Perception And Sensing For Autonomus Vehicle Under Adverse Weather Conditions

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Abstract- *Combining distributed computing and vehicular networks, particularly vehicular clouds is crucial for advancing traffic analytics.Deep learning, a subset of machine learning employing artificial neural networks, is crucial for tasks like vehicle path tracking, path prediction, and congestion detection in road traffic analysis. Despite the traditional use of vehicular ad-hoc networks (VANET) for congestion detection, recent approaches incorporate data mining techniques. However, integrating a mechanism that encompasses detection, control, and prediction of both recurrent and non-recurrent traffic congestion remains challenging.This project aims to compare the effectiveness of data mining and VANET in detecting, controlling, and predicting road traffic congestion. Leveraging the computational power of cloud workers and vehicles, a framework is proposed using a Support Vector Machine (SVM) algorithm. The framework operates at three levels: vehicles, roadside units (RSUs), and a cloud worker. Vehicles collect data on their driving behavior and nearby vehicles, while RSUs gather and transmit data to the cloud worker. The cloud worker employs the SVM algorithm for traffic congestion detection and identifying reckless vehicles.*

Keywords- Adverse weather, Decision-making, Automated Driving Systems, Deep Learning.

I. LITERATURE SURVEY

1.1 MACGAN: AN ALL-IN-ONE IMAGE RESTORATION UNDER ADVERSE CONDITIONS USING MULTIDOMAIN ATTENTION-BASED CONDITIONAL GAN

The Multidomain Attention-based Conditional Generative Adversarial Network (MACGAN) is proposed to address challenges in vision-related tasks caused by adverse weather conditions and marine navigation issues. MACGAN, featuring a lightweight architecture and multiple attention blocks, aims to enhance scene visibility for ground, aerial, and marine navigation domains in a unified manner. Extensive qualitative and quantitative comparisons demonstrate MACGAN's superiority over existing models in image restoration quality and scene visibility improvement. Clear images are crucial for high-level vision tasks, prompting extensive research in image restoration, with methods tackling adverse weather conditions and underwater tones. Models considering atmospheric effects, such as mist and fog, contribute to improved defogging results. The uneven distribution of raindrops is addressed by a draining model that constructs rain-free images through attention to characteristics on various scales. Adverse weather conditions impacting autonomous vehicle vision underscore the need for effective image interpretation to ensure optimal decision-making. Literature methods, including model-based approaches and attention-based deep neural networks, contribute to advancements in image restoration and degradation removal. methods.

1.2RADARS FOR AUTONOMOUS DRIVING: A REVIEW OF DEEP LEARNING METHODS AND CHALLENGES

Autonomous vehicles heavily rely on radar as a crucial component of their perception sensor suite, excelling in long-range detection, occlusion handling, and reliable operation in adverse weather. However, radar data faces challenges like limited resolution, sparsity, clutter, uncertainty, and a lack of high-quality datasets, hindering progress in radar deep learning research. The paper discusses issues such as early and late fusion, occupancy flow estimation, uncertainty simulation, and multiple paths detection, aiming to encourage further exploration of deep learning applications in autonomous radar data. It also provides insights into state-of-the-art lidar and vision models relevant to radar research, offers a curated selection of recent radar datasets, and explores radar basics and data representation. As electric and hybrid vehicles pursue higher autonomy levels, the perception system, integrating cameras, lidars, and radars, faces challenges in diverse scenarios, making early fusion models crucial for reliable unified detection results. The analysis delves into the characteristics of 3D and 4D radar generations, emphasizing the potential of 4D radars in improving the performance of learned radar models.

1.3A REVIEW OF THE IMPACT OF RAIN ON CAMERA-BASEDPERCEPTION IN AUTOMATEDDRIVING SYSTEMS

The study investigates the crucial impact of rain on camera-based perception in automated driving systems, highlighting the vital role of visible spectrum camera data. This data is essential for fundamental functions like path planning, object recognition, and avoidance in autonomous vehicles. An innovative Image Creation Framework, inspired by data communication, is introduced to assess how bad weather affects these cameras. The framework evaluates rain-induced modifications on various model components using open-source datasets and examines the effectiveness of artificial rain simulation methods. The report concludes with recommendations for future adverse weather automotive dataset collection, aiming to comprehensively understand and optimize camera performance. The goal is to ensure the reliability and availability of sensors in adverse conditions, a critical factor for the safe and dependable operation of level 5 autonomous vehicles in diverse weather scenarios.

1.4 ASSESSING DISTRIBUTION SHIFT IN PROBABILISTIC OBJECT DETECTION UNDER ADVERSE WEATHER

The study addresses the critical safety aspect of object detection in autonomous driving, highlighting the shortcomings of point estimates and advocating for uncertainty estimation in detection outputs. Utilizing Bayesian theory, the research integrates uncertainty estimates for LiDAR and camera object detectors, leading to the development of an innovative uncertainty-based classifier. Results indicate the classifier's responsiveness to challenging conditions like night driving, obstacles in RGB camera lenses, snowfall, and simulated rain in LiDAR data. The study introduces the anomalous detections ratio (ADR) as a metric to assess sensor performance degradation under adverse situations, including poor lighting and varied weather conditions. It emphasizes the importance of improving estimation of uncertainty related to detection outputs for enhanced system resilience in diverse driving environments. The research contributes to the growing field of probabilistic object detection, showcasing the practicality of employing detection uncertainty to distinguish between true and false positives at inference time.

1.5CORRELATING EXTREME WEATHER CONDITIONS WITH ROAD TRAFFIC SAFETY: A UNIFIED LATENT SPACE MODEL

The study addresses the limitations of traditional imaging sensors by proposing AI-based intelligent thermal perception systems for enhanced driver-assistance systems (ADAS). The research focuses on refining object identification and classification frameworks for thermal vision, utilizing novel testing methods and a model ensemble-based inference engine. Evaluation involves accuracy, recall, and average precision scores, with optimization using TensorRT for thermal-YOLO architecture on resource-constrained Nvidia Jetson Nano. The study emphasizes the importance of thermal cameras in detecting objects in diverse environmental conditions and advocates the integration of AI-based imaging pipelines for sophisticated thermal perception systems. It underscores the significance of intelligent vehicle systems in enhancing transportation safety, discussing the role of sensor fusion and machine learning in obstacle detection. The challenges of object detection algorithms on temperature data are highlighted, with a specific focus on optimizing YOLO-v5 for thermal object detection using different optimizers and hyperparameter selection. The research employs three test methodologies, including test-time augmentation and model ensemble, for comprehensive validation.

1.6 CORRELATING EXTREME WEATHER CONDITIONS WITH ROAD TRAFFIC SAFETY: A UNIFIED LATENT SPACE MODEL

The study looks at the increased risk of auto accidents during extreme weather conditions and the challenges associated with quantifying this association given the range of affecting factors.It proposes a unified latent space model using time series embeddings to capture historical weather-related incidents in high-risk zones and weather measurements from regional meteorological stations. The model identifies periodic risk trends, determining each region's risk level within a spatial context. Real-world case study experiments validate the methodology's effectiveness in understanding traffic accidents for emergency management, preventive maintenance, and urban mobility planning. The study aims to measure the impact of extreme weather on traffic accidents, considering factors beyond weather and addressing uncertainties in crash statistics. The proposed data-driven methodology involves creating temporal sequences from weather measurements, incorporating them into a latent space model, and employing distinct risk models to estimate risk levels based on encoded data. This comprehensive approach offers insights into the complex interplay between extreme weather and traffic safety, facilitating more informed decision-making in various areas of accident prevention and management.

1.7 EVALUATION OF DETECTION PERFORMANCE FOR SAFETY-RELATED SENSORS IN LOW-VISIBILITY ENVIRONMENTS

This study looks into non-contact safety-related sensors' object detection capabilities in low-visibility conditions caused by adverse weather. Using the Minimum Object-detectable Transmittance (MOT) metric instead of traditional Meteorological Optical Range (MOR), the study assesses object detection performance more accurately in low visibility. MOT precisely measures the relationship between sensor detection distance and spatial transmittance, making it a suitable metric for low-visibility sensor assessment. Experimental results demonstrate MOT measurements in simulated fog environments, highlighting the metric's practical value. The research underscores the need for robust sensors in outdoor autonomous systems, emphasizing advancements in sensing technology and effective assessment tools for low-visibility environments. MOT is introduced as a crucial measure for confirming object detection accuracy in adverse visibility conditions for outdoor applications.

1.8 LEARN TO MODEL AND FILTER POINT CLOUD NOISE FOR A NEAR-INFRARED TOF LIDAR IN ADVERSE WEATHER

The integration of high-level autonomous cars faces challenges in LiDAR identification during adverse weather conditions, prompting the development of a data-driven approach. This innovative method utilizes noisy point clouds obtained in an artificial fog chamber to simulate the accuracy of a popular NIR time-of-flight (ToF) LiDAR in foggy scenarios. Dense fog and haze severely limit optical visibility, posing substantial challenges for laser-based systems, including LiDAR. The models generated can predict a probability distribution of noisy laser range measurements based on manually determined visibility levels. LiDAR, a critical sensor for high-level autonomous vehicles, demands robust denoising methods to enhance perception in challenging environments and ensure sustained autonomy. The imperative is to develop sophisticated denoising techniques and precise weather evaluations for reliable and secure autonomous driving, particularly in inclement weather conditions. Semantic segmentation proves efficacious for identifying noise in point clouds, with the proposed strategy exhibiting superior performance in comprehensive experiments. Auto-labeled noisy point clouds from the LiDAR model train a segmentation-based blurring network, ultimately reducing labor costs and increasing annotation efficiency. Rigorous quantitative and qualitative assessments are employed to evaluate the denoising network's effectiveness, particularly in the realms of obstacle detection and self-localization techniques.

1.9 DYNAMIC ADHERENT RAINDROP SIMULATOR FORAUTOMOTIVE VISION SYSTEMS

In the highly regulated automotive industry, safety-critical factors necessitate extensive testing to ensure the proper functioning of automotive systems in diverse environmental scenarios. Vision-based systems heavily rely on high-quality camera images, with adverse weather conditions like rain impacting image quality. Gathering representative datasets under various rainfall situations for testing purposes is traditionally resource-intensive. A practical solution proposed here involves enhancing real rainfall photographs with a simulated rain system during actual drive cycles. Popular picture similarity criteria are employed to compare the quality of simulated rainy photos with genuine rained images. The study contrasts the effectiveness of real and simulated rainy photos using deep learning-based object detectors, revealing similar performance in both scenarios. Vision-based technologies designed for ideal visibility often face performance degradations or failures in unpredictable conditions, such as raindrops on the windshield affecting image composition and dynamics. Gathering diverse data for testing vision-based vehicle systems under various conditions is essential, considering the unpredictability of the automobile environment. The study introduces a rain simulation technique to add rain to clean photos taken during actual drive cycles, demonstrating its suitability for validating object detectors' performance against dynamically adhering raindrops.

1.10 LOSSDISTILLNET: 3D OBJECT DETECTION IN POINT CLOUD UNDER HARSH WEATHER CONDITIONS

In optimal weather conditions, 3D object identification models, notably the SE-SSD model, excel through the exchange of features between teacher and student models. However, their efficacy diminishes in adverse conditions. To address this, a knowledge distillation process was employed, sequentially training the teacher with normal inputs and the student with distillation using adverse weather data. The model innovatively recovers missing points in point clouds caused by harsh weather, utilizing a probability estimation technique with a loss-convolution layer and a Deep Mixture with Factor Analyzer network.Evaluated against state-of-the-art models in diverse weather conditions, including fog and snow at varying densities, the proposed model demonstrated superior performance. Leveraging LiDAR for detailed information, self-driving technology enhances safety despite weather challenges. The SE-SSD paradigm, featuring teacher-student network interaction, addresses 3D object detection robustly. The model introduces shape-aware data augmentation for improved performance in adverse weather.The training strategy involves sequential training of the teacher and student models, utilizing both student and distillation loss functions.

II. COMPARITIVE TABLE

Ref. No	Authors	Title	Year	Methodology	Demerits
[1]	Maria Siddiqua, Samir Brahim Belhaouari Naeem Akhter, Aneela Zameer, Javaid Khurshid.	MACGAN: An All-in-One Image RestorationUnder Adverse Conditions Using MultidomainAttention-Based Conditional GAN	2023	Multidomain Attention-based Conditional Generative Adversarial Network (MACGAN)	1. Model Complexity 2.Adversarial Training Challenges
[2]	Arvind Srivastav Soumyajit Mandal	Radars for Autonomous Driving: A Review of Deep Learning Methods and Challenges	2023	Lidar, Vision Models	1. Low-Resolution Data 2. Integration Challenges
[3]	Tim Brophy, Darragh Mullins, Ashkan Parsi, Jonathan Horgan	A Review of the Impact of Rain on Camera-Based Perception in Automated Driving Systems	2023	Data Communication Inspired Image Formation Framework	1. Synthetic Rain Generation Challenges 2. Oversight of Hardware Solutions
[4]	Mathew Hildebrand, Andrew Brown Stephen Brown	Assessing Distribution Shift in Object Detection Under Adverse Weather	2023	Signal Detection Theory Object Detection Models	1. Limited Emitted Optical Power and Sudden Failures 2.Wavelength Considerations
[5]	Muhammad Ali Farooq Peter Corcoran Cosmin Rotariu	Object Detection In Thermal Spectrum For Advanced Driver-Assistance Systems (Adas)	2021	Ensemble-based inference engine	1. Overreliance on Test Data 2. Model Maintenance
[6]	J. Fior, L. Cagliero	Correlating Extreme Weather Conditions With Road Traffic Safety: A Unified Latent Space Model	2022	Latent Space Model Based on Time Series Embeddings Risk Estimation for Different Regions	1. Data Availability and Quality 2. Temporal Variability

[7]	Yasushi Sumi, Bong Keun Kim, Masato Kodama	Evaluation Of Detection Performance For Safety- Related SensorsInLowVisibility Environment	2021	Evaluation Metric Development (MOT)	1. Model Generalization 2.Resource-Intensive Simulation
[8]	Tao Yang, Qiyan Yu, You Li, Zhi Yan	Learn to Model and Filter Point Cloud Noise for a Near-Infrared ToF LiDAR in Adverse Weather	2023	Denoising Algorithm Data Collection in Artificial Fog Chambe	1.Complexity and Computational Overhead 2. Sensor Variability
[9]	Yazan Hamzeh, Zaid A. El-shair, Abdallah Chehade, Samir A. Rawashdeiiiih	Dynamic Adherent Raindrop Simulator for Automotive Vision Systems	2021	Rain Simulator System	1. Validation of Simulated Rain 2. Overfitting Risk
[10]	Anh The Do, Myungsik Yoo	LossDistillNet: 3D Object Detection in Point Cloud Under Harsh Weather Conditions	2022	SE-SSD model Deep Mixture of FactorAnalyzers (DMFA) network	1. Limited Applicability 2. Data Collection Challenges

III. CONCLUSION

The integration of machine learning (ML) and deep learning (DL) algorithms, coupled with Vehicular Ad-hoc Networks (VANET), presents a robust approach for enhancing autonomous vehicle capabilities in urban environments. Employing Support Vector Machines (SVM) and Decision Trees within this framework contributes to efficient decision-making and traffic management. Simulation tools like the Urban Mobility Simulator enable the testing and optimization of algorithms in realistic urban scenarios, refining the models' adaptability to complex city dynamics. Cloud computing facilitates the storage and processing of vast datasets generated by these simulations, enhancing scalability and computational efficiency. Data mining techniques applied to the collected data from VANET and simulation outputs provide valuable insights into traffic patterns, aiding in the development of predictive models for congestion detection and control. This holistic integration of ML and DL algorithms, VANET, SVM, Decision Trees, simulation tools, cloud computing, and data mining creates a comprehensive system for advancing autonomous vehicles' performance in urban environments, ensuring a safer and more adaptive transportation infrastructure.

REFERENCES

[1] M. Siddiqua, S. Brahim Belhaouari, N. Akhter, A. Zameer and J. Khurshid, "MACGAN: An All-in-One Image Restoration Under Adverse Conditions Using Multidomain Attention-Based Conditional GAN," in IEEE Access, vol. 11, pp. 70482-70502, 2023, doi: 10.1109/ACCESS.2023.3289591.

[2] DA. Srivastav and S. Mandal, "Radars for Autonomous Driving: A Review of Deep Learning Methods and Challenges," in IEEE Access, vol. 11, pp. 97147-97168, 2023, doi: 10.1109/ACCESS.2023.3312382.

[3] T. Brophy et al., "A Review of the Impact of Rain on Camera-Based Perception in Automated Driving Systems," in IEEE Access, vol. 11, pp. 67040-67057, 2023, doi: 10.1109/ACCESS.2023.3290143.

[4] M. Hildebrand, A. Brown, S. Brown and S. L. Waslander, "Assessing Distribution Shift in Probabilistic Object Detection Under Adverse Weather," in IEEE Access, vol. 11, pp. 44989-45000, 2023, doi: 10.1109/ACCESS.2023.3270447.

[5] M. A. Farooq, P. Corcoran, C. Rotariu and W. Shariff, "Object Detection in Thermal Spectrum for Advanced Driver-Assistance Systems (ADAS)," in IEEE Access, vol. 9, pp. 156465-156481, 2021, doi: 10.1109/ACCESS.2021.3129150.

[6] J. Fior and L. Cagliero, "Correlating Extreme Weather Conditions With Road Traffic Safety: A Unified Latent Space Model," in IEEE Access, vol. 10, pp. 73005-73018, 2022, doi: 10.1109/ACCESS.2022.3190399Y. Sumi, B. K. Kim and M. Kodama, "Evaluation of Detection Performance for Safety-Related Sensors in Low-Visibility Environments," in IEEE Sensors Journal, vol. 21, no. 17, pp. 18855-18863, 1 Sept.1, 2021, doi: 10.1109/JSEN.2021.3089207. "Object Detection Using Yolo: Challenges, Architectural Successors, Datasets And Applications", Tausif Diwan, 2023.

[7] A. The Do and M. Yoo, "LossDistillNet: 3D Object Detection in Point Cloud Under Harsh Weather Conditions," in IEEE Access, vol. 10, pp. 84882-84893, 2022, doi: 10.1109/ACCESS.2022.3197765.

[8] Y. Hamzeh, Z. A. El-Shair, A. Chehade and S. A. Rawashdeh, "Dynamic Adherent Raindrop Simulator for Automotive Vision Systems," in IEEE Access, vol. 9, pp. 114808-114820, 2021, doi: 10.1109/ACCESS.2021.3103895.

[9] A. The Do and M. Yoo, "LossDistillNet: 3D Object Detection in Point Cloud Under Harsh Weather Conditions," in IEEE Access, vol. 10, pp. 84882-84893, 2022, doi: 10.1109/ACCESS.2022.3197765.