

신태성* · 박재훈** · 이재철***

Thermal-Flow Analysis of High-Pressure Hydrogen Storage Vessels for Commercial Vehicles under Refueling Conditions

Tae-Sung Shin*, Jae-Hun Park**, Jae-Chul Lee***

Key Words : Hydrogen storage vessel(수소저장용기), Hydrogen refueling(수소 충전), Computational fluid dynamics (전산유체역학), Thermal-flow analysis(열유동 해석), Thermal safety(열적 안전성)

ABSTRACT

Hydrogen fuel cell vehicles (FCEVs) generate electricity through the electrochemical reaction between hydrogen and oxygen to drive electric motors and are recognized as zero-emission vehicles. The hydrogen storage vessels used in commercial FCEVs typically store hydrogen gas at a high pressure of 350 or 700 bar, and the amount of stored hydrogen determines the driving range. During refueling, the gas temperature increases as the pressure rises. According to the SAE J2601 protocol, the liner temperature of the hydrogen storage vessel must not exceed 85 °C, making the study of internal temperature variation in high-pressure hydrogen storage vessels essential for ensuring safety during refueling.

In this study, computational fluid dynamics (CFD) simulations were conducted to predict the internal temperature behavior of high-pressure hydrogen storage vessels for commercial vehicles during hydrogen refueling. The analysis considered vessel installation orientation (vertical and horizontal), injection direction, and the presence or absence of a nozzle. The results showed that the internal temperature distribution varied depending on the initial refueling pressure, injection direction, and nozzle configuration. At the early stage of refueling, temperature increased uniformly throughout the vessel. However, when the injection direction was not aligned with gravity, localized hot regions appeared near the end of refueling due to density differences induced by temperature gradients and gravitational effects. When a nozzle was installed, internal flow circulation improved, and localized hot spots were effectively suppressed. This study provides a thermal-flow analysis of high-pressure hydrogen storage vessels under various refueling conditions, which is expected to contribute to thermal safety evaluation and efficiency improvement in hydrogen refueling systems.

본 연구는 산업통상자원부(MOTIE)와 한국산업기술기획평가원(KEIT)의 “자동차산업기술개발”의 지원을 받아 연구한 과제입니다. (No. RS-2024-00507688)

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수소연료전지차량용 수소저장시스템 화재사고 안전성 검증

정해관* · 김부근*

Safety Verification of Fire Accident in CHSS of Fuel Cell Electric Vehicle

Haegwan Jeong*, Pookeun Kim*

Key Words : Fuel Cell Electric Vehicle(수소연료전지차), Compressed Hydrogen Storage System(수소저장시스템), Fire Test(화재시험),

ABSTRACT

In order to implement the global carbon neutrality goal, as the development of eco-friendly FCEV technology accelerates, safety verification through advanced tests and certification is required in advanced countries including Europe. In line with these global demands, Korea's certification standards are also being revised to the same level. Existing fire test regulations for verifying the fire safety of CHSS stipulate only the size and temperature of the test burner, but recently revised regulations stipulate the shape, size and installation interval of the nozzle of the test burner as well as the amount of heat during the test. In particular, it requires pre-verification of the overall test environment using standard containers.

Through this study, we intend to develop and build a fire test system according to the revised global regulations to verify the fire safety of composite containers under development through national research projects.

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KAIDA Special Session I

소프트웨어 중심 생태계와 자동차 사이버보안 인증

남알렉스*

Cybersecurity Certification in a Software-Driven World

Alex Nam*

Key Words : Cybersecurity(사이버보안), Vehicle certification(차량인증), Software(소프트웨어), Regulation(법규), CSMS(자동차 사이버보안 관리체계), Self-certification(자기인증), Type approval(형식승인)

ABSTRACT

The evolution of vehicles from mechanical machines to software-defined systems has transformed both their functionality and their certification processes. Modern automobiles now operate as complex computer networks on wheels, demanding new regulatory frameworks to ensure cybersecurity and software integrity. Traditional type approval methods, once focused on hardware-based inspections and reproducible tests, are no longer sufficient in addressing the dynamic nature of cyber threats. To meet these new challenges, the United Nations Economic Commission for Europe (UNECE) introduced two key regulations: UN-R155 on Cybersecurity and UN-R156 on Software Updates.

Unlike traditional certification, UN-R155 emphasizes continuous cybersecurity risk management through the implementation of a Cybersecurity Management System (CSMS). This system requires organizations to monitor, identify, assess, and mitigate risks across the vehicle lifecycle. Certification under UN-R155 is audit-based rather than test-based, prioritizing on-site assessments that verify real-world processes instead of static documentation. This adaptive approach ensures that manufacturers demonstrate resilience against evolving, unpredictable cyber threats.

However, the transition poses challenges for countries such as Korea, where the regulatory framework is rooted in self-certification and fixed test procedures. Integrating dynamic cybersecurity requirements into such systems raises structural and procedural issues, particularly concerning documentation handling and audit implementation. As vehicle technologies continue to evolve, future regulations must become more agile, process-oriented, and globally harmonized. Korea’s strategic path—whether toward enhanced self-certification autonomy or UNECE-aligned type approval—will determine its competitiveness in the global automotive landscape. Establishing flexible, adaptive, and audit-driven regulatory mechanisms will be crucial to maintaining both innovation and safety in an increasingly software-driven world.

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포르쉐의 어제, 오늘 그리고 미래

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Porsche in Portrait

Byonghwee Lee*

Key Words : Porsche(포르쉐), Product Strategy(제품전략), Product Safety(제품안전)

ABSTRACT

Since introducing its first independently developed vehicle model, the 356, in 1948, Porsche has established its brand value through distinctive design and technological innovation in the high-performance sports car market. Iconic models such as the 911 and Taycan have evolved in line with changing times, reflecting Porsche's commitment to balancing tradition with future-oriented technologies. Electrification, digitalization, and sustainability have become central pillars of the brand's product strategy, accelerating its transformation into a brand that delivers both high performance and environmental responsibility. In terms of safety, Porsche integrates high-strength body structures and advanced driver assistance systems to ensure stability at high speeds, while applying race-proven technologies to enhance real-world safety. This presentation aims to highlight the key drivers behind Porsche's sustained growth and explore its strategic direction in the future mobility landscape, grounded in the brand's core philosophy.

포르쉐는 1948년 첫 자체 제작 차량인 356을 시작으로, 고성능 스포츠카 시장에서 독창적인 디자인과 기술 혁신을 통해 브랜드 가치를 확립해왔다. 911, 타이칸 등 주요 모델은 시대의 흐름에 맞춰 진화하며, 포르쉐는 전통과 미래 기술의 균형을 추구하고 있다. 특히 전동화, 디지털화, 지속가능성은 향후 제품 전략의 핵심 축으로 자리잡고 있으며, 이를 통해 포르쉐는 고성능과 친환경을 동시에 만족시키는 브랜드로의 전환을 가속화하고 있다. 제품 안전 측면에서도 고강도 차체 구조와 운전자 보조 기술을 통해 고속 주행 시 안정성을 확보하고 있으며, 레이싱 기술의 양산차 적용은 실도로 안전성 향상에 기여하고 있다. 본 발표에서는 포르쉐의 지속적인 성장 배경과 함께, 미래 모빌리티 시장에서의 전략적 방향성과 브랜드 철학을 조명하고자 한다.

* 포르쉐코리아

무공해 상용차 로드맵 다임러 트럭의 상품 로드맵 전략

이원장*

Strategy for Zero-Emission Commercial Vehicles Daimler Truck's Product Roadmap

Johann Lee*

Key Words : Hydrogen(수소), Fuel Cell Truck(연료전지트럭), eActros(이액트로스), CO_2Neutrality(탄소중립), Commercial Vehicle(상용차), Procabin Safety(프로캐빈 안전기능)

ABSTRACT

Daimler Truck, the world's largest commercial vehicle manufacturer, is accelerating its transition toward CO_2 -neutral transport through a dual-path strategy combining battery-electric and hydrogen fuel-cell technologies. The eActros focuses on regional and urban logistics, while the GenH2 Truck targets long-haul applications requiring high energy density. A 1,000-kilometer hydrogen test run demonstrated the maturity of this technology. However, zero-emission trucks still involve higher acquisition costs compared to diesel, emphasizing the importance of policy incentives and infrastructure development to achieve cost parity and operational efficiency. This presentation outlines Daimler Truck's product roadmap, decarbonization strategy, and advanced safety systems exceeding GSR requirements, as well as Star Truck Korea's localization initiatives for introducing sustainable transport solutions to the Korean market.

다임러 트럭은 세계 최대 상용차 제조사로서, 배터리 전기트럭과 수소연료전지 트럭을 병행하는 이중 기술 전략(Dual-Path Strategy)을 통해 CO_2 중립 운송 전환을 가속화하고 있다. eActros는 도시 및 단거리 물류 운송에, GenH2 트럭은 고에너지 효율이 요구되는 장거리 운송에 최적화되어 있으며, 1회 충전 1,000km 주행 실증을 통해 기술 성숙도를 입증하였다. 그러나 무공해 트럭은 여전히 디젤 대비 높은 초기비용을 지니므로, 정책적 지원과 충전·충전소 인프라 확충이 필수적이다. 본 발표는 다임러 트럭의 상품 로드맵과 탈탄소화 전략, GSR 기준의 안전 기술, 그리고 스타트럭코리아의 한국형 현지화 추진 방향을 중심으로, 지속가능한 운송체계 전환을 위한 실질적 접근 방안을 제시한다.

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K-CRASH 2025

K-CRASH 2025

박종진*

K-CRASH 2025

Jongjin Park*

Key Words : Event data recorder(사고기록장치), Data Storage System for Automated Driving(자율 주행 정보 기록장치), Advanced Driver Assistance Systems(첨단 운전자 보조 시스템), Edge Case(극단적 사례)

ABSTRACT

In accordance with the governments mobility innovation roadmap, Level 4 automated buses have been operating at Cheonggye-cheon since the end of last September. However, there is still insufficient research on verifying the reliability of EDR and DSSAD data and on Edge cases, which are crucial for clearly determining liability and analyzing the cause of accidents involving automated vehicles. In particular, there is no programs at all in Korea that are privately-led, publicly verified, mutually share information, and provide professional education on recorded data. To address this, the K-CRASH, which is being jointly promoted by the automotive industry, academia, and research institutes in Korea, has been launched. The first program was a seminar held from July 21-22, 2025, at KART(Korea Automobile Insurance Repair Research & Training Center) on the topic of “ADAS & EDR Accident Analysis and Improving Perception of Intentional Accidents”; it also involved a comparative analysis of FCA(Forward Collision Avoidance) data recorded on the EDR and actual vehicle data in car-to-car collision scenarios. The second program was held from October 20-21, 2025, at KIAPI(Korea Intelligent Automotive Parts Promotion Institute) under the theme “Beyond Compliance-Real World AEB Failure Scenarios”; it aimed to raise public awareness of traffic safety by introducing the superior technologies of ADAS and demonstration ‘edge cases’ where real-world accidents can occur even if regulations are met. The K-CRASH is expected to become a platform for cooperation among industry, academia, research institutes, and government to establish the reliability of automated vehicles and to formulate policies. It is anticipated that it will serve as a foundation for building a safer automated driving environments.

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Performance Evaluation of ADAS for Heavy Goods Vehicles Based on Real-World Accident Data

Sanghyeon Lim*, Namhyung Kim**

Key Words : Heavy Goods Vehicles(화물자동차), Autonomous Emergency Braking(자동비상제동장치), Real-world Crash Analysis(실사고 분석), Performance Evaluation(성능평가)

ABSTRACT

The Autonomous Emergency Braking (AEB) system is a core advanced safety technology that uses sensors and cameras to prevent accidents. An analysis of automobile insurance statistics from 2021 to 2024 revealed that although heavy goods vehicles (HGVs) over 3.5 tons account for a relatively small share of crashes, they represent the highest proportions of severe injuries and fatalities. As of 2024, the AEB installation rate in domestic trucks was only 14.2%, and pedestrian-detection functions were mostly limited to light trucks, with very limited application in HGVs.

This study analyzed 6,255 real-world crash videos to classify accident types and conducted AEB performance tests using an HGV (Hyundai Mighty, 4-ton, 2023 MY). Among 3,696 HGV-to-vehicle crashes, more than half (51%) were rear-end collisions, many of which occurred while the struck vehicle was braking. In 2,559 HGV-to-pedestrian crashes, pedestrian crossing during vehicle turning accounted for 52.9% of corner impacts, indicating a higher frequency than center impacts. Current AEB evaluation protocols assume pedestrian impacts during straight-ahead driving, considering both center and corner contacts. However, this turning situation is not well represented in current protocols, which focus on center impacts.

Performance tests were based on the Euro NCAP stationary target protocol, with additional scenarios including 25% overlap, oblique target conditions (15° and 30°), and inter-vehicle distances of 30m and 80m between the target and the HGV. Results showed that at 30m, only forward collision warning was activated and AEB was not activated, resulting in collisions. At 80m, collision avoidance was possible up to 70km/h with 100% overlap, while AEB was not activated under 50% or 25% overlap or oblique target conditions.

These findings suggest that current AEB systems for HGVs do not adequately reflect real-world crash conditions. Improvements in system performance and expansion of test scenarios are therefore necessary to enhance crash prevention and reduce societal costs.

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K-CRASH EDGE 2025 컨퍼런스 결과 및 향후 추진방향

이태희* · 엄준식** · 하상욱*** · 김기주**** · 이학주*** · 허 진***

Outcomes and Future Directions of the K-CRASH EDGE 2025 Conference

Tae-hee Lee*, Jun-sik Um**, Sang-wook Ha***, Ki-ju Kim****, Hakju Lee***, Jin Hur***

Key Words : Autonomous Emergency Braking(AEB), Advanced Driver Assistance System(ADAS), Crash Reconstruction, Event Data Recorder(EDR), Pedestrian Safety

ABSTRACT

Recent studies indicate that vehicles equipped with pedestrian detection–based Autonomous Emergency Braking (AEB) systems experience 9.5% fewer pedestrian crashes and 33.9% fewer fatalities than those without. These results confirm AEB's preventive effect, yet accidents still occur due to overreliance or system malfunction. Recognizing that compliance with Advanced Driver Assistance System (ADAS) regulations does not ensure safety in real driving conditions, the K-CRASH EDGE 2025 Conference was held to examine and reproduce accident scenarios that meet standards but can still result in collisions. The conference focused on AEB, conducting full-scale crash and reconstruction tests, Event Data Recorder (EDR) analyses, and simulation-based evaluations to assess system limitations. Expert lectures and discussions covered current AEB technologies and future research directions. While similar crash reconstruction conferences have been held abroad for decades, this event marks the first of its kind in Korea. It highlights the need for accident reconstruction training and certification programs and aims to advance pedestrian and occupant safety while improving public trust in autonomous driving safety technologies.

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페달 오조작 방지 기능 소개

김동호*

Introduction to Pedal Misapplication Prevention Feature

DongHo Kim*

Key Words : Pedal Misapplication Accidents(페달 오조작 사고)

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EDR 데이터의 다각적 신뢰성 검증을 통한 급발진 주장사고의 법공학적 분석

김종혁* · 박종진* · 이연섭** · 박정우** · 한현서** · 전우정***

Forensic Engineering Analysis of Alleged SUA Incidents: A Multi-faceted Approach to EDR Data Reliability Verification

Jonghyuk Kim*, Jongjin Park*, Yeonsub Lee**, Jungwoo Park**, Hyunseo Han**, Woojeong Jeon***

Key Words : SUA(급발진 주장사고), EDR(사고기록장치), Forensic Engineering(법공학), Reliability Verification(신뢰성 검증), Pedal Misapplication(페달 오조작)

ABSTRACT

Sudden Unintended Acceleration (SUA) is a phenomenon in which a vehicle rapidly accelerates at high power, independent of the driver's intent. It has become a significant social concern due to the severe casualties and property damage it causes, often leading to sharp legal disputes between drivers and manufacturers. According to the National Forensic Service (NFS), the number of analyzed SUA-claimed incidents peaked recently, rising sharply to a peak of 133 cases in 2024. However, the numbers have shifted to a downward trend, with 40 cases reported as of August 2025. This change suggests an enhanced public awareness of the importance of objective evidence, such as Event Data Recorder (EDR) data, and a more rational approach to the possibility of driver pedal misapplication. This statistical trend is reinforced by the case-by-case findings: of the 396 cases analyzed by the NFS from 2021 to August 2025, none have been concluded as SUA caused by a vehicle defect, while pedal misapplication was identified in 340 of these cases (86%). The remainder were inconclusive due to severe vehicle damage or the absence of EDR data. Given this statistical background and the ongoing public debate, this presentation introduces the multi-faceted cross-validation methodology that the NFS applies to verify the objective reliability of EDR data. The key validation processes include: (1) comparing RPM change patterns through black box sound spectrogram analysis, (2) cross-validating brake signals from EDR with external footage such as CCTV, (3) conducting accident reconstruction simulations using EDR data, and (4) performing dynamic reliability tests of EDR data through actual vehicle testing. Therefore, by providing a detailed account of the NFS's systematic and scientific analysis process, this presentation seeks to clarify the evidentiary value of EDR data as engineering evidence and to provide a rational solution to the public controversy surrounding the SUA phenomenon.

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Next Level Safety:
기술 혁신이 이끄는 국제 안전기준의 진화

WP.29 국제기준 제·개정 동향 및 국내도입 방안

김형구* · 이현우** · 안호순***

The status of International Vehicle Regulations in UN ECE WP.29 and Activities for Implementation in Korea

Hyoung Gu Kim*, Hyune Woo Lee**, Ho-Soon Ahn***

Key Words : UN ECE WP.29(유엔 유럽경제이사회 자동차국제기준 조화기구), UN Regulations(자동차 국제기준), Autonomous vehicles(자율자동차), Electric Vehicle(전기자동차), Thermal propagation(열폭주), Child restraint system(어린이 구속 시스템)

ABSTRACT

Since 2021, New 19 UN Regulations and 4 UN GTR(Global Technical Regulation)s have been established including enhanced Level 2 requirements for autonomous vehicles, systems for detecting and warning to driver to pedestrians and cyclists in blind spot area to prevent accidents involving large buses and trucks and 582 amendments such as thermal propagation of EVs and child restraint system of existing each UN regulations were adopted in WP.29.

The major newly established and amended UN regulations and UN GTR regulations in WP.29 and the current activities for their implementation will be presented.

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운전자제어지원시스템의 자동차 관리제도 도입 방향성 고찰

최동석* · 전영돈** · 이현우*** · 안호순****

A Review and Future Directions for the Introduction of Vehicle Management Systems for DCAS

Dongseok Choi*, Yeong Don Jeon**, Hyune Woo Lee***, Ho-Soon Ahn****

Key Words : Driver control assistance system(DCAS,운전자제어지원시스템), Vehicle management systems(자동차관리제도), ADAS(첨단운전자지원시스템), ADV(자율주행자동차), UN Regulation No. 171(UN R171)

ABSTRACT

Research on the commercialization of automated vehicles is actively progressing in the AI era. With the widespread adoption of Advanced Driver Assistance Systems (ADAS), Driver Control Assistance Systems (DCAS) offering Level 3-equivalent performance have been developed, and the international regulation UN R171 for their commercialization has been established. However, Level 2 systems must be operated under the driver's supervision and responsibility, which distinguishes them from Level 3. While the Automated driving vehicles' Commercialization Promotion Act provides a certification framework for Level 3 vehicles, vehicles equipped with advanced ADAS still require improvements in the Motor Vehicle Management Act beyond the current regulations for advanced steering control devices. This paper analyzes existing automotive certification systems and examines directions for introducing Level 2-plus international regulations into domestic regulations.

AI시대의 시작과 더불어 자동차분야에서도 자율주행자동차의 개발 및 상용화를 위해 많은 연구가 수행되고 있다. ADAS의 보편화와 더불어 그 기능이 시스템화 및 고도화 되어 레벨 3 자율주행자동차의 성능과 유사한 시스템이 개발되고 상용화를 위한 국제기준(UN R171)도 마련되었다. 그러나 레벨 2로 제한되어 운전자의 감독과 책임아래 그 기능을 사용할 수 있는 것이 레벨 3와 큰 차이점이라 하겠다. 자율주행자동차 상용화 촉진법을 통해 레벨 3 자율주행자동차를 생산하여 인증할 수 있는 체계는 마련되어 있으나, 레벨 2 수준의 자동차는 첨단조향제어장치 기준이외에는 보다 고도화된 기준은 아직 자동차관리법 체계하에서 적용하기에는 미흡한 점이 발견된다. 본 논문에서는 기존의 자동차 관련 인증제도를 분석하고 레벨 2 플러스 수준으로 고도화된 국제기준을 국내 기준에 도입하는 방향성을 고찰해 보고자 한다.

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Holistic Risk Management:
첨단차의 운행 안전 전략

전기자동차 충전구 절연저항 검사 개선에 관한 실증 연구

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Empirical Study on Improving Insulation Resistance Testing of Electric Vehicle Charging Ports

Hyunjun Kim*, Byunghwan Yoon**, Soonil Kwon***, Jaemook Kang****

Key Words : Periodic technical inspection(정기검사), Electric vehicles(전기자동차), Technical inspection(검사기술), Empirical(실증), Insulation Resistance(절연저항)

ABSTRACT

Globally, the development of electric vehicle technology has been actively pursued due to carbon neutrality policies. Accordingly, the number of electric vehicle registrations has also increased rapidly. Although electric vehicles have become widely available, methods regular inspection of electric vehicles have not been developed. In this paper, we developed an automatic insulation resistance inspection device for the charging port of an electric vehicle and conducted a verification study. A feasibility study was conducted on 10 electric vehicles at an automobile inspection center, and a comparative analysis was conducted with existing equipment.

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전기자동차 관리체계 활성화를 위한 제도화 방안 연구

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Proposals for Legal System Measures to Activate the Electric Vehicle Repair & Management System

Jaegon Yun*, Sungho Kim*, Munpyo Hong**, Hyunjun Kim***

Key Words : High-voltage batteries(고전압배터리), Mandatory training(의무교육), Legal system(제도화)

ABSTRACT

With the recent increase in the number of high-capacity, high-voltage battery-equipped vehicles, such as electric vehicles and hydrogen fuel cell vehicles, there is a pressing need for thorough and safe maintenance by skilled maintenance personnel.

Currently, maintenance and training for high-voltage electric devices in electric vehicles are left to the discretion of maintenance businesses. However, the government must ensure the safety of not only electric vehicle maintenance personnel but also electric vehicle users. To achieve this, standards for facilities and equipment necessary for the safety of maintenance personnel performing high-voltage electric device maintenance should be established, and maintenance personnel should be required to complete mandatory training.

Therefore, we seek legal system measures to ensure consumer safety and revitalize the automobile management system.

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전기차와 수소전기차의 기술경영 전략 및 경제 혁신 비교 연구

이준석* · 김호경** · 오태석***

A Comparative Study on Technology Management and Economic Innovation between Electric Vehicles and Hydrogen Fuel Cell Vehicles

Junseok Lee*, Hokyung Kim**, Taeseok Oh***

Key Words : Electric Vehicle(전기차), Hydrogen Fuel Cell vehicle(수소전기차), Technical Management(기술경영) Strategy(전략), Economic Innovation(경제혁신), Hydrogen(수소), Response to Change(변화대응), National Policy(국가정책)

ABSTRACT

The global response to the climate crisis and the ongoing energy transition are driving a rapid restructuring of industrial systems worldwide. In the transportation sector, Battery Electric Vehicles (BEVs) and Hydrogen Fuel Cell Vehicles (FCEVs) are emerging as central technologies for achieving carbon neutrality and sustainable mobility. This study conducts a comparative analysis of BEVs and FCEVs from the perspectives of technology management and economic innovation. It further examines domestic and international policy responses and industrial strategies to assess the competitiveness and sustainability of each technology. Based on the findings, this paper offers strategic insights for securing competitive advantage in the global eco-friendly vehicle market.

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자동차검사소 안전사고 예방을 위한 현장형 기술개발과 실증적 성과분석 연구

이정재* · 하우영* · 이준석**

Development of On-Site Safety Technologies for Accident Prevention in Vehicle Inspection Stations and Analysis of Empirical Outcomes

Jeongjae Lee*, Wooyoung Ha*, Junseok Lee**

Key Words : Automotive Inspection Station(자동차 검사소), Safety Accident Prevention(안전사고예방) On-site Technology Development(현장형 기술개발), Field Application(현장적용), Empirical Performance Analysis(실증적 성과분석), Safety Device Innovation(안전장치 개발), Case Study(사례 중심 연구)

ABSTRACT

This study aims to develop field-oriented safety devices to prevent industrial accidents in automobile inspection stations and to analyze their empirical performance. Conventional inspection tasks are characterized by limited workspace and repetitive operations, which inherently increase the risk of worker injuries and equipment damage. To address these issues, this research presents the design and development process of safety devices and evaluates their effectiveness through on-site implementation. The empirical results indicate that the introduction of safety devices significantly reduced the likelihood of accidents, decreased worker fatigue, and enhanced operational efficiency. This study is expected to provide fundamental insights for the development of safety technologies that can be applied not only in automobile inspection stations but also in related inspection and maintenance industries.

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일본 자동차 정비 · 검사 제도 개선 사례 연구: 특정 정비 및 OBD검사 제도 도입 · 시행을 중심으로

백안선*

Implications of Japan's Automotive Maintenance and Inspection System Reform: Introduction of Specified Maintenance and OBD Inspection

Anseon Baek*

Key Words : Automotive maintenance(사용후 배터리자동차 정비), OBD inspection(OBD검사), Specified maintenance (특정정비), Vehicle inspection(자동차검사), Regulatory reform(규제 개혁)

ABSTRACT

Japan's vehicle management system assigns maintenance responsibilities to owners through daily and periodic inspections, while ensuring roadworthiness through regular government inspections (shaken). With the proliferation of advanced driver assistance systems—including collision mitigation braking, lane-keeping support, and automated driving systems—across all vehicle classes including kei-cars, the Japanese government, industry, and academia established the "Study Group on Advanced Automotive Maintenance Technology." This led to implementation of the specified maintenance system in April 2020, integrating on-board diagnostics (OBD) with traditional disassembly-based practices dating from 1951, followed by OBD inspection in periodic inspections (shaken) in October 2024.

This study investigates the development process and implementation framework of Japan's specified maintenance and OBD inspection systems through systematic policy analysis and industry data review. The research examines regulatory evolution, stakeholder consultation mechanisms, and technical infrastructure requirements. Comparative analysis with Korea's current maintenance and inspection regime identifies critical implications for domestic policy reform: (1) establishment of automotive maintenance information sharing platforms between manufacturers and service providers, (2) integration pathways for OBD-based diagnostics in periodic inspections, and (3) capacity-building strategies for under-resourced maintenance facilities. The findings provide evidence-based recommendations for modernizing Korea's automotive safety infrastructure to accommodate increasingly complex vehicle technologies.

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사용후 배터리 3단계 안전관리 기술 개발에 관한 연구

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A Three-Step Safety Management Strategy for EOL Battery

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Key Words : Eol battery(사용후 배터리), Safety management(안전관리), Electric vehicle(전기차), Circulation system (순환 체계), Legislation(법제화)

ABSTRACT

The widespread adoption of electric vehicles (EVs) is leading to a surge in the generation of EOL batteries, necessitating the vitalization of the remanufacturing and reuse market to realize a circular economy. Although remanufactured batteries hold significant economic value, the absence of a standardized safety management system acts as a major impediment to the growth of the related industry.

This study proposes a '3-Step Safety Management System for EOL Batteries' to ensure full-lifecycle safety, from the initial generation of a EOL battery to the operation of an EV equipped with a remanufactured one. This system consists of three stages: Step 1, ‘Performance Evaluation before dismantling’; Step 2, ‘Safety Inspection before distribution’; and Step 3, ‘Periodic Inspection’. It comprehensively covers the entire process, from the initial application grading of EOL batteries to the continuous safety management of vehicles with remanufactured batteries installed.

Additionally, by integrating a ‘Remanufactured Battery Management Platform’, this study aims to build a highly complete, data-driven management system that manages the histories of the remanufactured battery and the EV—such as the battery's repair history and the installed EV's history—and links them with the battery's full-lifecycle history

본 결과물은 국토부의 재원으로 국토교통과학기술진흥원의 사용후 배터리 안전점검 및 재제조 배터리 순환 체계 안전관리 기술 개발 과제의 지원을 받아 연구되었습니다.(RS-2025-02309323)

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건설기계 안전 고도화 방안 연구

영상처리 기반 사람–사물 인식 알고리즘을 활용한 건설기계 협착 사고 예방 연구

박현준* · 조정우** · 오주영**,†

Preventing Crush Accidents in Construction Machinery Using Image Processing-Based Human–Object Recognition

Hyune-Jun Park*, Jung-Woo Cho**, Joo-Young Oh**,†

Key Words : Image Processing(영상 처리), Worker Detection(작업자 인식), Crush accident prevention(협착 사고 예방), Safety system(안전 시스템), Automatic stop(자동 정지)

ABSTRACT

Crush accidents between heavy construction machinery—such as excavators, rollers, and motor graders—and workers frequently occur at construction sites. These accidents are mainly caused by operators' blind spots and the absence or limited performance of detection devices. Conventional accident prevention technologies rely on safety bars or simple video cameras, which have limitations in enabling operators to accurately detect workers located in blind areas. To address this issue, this study developed an image processing–based human–object recognition algorithm to detect crush hazards at an early stage and examined the feasibility of controlling machine operations in response. The algorithm processes video data from cameras in real time to identify workers, and when a worker is detected, it is linked to a safety control logic that automatically stops the machine or issues a warning signal. In future work, experiments will be conducted in a test environment that simulates real construction sites, considering various field conditions such as the number of workers and background complexity. The system's detection performance will be evaluated, and the integration of additional sensors such as LiDAR will be explored to improve distance and relative position estimation and real-time coordination with machine control systems. This study presents the potential of image processing–based crush accident prevention technology for application to high-risk construction machinery, and it is expected to become a key element of future safety management technologies for construction equipment.

이 연구는 국토교통부/국토교통과학기술진흥원이 시행하고 대한건설기계안전관리원이 총괄하는 "고위험 건설기계 안전성 평가 및 관리 기술개발 사업(과제 번호 RS-2023-00244879)"의 지원으로 수행하였습니다.

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디젤엔진 건설기계의 DPF 매연 적설량 측정 방법

진승호* · 김용국** · 기태균***

A Method for Measuring Soot Accumulation in DPF for Diesel-Powered Construction Machinery

Seungho Jin*, Yongkook Kim**, Taegyun Ki***

Key Words : Construction machinery(건설기계), DPF(디젤 미립자 필터), Soot accumulation(매연 적설량)

ABSTRACT

The Air Quality Conservation Act mandates that operating vehicles and construction machinery be equipped with emission reduction devices to improve air quality and reduce the emission of substances that cause climate and ecosystem changes. For construction machinery that primarily uses diesel fuel, Diesel Particulate Filters (DPFs) and Selective Catalytic Reduction (SCR) are used as emission reduction devices.

A DPF operates by trapping particulate matter (soot) and then incinerating it to reduce emissions. If the trapped soot is not burned off, it can lead to reduced emission reduction performance and a decrease in engine power. Therefore, it is necessary to check the accumulated amount of trapped soot and burn it when it reaches a certain level. However, there is currently no quantitative method to do this in the field, so inspectors must rely on the qualitative criterion of exhaust gas color.

This study aims to find a quantitative method to measure the amount of soot accumulated in a DPF. The research focuses on construction machinery with diesel engines and investigates an electronic method, specifically through communication, to measure the amount of trapped soot in the DPF. The goal is to improve the inspection and management procedures for construction machinery in real-world field environments, making them more intuitive and straightforward than the current methods.

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타워크레인 외관 검사에 대한 UAV 활용 가능성 분석

고지혜* · 김성도** · 최요순*** · 조정우****

Evaluation of UAV Utilization in Safety Inspection of Tower Cranes

Chihye Ko*, Seungdo Kim**, Yosoon Choi***, Jung-Woo Cho****

Key Words : Unmanned Aerial Vehicle (UAV), Tower Crane, Construction Machinery, Structural Inspection, Safety Management, Maintenance

ABSTRACT

Unmanned aerial vehicles (UAVs) are increasingly used in industrial sites to inspect areas that are difficult or hazardous for human access. With the advancement of UAV technologies and the expansion of related markets, their applications have extended to diverse fields, driven by advantages such as reduced labor costs, improved inspection accuracy, and enhanced safety. This study focuses on the applicability of UAV-based inspection techniques to tower cranes, which are classified as high-risk construction machinery.

To achieve this, previous studies and both domestic and international inspection manuals were reviewed. Through this analysis, potential inspection items and methods that can be performed by UAVs were identified. The study particularly highlights external inspection tasks that can be effectively conducted without direct human intervention, such as assessing structural components, detecting visible defects, and monitoring operational conditions.

The results suggest that UAV-based inspection technologies hold significant potential for integration into safety management practices for tower cranes. By adopting such technologies, it is possible to reduce inspectors' exposure to dangerous environments while ensuring consistent and reliable inspection outcomes. Ultimately, the findings of this research are expected to contribute to establishing safer and more efficient maintenance systems for tower cranes and, more broadly, for other large-scale construction equipment.

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건설기계 안전기준 시행세칙 고도화 연구 소개

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Introduction to Research on Advancing the Enforcement Regulations of Construction Equipment Safety Standards

Jungyun Kim*, Donghyun Lim**

Key Words : Construction machinery(건설기계), Safety regulations(안전기준), Enforcement rules(시행세칙), Advanced research(고도화 연구)

ABSTRACT

The Rules on Construction Equipment Safety Standards were promulgated on February 12, 2008, as Ordinance No. 606 of the Ministry of Construction and Transportation. Since their initial enactment, these regulations have undergone multiple revisions, primarily aimed at enhancing on-site safety and related systems. However, in certain instances, detailed testing methodologies for verifying compliance with safety standards have been lacking, and the most recent advancements in construction equipment technologies have not been adequately incorporated. To address these shortcomings and comprehensively strengthen construction equipment safety, the Korea Transportation Safety Authority commissioned a research initiative in 2025 to advance the Enforcement Rules for Construction Equipment Safety Standards. The Enforcement Rules for Construction Equipment Safety Standards delineate specific testing protocols designed to verify performance criteria, thereby ensuring conformity with established safety standards. Moreover, compliance with equivalent Korean Industrial Standards (KS) or International Standards (ISO) for the corresponding test items is also deemed to fulfill the requirements stipulated in the Enforcement Rules. This study aims to identify and analyze components of the current safety standards and enforcement regulations that necessitate revision in order to improve construction equipment safety.

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건설기계 안전관리 관점의 건설기계관리법 통합해설서 개발

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An Integrated Commentary on the Construction Machinery Management Act: A Safety-Management Perspective

Soo-Yeun Park*

Key Words : Construction Machinery Manegment Act(건설기계관리법), Integrated Commentary(통합해설서), Safety Management(안전관리), Legisltive History(개정연혁), Authoritative Interpretation(유권해석)

ABSTRACT

This study aims to develop an integrated commentary on the Construction Machinery Management Act (CMMA) from a safety-management perspective by systematically analyzing the Act and its subordinate regulations and preparing clause-by-clause interpretations. The commentary organizes practical issues and proposes policy ideas for institutional improvement. We first outline the system's formation and changes through the amendment history and identify the law's purpose and intent. We then compare the CMMA with the Motor Vehicle Management Act and the Occupational Safety and Health Act to extract similarities and differences in governing actors, requirements, procedures, and structure. We also map the delegation structure across the Act, Enforcement Decree, and Enforcement Rule at the clause level and align it with safety-management institutions. Finally, we analyze authoritative interpretations for each clause and design a practitioner-oriented annex. The results provide basic guidance for policy reports and legislative amendments and offer a legal and institutional basis to enhance lifecycle safety management across all machine categories, including high-risk equipment.

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KAIDA Special Session II

새로운 자동차 규제 및 제도 도입 시 고려해야 할 신차 개발 process

박주선*

The New Car Development Process to Have to Consider When the New Regulation and System Will be Planned and Introduced

Joo-Sun Park*

Key Words : PR(Public Relations: 홍보), Legislation(법률제정), Statistical(통계)

ABSTRACT

When introducing new systems or regulations related to automobiles, it is essential to understand the vehicle development process. Such understanding plays a crucial role in ensuring that these regulations are effectively applied to actual vehicles and that their intended impact is achieved.

This report aims to describe the overall procedure of new vehicle development — starting from the initial concept creation of an entirely new automobile product, followed by detailed product planning and market research, establishment and finalization of the initial design concept, engineering design and performance evaluation through simulations, production of actual components, pilot vehicle manufacturing and testing, pre-mass-production quality evaluation and improvement, and finally, certification and manufacturing quality assessments leading up to full-scale mass production.

In addition, a comprehensive understanding of the entire process — from the early stages of vehicle development to the commencement of mass production — is often difficult even for professionals working in the automotive industry, as many of these stages are not directly experienced in day-to-day operations. Therefore, this report seeks to provide and share an overview of the full vehicle development process to enhance general understanding across all stages.

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자동차 첨단안전장치의 선제적 적용을 위한 안전기준 특례절차 실증 연구

엄성복* · 김규현**

Key Words : Vehicle management system(자동차관리제도), Exemptions for vehicle safety standards(자동차 안전기준 특례), Regulatory sandbox(규제샌드박스)

ABSTRACT

Recently, various advanced safety devices have been developed for vehicles. In addition, with the emergence of autonomous vehicles and Software-Defined Vehicles (SDVs), new technologies that are distinct from traditional automotive technologies are being created. The government regulates vehicle safety standards to ensure that citizens can use safer vehicles. However, the pace of developing and applying new technologies is always faster than the pace of institutional regulation. To address such situations, the government operates special exemption systems (special provisions) for new technologies or technologies with public benefits, etc. The vehicle industry has raised concerns that the current special provision clauses in the vehicle safety standards lack specific procedures and therefore need to be improved. Therefore, this study aims to present a clear and practical procedure for operating the special exemption system by conducting research on the history of the vehicle special exemption system, the current status of regulatory sandboxes, and domestic and international cases of special exemption systems.

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ADAS & 사고분석

차량의 계기판 게이지가 운행 상태로 정지된 원인의 사례 분석

윤석현* · 박명철**

Analysis of the Cause for a Vehicle's Instrument Cluster Gauges Being Stuck in an Operational State

Seok-Hyun Yoon*, Myung-Cheol Park**

Key Words : Accident investigation(사고조사), Instrument Cluster(계기판), Worm Gear Gauge(웜기어식 게이지), Power Interruption(전원 차단), Accident Reconstruction(사고 재구성)

ABSTRACT

The vehicle's Instrument Cluster is an essential safety system that provides the driver with real-time information on critical operating conditions such as speed, engine revolutions per minute (RPM), and fuel levels, ensuring safe and efficient driving. This study focuses on the gauge freezing phenomenon—specifically involving Worm Gear Type gauges—that occurs during a vehicular accident, and conducts a focused Root Cause Analysis of the electrical failures that allow the vehicle's state at the moment of impact to be deduced.

The analog needles driven by the Worm Gear Type mechanism become mechanically stuck (frozen) in their last position when the main power supply to the instrument cluster module is abruptly cut off. This power interruption is primarily caused by physical impact (accident) resulting in the severance of power supply wires or the blowing of a protective fuse. The instant power is lost, the stepper motor controlling the gauge needle loses all electrical control, locking the needle at the reading corresponding to the exact operational state just prior to the power loss.

The core contribution of this analysis is the finding that this gauge freezing reliably indicates the precise moment of electrical disconnection during a collision. Consequently, the value displayed on the frozen gauge provides a direct basis for estimating the vehicle's state (speed, RPM, etc.) immediately preceding or at the moment of the accident. This interpretation is expected to serve as objective and effective evidence in future traffic accident investigations, aiding in the accurate accident reconstruction by decoding the vehicle's operational status at the time of impact.

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실사고 자료 기반의 AEB 시뮬레이션에 관한 연구

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AEB Investigation Research Based on Real Vehicle Collision Data

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Key Words : AEB(자동긴급제동), CDR(충돌자료기록장치), EDR(사고기록장치), Real Vehicle Collision(실사고), Safety Performance(안전 성능)

ABSTRACT

This study analyzes fatal accidents related to AEB reported in NHTSA accident investigations. Using accidents with CDR/EDR speed records as a reference, the initial speed, braking initiation, and collision speed were considered. The vehicle's pre-crash motion was reconstructed with an advanced automobile simulation program, and a basic AEB algorithm (warning–partial braking–full braking) was applied. The initial speed and collision speed were compared, and the concept of CCRs lateral overlap was additionally analyzed. Driving simulations were conducted under conditions of 100% and approximately 10% overlap by modifying vehicle sensor inputs, and the detection/response timing, collision occurrence, and variations in collision speed were compared. Based on publicly available accident data, the accident conditions were simplified, and changes in sensor settings and road conditions were applied to analyze the resulting vehicle safety performance. By reproducing real-world crash accidents and evaluating vehicle crash avoidance performance, this study proposes an analytical research methodology for autonomous driving technologies.

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다양한 ADAS 카메라 센서 아키텍처에 대한 KADAS 호환성 연구

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A Study on KADAS Compatibility with Diverse ADAS Camera Sensor Architectures

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Key Words : ADAS(첨단 운전자 보조시스템), KADAS(한국형 자율주행차 검사 시스템), Compatibility(호환성), Mono Camera(모노카메라), Stereo Camera(스테레오 카메라)

ABSTRACT

This study investigates the compatibility of the KADAS(Korea Automated Driving Vehicle Assessment System) - Based Vehicle in the Loop Simulation(VILS) environment with diverse ADAS Camera sensor architectures. Specifically, it analyzes the functional performance of Advanced Driver Assistance Systems(ADAS) for Vehicle A, equipped with a mono-camera system, and Vehicle B, utilizing a Stereo/Dual-camera system. The findings reveal that Vehicle A demonstrated high success rates in Adaptive Cruise Control(ACC) and Autonomous Emergency Braking(AEB) functions. In contrast, Vehicle B exhibited Severe performance degradation in the same VILS environment. This degradation is attributed to the VILS environment's inherent limitations in supporting the depth perception mechanisms of stereo/dual cameras and the conservative nature of their sensor fusion logic. This research underscores the critical need for improving ADAS evaluation technologies within VILS environments to accommodate various sensor architectures, thereby contributing essential foundational data for standardized ADAS performance assessment.

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국내 페달 오조작 사고 특성 분석에 관한 연구

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A Study on the Characteristics of Pedal Misapplication Accidents in Korea

Yohan Park*, Wonpil Park*, Seungki Kim***

Key Words : Pedal Misapplication(페달오조작), Advanced Driver Assistance Systems(첨단운전보조장치)

ABSTRACT

In recent years, a growing number of sudden unintended acceleration cases—such as the recent incident at Seoul City Hall—have raised public concern. According to investigations conducted by the National Forensic Service and the Korea Automobile Testing & Research Institute, most of these incidents were found to result from pedal misapplication rather than mechanical failure. This study aims to analyze the current status and characteristics of pedal misapplication accidents occurring in South Korea. To this end, accident data reported to a domestic insurance company over the past five years (January 1, 2019 – June 30, 2024) were examined using text analysis techniques. The results show that an average of 2,008 pedal misapplication accidents occur annually. These accidents frequently take place in situations requiring alternating use of the accelerator and brake pedals, particularly during parking or exiting maneuvers, which account for 48.0% of all cases. Notably, approximately one in four pedal misapplication accidents involved elderly drivers aged 65 or older—a rate about 1.5 times higher than their share of overall traffic accidents. Therefore, the findings highlight the urgent need to promote advanced driver assistance systems (ADAS) to help prevent pedal misapplication among elderly drivers.

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CCTV 영상 기반 차량 추적과 Gaussian Splatting 기반 3D 재구성을 활용한 교통사고 분석 지원 시스템

최동민* · 백세룡** · 김형규* · 김천호*** · 조민제****

Traffic Accident Analysis Support System Using CCTV-Based Vehicle Tracking and Gaussian Splatting 3D Reconstruction

Dongmin Choi*, Seryong Baek**, Hyungkyu Kim*, Cheonho Kim***, Minje Cho****

Key Words : Traffic accident analysis(교통사고 분석), Gaussian Splatting(가우시안 스플래팅), Point Cloud Visualization (포인트 클라우드 시각화), CCTV footage(CCTV 영상), Opencv csrt tracker(OpenCV CSRT 추적기)

ABSTRACT

The growing adoption of autonomous driving technology underscores the need for prompt and accurate determination of accident causes and responsibilities to ensure social and legal credibility. To address this, we propose a traffic accident analysis support system that leverages CCTV footage to selectively track target vehicles and reconstruct accident scenes into three-dimensional point clouds from two-dimensional images. The system employs an OpenCV-based CSRT tracker with BackgroundSubtractorMOG2 to extract target trajectories while suppressing non-target vehicles through background composition. A COLMAP-based 3D reconstruction module with scale correction and Gaussian Splatting further enhances visual realism and spatial accuracy. Experimental results demonstrate that the proposed approach improves the reliability and efficiency of accident investigations. Future integration with deep learning–based tracking and real-time 3D reconstruction is expected to establish a more advanced framework for accident analysis in the autonomous driving era.

This research was conducted with the support of the Korea Institute of Advancement for Police-technology (KIPoT), funded by the Government (Korea National Police Agency and Ministry of Science and ICT) in 2025 (No. 25442072).

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차량용 영상기록장치의 이미지 품질 결정 요소

백승학* · 조현철* · 이호관**

Factors Determining Image Quality in Digital Video Recording Systems

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Key Words : Digital video recording systems(디지탈영상기록장치), Image Performance(이미지성능), Image Quality (이미지품질)

ABSTRACT

In-vehicle video recorders are increasingly used not only for accident evidence collection but also for driver assistance systems (ADAS) and general vehicle management. The performance of such devices is evaluated less by storage capacity or hardware specifications than by the quality of the recorded images.

This study categorizes the determinants of image quality into IP (Image Performance) factors and IQ (Image Quality) factors.

IP factors refer to objectively measurable indicators such as resolution, signal-to-noise ratio (SNR), and dynamic range, which directly affect the fidelity of image reproduction under various driving conditions, including day/night and low-light environments. IQ factors, on the other hand, reflect perceptual attributes such as color reproduction, sharpness, and distortion minimization, thereby contributing to the reliability of accident scene reconstruction and user satisfaction. Through experimental case studies, this work confirms that IP and IQ factors function in a complementary manner, and that a balanced enhancement of both is essential to improving the overall quality of video recorders. These findings are expected to support the establishment of perfo쫘rmance evaluation criteria for automotive video recorders and, in the longer term, indirectly contribute to the reliability of driver assistance and safety-related functions.

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K-CRASH 충돌/EDGE

Intelligent Traffic Accident Data Processing and Smart Analysis System

김천호*

Intelligent Traffic Accident Data Processingand Smart Analysis System

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Key Words : PC-Crash(피시크래쉬), Traffic Accident Simulation(교통사고 시뮬레이션), Collision Dynamics Analysis (충돌 역학 분석), Accident Reconstruction(사고 재현), AI-based Analysis(인공지능 기반 분석), Autonomous Vehicles(자율주행차), Deep Learning(딥러닝)

ABSTRACT

With the commercialization of autonomous vehicles and advances in AI technology, the transportation environment is rapidly evolving. Traffic accident analysis is a critical process for identifying accident causation and preventing recurrence; however, conventional field investigation and qualitative analysis alone have limitations in elucidating complex accident mechanisms. Analysis of 100 actual traffic accident cases from prior research revealed that only 23% were amenable to PC-Crash-based simulation analysis, while analysis time was reduced by an average of 60% per case compared to manual methods. Simulation programs are essential for quantitatively reconstructing sophisticated collision dynamics in multi-vehicle accidents and velocity variations at each phase.

This study presents a smart analysis tool that maximizes analytical efficiency through machine learning-based video processing and frame analysis for vehicle speed and trajectory tracking, traffic accident database construction based on collision dynamics analysis, and field surveying methods utilizing photogrammetry. The system is designed to integrate with accident reconstruction programs utilized by Korean law enforcement agencies for future application in autonomous vehicle accident reconstruction, liability determination, and analysis. This system is applicable to traffic accident investigation agencies, insurance companies, and courts, and is expected to contribute to traffic safety policy formulation and enhanced safety in the era of autonomous vehicles.

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정밀 도로지도 기반 객체인식 연동 및 속도 분석

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HD Map-Based Integration of Object Detection and Speed Analysis

Kaeul Kim*, Taehyun Yoo*, Seryong Baek**, Dongjoon Chun***, Daebong Lee****

Key Words : HD map(정밀도로지도), Object detection(객체인식), Dashcam(블랙박스), Speed analysis(속도분석)

ABSTRACT

High-definition (HD) maps have primarily been developed and utilized for autonomous driving applications. However, the precision and standardized spatial information embedded in HD maps provide significant potential for accident analysis. Traditional traffic accident investigations often rely on dashboard camera (black box) footage and satellite imagery, where the accuracy of speed estimation is highly dependent on the analyst's expertise and the manual selection of reference points. This subjectivity frequently leads to inconsistent results. To address these limitations, this study proposes an accident analysis framework that integrates HD map data with object detection techniques for speed estimation using black box videos. The proposed method employs an object detection model to automatically identify and track relevant objects within accident footage. By mapping the detected object positions onto the precise spatial coordinates provided by HD map data, the actual distance traveled by the object can be calculated. Subsequently, the number of video frames over a given interval is used to derive the speed of the moving object. This approach eliminates the reliance on manually chosen fixed points and reduces the variability caused by human interpretation. As a result, the method enables more consistent and reliable speed estimation in accident analysis. The study highlights the potential of combining HD map data with object detection models to establish a novel methodology for accident reconstruction and traffic safety research. Beyond the context of autonomous driving, this work demonstrates how HD maps can serve as a valuable tool in forensic traffic analysis, offering a new direction for leveraging geospatial intelligence in transportation safety.

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실차 시험을 통한 보행자 긴급제동장치 엣지 케이스 감정 기법에 관한 연구

이재형* · 김종혁** · 최지훈*** · 박종진**** · 전우정*****

A Study on Accident Reconstruction for Pedestrian AEB Edge Cases through Full-Scale Vehicle Test

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Key Words : Pedestrian AEB(보행자 긴급제동장치), Accident Reconstruction(사고재구성), ADAS(첨단운전자보조시스템)

ABSTRACT

When a pedestrian accident involves a vehicle equipped with a Pedestrian Automatic Emergency Braking (AEB) system, the National Forensic Service may conduct forensic analysis to determine driver negligence upon request from investigative authorities. Understanding the operational characteristics and limitations of the AEB system assists in estimating the driver's hazard perception timing. However, manufacturers do not disclose system logic, and ADAS sensor data in the EDR are recorded only for limited vehicle models. Therefore, this study proposes a method to reconstruct the vehicle and pedestrian positions, speeds, and collision points from accident footage and data, and to verify AEB activation through full-scale vehicle tests.

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K-crash 자율주행 Edge case 실험 결과 분석

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Analysis of Experimental Results for Autonomous Driving Edge Cases on K-Crash

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Key Words : ADAS(첨단운전자보조시스템), ODD(작동설계영역), NCAP(신차안전도평가), Edge Case(엣지케이스)

ABSTRACT

The Advanced Driving Assist System (ADAS) primarily involves technologies that individually or collectively implement functions of Lv. 1~2, which are necessary elemental technologies prior to the Lv. 3~5 classified as autonomous driving. However, ADAS is generally highlighted more for its effect on safety enhancement rather than the perspective of autonomous driving meant to replace the driver. This recognition is further amplified as various global New Car Assessment Programs (NCAP) adopt it as an evaluation item in the active safety domain, awarding points based on accident prevention and damage minimization. However, compared to Lv. 3~5, the Operational Designed Dimension (ODD) for each ADAS function has a limited operational domain and operating conditions.

This paper analyzes the ODD of the ADAS function evaluation scenarios presented by NCAP, among others, and in contrast, suggest s scenarios for edge cases that can deviate from the operational domain based on actual accident cases. The reviewed edge scenarios were tested on actual vehicles equipped with ADAS functions. The experiments confirmed that the risk of accidents increases when there are variables in the driving situation outside the scope presented by NCAP, and this paper proposes improvements.

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사고기록장치(EDR) 속도 데이터를 활용한 자동차 주행속도 추정 연구

천정환* · 이철기** · 이대봉*** · 백세룡****

A Study on Estimating Vehicle Driving Speed Using Event Data Recorder(EDR) Speed Data

Jeonghwan Cheon*, Choulki Lee**, Daebong Lee***, Seryong Baek****

Key Words : EDR(사기록장치), Accident reconstruction (사고 재현), PC-Crash(사고재현프로그램), Traffic accident analysis(교통사고 분석), Vehicle speed estimation(차량 속도 추정)

ABSTRACT

Accurate vehicle speed estimation is essential for accident reconstruction and liability assessment. Event Data Recorder speed, however, often reflects wheel rotation rather than vehicle body motion, leading to discrepancies. This study analyzes three real-world accidents where EDR-recorded speed differed from actual vehicle dynamics. Using PC-Crash, reconstructions were performed both by directly applying EDR data and by aligning trajectories with physical evidence such as video, tire marks, and damage patterns. Results show that EDR speed aligns with wheel speed but diverges from body speed, especially in yaw and low-friction conditions. While PC-Crash reproduced cases where wheel speed underestimated body speed, it could not replicate scenarios where wheel speed exceeded body speed, such as wheel lift-off. The findings highlight that these discrepancies stem from recording methodology rather than error or malfunction. This approach improves the reliability of accident reconstruction and provides a framework for clarifying EDR data interpretation.

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실사고

실사고 기반 잠재적 자율주행 혼재주행 상황 탑승자 상해위험 연구

최두루* · 공준석** · 추연일** · 이강현**

Potential Occupant Injury Risks of Mixed Traffic Crashes in Automated Vehicles

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Key Words : Injury risk(상해위험), Automated vehicles(자율주행차), Mixed traffic crashes(혼재주행 사고), Finite element analysis(유한요소해석), Korean-in-depth accident Study(KIDAS)

ABSTRACT

The ADS and ADAS features of Automated Vehicles (AV) reduce crash and injury severity by reducing crash speed. The penetration of the AV will gradually increase and is expected to lead to an increase in mixed traffic crashes between autonomous and non-autonomous vehicles, but data on such crashes is limited. This study aimed to simulate a mixed traffic crash of AV and analyze the expected injury reduction effect based on real-world data. The study used the Korean In-Depth Accident Study (KIDAS) as a data source. We chose 446 occupants who suffered MAIS2+ injuries in car-to-car single frontal collisions out of 5,179 occupants. The included data were partitioned using k-medoids clustering based on the difference of car-to-car crash angle. The crash speeds of the two vehicles were analyzed within the 0–90th percentile range for each cluster, and 90th percentile results were integrated into the mixed traffic crash simulation. AEB engagement was implemented for both vehicles through prescan-based simulations to evaluate pre-crash speed reduction in mixed traffic crashes. FE analysis was performed using the FE sled model with Hybrid III ATD for occupant injury evaluation.

Four clusters were partitioned according to crash angle, which comprises two head-on and two longitudinal crashes. Among eight AEB simulation scenarios two avoided a crash and one showed no AEB activation. The other five produced three cases of reduced crash speed at 18.0 ± 8.9 km/h and two cases of increased speed at 36.0 ± 12.7 km/h. The Hybrid III dummy's probability of injury tends to decrease in FE analysis of the most frequent head-on crash configuration.

In conclusion, the injury reduction effect was confirmed in mixed traffic crashes in a real-world data-based computational simulation. Continuous research is needed to track injury reduction because AV features have not yet fully secured crash prevention

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정면충돌 교통사고에서 벨트 착용 탑승자의 늑골골절 해부학적 특성

최두루* · 공준석** · 추연일* · 강찬영* · 이강현**

Anatomical Characteristics of Rib Fractures on Belted Occupant in Frontal Crashes

Dooruh Choi*, Joon Seok Kong**, Yeon Il Choo*, Chan Young Kang*, Kang Hyun Lee**

Key Words : Rib fracture(늑골골절), Musculoskeletal anatomy(근골격 해부학), Frontal crashes(정면충돌), Seatbelt(안전벨트), Motor vehicle occupant(승객), Korean in-depth accident study(KIDAS)

ABSTRACT

Thorax is a major injury region of serious injury in motor vehicle crashes and rib fractures are a common thoracic injury types with a high incidence. This study aimed to examine the detailed rib fracture patterns based on musculoskeletal anatomy data of occupants in real-world crashes.

The study used the Korean In-Depth Accident Study (KIDAS) database. Among 5,179 occupants, we excluded cases with missing sex, age, or injury information and included 81 first row seated belted passenger-car occupants involved in frontal crashes with rib fracture image and diagnosis. The specific locations of rib fracture were examined by categorizing them into left and right, vertical (ribs 1-12), and horizontal (anterior, antero-lateral, lateral, postero-lateral, and posterior). The rib fracture patterns was analyzed by occupants.

Among occupants involved in frontal crashes 107 occupants (16.8%) sustained rib fractures. Detailed rib fracture analysis based on radiology imaging was possible in 81 cases (75.7%). Female occupants had a higher rib fracture incidence than males. The left rib suffered higher fractures than the right. The most frequently fractured ribs in the vertical direction were the fourth and fifth ribs. In the horizontal direction, the most common rib fracture occurred in the antero-lateral region. The outer rib suffered higher fractures than the inner rib after adjusting for occupant position.

In analyses of occupant rib fractures based on real-world crash data sex-specific musculoskeletal differences were identified. Future work will conduct demographic analyses to identify crash types associated with increased rib fracture risk.

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NHTSA SGO 데이터 기반 자율주행레벨2 차량사고의 상해중증도에 따른 사고특성

추연일* · 이강현** · 최두루* · 강찬영* · 김오현** · 공준석**

Investigating Level 2 Autonomous Driving Vehicle Crashes According to Injury Severity Based on NHTSA SGO Data

Yeon Il Choo*, Kang Hyun Lee**, Dooruh Choi*, Chan Young Kang*, Oh Hyum Kim**, Joon Seok Kong**

Key Words : Standing general order(SGO), Autonomous vehicle(자율주행차), Advanced driver assistance system(첨단운전자지원시스템), Injury surveillance(손상감시)

ABSTRACT

Manufacturers annually introduce new vehicles with partial automation and advanced driver-assistance systems (ADAS) intended to mitigate human-error–related crashes. However, these technologies are not yet mature enough to prevent all crashes. This study investigates the differences in crash characteristics between minor and moderate-or-fatal injury groups in level 2 autonomous vehicles. We analyzed 492 crash reports from the National Highway Traffic Safety Administration's Standing General Order (SGO) database (January 2021-August 2025). Variables of interest included model year, driver and operator type, crash object, airbag deployment, passenger belted, and injury severity. A statistical analysis was performed to observe significant differences between injury seveirty groups. Vehicle's model year 2024–2026 had the lowest risk of moderate injury (AOR, 0.316; 95% CI, 0.115–0.868). According to crash object, the highest risk was in crashes with commercial vehicles (AOR, 1.985; 95% CI, 1.047–3.765) and non-motorists (AOR, 4.159; 95% CI, 1.113–15.541). Compared with airbag deployment, the non-deployment had increased risk of moderate injury (AOR, 3.617; 95% CI, 2.442–5.358). Particularly, the risk of moderate injury increased at higher pre-crash speeds of 41–50 mph (AOR, 2.827; 95% CI, 1.281–6.240) and ≥60 mph (AOR, 2.718; 95% CI, 1.474–5.012). In this study, the crash characteristics of level 2 automated vehicles were analyzed by injury severity. Latest model years showed a reduced likelihood of moderate injury, whereas crash object commercial vehicles or non-motorists, airbag non-deployment and higher pre-crash speeds were associated with increased injury severity. The results suggest the need for improvments of advanced vehicle systems to ensure avoiding crashes assoicated with vulnerable road users (VRUs) under high-speed conditions.

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경트럭 탑승자 교통사고에서 중증도에 따른 하지 손상 부위별 위험요인

백소빈* · 이강현** · 김선주** · 강찬영* · 김오현**

Risk Factors for Lower Extremity Injuries Across Injury Severity among Cab-Over Truck Occupants in Road Traffic

Sobin Baek*, Kang Hyun Lee**, Sun Ju Kim**, Chan Young Kang*, Oh Hyun Kim**

Key Words : Cab-Over Truck(캡오버 트럭), Lower Extremity(하지), Injury(손상), Risk Factor(위험요인), Korea In-Depth Accident Study(KIDAS)

ABSTRACT

This study aimed to analyze LE injury patterns and severity among cab-over truck occupants and to identify independent risk factors associated with these injuries.

A retrospective study was conducted using data from the Korean In-Depth Accident Study (KIDAS) collected between 2011 and 2024. Among cab-over truck occupants, those aged <15 years or with unclear injury sites or collision directions were excluded, leaving 547 cases for analysis. Injury severity was assessed using the Abbreviated Injury Scale (AIS) across six body regions, and lower extremity injuries were categorized as pelvis, femur, knee, lower leg, and foot. Logistic regression identified predictors of injury by subregion.

An extent ≥6 had a significantly higher risk of lower leg injury than those with extent 1–2 (OR: 7.21, 95% CI: 1.45–35.92). Rear impacts were associated with increased risk of knee injury compared with frontal impacts (OR: 11.62, 95% CI: 1.18–114.42). Frontal airbag deployment was signassociated with pelvis, femur, and foot injuries. Among occupants with Injury Severity Score (ISS) <16, airbag deployment remained persisted as a significant factor for pelvis and foot injuries, whereas knee and lower leg injuries were mainly associated with vehicle intrusion. In the high-severity group (ISS ≥16),Severely injured group sustained in only foot injuries which had a statistically significant related to airbag deployment.

Severe vehicle deformation (intrusion ≥6 cm) was identified as a major risk factor for lower leg and foot injuries. The association between airbag deployment and foot injury likely reflects higher crash severity rather than a direct effect. These findings highlight the vulnerability of the lower extremities in cab-over truck occupants and the need for improved structural reinforcement vehicle design and geometry to reduce lower limb traumainjuries in frontal crashes. In this study, vehicle deformation (intrusion ≥6 cm) was identified as a major risk factor for lower leg and foot injuries. Among the severely injured occupants, frontal airbag deployment was significantly associated with foot injuries, likely serving as a surrogate marker of higher crash severity rather than a direct airbag effect. These findings highlight the structural vulnerability of light trucks, indicating that occupants' lower limbs are highly exposed to impact forces, emphasizing the need for reinforced structures and enhanced energy-absorbing designs to prevent lower extremity trauma.

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차대차 사고에서 탑승열과 안전벨트 착용 여부에 따른 탑승자 상해 양상 및 중증도

이범영* · 이강현** · 공준석** · 추연일* · 강찬영* · 최두루* · 강동구* · 백소빈* · 김오현**,†

Occupant Injury Patterns and Severity According to Seating Row and Seatbelt Use in Vehicle-to-Vehicle Crashes

Bum Young Lee*, Kang Hyun Lee**, Joon Seok Kong**, Yeon Il Choo*, Chan Young Kang*, Dooruh Choi*, Dong Gu Kang*, Sobin Baek*, Oh Hyun Kim**,†

Key Words : Vehicle-to-vehicle crashes(차대차사고), Seating row(탑승 열), Seatbelt(안전벨트), Injury patterns(상해양상), Injury severity(상해중증도), Korea In-Depth Accident Study(KIDAS)

ABSTRACT

This study aimed to analyze serious injury patterns by seating row and seatbelt use among occupants involved in vehicle-to-vehicle (V2V) crashes. A retrospective observational study was conducted using data from the Korean In-Depth Accident Study (KIDAS) collected between 2011 and 2024. We analyzed 595 adults (≥18 years) patients sustained in V2V crashes. Serious injury was defined as ISS ≥15 and body-region–specific serious injury as AIS ≥3. Independent variables included sex, age, BMI, seating position, seatbelt status, airbag deployment, vehicle type, road category, road type, crash object, crash type, and crash extent. Statistical analyses were performed using the IBM SPSS Statistics 25.0 (t-test, chi-square, Fisher's exact, logistic regression). In the serious-injury group (ISS ≥15), 40.0% were unbelted, higher than in the non-serious group (p=0.010). Rear-seated occupants had higher serious injury rates in head, face, and neck injuries compared to front-seated occupants (p<0.05). Among front-seat occupants, the proportion with serious thoracic injury was 21.3% in the unbelted group, higher than in the belted group (p=0.028). The mean ISS was also higher in the unbelted (9.79±8.59) than in the belted (6.56±6.71) group (p<0.001). Among rear-seat occupants, the proportion with serious abdominal injury was higher in the belted group than in the unbelted group (p=0.030). In logistic regression, increasing age (OR 1.02, 95% CI 1.01–1.04), unbelted (OR 1.69, 95% CI 1.01–2.85), and intrusion (OR 3.80, 95% CI 1.92–7.53) were associated with serious injury. When MAIS ≥3 was defined as the dependent variable, rear-seat occupants had twice the odds of serious injury compared with front-seat occupants (OR, 1.975; 95% CI, 1.005–3.878). These findings indicate that seating row and seatbelt use are key determinants of injury patterns and outcomes in V2V crashes, underscoring the need for seat-specific protection enhancements and policies to improve seatbelt use.

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도로교통약자 유형별 중증손상 상대위험도 비교

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Comparison of Relative Risk for Severe Injuries Among Types of Vulnerable Road Users

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Key Words : Vulnerable road users(도로교통약자), Relative risk(상대위험도), Severe injury(중증손상), Poisson regression model(포아송 회귀 모델), Emergency Department-based In-depth Injury Surveillance(응급실 손상환자심층조사)

ABSTRACT

Purpose: This study aimed to identify the relative risk and key factors associated with severe injuries among vulnerable road users (VRUs)—including pedestrians, cyclists, motorcyclists, and electric scooter users—who differ from general motor vehicle occupants in terms of exposure and protection.

Methods: Data were derived from the Emergency Department-based In-depth Injury Surveillance (EDIIS) system operated by the Korea Disease Control and Prevention Agency, covering 23 hospitals from 2011 to 2024. Injury severity was classified using the Excess Mortality Ratio–adjusted Injury Severity Score (EMR-ISS): scores <25 were defined as non-severe and ≥25 as severe. Independent variables included month, time of day, sex, age group, alcohol use, work-relatedness, road type, collision object, and helmet use. A Poisson regression model with a log link function was used to estimate the adjusted Relative Risk (RR) and 95% Confidence Intervals (CI) for severe injury, using SAS 9.4 (SAS Institute, Cary, NC, USA).

Results: The risk of severe injury significantly increased with age($p<0.05$). Among those aged ≥65 years, the adjusted RRs were 2.56 (95% CI 2.43–2.70) for pedestrians, 3.84 (3.58–4.13) for cyclists, and 2.58 (1.75–3.79) for motorcyclists compared with those aged <25 years. Female users had a statistically lower risk than males (pedestrians: RR=0.88, 95% CI 0.83–0.93; bicycles: RR=0.75, 0.69–0.82; motorcycles: RR=0.89, 0.81–0.97; all $p<0.01$). Alcohol involvement significantly increased the risk across all user types ($p<0.001$), with RRs ranging from 1.33 in pedestrians to 1.68 in cyclists. Nighttime crashes (18:00–24:00) were also associated with increased risk, particularly among electric scooter users (RR=2.63, 95% CI 2.10–3.29).

Helmet use was associated with a significantly lower risk of severe injury among motorcyclists (RR=0.67, 95% CI 0.61–0.73) and electric scooter users (RR=0.62, 0.48–0.81), whereas no protective effect was observed for cyclists (RR=0.98, 0.93–1.04; $p=0.41$). Collisions involving large vehicles (RR=2.71, 95% CI 2.33–3.15) or railway vehicles (RR=4.88, 3.42–6.96) markedly increased the risk of severe pedestrian injury.

Conclusion: Older age, alcohol use, nighttime crashes, and lack of helmet use were significant risk factors for severe injuries among all VRU types. These findings underscore the need for targeted prevention strategies and policy interventions to enhance safety for vulnerable road users.

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Human-Centered Physical AI

Designing the Passenger Experience in Automated Vehicles: Proven UX Methods and Real-World Findings

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Key Words : Automated Vehicles, Passenger Experience, User Experience(UX) Design, Human-Centered Design, Participatory Design, Prototyping and User Testing, Simulator Validation, Trust and Acceptance

ABSTRACT

As vehicles become increasingly automated, the passenger experience becomes a key differentiator and a critical factor for acceptance. This talk highlights the strategic value of User Experience (UX) design in automated driving and demonstrates how different UX methods can be applied effectively across development stages. Drawing on several real-world projects, I will present four proven approaches: (1) Observation and surveys to understand user needs, expectations, and concerns; (2) Participatory design to co-create solutions with users and ensure relevance and acceptance; (3) Prototyping and user testing to evaluate interaction concepts, interfaces, and usability; and (4) Simulator and on-road validation to assess comfort, motion effects, trust, and overall experience in realistic contexts. By comparing insights from these methods, I will show how each contributes unique value and how they can be combined to reduce development risks, improve safety and comfort, and increase user trust and adoption.

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강화학습 기반 Steer-by-Wire 제어기술 및 일반도로 환경 검증

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Reinforcement Learning-Based Steer-by-Wire Control Technology and General Road Environment Validation

Yujin Kim*, Minjun Kim**, Jaepoong Lee***

Key Words : Reinforcement Learning(강화학습), Vehicle Control(차량 제어), SbW(전자식 조향 시스템), Steering System(조향시스템), Road Environment Validation(도로 환경 검증)

ABSTRACT

Conventional Steer-by-Wire (SbW) control has mainly relied on linear control theory or model-based control methods such as Model Predictive Control (MPC). However, these approaches have limitations in fully capturing nonlinear vehicle responses and often suffer from high computational complexity, which restricts their real-time applicability in diverse driving conditions. As a result, their control performance tends to degrade in nonlinear response regions, such as tire saturation, or under external environmental variations.

In this study, we propose a reinforcement learning–based SbW steering control technique that defines the driver's steering intention in terms of a target curvature and aims to accurately track it. The proposed method takes the vehicle's dynamic state information as input and generates steering commands through a reinforcement learning policy, trained to stably follow the target curvature. This enables the vehicle to maintain curvature-tracking performance that reflects the driver's intention even when entering nonlinear response regions.

The Soft Actor-Critic (SAC) algorithm was adopted as the learning framework, allowing efficient learning in continuous state and action spaces and achieving a robust control policy through a stable balance between exploration and exploitation. The performance of the proposed controller was validated using IPG CarMaker–based simulations across various scenarios representing typical road environments. The experimental results demonstrate that the reinforcement learning–based SbW controller outperforms conventional control methods in terms of target curvature tracking accuracy and vehicle stability, particularly maintaining robust steering control that faithfully represents the driver's intention even in nonlinear dynamic regions. This study presents a pathway toward the advancement of SbW control technology and its potential for real-world road implementation.

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End-to-End 자율주행 데이터 확보를 위한 시뮬레이터 기반 시나리오 자동 생성 및 의미론적 분류

박찬미* · 이영호* · 정범교* · 한민규* · 이기범**

Simulator-Based Automatic Scenario Generation and Semantic Classification for End-to-End Autonomous Driving Data Acquisition

Chanmi Park*, Yeongho Lee*, Beomgyo Jeong*, Mingyu Han*, Kibeom Lee**

Key Words : End-to-End Autonomous Driving(종단 간 자율주행), Coreset Selection(코어셋 선택), Frame-Level Semantic Selection(프레임 수준 의미 기반 선택), Data Efficiency(데이터 효율성), Importance Sampling (중요도 샘플링)

ABSTRACT

End-to-End autonomous driving requires large-scale and diverse driving data, but collection in real-world environments has limitations in terms of cost, safety, and event frequency. To solve this problem, this study proposes a pipeline that automatically generates scenarios based on simulators and maximizes data efficiency by removing low-value segments with limited training utility from generated and collected data. A scenario space parameterized by road structure, traffic density, weather, signal/regulation, interaction events (lane change, merges, pedestrian/bicycle sudden events, etc.) is defined; scenarios are automatically sampled, guided by coverage metrics and event distributions. Then, to train the end-to-end autonomous driving model, the scene is classified and annotated at the frame level through a semantic classifier, and an importance score is calculated by integrating scarcity, event intensity, and end-to-end autonomous driving model uncertainty information. Based on the score, importance sampling and coreset selection are performed to suppress duplicate frames and select samples with high learning contribution. The proposed method aims to secure wider scenario coverage under the same simulation resource while reducing the training data volume with frame-level semantic-based selection while without degrading policy performance. This pipeline presents a general procedure to increase the data efficiency and practicality of end-to-end autonomous learning by organically linking simulator-led data acquisition, semantic classification, and importance sampling/coreset selection.

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Physical AI를 활용한 운전 성향 기반 차량 부품 마모 및 거동 특성 해석

정건희* · 윤택한* · 정인성* · 신동훈*,† · 한용하** · 유영민**

Physical AI-Driven Analysis of Vehicle Component Wear and Dynamic Behavior According to Driving Styles

Geonhui Jung*, Taekhan Yoon*, Insung Jung*, Donghoon Shin*,†, Yongha Han**, Yeongmin Yoo**

Key Words : Driving style(운전 성향), Component wear(부품 마모), Dynamic behavior(차량 거동), Physical AI (Physical AI)

ABSTRACT

This paper presents a Physical AI-driven analysis of vehicle component wear and dynamic behavior under driving styles. Driving styles—typically categorized as defensive, normal, and aggressive—are abstract behavioral concepts, yet they play a vital role in influencing remaining useful life of chassis components and vehicle dynamics. It is known to be establishing a direct connection between such behavioral tendencies and measurable physical phenomena remains challenging. To address this limitation, a Physical AI-based framework is proposed that integrates driving-style classification, component wear modeling, and vehicle dynamics analysis. Physical AI serves as a medium for quantitatively interpreting and visualizing the interrelationship among driving style, component wear, and vehicle dynamics, thereby physically expressing how behavioral tendencies manifest as component degradation and dynamic responses. Driving styles were quantified using a driving-aggressiveness indicator and validated through spectral clustering of RGB feature vectors derived from an LSTM-Autoencoder. With successfully quantified driving styles, experimentally validated physical wear models from previous studies were used to derive the wear characteristics of key chassis components (e.g., brake pads and dampers), which were then implemented in a Digital Twin environment to reproduce variations in component degradation and vehicle behavior according to driving styles. As a result, it has been shown that, even under identical driving conditions, differences in driving style lead to distinct wear patterns, which in turn cause measurable changes in vehicle dynamics such as vibration, rolling, and braking performance. In particular, aggressive driving styles accelerate wear progression—damper degradation amplifies body vibration and rolling, while brake-pad wear leads to a noticeable decline in braking performance.

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도시 감지와 상호작용 관점에서의 인간 중심 스마트 모빌리티 연구

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Toward Human-Centered Smart Mobility: Urban Sensing and Interaction Perspectives

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Key Words : Urban sensing networks(도시 감지 네트워크), Multi-modal sensor data(이기종 센서 데이터), Human-urban interaction(인간-도시 인터랙션), External human-machine interfaces(외부 HMI)

ABSTRACT

The Stanford Center at the Incheon Global Campus (SCIGC) serves as Stanford University's flagship research hub in South Korea. Guided by its long-term vision to establish a smart city model, SCIGC conducts multidisciplinary research encompassing urban sensing, human–technology interaction, and sustainability. Among these efforts, SCIGC's research on smart mobility in urban environments focuses on developing mobility solutions tailored to the specific characteristics and needs of each city. Achieving this requires an accurate and dynamic understanding of the city's condition. To that end, SCIGC is advancing the development of Urban Sensing Networks through the integrated analysis of multi-modal sensor data. Data from mobile sensing platforms and infrastructure such as CCTVs and loop detectors are systematically analyzed and fused to enhance the precision of city- and traffic-monitoring systems.

Furthermore, realizing smart mobility goes beyond technological advancement alone; it also requires effective interaction between humans and mobility systems. SCIGC therefore conducts human-centered research on the interaction between people and autonomous vehicle technologies. Using a driving simulator, studies have been carried out on driver responses under semi- and fully autonomous driving conditions to improve in-vehicle human–machine interaction. External human–machine interfaces (eHMI) that facilitate communication between autonomous vehicles and pedestrians have also been examined through theoretical analyses and field tests. These research activities aim to enhance social acceptance and ensure the safe and sustainable integration of emerging mobility technologies within future urban environments.

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인간 중심 기반 적응형 협업을 위한 인간–로봇 상태 모델링의 통합 프레임워크

임치호*

An Integrative Framework of Human–Robot State Modeling for Human-Centered Adaptive Collaboration

Chiho Lim*

Key Words : Human-Robot Interaction(인간-로봇 상호작용), Human–Robot State Modeling(인간-로봇 상태 모델링), Bidirectional Interaction(양방향 상호작용)

ABSTRACT

Despite the growing adoption of industrial robots and intelligent mobility systems, research on Human-Robot Interaction (HRI) has largely remained one-directional, with most studies focusing on how robotic and mobility agents monitor and interpret human states. However, such approaches often overlook the robot's own state and its influence on the human partner's perception, decision-making, and trust. HRI should instead be understood as a bidirectional and dynamic system, in which the user's cognitive and physiological states can change depending on the robot's behavior or condition. To capture this reciprocal relationship, this study proposes an integrative framework that combines the User Agent Module and the Robot Agent Module. The User Agent Module represents the human side of interaction and includes real-time observation of physiological and behavioral indicators such as fatigue, attention, and engagement. The Robot Agent Module represents the robot's operational state and covers motion control, task performance, and behavioral feedback that affect the user's perception and trust. By integrating these two modules, the proposed framework establishes a mutually adaptive HRI structure that enables continuous state exchange and co-regulation between human and robot agents. To demonstrate this concept, this study presents empirical research on both the User Agent Module and the Robot Agent Module. By presenting studies on each module, the research highlights key considerations for achieving an integrated framework. Accordingly, the proposed approach provides a roadmap for future research toward the development of more robust human-centered HRI systems.

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자율주행기술 & 제어

국립한국해양대학교의 C-ITS 기반 자율주행 기술: K-City 실증

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C-ITS Based Self-Driving Technologies of Korea Maritime and Ocean University – An Autonomous Journey on K-City

Insung Jung*, Junghoon Han*, Jaehyung Choi*, Sungjae Lee*, Hankyeol Song*, Minjeong Byun*, Donghoon Shin**,†

Key Words : Cooperative Intelligent Transport Systems(협력 지능형 교통시스템), Cooperative Control(협력 제어), Dilemma Zone(딜레마 존), Autonomous Vehicle(자율주행 차량)

ABSTRACT

This paper presents an integrated perception–decision–control framework based on Cooperative Intelligent Transport Systems (C-ITS) to enable autonomous vehicles to drive stably at intersections, particularly in dilemma zones where stop-or-go decisions during yellow-signal transitions are ambiguous. Autonomous vehicles are increasingly required to make safe and accurate driving decisions in complex traffic environments characterized by frequent signal transitions at intersections. Dilemma zones formed during yellow-signal changes increase the risk of accidents, and perception sensors alone exhibit limitations in reliable decision-making. To address these limitations, a C-ITS–based integrated system is developed to allow autonomous vehicles to establish and execute optimal driving strategies through vehicle–infrastructure communication. During perception, data from onboard sensors (camera, LiDAR, and GPS) are fused with Signal Phase and Timing (SPaT) information provided by Roadside Units (RSUs) to determine the vehicle's position and signal state. Decision computes the optimal driving strategy by considering SPaT data, vehicle speed, and distance to the stop line. Under yellow-signal conditions, the remaining signal time and vehicle dynamics are analyzed to evaluate the appropriateness of acceleration or deceleration. Control delivers the computed decision to the vehicle controller, enabling safe stopping or smooth intersection traversal. It has been shown that the proposed C-ITS–based framework achieves stable transition behavior under yellow-signal conditions and enhances both safety and operational efficiency at intersections through real-world experiments.

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자율주행차량의 교차로 회전을 위한 차선 변경에 관한 연구

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A Study on Lane Changes for Autonomous Vehicles Turning at Intersections

Gwangmin Lee*, Jinwan Kim**

Key Words : Van-class vehicles(승합차급차량), Lane change timing(차로 변경 시점), Maintain specific lanes(차로 유지)

ABSTRACT

Van-class autonomous vehicles must maintain specific lanes at intersections and consecutive turning sections on multi-lane roads. For left turns, maintaining the first lane is required beforehand, while for right turns, maintaining the last lane is required beforehand. Therefore, to enable autonomous vehicles to turn at intersections and consecutive turning sections, a path must be provided that offers sufficient time and spatial margin for lane changes. Specifically, an algorithm is needed to determine the optimal lane position for turning by judging the lane change timing based on the previous lane's position and the feasibility of moving to the designated lane for the specified lane turn. The lane change decision algorithm can generate a path for a Van-class autonomous vehicle by calculating the lane required for the turn and the minimum distance needed to change lanes to reach that position. Furthermore, when consecutive turns occur, the vehicle can verify whether safe movement is possible by considering the location where each turn occurs and the location where the next turn will occur. The path generated through this process minimizes abrupt lane changes by the vehicle, enabling the expectation of safe driving for the autonomous vehicle.

본 연구는 2025도 산업통상자원부 및 한국산업기술기획평가원(KEIT)의 자율주행기술개발혁신사업(과제명 : 지정 구역 기반 Point-to-Point 이동 Lv.4 승합차급 자율주행 차량 플랫폼 기술 개발, 과제번호 : 20014361) 연구비 지원에 의해 수행됨

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Point-to-Point Level 4 자율주행을 위한 HD Map 기반 경로정보 표준화 연구

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A Study on Standardization of HD Map-Based Path Information for Point-to-Point Level 4 Autonomous Driving

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Key Words : Autonomous Driving; Point-to-Point (P2P) Level 4, HD Map; Path Information, Trajectory; ADASIS V3, Standardization, Interoperability

ABSTRACT

In Level 4 autonomous driving, the implementation of Point-to-Point (P2P) services requires the provision of precise path information to ensure that vehicles can reach their destinations safely and efficiently. In particular, lane-level trajectory-based path information plays a critical role in trajectory prediction and motion planning. However, when proprietary trajectory formats are applied to different autonomous driving systems, issues of interoperability and limitations in scalability arise.

To address these challenges, this study proposes a method of mapping and applying lane-level trajectory path information to the standardized structure of ADASIS V3. ADASIS V3 defines road and path information within a hierarchical structure and provides trajectories and various metadata in a standardized format, thereby resolving interoperability and scalability issues among autonomous vehicles. In this study, we present a strategy for converting trajectory formats into the ADASIS V3 message structure and validate its feasibility through dataset-based evaluation.

The results demonstrate that the proposed approach significantly improves the reusability and interoperability of path information, and is expected to contribute to the realization of P2P-based Level 4 autonomous driving services.

본 연구는 2025도 산업통상자원부 및 한국산업기술기획평가원(KEIT)의 자율주행기술개발혁신사업(과제명 : 지정 구역 기반 Point-to-Point 이동 Lv.4 승합차급 자율주행 차량 플랫폼 기술 개발, 과제번호 : 20014361) 연구비 지원에 의해 수행됨

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카메라–라이더 센서 융합 모델의 효율적 학습을 위한 유사성 기반 데이터 선택: 일반화 성능 및 강건성 향상

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Similarity-Based Data Selection for Efficient Learning of Camera-LiDAR Sensor Fusion Models: Enhancing Generalization and Robustness

Jin Hwan Kim*, Jong Hun Sung**

Key Words : Sensor fusion model(센서 융합 모델), Efficient(효율성), Generalization(일반성), Robustness(강선성), Data Selection(데이터 선별), Similarity(유사도), Clustering(군집화)

ABSTRACT

The training of sensor fusion models faces several challenges, including the demand for vast amounts of data and computational resources, degradation of generalization performance due to redundant data, and insufficient robustness to sensor noise. This study aims to enhance training efficiency, generalization performance, and robustness simultaneously by applying a similarity-based data selection strategy in the training process of camera-LiDAR fusion models.

Specifically, feature vectors extracted from images were used to measure similarities between data samples and cluster them accordingly. Representative samples were then selected from each cluster to construct the training dataset. This dataset was compared against randomly sampled datasets and the entire dataset and was applied to train the BEVFusion model.

Experimental results demonstrated that the proposed data selection strategy significantly reduced training time, thereby improving efficiency, while maintaining or enhancing generalization performance compared to conventional methods. Furthermore, robustness was also improved, showcasing the potential of this approach as a reliable data utilization strategy for large-scale autonomous driving training.

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e-코너 모듈 기반 액티브 서스펜션 모델링

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Modeling of an Active Suspension System for e-Corner Module-Based Mobility Platform

Yusun Kim*, Jaepoong Lee**

Key Words : Active suspension(액티브 서스펜션), e-Corner module(이코너 모듈), Vehicle modeling(차량 모델링)

ABSTRACT

This study focuses on the modeling phase of an active suspension system applied to an e-Corner module based mobility platform. The aim is to build a physical model that can describe the vehicle body's heave, pitch, and roll motions when the vehicle moves over different road and load conditions. Since each e-Corner module independently performs driving, steering, braking, and suspension functions, an accurate description of how the body moves and tilts is important for understanding the vehicle's overall behavior.

The proposed model represents how the suspension structure, vehicle body, and road surface move together, considering the spring and damping characteristics that influence vertical and tilting motions. It also includes the effect of active forces generated by the actuators inside each corner module, which help control the vehicle's height and body posture. Main parameters such as body and wheel masses, stiffness, damping, and geometric layout are defined using practical industrial data.

The developed model provides a basic framework for studying how the vehicle's height and tilt change under various road conditions. This model will be further expanded to design and test active suspension controllers that can coordinate the vehicle's vertical and tilting motions. The outcome of this study will contribute to improving the stability and comfort of future mobility platforms that use e-Corner modules.

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Frontier of Cyber War:
K-사이버보안의 기술 주권과 미래

자율주행 기술 트렌드에 따른 반도체 센서 동향 및 사이버보안 기술의 필요성

이정규*

Trends in Semiconductor Sensors According to Autonomous Driving Technology Trends and the Necessity of Cybersecurity Technology

Junggue Lee*

Key Words : Autonomous driving(자율주행), Cybersecyrity(사이버보안), Semiconductor(반도체)

ABSTRACT

자율주행 기술 트렌드는 인식 판단 제어의 전통적인 기술이 고정밀, 고성능 반도체 및 센서의 개발에 의해 확장되고 있는 형태로 바뀌고 있다. 고정밀의 인식 센서의 개발로 기존에 구현하기 어려웠던 안전, 편의 기술에 대한 세부 기술들이 개발되고 있으며, 고성능 반도체 AP 개발로 복잡한 AI 알고리즘을 적용한 정확하고 빠른 판단 로직을 구현할 수 있게 되었다. 자율주행기술은 하드웨어의 진화에 따라 다양한 소프트웨어 기술로 확장되기 때문에 원격 소프트웨어 업데이트(OTA, Over The Air)가 필수적인 미래차 발전 기술로 대두되고 있으며, 중앙집중형 HPC로 차량 아키텍쳐가 구성됨에 따라 업데이트 대상이 '제어' 뿐만 아니라 '인식'. '판단' 에 대한 소프트웨어도 네트워크를 통한 업데이트가 가능하도록 진화하고 있다. 이에 따라 네트워크에 대한 각 소프트웨어의 사이버보안 기술이 필수 기술로 논의가 되고 있다. 본 자료를 통해 자율주행 기술 트렌드 소개와 반도체 센서의 기술 동향, 이에 따른 사이버보안 기술과의 연관성 및 필요성에 대해 소개하고자 한다.

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AI 활용 사이버보안 코드 검증 및 테스트 케이스 자동화

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AI-driven Security Code Remediation and Test Case Generation

Won-young Chung*

Key Words : Cyber security(사이버보안), Static analysis(정적분석), Ai-driven security(AI기반보안), Test case generation(테스트케이스생성), Code remediation(코드결함수정), Rag(검색증강생성)

ABSTRACT

This research presents AI-driven approaches for enhancing cyber security code quality and automating test case generation.

First, we address the high false positive rate problem in AI code guidance. When static analysis tools detect code defects, our RAG-based system retrieves relevant coding rules and guidelines from a pre-constructed knowledge base containing organizational coding standards and security best practices. Unlike generic AI models, this retrieval-augmented approach provides precise, context-aware remediation guidance grounded in established policies. The system explains each defect clearly and offers actionable solutions aligned with domain-specific requirements, significantly reducing false positives.

Second, we develop a GAN-based automated test case generation system for CAN protocol security testing. The GAN model is trained on existing CAN protocol test cases to learn valid patterns and generate comprehensive test scenarios. A key feature is the continuous learning mechanism where failed test cases are incorporated back into the training dataset, enabling the model to iteratively improve its generation capabilities and achieve better test coverage organizational policies.

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민간 스마트선박 사이버보안 기반 조성 추진 현황

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Progress of Pribate Sector Initiatives to Establish a Cybersecyrity Framework for Smart Ships

Jimyung Kim*

Key Words : Smart Ship(스마트선박), Cybersecyrity(사이버보안), Cybersecurity Drill(모의훈련), Security Assessment (보안점검)

ABSTRACT

As advanced technologies such as AI and big data continue to converge with traditional industries, new forms of converged industries are steadily emerging. While these industries bring greater convenience and prosperity to our daily lives, they also introduce unforeseen risks and incidents.In particular, the maritime shipping industry, which serves as the backbone of national economic activity, is no longer operating in isolation. With the adoption of cutting-edge IT and OT technologies and the increasing connectivity between ship and shore, cyber threats traditionally seen in IT environments are now extending into the maritime domain. To address this, the Korea Internet & Security Agency (KISA) is promoting a cybersecurity internalization initiative that aims to proactively identify potential security threats in smart ships and provide various solutions to mitigate them. Through this presentation, KISA seeks to introduce the key activities and progress of its ongoing Smart Ship Cybersecurity Program.

AI와 빅데이터 등의 첨단 기술이 기존 산업과 융합되면서 새로운 융합산업이 지속 등장하고 있습니다. 이러한 융합산업은 우리의 삶을 더욱 편리하고 풍요롭게 만드는 동시에, 예기치 못한 사고를 초래하기도 합니다. 특히 국가 경제 활동에 필수적인 역할을 수행하는 해상 물류의 중심인 선박 산업도 더 이상 폐쇄적으로 운영되지 않고, 최신 IT 및 OT 기술을 도입하기 시작하며, 육상과의 통신 접점이 증가함에 따라 전통적인 IT 산업에서 발생하던 보안 위협이 선박 산업으로 전이되고 있습니다. 이에 한국인터넷진흥원(KISA)은 스마트선박에서 발생할 수 있는 보안 위협을 사전에 식별하고, 식별된 위협에 대응하기 위한 다양한 솔루션을 제공하기 위한 보안 내재화 지원 사업을 추진하고 있습니다. 이번 발표를 통해 KISA가 추진 중인 스마트선박 보안 사업에 대한 구체적인 내용을 소개하고자 합니다.

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자동차 사이버보안 관리체계(CSMS) 인증 절차

최병국* · 이민표** · 구성서***

Automotive Cybersecurity Management System (CSMS) Certification Procedure

Beoungkug Choi*, Minpyo Lee**, Seongseo Ku***

Key Words : Cybersecurity(사이버보안), UNR155/156, CSMS(사이버보안관리체제), SUMS(소프트웨어업데이트 관리체제)

ABSTRACT

South Korea implemented its automotive cybersecurity regulations starting in August 2025, mandating the compulsory application of cybersecurity measures to all vehicles produced and sold domestically. Europe also enforced its legislation from July 2024. To sell vehicles in both South Korea and Europe, vehicle manufacturers must establish a Cybersecurity Management System (CSMS) and a Software Update Management System (SUMS), apply cybersecurity to their vehicles, and obtain the corresponding certification for compliance. This document introduces the current state of cybersecurity in the automotive market and the trends in cybersecurity legislation, and it explains South Korea's Automotive Cybersecurity Management System (CSMS) certification procedure.

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친환경차 & 파워트레인

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

Jaeseung Lee*, Seohyung Cheon**, Jehyeok Rew***,†

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

Jiyun Han*, Suhyeon Kim*, Sujin Ko*, Heeyun Lee**

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

박건영* · Brilianto Rivaldo Mersis** · 안용수**이호길***

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

Jiyang Park*, Seongjae Ko*, Jaehwan Jeong*, Jinho Yang*, Byeongil Kim*, Changhwan Choi*, Haeden Lee*, Jongwoo Park*

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

김기후* · 이성윤** · 정한석** · 한종호*** · 윤윤기**** · 윤경수*****

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

Gi-Hu Kim*, Seong-Yun Lee**, Han-Seok Jung**, Jong-Ho Han***, Yun-Ki Yoon****, Kyung-Su Yun*****

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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차량 시스템 & 제도

차량 안정성 향상을 위한 타이어 마모 수명 조기 예측

조기연* · 황준수* · 이중호* · 최대원*

Proactive Prediction Method for Tire Wear Mileage to Enhance Vehicle Safety

Kiyoun Cho*, Junsu Hwang*, Joongho Lee*, Daewon Choi*

Key Words : Tread wear(트레드 마모), Mileage(주행거리), RandomForest(랜덤 포레스트), Safety(안전)

ABSTRACT

Tire wear is mostly evaluated using vehicles, which requires a test period of 1 to 2 months. Tread depth is recorded after a regular intervals, and the final predicted mileage is calculated at the end of the test. Although abrasion is also measured using tire weight, tread depth measurement is useful for predicting uneven wear and weak points of the tread pattern. Tread patterns that change due to wear are important factors for vehicle stability and wet handling. Especially, Tire wear is becoming increasingly important in autonomous vehicles, as it can cause unstable control due to reduced road contact, irregular vibrations and increased braking distance on roads. Initial prediction of wear performance can offer various benefits, such as reduced test costs and decreased safety risks for drivers. Although conventional regression analysis is often used for wear prediction, non-linear and low predictability of wear, and the need for a minimum of two or more data for prediction, it is used as a reference value. In this paper, we utilized Random Forest, a machine learning technique to predict tire wear mileage. To increase predictability, major wear factors were utilized, and also initial wear data was used for cost-effectiveness. Finally, the validity of the machine learning prediction method was confirmed through comparison with conventional regression and statistical analysis methods.

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주행특성 분석 기술을 이용한 스마트 타이어 시스템 성능향상에 관한 연구

신동철* · 김형석** · 박태성*** · 양동민**** · 송강종*****

Study on Enhancing the Performance of Smart Tire Systems Using Driving Behavior Analysis Technology

Dong Chul Shin*, Hyoung Seok Kim**, Tae Seong Park***, Dong Min Yang****, Kang Jong Song*****

Key Words : Smart Tire System(스마트 타이어 시스템), Driving Behavior(주행 특성), IMU(관성측정장치), On-road Experiment(실차 시험), Vehicle Dynamics(차량 거동)

ABSTRACT

Smart tire systems are an important technology for improving vehicle safety and driving performance. However, most current systems mainly use pressure and temperature data from inside the tire. This is not enough to clearly understand important factors like tire wear, load changes, and road surface conditions. To improve the system, it is helpful to include driving behavior data that shows how the vehicle moves during driving.

In this study, we developed a system that measures real-time vehicle dynamics using an Inertial Measurement Unit (IMU) sensor to capture acceleration and yaw, and a GPS sensor to measure speed. The system collects data during actual driving conditions, focusing on events such as acceleration, deceleration, and turning. From the collected data, key driving indicators such as acceleration, yaw angle, and jerk were extracted and compared against those measured by a high-precision reference sensor to evaluate accuracy and reliability.

Field tests demonstrated that the proposed system achieved more than 90% similarity in signal patterns, indicating sufficient performance in on-road conditions. The proposed technology shows strong potential for future applications such as tire wear prediction, driver behavior analysis, and vehicle stress evaluation in smart mobility platforms.

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CarMaker를 이용한 Euro NCAP 2026 프로세스 대응

이장우* · 박연수* · 조윤호**

Implementation of Euro NCAP 2026 Protocols Using CarMaker Simulation Environment

Jangu Lee*, Yeonsoo Park*, Yoonho Cho***

Key Words : Euro NCAP, Virtual Testing(가상 테스트), Virtual Driving Environment(가상 주행 환경), CarMaker (카메이커), Simulation(시뮬레이션)

ABSTRACT

In recent vehicle safety assessments, the significance of simulation-based approaches has been steadily increasing. Among the four evaluation areas defined by Euro NCAP, the Crash avoidance area introduces the VTA framework to evaluate Advanced Driver Assistance Systems (ADAS). This study presents the implementation and automation of a virtual simulation environment using CarMaker, incorporating diverse road models and scenarios to conduct VTA. This process includes In-house Qualification to validate the simulation tool and Final Scoring. Through this approach, this paper illustrates how CarMaker can be effectively utilized to fulfill the requirements of Euro NCAP 2026.

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주요국 자동차인증제도 및 인증산업에 대한 고찰과 시사점

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A Study on Vehicle Type-Approval Systems and the Homologation Industry in Major Countries: Implications and Insights

Judon Choi*

Key Words : Vehicle Type-Approval Systems(자동차인증제도), Component Type-Approval System(부품인증제도), Technical Service(기술서비스기관, 인증기관), Approval authority(인증당국), 1958 Agreement(1958협정), Homologation Industry(인증산업), Testing Lab.(시험소), Type Approval(형식승인), Self-Certification (자기인증)

ABSTRACT

Until now, homologation in the automotive sector has largely been addressed from an institutional perspective by the relevant stakeholders, and this perspective is expected to remain to some extent in the future. Since 2003, Korea has operated a self-certification system, under which certification is structurally limited from being regarded as an industry in its own right. By contrast, under the type-approval system adopted in most countries worldwide, homologation is considered an industry, and in fact its scale is already significant. Furthermore, with the advent of electric vehicles and automated driving, the potential for expansion of the homologation industry is growing even greater. Against this background, the present study compares the approval systems and the scale of the homologation industry in major countries, with the aim of examining the future direction of Korea’s regulatory framework from an industrial perspective and identifying appropriate responses.

지금까지 인증은 관련자들에 의해 제도적 관점에서 다루어지고 있고, 앞으로도 그 관점은 일정부분 유지될 것으로 예상된다. 한국은 2003년부터 자기인증제도를 운용 중에 있으며, 이 제도하에서 인증은 산업으로 여겨지기 어려운 구조적 한계가 있다. 그러나, 전세계 대부분의 국가가 채택하고 있는 형식승인제도하에서는 인증이 하나의 산업으로 여겨지고 있으며 실제 그 규모도 상당하다. 또한 전기차, 자율주행차 시대가 도래하면서 인증산업의 확대가능성은 더욱 커지고 있다. 따라서, 주요국가의 인증제도와 그에 따른 인증산업 규모를 비교고찰하여, 향후 한국 인증제도의 나아갈 방향을 산업적 측면에서 바라보고 대응하기위해 본 연구를 진행하였다.

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친환경 저상버스 도입 과제에 관한 실증연구; 도입 과제 우선순위를 중심으로

정민의* · 김범석** · 이양호***

An Empirical Study on the Introduction of Eco-Friendly Low-Floor Buses - Focusing on Prioritizing Challenges in Introduction

Min Eui Jeong*, Beomseok Kim**, Yang Ho Lee***

Key Words : Eco-friendly low-floor bus(친환경 저상버스), 도입(Introducing), Charging infrastructure(충전 인프라), Priority(우선순위)

ABSTRACT

This study is an empirical study on the challenges of introducing eco-friendly low-floor buses through an Analytic Hierarchy Process (AHP) questionnaire. The study found that charging infrastructure improvement was the top priority for introduction by Pairwise comparisons. This study is the first empirical study on the challenges of stakeholders and provides policy implications for promoting them.

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포스터 발표

차선 인지 기반 UKF 멀티 센서 로컬라이제이션

김민기* · 성윤모* · 이재풍**

Lane Detection-Based UKF Multi-Sensor Localization

Mingi Kim*, Yunmo Sung*, Jaepoong Lee**

Key Words : Lane-aided localization(차선보조 로컬라이제이션), Sensor fusion(센서 융합), Unscented kalman filter (무향 칼만 필터), Inertial measurement unit(관성측정장치), Wheel odometry(휠 오도메트리)

ABSTRACT

This paper presents a practical lane-aided localization approach that fuses GPS, an inertial measurement unit (IMU), wheel encoder odometry, and a fast lane detector (UFLD v1). The camera image is undistorted and converted to a simple bird's-eye view so that lane points are measured in meters near the vehicle. From these points we compute two intuitive observations: the lateral offset from the lane center and the heading difference between the vehicle and the lane. An Unscented Kalman Filter (UKF) combines these lane observations with short-term motion from IMU and wheel encoders, while GPS provides global position when available. The result is a stable and real-time localization output that reduces lateral drift and heading error when GPS is weak (e.g., tunnels or tree shade). The system runs on ROS and can be integrated into lane-centric autonomous driving stacks with minimal effort.

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등가강성 기반 R-MDPS 모델링 및 전차량 시뮬레이션 적용

김승한* · 정재일**

Equivalent-Stiffness Modeling of Rack-Driven EPS (R-MDPS) and Full-Vehicle Simulation

Seunghan Kim*, Jayil Jeong**

Key Words : Electric Power Steering(전동식 조향장치), Equivalent-Stiffness(등가강성), Adams Full-Vehicle Simulation (Adams 전차량 시뮬레이션), Ball Screw reducer(볼스크류 감속기).

ABSTRACT

propose an equivalent-stiffness steering model for rack-driven electric power steering (R-MDPS) that reproduces full-vehicle behavior at reduced computational cost. In the ball screw, contact at the ball-race interface and the axial, bending, and torsional compliances of the nut and screw are evaluated static structural analyses to obtain stiffness, preload and friction. these are then mapped to a spring-damper representation. we construct the steering subsystem in MSC Adams with joint-level constraints that reflect the physical relationship between the rack and the motor, the housing while applying external loads that the real vehicle imposes on the rack (lateral forces transmitted from the front tires through the tie-rods and steering-input-induced torques). Embedding this equivalent model in a full vehicle assembly, we predict responses under combined maneuvers while explicitly accounting for rack force. The result is a modeling that preserves the key force transmission characteristics of R-MDPS enables low resource simulation for design and calibration work.

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자동차 엔진제어기 하우징 유·무에 따른 열적 특성 평가

김우준* · 심우철** · 홍도영*** · 전유재****

Thermal Characteristics Evaluation of Automotive Engine Control Unit with and without Housing

Woojun Kim*, Woochul Sim**, Doyoung Hong***, Yujae Jeon****

Key Words : Engine Control Units(엔진제어기), Micom(마이컴), Thermal Damage(열손상), Driving Safety(주행안전성), Sudden Unintended Acceleration(의도하지 않은 가속)

ABSTRACT

This study investigates the behavior and driving safety of automotive Engine Control Units (ECUs) under thermal damage conditions. Thermal input was applied directly to the Micom location, starting at room temperature and increasing to 90 °C, then in 20 °C increments up to a maximum of 220 °C. When the housing cover remained in place, the surface temperature of the housing stabilized at approximately 160 °C, and the Micom temperature was maintained at about 60 °C, indicating normal ECU operation. However, when the housing cover was removed, the Micom surface temperature rose to approximately 220 °C, resulting in engine shutdown. Post-experiment X-ray imaging of the Micom revealed no structural abnormalities. It was concluded that when the Micom surface temperature exceeds 220 °C, damage to the internal conductor circuitry prevents normal ECU function. However, regardless of whether the housing was present or not, no sudden speed changes, malfunctions, or abnormal behaviors such as unintended gear shifting were observed before the engine stopped. The engine torque also remained within the normal range during brake operation. Under driving conditions, both the air flow and the air–fuel ratio remained close to 1, indicating stable and normal operation. These findings provide foundational data for understanding sudden unintended acceleration and abnormal automotive behavior induced by thermal input to the ECU.

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스마트 시티 환경 엣지 기반 차량 운행 안전 모니터링 단말기 설계 및 구현

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Design and Implementation of an Edge-Based Vehicular Safety Monitoring Device for Smart City Environments

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Key Words : Smart City(스마트시티), Edge Computing(엣지 컴퓨팅), Risky Driving Behavior(위험운전행동), Road Anomaly Detection(도로이상감지), Traffic Management(교통관리), FMS(차량관제시스템)

ABSTRACT

In recent years, the frequency of traffic accidents has shown a significant upward trend due to multiple converging factors such as risky driving behaviors, drowsy driving, driver distraction, and the presence of abnormal road conditions including potholes and surface irregularities. This study aims to reduce accident rates and protect human lives by designing and implementing an edge-based in-vehicle terminal that enables real-time monitoring of both driver behavior and road conditions within the context of smart city integration. The proposed device integrates three essential functional modules. First, eleven categories of risky driving behaviors such as rapid acceleration, sudden braking, and abrupt lane changes are analyzed in real time using vehicle speed and heading data. Second, an accelerometer sensor is employed to detect abnormal road conditions, including potholes, cracks, and uneven surfaces, thereby providing critical information for road infrastructure management. Third, the driver state is analyzed through a Driver Monitoring System. All detected events, along with contextual information such as event type, occurrence time, vehicle information, and location, are transmitted to a Fleet Management System via LTE communication. By edge computing, improving vehicle safety monitoring efficiency. The research shows that the proposed edge-based device can serve many stakeholders in a smart city. Transportation authorities can utilize the collected data for road maintenance planning, governments can formulate driver safety-related policies, and fleet operators can optimize vehicle operation management. Ultimately, this device contributes to the establishment of a safer and more sustainable transportation infrastructure, offering a practical solution to the rising challenges posed by hazardous driving behavior and deteriorating road environments.

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Design of an Anomaly Detection and Automatic Fire Notification System for Removable Battery Packs in Personal Mobility

Yoowon Kim*

Key Words : Personal Mobility(개인형 이동수단), Removable Battery Pack(탈착식 배터리), Thermal Runaway(열폭주), Automatic Fire Notification(자동소방신고), SMS(문자메시지)

ABSTRACT

The rapid expansion of personal mobility such as electric scooters and e-bikes has introduced significant safety challenges, particularly regarding the use of removable battery packs during household charging and storage. Lithium-ion secondary batteries, widely adopted in these devices, are prone to risks such as thermal runaway, gas emission, and overheating, which may lead to fire accidents. With the number of such incidents steadily increasing, early detection of battery anomalies and rapid notification to emergency services are essential. The purpose of this study is to present a design proposal for a compact system that performs anomaly detection and provides automatic fire notification for removable battery packs in personal mobility. The proposed system integrates three key sensors—gas, heat, and temperature—to continuously monitor abnormal battery conditions. Data collected from these sensors are processed by an embedded processor, which executes real-time detection algorithms to identify hazardous states, including excessive heating, abnormal gas release, and sudden temperature fluctuations. Upon detecting such anomalies, the system triggers a local alarm and transmits an automatic fire notification directly to fire departments via LTE or Bluetooth module. The expected outcome of this design is a practical and effective safety measure that significantly enhances fire prevention and emergency response for personal mobility battery packs. By minimizing the time delay between anomaly detection and fire notification, the system has the potential to reduce casualties, protect valuable property, and increase user trust in battery-powered personal mobility.

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저마찰 구간에서 자율주행 화물차의 미끄러짐 방지를 위한 안전 속도 산정 방법

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Determination of Safe Driving Speed for Preventing Skidding of Autonomous Heavy Trucks on Low-Friction Roads

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Key Words : Heavy vehicle(화물차), Skidding(미끄러짐), Safe speed(안전 속도), Low friction(저마찰 노면), Simulation (시뮬레이션)

ABSTRACT

Heavy vehicles are highly susceptible to skidding accidents on curved roads, particularly under low-friction conditions such as icy or snowy surfaces. This study presents a method to determine the safe driving speed of heavy vehicles on horizontal curves by analytically modeling the relationship among vehicle speed, road curvature, and tire–road friction. The proposed approach constrains both longitudinal and lateral tire forces within the available friction limit to prevent skidding. TruckSim–MATLAB co-simulations were conducted under low pavement friction coefficients, demonstrating that the proposed speed profile enables stable cornering without vehicle skidding while maintaining sufficient braking distance before curve entry. The results provide a practical basis for enhancing the safety of autonomous heavy vehicles operating on low-friction curved roads.

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AI 기반 자율주행 시스템의 엣지 케이스 차량 인지 한계 분석 및 안전성 개선 방안 연구

김형규* · 백세룡** · 최동민* · 김천호***

Edge-Case Vehicle Perception Limitations and Safety Improvement Study in AI-Based Autonomous Driving Systems

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Key Words : Autonomous Driving(자율주행), Edge-Case(엣지 케이스), Vehicle Perception(차량 인지), Fine-tuning (파인튜닝), Recognition Accuracy(인식 정확도)

ABSTRACT

The object recognition capability of autonomous driving systems has advanced considerably with AI-based models. However, the reliable detection of atypical vehicles—such as damaged cars or those with open trunks—remains a critical safety challenge. These edge cases deviate from standard appearances and often cause perception failures, posing serious risks in real-world scenarios. This study quantitatively analyzes the limitations of current perception models in recognizing such edge cases and proposes a data augmentation strategy to address them. A YOLO-based model was employed as the baseline to evaluate detection performance and identify weaknesses. To overcome data scarcity and enhance diversity, a synthetic dataset of atypical vehicles was generated using a vehicle simulation environment, incorporating variations in damage, trunk opening, and lighting conditions. The combined use of synthetic and real-world data was applied to fine-tune the baseline model. Experimental results demonstrate that synthetic data augmentation effectively mitigates perception failures. These findings underscore the importance of including edge-case data in training to ensure the reliability and safety of autonomous driving systems.

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차량 내 저주파 자기장 인체 노출량 평가 연구

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Evaluation of Low-Frequency Magnetic Field Human Exposure in Vehicles

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Key Words : Electromagnetic field exposure(전자파 인체노출), KS C 3380 standard(KS C 3380 표준), Low-frequency magnetic field(저주파 자기장), Human safety assessment(인체 안전성 평가), Vehicle interior measurement (차량 내부 측정)

ABSTRACT

Recently, concerns over the safety of human exposure to electromagnetic fields (EMF) have significantly increased worldwide. In response, Korea legislated human protection standards for electromagnetic fields through Article 47-2 of the Radio Waves Act in 2002. These standards regulate limits on specific absorption rate (SAR), electric field strength, and magnetic field strength, maintaining levels comparable to guidelines recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

In this study, the domestic standard KS C 3380 was applied to evaluate low-frequency magnetic field exposure inside vehicles, targeting both internal combustion engine vehicles and electric vehicles. EMF exposure characteristics were comparatively analyzed according to measurement locations and vehicle operational conditions, including constant-speed driving and stationary states. The results are intended to serve as foundational data for the establishment of future EMF safety standards and policy development.

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건설기계 전기전자 분야 관리체계 개선에 관한 연구

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A Study on the Improvement of the Management System in the Electrical and Electronic Sector of Construction Machinery

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Key Words : Construction Machinery(건설기계), Safety(안전), Standard(표준), Electric(전기), Electronic(전자)

ABSTRACT

The construction industry continues to experience a high incidence of accidents, and with the recent enactment of the Serious Accidents Punishment Act, companies have increasingly promoted the development of advanced safety devices by integrating IT technologies with various sensors and control systems. As a result, the application of electrical and electronic components in construction machinery has expanded significantly. In Korea, the Construction Machinery Management Act provides the institutional framework for the regulation and promotion of the construction machinery industry. The purpose of this study is to support the advancement of the Rules on Safety Standards for Construction Machinery by reviewing the electrical and electronic provisions within its common clauses, along with applicable domestic and international standards, in order to identify and propose quantifiable elements. The findings of this study are expected to serve as a critical reference for future policy development, particularly when further validated through in-depth research and expert evaluation at the national level.

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복수 노선 차량 기반 불법 주정차 자동 인식 및 신고 시스템

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A Multi-Vehicle Based System for Automated Detection and Reporting of Illegal Parking

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Key Words : Autonomous driving(자율주행), Object detect(객체 인지), Perception performance evaluation(인지 성능 평가), Sensor fusion(센서 융합), Deep learning(딥러닝)

ABSTRACT

Illegal parking is a persistent urban issue that undermines road safety and traffic efficiency. Conventional enforcement methods, such as patrol vehicles and fixed CCTV systems, are constrained by limited coverage and high labor costs. To address these limitations, this paper proposes a system that leverages multiple route vehicles, such as buses, equipped with license plate recognition and GPS modules to automatically detect and report illegally parked vehicles. During normal operation, each vehicle continuously records surrounding license plates along with their GPS coordinates, and the collected data are transmitted to a central server. The server aggregates and analyzes duplicate detections from multiple vehicles, determining illegal parking only when the same license plate is repeatedly observed at the same location by different vehicles, thereby minimizing false positives. The proposed system offers three major advantages: (1) enhanced reliability through multi-vehicle cross-validation, (2) wide-area coverage without the need for dedicated patrols or fixed infrastructure, and (3) efficient centralized management through server-based aggregation and analysis. By integrating existing public transportation fleets with intelligent enforcement technologies, this approach enables automated, reliable, and scalable illegal parking management.

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인체 모델의 주요 신체 부위별 생체충실도 평가

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Evaluation of the Biofidelity of a Human Body Model for Key Body Regions

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Key Words : Human body model(인체모델), Biofidelity(생체충실도), Finite element(유한요소), Thorax(흉부), Spine (척추), Neck(경부)

ABSTRACT

The advancement of autonomous driving technology has enabled diverse in-vehicle seating arrangements, raising the need for occupant safety evaluation in novel configurations such as rear-facing seats. Although Post-Mortem Human Subject (PMHS) experiments provide fundamental insights, the limited number of available tests limits the amount of data that can be collected. Finite element human body models (HBMs) have emerged as an effective alternative; however, previous studies have identified limitations in the biofidelity of HBMs in replicating the complex kinematics of rear-facing occupants. Therefore, to enhance the reliability of simulations, a systematic biofidelity validation of key body regions—the thorax, spine, and neck—is required.

In this study, the biofidelity of the HBM was evaluated and improved by comparing simulation outcomes with PMHS experimental data associated with injury mechanisms in each body region. Specifically, the thorax was validated by comparing chest deflection against PMHS data under four loading conditions: single belt, double belts, distributed belt, and hub impact. The spine was evaluated through dynamic analyses of six loading modes at the L3–L4 level and eight loading modes at the T12–L5 level, focusing on moment–angle and force–displacement responses. For the neck, rear-impact (4G) conditions were analyzed with emphasis on head angle variations and comparison to experimental corridors. The findings of this study provide a fundamental basis for enhancing the predictive accuracy and reliability of HBM simulations under diverse crash environments.

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ISO26262 차량 기능안전 – 계층적 안전 컨셉

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ISO26262 Automotive Functional Safety - Layered Safety Concept

Ilnam Park*

Key Words : Functional safety(기능안전), Safety concept(안전컨셉), Safety architecture(안전 아키텍처)

ABSTRACT

The complexity of automotive electronic control systems increases the likelihood of diverse faults at the controller level. ISO 26262 requires establishing a vehicle-level safety concept to achieve safety goals (SGs), but this often remains abstract and does not clarify how it can be implemented at ECU or SoC level. To address this gap, controller-level safety concepts must present a static safety architecture, defined as a set of elements and their interactions to fulfill safety requirements. However, conventional block diagrams, which merely include safety mechanism blocks alongside functional ones, are limited in showing which faults in lower-level functional blocks can actually be detected by specific mechanisms.

This paper proposes a Layered Safety Architecture that separates the Intended Function Layer and the Safety Mechanism Layer. The intended function layer includes ECU functions such as signal acquisition, torque calculation, and actuator control. The safety mechanism layer covers monitoring functions such as sensor plausibility checks, watchdogs, and fallback strategies. By mapping faults in functional blocks to their detectability by monitoring mechanisms, the approach makes explicit which faults are covered and which remain uncovered.

The methodology is illustrated using the E-gas concept. In this example, throttle control functions are monitored by redundant sensors, plausibility checks, and actuator feedback monitoring. The layered representation clearly demonstrates the relationship between fault sources and their detectability by safety mechanisms.

The proposed approach provides a systematic way to communicate controller-level safety concepts beyond conventional block diagrams. It highlights the strengths and limitations of monitoring mechanisms and offers a reference framework for designing and evaluating safety concepts in compliance with ISO 26262.

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EV 컨버전 1톤 트럭의 배터리 연결 프레임 단면 형상에 따른 구조해석 연구

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Structural Analysis Study on the Cross-Sectional Shape of the Battery Connection Frame of a 1-Ton EV Conversion Truck

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Key Words : Vehicle safety(자동차 안전), Electric vehicle(전기 자동차), EV conversion(전기자동차 변환), Structural analysis(구조해석)

ABSTRACT

According to the Life Cycle Assessment (LCA) of automobiles, eco-friendly vehicles produce significantly lower greenhouse gas emissions during operation, while internal combustion engine vehicles (ICEVs) have relatively low carbon emissions during manufacturing. Based on these environmental benefits, various studies are being conducted on EV conversions, which convert existing ICEVs to electric vehicles without scrapping them. This study aims to design a frame specifically designed for ICEs to prevent fatigue deformation and breakage at the connection point where a heavy battery is mounted. The target vehicle model was a compact 1-ton truck, a common type of truck in Korea, which is easier to convert than passenger vehicles. The actual vehicle frame was 3D scanned and reverse-engineered to create a 3D model using Fusion 360. Previous studies have used simple, easy-to-install L-shaped brackets for experiments. Analysis results have shown that the brackets are prone to deformation during long-term operation, and impacts can cause welds to break, potentially damaging the main frame. Accordingly, this study designed a subframe mounting method that minimizes damage to the main frame and is easy to replace, and measured and compared the structural safety according to the cross-sectional shape of the subframe pipe to suggest the optimal cross-sectional shape.

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MORAI 시뮬레이터를 활용한 자율주행 교통사고 재현 및 차량 거동 분석 연구

송치원* · 홍 준** · 백세룡*** · 이기범****

Autonomous Vehicle Traffic Accidents Reconstruction and Vehicle Behavior Analysis Using the MORAI Simulator

Chiwon Song*, Jun Hong**, Seryong Baek***, Kibeom Lee****

Key Words : MORAI Simulator(모라이 시뮬레이터), Traffic Accident(교통사고), Accident Recontruction(사고 재현)

ABSTRACT

With the increasing adoption of autonomous vehicles, accidents caused by interactions with human drivers have also been on the rise. Consequently, the need for systematic analysis of traffic accidents involving autonomous vehicles has become more critical. Such accident simulations require higher levels of realism and accuracy than ordinary autonomous driving simulations, and the precise reconstruction of vehicle behavior during accident scenarios is a key requirement. In this study, scenarios corresponding to SAE Level 3–4 conditions were defined to reproduce traffic accident cases of autonomous vehicles. These scenarios were implemented using the MORAI autonomous vehicle simulator, through which the consistency of vehicle behavior in autonomous driving accident situations and the validity of simulation-based accident reconstruction were verified.

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마찰 특성의 벤치마킹 분석을 통한 복합재 브레이크의 제동 성능 고찰

심재훈* · 황세라* · 심형식* · 김성신* · 유 강** · 김성완*** · 이성주**** · 신재호*****

A Study on Braking Performance of Composite Brake through Benchmarking Analysis of Friction Characteristics

Jaehun Shim*, Sera Hwang*, Hyungshik Shim*, Sungshin Kim*, Kang Yoo**, Sungwan Kim***, Sungjoo Lee****, Jaeho Shin*****

Key Words : Composite Brake Disc(복합재 브레이크 디스크), SiC(탄화 규소), Friction Characteristic(마찰 특성), Cu Free Friction Material(구리 배제 마찰재), Friction Material(마찰재)

ABSTRACT

Carbon ceramic composite brake is widely applied in high-end vehicles of many car manufacturers and we have also developed our unique carbon ceramic composite brake to compete with our competitors for a long time. Although carbon ceramic composite disc has excellent mechanical properties such as thermal and wear properties, we found it weakness generating cracks between friction layer and loading layer under salt water environment. So, we improve this weakness for the new carbon ceramic composite disc. In this paper, we suggest the new fiction material for the new carbon ceramic composite disc. To do this, we set up the criteria of friction characteristics through benchmarking. Sequentially, a variety of tests such as stability of friction coefficient, braking temperature rise are conducted to confirm its friction characteristics. In addition, we consider regulation of heavy metal in the friction material and development direction setup to response it. Finally, we hope that this study is used to principal research for the new carbon ceramic composite brake.

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고속 정면 충돌 환경에서 후향좌석 탑승자 보호를 위한 에어백 영향 평가 및 HBM 거동 비교

안용진* · 정대창** · 정가람** · 이동길** · 김성래*** · 김태웅*

Assessment of Airbag Effects and Human Body Model Responses for Rear-Facing Seat Occupants in High-Speed Frontal Collisions

Yong-Jin An*, Dae-Chang Jung**, Ga-Ram Jeong**, Dong-Gil Lee**, Sung-Rae Kim***, Tae-Wung Kim*

Key Words : Rear-facing seat(뒤보기 시트), Post-mortem human subjects(사후 인간 피험자), Human body model(인체 모델), Finite element(유한요소), Head injury criterion(머리 상해치), Rib fracture(갈비뼈 골절)

ABSTRACT

With the advancement of autonomous driving technology, seating arrangements are diversifying, and front seats may rotate 180 degrees to face the rear in future vehicles. Such configurations increase the risk of severe injuries during high-speed frontal collisions, as confirmed by recent Post Mortem Human Subject (PMHS) tests, underscoring the need for new restraint systems. Since no crash test dummies currently replicate human kinematics in this scenario, Human Body Models (HBMs) have emerged as a viable alternative.

This study evaluates the protective effects of airbag deployment and compares the responses of two HBMs: the Global Human Body Models Consortium (GHBMC) and the Total Human Model for Safety (THUMS). A simulation environment was developed using manufacturer-provided seat and cockpit models, and sled pulses identical to physical tests were applied. Results showed that airbag deployment significantly reduced head and thoracic injuries in both models.

In conclusion, this work quantifies airbag protection and highlights behavioral differences between HBMs, providing a basis for future crash safety assessments under diverse seating configurations.

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자동차 주행 중 발생하는 BSR 진단 프로세스에 관한 연구

유종구* · 이원철** · 손성배*** · 손선익****

A Study on the BSR Diagnostic Process Occurring During Automotive Operation

Jonggoo Yoo*, Wonchul Lee**, Sungbae Son***, Suneik Son****

Key Words : Noise observe(노이즈 옵저버), BRS(버즈, 스퀵, 래틀), Assembly Tolerance(조립 공차), Abnormal Noise (이상 소음), Automotive Quality(자동차품질)

ABSTRACT

This study quantitatively analyzes Buzz, Squeak, and Rattle (BSR) noises occurring during automotive operation and proposes methods for diagnosis and repair to enhance automotive safety and comfort. Drivers typically perceive automotive abnormalities through auditory and visual cues, with warning lights and sounds controlled by an integrated system of sensors, controllers, and actuators. However, BSR noises originate from mechanical interactions such as friction and gaps between suspension components, exhaust systems, doors, and body panels, often serving as early indicators of potential automotive defects. In this research, a automotive exhibiting a rattle noise during inertial driving (from 60 km/h to 30 km/h at 1,300 rpm) was examined. Utilizing Noise Observer technology, the noise source was localized to the first exhaust muffler bellows. Structural investigations revealed assembly tolerances that caused differential gaps between the hanger bracket and the automotive body (7 mm on the left side and 3 mm on the right), correlating with noise generation on the left. By inserting shims to reduce the larger gap, both audible noise and abnormal vibration signals measured by the Noise Observer were effectively eliminated. This demonstrates that even minor structural variations can induce mechanical stress and vibrations contributing to BSR noise. Additionally, analysis of engine assembly deviations highlighted how manufacturing tolerances affect noise generation. The findings emphasize the importance of combining advanced measurement tools with deep learning-based diagnostic algorithms for accurate noise source identification. Such integration enables timely maintenance, reduces misdiagnoses, and improves overall automotive quality. This study provides practical methodologies for manufacturers to address BSR noise challenges in modern automotive system, where tighter component clearances and higher performance demands increase susceptibility to such issues.

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NVIDIA Omniverse 기반 디지털 트윈 시뮬레이션을 활용한 가상 주행 데이터 검증 연구

이은지* · 우태걸* · 이수천* · 이세훈* · 정세연** · 권희재** · 박강문***

Validation of Virtual Driving Data Using a Digital Twin Simulation Based on NVIDIA Omniverse

Eunji-Lee*, TaeGeol Woo*, Su-cheon Lee*, Sehun Lee*, Hee Jae Kwon*, Jungse Yeon*, Kang-moon Park***

Key Words : Digital Twin(디지털 트윈), Nvidia Omniverse(엔비디아 옴니버스), Simultation Data(시뮬레이션 데이터), Automotive Driving Data(자동차 주행 데이터)

ABSTRACT

Acquiring edge cases and rare driving scenarios, such as aggressive or abnormal driving, in real-world data collection is limited by cost and time constraints. Moreover, intentionally generating such rare situations in real-world environments is practically challenging. In order to overcome these limitations, research is increasing to generate simulation data constructed through a digital twin environment. However, for the generated virtual data to be effective, the results extracted from the simulation environment must closely resemble real-world observations, necessitating a systematic validation framework. In this study, we construct a simulation environment identical to the real-world setting based on measured data using NVIDIA Omniverse. This study aims to verify the practical utility of the omnibus virtual data through comparative analysis with actual data. To verify this, a simulation is executed in the same environment, and quantitative comparison is performed on the extracted driving data through time series consistency of the actual vehicle data, the reconstruction error, etc. Through this quantitative comparison, it can be demonstrated that the omnibus virtual data can sufficiently simulate the actual data. As a result, the existing real-vehicle data and omnibus output data show very high similarity, which can reduce costs and free driving environment configuration, and support the effectiveness of using driving data generated by digital twins as an alternative to real-vehicle.

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차량 경량화 및 안전성 향상을 위한 TPMS 구조 소재의 충격 특성 시뮬레이션 연구

임세준* · 정석환** · 임성한***

A Study on the Simulation of Impact Characteristics of TPMS Structural Materials for Vehicle Lightweighting and Safety Improvement

SeJun Im*, SeokHwan Jung**, Sung-Han Rhim***

Key Words : Triply periodic minimal surface(삼중 주기 최소 표면), Lightweight design(경량 설계), Energy absorption (에너지 흡수), Finite element analysis(유한요소해석)

ABSTRACT

현대 자동차 산업에서 차체 경량화와 충돌 안전성 확보는 상충되는 핵심 설계 과제이다. 이에 대한 해결책으로, 높은 비강도와 에너지 흡수 효율을 지닌 삼중 주기 최소 표면(Triply periodic minimal surface, TPMS) 구조를 구현한 소재의 차량 부품 적용 가능성이 주목받고 있다. 그러나 이러한 TPMS 기반 구조의 기하학적 매개변수와 충격 성능 간의 관계에 대한 정량적 데이터는 아직 부족하다.

본 연구는 슈바르츠 다이아몬드(Schwarz Diamond) TPMS 구조를 기반으로, 차량용 충격 흡수 부품(범퍼 빔, 에너지 흡수재, 크래시 박스 등)의 경량 설계를 위해 설계 변수에 따른 낙하 충격 응답을 정량적으로 분석하였다. 단위 셀 크기(10-20 mm), 회전 각도(0°-45°), 상대 밀도(50%-80%)를 조합한 48개 조건을 설정하였다. ABS(Acrylonitrile Butadiene Styrene) 시편을 이용한 낙하 실험을 통해 유한요소 시뮬레이션 모델을 검증하였으며, 시뮬레이션 결과와 비교 시 오차는 6% 미만이었다. 이후 모든 조건은 50J 충격 하에서 시뮬레이션을 통해 분석하였고, 충격 흡수 성능은 크레이터 깊이로 평가하였다.

분석 결과, 크레이터 깊이는 상대 밀도 증가에 따라 선형적으로 감소했으며, 셀 크기와 회전 각도는 비선형적 반응을 보였다. 최적 조건에서는 0.49 mm, 최악 조건에서는 2.47 mm의 깊이를 나타냈으며, 회귀모델(R^2=0.93)을 통해 성능 예측도 가능함을 확인하였다. 이는 향후 TPMS 구조를 활용한 차량 부품의 초기 설계 단계에서 고려할 수 있는 유용한 참고 자료가 될 수 있다.

이 논문은 2025년도 정부(산업통상자원부)의 재원으로 한국산업기술진흥원의 지원을 받아 수행된 연구임(RS-2023-KI002686, 2025년 산업혁신인재성장지원사업)

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임베디드 에지 디바이스 기반 다종 센서 통합 아키텍처 설계 및 구현

임재원* · 문성철* · 김인수** · 박재홍***

Design and Implementation of an Embedded Edge Device-Based Multi-Sensor Fusion Architecture

J.W. Lim*, S.C. Moon*, I.S. Kim**, J.H. Park***

Key Words : Embedded edge computing(임베디드 에지 컴퓨팅), Low-latency data path(저지연 데이터 경로), On-board sensor networking(온보드 센서 네트워킹)

ABSTRACT

In field edge environments for autonomous driving or industrial safety, perception results from cameras, LiDAR, and radar must be fused with low latency and high reliability; however, limited compute/memory budgets and both data copies and UDP non-determinism undermine real-time performance. We design and implement a unified data path comprising a zero-copy camera pipeline, a shared-memory–based inter-process data exchange layer, and a single SPI fusion/egress endpoint to simultaneously reduce copy overhead and latency variability. The proposed architecture integrates UDP-ingressed LiDAR/Radar detections and on-board vision processing within the same pipeline: a shared-memory–based inter-process data exchange layer that enables low-copy transfer, while the single SPI endpoint executes final fusion and deterministic output. Our prototype confirms the feasibility and functional correctness of the unified pipeline under edge constraints.

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컷아웃 상황에서 정지 보행자와 차량 표적에 따른 자율주행자동차의 반응 특성 차이 연구

조준성* · 정재일**

A Study on the Differences in Response Characteristics of Autonomous Vehicles to Stationary Pedestrian and Vehicle Targets in a Cut-Out Situation

Jun Seong Jo*, Jayil Jeong**

Key Words : Autonomous Vehicle(자율주행자동차), Cut-Out Scenario(컷아웃 시나리오), Stationary Pedestrian(정지 보행자)

ABSTRACT

Standard Euro NCAP safety protocols for autonomous systems primarily focus on vehicle-to-vehicle scenarios. This study investigated system responses to vulnerable road users by modifying the Euro NCAP 'Cut-Out' protocol, replacing the standard stationary vehicle target with a stationary pedestrian dummy. The differences in system reactions were quantitatively analyzed under identical dynamic conditions, focusing on the activation timing of Forward Collision Warning (FCW) and Autonomous Emergency Braking (AEB), deceleration initiation, and peak deceleration. The results revealed clear differences in system response. This suggests limitations in current sensor perception or decision logic for atypical stationary pedestrians and highlights the need to enhance system capabilities and test protocols to improve pedestrian safety.

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실험실 환경에서 차량 내부의 외부 오염물질 측정을 위한 CFD 기반 가스상 오염물질 분사 위치 최적화

최규권* · 유성식** · 하성용*** · 이흥식****

CFD-Based Gaseous Pollutant Injection Location Optimization for Measuring External Pollutants Inside a Vehicle in a Laboratory Environment

Kyu Kwon Choi*, Sungsik Yoo**, Sung Yong Ha***, Heung Sik Lee****

Key Words : CFD(전산 유체 해석), Wind Tunnel Test Chamber (풍동실험실), Exterior Pollutant Material(외부 오염물질), $k-\omega$ Turbulence Model($k-\omega$ 난류 모델), Case Study(사례 연구)

ABSTRACT

On-road driving is essential for evaluating the infiltration of external pollutants into vehicle cabins; however, quantitative comparisons are limited due to the difficulty of controlling environmental conditions. To overcome this limitation, laboratory experiments are conducted in which a blower reproduces driving airflow, and external pollutants are injected into the airflow within a controlled chamber. Since installing the injection device inevitably risks damage to the experimental equipment, selecting the optimal injection location is crucial. In this study, the flow behavior of NO_2 was analyzed using computational fluid dynamics (CFD) considering various injection locations inside the blower. NO_2 was injected at arbitrary positions while the blower rotor operated at a constant speed for 10 seconds. The NO_2 mass fraction was measured at designated points on the bonnet, and four injection locations were compared and analyzed for both SUV and sedan vehicles. The results indicated that Case-4 produced the highest NO_2 mass fraction for the SUV, whereas Case-1 yielded the highest value for the sedan. When the average results across both vehicle types were considered, Case-4 exhibited the highest concentration, suggesting that it represents the optimal injection location for pollutant introduction within the blower.

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PC-Crash 상해 정도 분석 결과를 적용한 자동차 기능 안전 위험 상황 심각도 설정 방법론

최영준* · 천동준**

Methodology for Determining Hazard Severity in Functional Safety Using PC-Crash Injury Analysis

Youngjun Choi*, Dongjoon Chun**

Key Words : Hazard analysis and risk assessment(위험 요소 분석 및 위험 평가), Functional safety(기능 안전), Abbreviated injury scale(미국의 약식 상해 등급), Safety integrity level(안전 무결성 등급), Pc-crash(피씨 크래시), Severity(심각도)

ABSTRACT

The modern automotive development industry is rapidly transitioning from traditional mechanical component-based designs to Electrical/Electronic (E/E) system-oriented architectures, bringing increased attention to safety issues arising from E/E system malfunctions. The international standard ISO 26262 regulates the determination of the Automotive Safety Integrity Level through Hazard Analysis and Risk Assessment using three parameters: Severity, Exposure, and Controllability. However, Severity is currently assessed mainly from a qualitative perspective, limiting its ability to quantitatively reflect actual accident risks. This study proposes a quantitative assessment method for Severity by employing the widely used accident analysis software PC-Crash to simulate vehicle–pedestrian collisions and applying the Abbreviated Injury Scale to the simulation results. The proposed approach enables the derivation and integration of safety requirements into E/E system design and development, providing a more realistic basis for functional safety integrity management in the automotive domain.

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횡방향 안정성 향상을 위한 능동 현가장치 제어 전략 연구

하현식* · 김태빈* · 안가연* · 신현승* · 우승훈**

Active Suspension Control Strategies for Improving Lateral Stability

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Key Words : Active suspension(능동 현가장치), Stability(안정성), Lateral(횡방향), Tilting control(기울임 제어)

ABSTRACT

Modern vehicle suspension systems have evolved from conventional passive damper and coil spring configurations to semi-active systems and air spring technologies. Recently, active suspension systems have begun to be selectively applied to premium vehicles. Conventional active suspension strategies have primarily focused on controlling roll and pitch motions to enhance ride comfort.

In this study, a tilting control strategy is proposed and experimentally validated as an alternative to conventional roll suppression approaches. Tilting control refers to a method that intentionally inclines the vehicle body toward the inside of the corner during turning maneuvers. This strategy effectively reduces the lateral acceleration perceived by the driver, minimizes vertical load transfer between the inner and outer sides of the vehicle, and improves tire grip, thereby offering a distinct advantage over traditional roll suppression control.

To evaluate the effectiveness of the proposed control strategy, a ramp steering maneuver was conducted. The results show that the vehicle equipped with the tilting control exhibited superior performance in terms of yaw rate and lateral acceleration compared to both a conventional vehicle and a vehicle with suppressed roll motion control. This indicates that the tilting control strategy enhances the lateral limit performance and overall lateral stability of the vehicle during cornering.

These findings demonstrate that the proposed tilting control strategy can more effectively improve lateral stability compared to conventional roll suppression control. Furthermore, the results suggest that this approach has strong potential to improve vehicle stability under extreme driving conditions, such as high-speed cornering and rapid lane changes, particularly for future electrified vehicles.

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e-Axle 시스템의 기능안전설계 및 안전목표에 관한 연구

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A Study on the Functional Safety Design and Safety Goals of the e-Axle System

Jongho Han*, Gyedo Park**, Bonggyun Jo***, Bongseob Kim***, Kyungsu Yun****

Key Words : Safety Goal(안전목표), Functional Safety Concept(기능적안전개념), e-Axle(전동액슬), Electric Vehicle (전기자동차), Traction Motor(구동모터)

ABSTRACT

본 논문은 e-Axle 시스템에 대한 위험원 분석 및 리스크 평가(HARA: Hazard Analysis and Risk Assessment)를 기반으로 안전목표(SG: Safety Goal) 및 기능적 요구사항(FSC: Functional Safety Concept)을 도출하고 이에 대한 연구를 수행하였다. 먼저 개발 대상인 e-Axle 시스템에 대해 기술적 조사 및 분석을 실시하였으며, 이를 바탕으로 잠재적인 위험요소를 식별하고 환경 조건을 고려한 리스크 분석을 통해 안전목표 및 기능적 요구사항을 정의하였다. 본 연구의 목적은 개발 중인 e-Axle 시스템을 적용한 차량의 전자전기 시스템(HW 및 SW)에 대한 기능 안전성을 확보하는 데 있다.

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카메라 센서 악의 상황에서 ADAS 성능 평가를 위한 VILS 환경 구축

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VILS Environment for Evaluating ADAS Performance in Adverse Camera Sensor Conditions

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Key Words : ADAS(첨단 운전자 보조 시스템), Adverse Sensor Condition(센서 악의 상황), Vehicle-in-the-Loop Simulation (차량 포함 루프 시뮬레이션),

ABSTRACT

Many functions of ADAS (Advanced Driver Assistance Systems) have become highly dependent on camera sensors. During driving, cameras may experience failures under various environmental conditions, and their performance can also degrade due to factors such as lens breakage or dust contamination. However, research on whether ADAS can operate safely under such adverse conditions remains limited. In this study, three major adverse scenarios-dust contamination, lens breakage, and camera failure-were defined, and a DCGAN-based model was designed to generate degraded images. An overlapping algorithm was developed to synthesize these generated images with video data. Through this algorithm, real-time images acquired from vehicle sensors can be transformed into representations reflecting faults, dust, or breakage. To evaluate ADAS performance when interacting with surrounding vehicles under such adverse sensor conditions, the proposed fault-image generation algorithm was applied to the sensor environment of the autonomous driving simulator (MORAI SIM), and a Vehicle-in-the-Loop Simulation (VILS) framework was constructed with an autonomous vehicle. This enables the analysis of performance for lane keeping, emergency braking, and emergency steering under adverse sensor conditions.

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초저상 스키드 조향 로봇의 경로 추종 향상을 위한 토크 최적화 알고리즘

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Torque Optimization Algorithm for Enhanced Path Following in Low-Profile Skid-Steering Robots

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Key Words : Skid-steering robot(스키드 스티어링 로봇), Torque distribution(토크 분배), Motor current allocation(모터 전류 할당)

ABSTRACT

This study fundamentally addresses the problem of target path following performance degradation resulting from hardware design uncertainties in low-profile 4WD skid-steering robot platforms. Conventional skid-steering control systems only distribute motor current into two groups thereby losing the opportunity for active compensation of individual driving wheel dynamic imbalances. This deficiency acts as a primary cause of critical path deviation and lateral instability, particularly in situations demanding high maneuverability. To overcome these limitations and ensure the robot's precision controllability, this paper proposes a 4-wheel individual torque optimization and distribution algorithm. The proposed algorithm is based on the robot's accurate dynamic model and comprehensively considers real-time path errors and vehicle dynamic states to calculate and assign the optimal Torque Vector required for each wheel. This approach effectively cancels out hardware uncertainty factors within the control domain, minimizes driving Slip, and thus secures the robot's lateral stability and path-following accuracy. The performance and robustness of the proposed control scheme were experimentally verified through complex driving scenarios, including S-curve path following and high-speed cut-in maneuvers.

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