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Spatio-Temporal Transportation Images Classification Based on Light and Weather Conditions

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Abstract: Advancements transportation systems and proliferation of imaging technologies have provided an safety and efficiency through intelligent analysis using spatio-temporal images. This research focuses on the development of a robust classification system capable of discerning transportation images based on both spatial and temporal features, with a specific emphasis on light and weather conditions. The study begins with the collection of a diverse dataset encompassing various lighting scenarios (day, night, dawn, dusk) and weather conditions (sunny, rainy, snowy, foggy). Through meticulous preprocessing, images are standardized and relevant metadata, including timestamps and location information, is extracted. Feature extraction techniques, such as color histograms and texture features, are employed to capture spatial characteristics, while pre-trained Enchanced convolutional neural networks (ECNNs) aid in learning high-level spatial representations. To account for temporal dependencies in transportation images, a Hybrid novel neural network architecture is designed, incorporating recurrent neural networks (RNNs) or 3D CNNs or ECNN. The model is trained on the labeled dataset, enabling it to predict classes associated with different lighting and weather conditions through the implementation of softmax layers in the output. Evaluation of model is identifying based on accuracy, precision, recall, and F1 score. The satisfactory results i.e. more than 90% accuracy performance received using proposed model and it is useful to deploy for real-time or batch classification of spatio-temporal transportation images. Continuous improvement is emphasized through regular updates with new data to adapt to evolving lighting and weather conditions. The proposed classification system presents a promising avenue for enhancing transportation safety and efficiency through intelligent image analysis, with potential applications in autonomous vehicles, traffic management, and emergency response systems.

Keywords: *ECNN, Hybrid fusion neural network, RNN, CNN*

1. Introduction

Traffic management and scene understanding in urban environments have become increasingly critical with the rise in vehicular density, particularly in crowded cities. The impact of weather conditions, road visibility, and the recognition of traffic density play pivotal roles in ensuring effective traffic control, public safety, and efficient transportation systems. Computer vision techniques have emerged as key tools in addressing these challenges, ranging from weather-related impediments to traffic congestion issues.

The transportation issues have evolved significantly in recent years, propelled by technological advancements, urbanization, and the growing demand for efficient mobility solutions. With this dynamic context, understanding the spatio-temporal aspects of transportation has become important for optimizing systems, enhancing user experience, and addressing the challenges associated with congestion, environmental impact, and safety. Spatio-temporal transportation refers to analyse the spatial and temporal dimensions of movements, providing insights into the patterns, trends, and dynamics of various transportation modes.

1.1. Emerging Technologies and Innovations:

The smart cities are deploying connected infrastructure and utilizing data-driven insights to create adaptive transportation ecosystems. Ride-sharing platforms optimize routes based on real-time demand, and autonomous vehicles rely on spatio-temporal data for navigation and coordination.

1.2. Research Focus and Future Prospects:

The academic and research community plays a pivotal role in advancing spatio-temporal transportation analysis. Scholars delve into topics such as predictive modelling, anomaly detection, and sustainable transportation solutions. As technology continues to evolve, the prospect of integrating quantum computing, advanced simulations, and enhanced data visualization promises to take spatio-

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temporal transportation analysis to new frontiers.

2. Literature Survey

If B. Nugroho et al.[2] focused on contrast adjustment using Contrast-limited AHE for illumination normalization and the experimental evaluation of its impact on face recognition under various lighting conditions.

Yihong Liu et al.[3] addressed the estimation of discomfort study involving multiple variables and their interactions with different lights. The findings suggest similarities perception between LED and traditional lights, contributing valuable insights for the design and improvement of outdoor lighting systems.

P. Žák et al.[4] introduced visual perception within the context of street light. The study emphasizes the importance of understanding the spectral properties of light sources and their impact on human visual experiences to inform decisions in street lighting design.

G. Florian et al.[5] introduced a methodology for designing an runtime road light environment. The study demonstrates the overall optimization of lighting operations in terms of both photometric and energy aspects, highlighting the potential for improved visibility and energy efficiency in road lighting installations.

H. Sakaino et al.[6] introduced PanopticBlue, a novel transformer-based model. The proposed model, DeepTex, demonstrates superior performance in recognizing various cloud types and adverse weather changes, addressing limitations in existing DL models. The incorporation of vision language enriches the auto-briefing process in weather conditions.

H. Sakaino et al.[7] addressed the challenges of recognizing lighter precipitation patterns using traditional sensors and DL models.

R. Blin et al.[8] addressed the challenges of road scene analysis under altered visibility conditions and explores multimodal fusion schemes, emphasizing the effectiveness of combining polarimetric and color information.

M. A. Kenk et al.[9] addressed the challenges posed by poor weather conditions on camera functionality and computer vision algorithms.

2.1 Objective:

The overarching objective of the paper is to enhance the capabilities of computer vision algorithms for traffic-related tasks, encompassing weather-influenced scene analysis, object detection, and accurate traffic density recognition. The focus is on developing innovative methodologies and leveraging advanced techniques to improve accuracy, and adaptable nature of computer vision systems under diverse and challenging conditions.

3. Classification of Light and Weather image data with ECNN

The images on light and weather are classified remarkable advancements, we have introduced innovative architectures, and one such advancement is the Enhanced Consolidated Convolutional Neural Network (ECCNN).

Evolution of Image Classification:

The task of image classification involves assigning light and weather conditions images. However, the advent of CNNs, particularly with the success of AlexNet, marked a paradigm shift by allowing the automatic extraction of hierarchical features directly from raw pixel data.

Importance of Enhanced Consolidated CNNs:

While traditional CNN architectures have demonstrated substantial success, the need for further improvement persists, especially concerning accuracy, efficiency, and adaptability to diverse datasets. The Enhanced Consolidated CNN represents a response to this need, incorporating advancements in architecture, feature extraction, and model consolidation to enhance the overall performance of image classification for light and weather condition classified systems.

Applications in Real-World Scenarios:

The ECNN classification model tailored for light and weather conditions finds applications in various real-world scenarios. It proves invaluable for traffic surveillance systems, outdoor security cameras, and autonomous vehicles where accurate object recognition under diverse environmental conditions is paramount for safety and efficiency.

In the proposed model, the light condition is classified based on darkness and daylight. The darkness is again classified with darkness with no light and darkness with lit light.

The same weather condition is classified with fine i.e. normal weather, snow, fog and rainy weather with sub type winds and with no winds. The complete classification is like fine weather with no winds, fine weather with winds, same with for snowing fog as well as for raining classification.

The complete classification is based on different scenes on the highway. Different classes are used to classify the images which are received as input and train the complete model.

ECNN algorithm classified with various values. After light and weather classifications, the hybrid fusion algorithm is proposed and design to merge both classifications result and to generate recommendation system to based on input images.

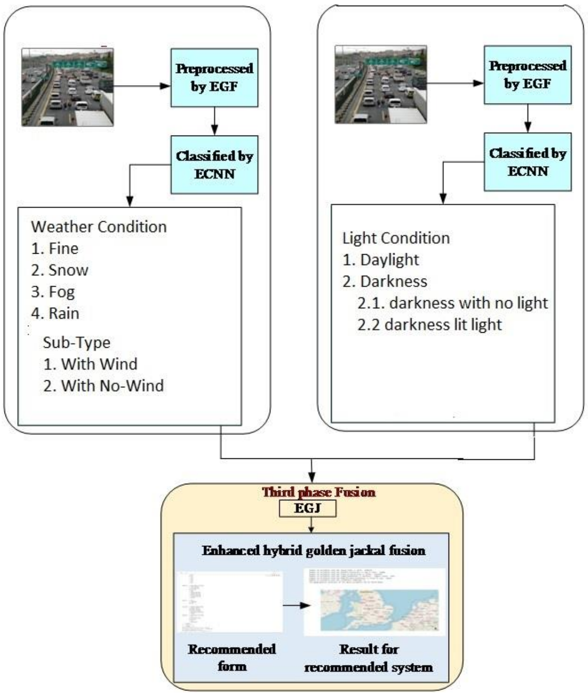


Fig. 1. Flow of Proposed work for hybrid fusion of 2 different ECNN methods for light and weather

The hybrid fusion algorithm is fusing two same or different neural network methods. Here is algorithm for ECNN and fusion:

Step-by-Step Algorithm:

Step 1: Import Necessary Libraries and Frameworks

Import the required libraries and frameworks for deep learning, such as TensorFlow and NumPy.

Step 2: Define ECNN Architecture

Design the architecture of the ECNN, incorporating consolidated convolutional pathways, adaptive convolutional layers, attention mechanisms, and normalization layers. Customize the architecture based on specific requirements.

Step 3: Preprocessing

Preprocess input images by normalizing pixel based value (e.g., [0, 1]range).

Implement adaptive histogram equalization or normalization to address varying lighting conditions.

Step 4: Adaptive Attention Mechanism

Develop an adaptive attention mechanism within the ECNN to dynamically adjust the importance of features based on the prevailing lighting condition.

Step 5: Training Procedure

The ECNN model is compile with optimizer as well with loss function.

The model is trained using the different dataset, incorporating data augmentation techniques to simulate various lighting and weather scenarios.

Step 6: Validation Tuning

The trained model is validated on a separate validate dataset to assess its performance.

Hyperparameters is tune using the number of layers, filters, and attention weights, based on validation results.

Step 7: Testing and Evaluation

Evaluate the ECNN model on a different testing dataset to get new light and weather conditions.

Collect and analyze performance metric.

Step 8: Real-Time Adaptation

Implement dynamic lighting adjustments based on environmental live images to adapt the model in real-time.

Step 9: Iterative Improvement

The model is tune based on real-world feedback to improve adaptability and performance.

Step 10: Deployment

Deploy the trained and adapted ECNN model for real-world applications, ensuring seamless integration into the target environment.

The below equations are used in ECNN:

$$F\_out = Con(F\_in, L) + e \qquad \text{..eqn (1)}$$

Where F_out and F_in are output and input attributes of ECNN

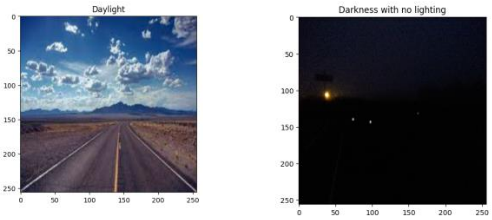
$$RLU(s) = \max(0, s) \qquad \ldots \text{ eqn(2)}$$

Rectified Linear Unit (RLU) is used to identify non-linearity.

4. Result and Test Cases

The following are the images are taken for classification purpose

Fig. 2. Sample images of road vehicle images for weather and light condition classifications.



(a) (b)

Fig. 3. Light and weather condition classification (a) Day light, fine weather (b) Darkness-light lit fine weather

4.1. Multipart results and figures

Following are the results received using ECNN and Hybrid fusion neural algorithm:

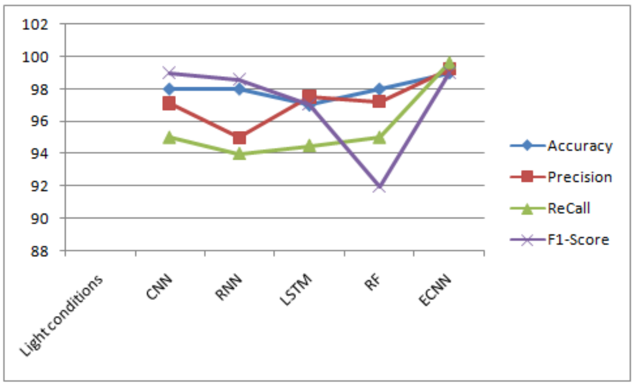


Fig. 4. Accuracy, precision, recall and f1-score compare ECNN with existing methods

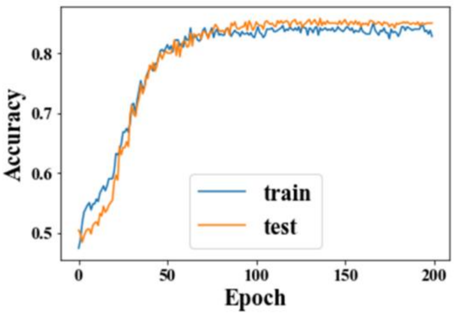


Fig. 5. Accuracy rate for 200 epochs

5. Conclusion

The ECNN classification model stands as a powerful solution for addressing the challenges posed by varying light and weather conditions in computer vision applications. Its adaptability, robustness, and real-time capabilities position it as a valuable asset for enhancing the performance of systems operating in dynamic and unpredictable environments. Further research and refinement of the ECNN architecture could potentially lead to even more sophisticated models capable of handling an even broader range of environmental conditions. The evaluation metrics, including accuracy more than 97%, precision, recall, and F1 score, reflect the reliability of the ECNN in accurately classifying light and weather conditions.

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