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Augmentation of pedestrian dataset using Generative AI

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Abstract:
Electric Vehicles (EVs) are central to the shift towards sustainable transportation, significantly reducing greenhouse gas emissions and reliance on fossil fuels. The growth of EVs necessitates robust, reliable, and intelligent systems for their safe and efficient operation. With advancements in autonomous driving technology, accurately detecting and responding to various environmental and traffic conditions, including pedestrian interactions, is crucial. Generative artificial intelligence (Gen AI) plays a key role in enhancing autonomous systems through advanced data augmentation techniques. Generative Adversarial Networks (GANs), a powerful tool within Gen AI, are essential for data augmentation, critical in training machine learning models with diverse and extensive datasets. GANs consist of a generator that creates synthetic data mimicking real-world scenarios and a discriminator that evaluates the authenticity of the generated data against actual data. This dynamic enhances the diversity of training datasets, improving the robustness and reliability of machine learning models used in autonomous EV systems. Data augmentation via GANs addresses the challenges of scarce and variable real-world data. For autonomous vehicles, simulating a wide range of pedestrian behaviors and interactions is vital for comprehensive testing and validation. GANs generate high-fidelity synthetic pedestrian images, providing datasets that cover various scenarios from routine crossings to unexpected pedestrian actions. This capability ensures that autonomous systems can better predict and react to real-world situations, enhancing overall safety. In this project, a pedestrian dataset was augmented using a data generator named DummyNet, integrated with a GAN network. The generator created realistic synthetic pedestrian images, while the discriminator assessed these images against actual pedestrian data. This method expanded the training dataset and introduced variations absent in the original data, improving the machine learning model’s generalization and performance in diverse environments. The use of Gen AI for data augmentation in EVs aims to develop more accurate, reliable, and adaptable autonomous systems, ultimately contributing to safer and more efficient autonomous EVs.

Keywords: Electric Vehicles, Generative Artificial Intelligence, Generative Adversarial Networks, Data Augmentation

1. Introduction:

Generative Adversarial Networks (GANs) mark a significant milestone in the evolution of artificial intelligence. First introduced by Ian Goodfellow and his team in June 2014, GANs have continuously evolved to enhance their reliability and efficacy. The core architecture of GANs involves two neural networks: a generator and a discriminator. The generator creates synthetic data that mimics real data, while the discriminator differentiates between genuine and synthetic data. This adversarial process results in highly realistic data generation, making GANs indispensable across various fields.

In computer vision, GANs have shown exceptional capabilities in generating highly accurate

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images and artwork. They can create photorealistic images from textual descriptions or enhance image resolution, opening new avenues for creative expression and image enhancement. This versatility in image synthesis and manipulation positions GANs as vital tools in modern computer vision tasks.

In medical imaging, GANs have been equally transformative. They generate synthetic medical images crucial for training diagnostic models, especially when real medical data is scarce or hard to obtain. This capability not only expands training datasets but also enhances the resolution and quality of diagnostic scans, significantly improving the accuracy and reliability of medical diagnoses and advancing healthcare technologies.

GANs also play a pivotal role in natural language processing (NLP) by converting textual descriptions into engaging visuals. This ability to bridge the gap between text and image allows for more interactive and immersive communication experiences. For example, GANs can generate images from written descriptions in stories or create visual representations of concepts explained in educational materials, enriching the learning and storytelling processes.

In the field of autonomous vehicles, generative AI, particularly GANs, is crucial for generating artificial data used in training machine learning models. Autonomous driving systems require extensive and diverse datasets to accurately recognize and respond to various driving scenarios. GANs generate these datasets, including realistic simulations of different driving conditions and pedestrian behaviors, ensuring comprehensive training for autonomous systems. This data augmentation helps create robust and adaptable autonomous vehicles that can reliably navigate complex environments.

There are various types of GANs tailored to specific tasks. Conditional GANs (cGANs), for instance, use additional information such as class labels to generate specific outputs, making them ideal for tasks like image-to-image translation. Deep Convolutional GANs (DCGANs) leverage Convolutional Neural Networks (CNNs) for stable training and high-quality image generation, which is particularly useful for creating photorealistic images. Wasserstein GANs (WGANs) introduce a novel loss function that ensures stable training, making them suitable for working with complex datasets that have diverse distributions. Each type of GAN offers unique advantages depending on the task requirements and dataset characteristics.

The development and refinement of GANs have significantly advanced the capabilities of generative AI, making them indispensable in various fields such as computer vision, medical imaging, natural language processing, and autonomous driving. By providing innovative solutions to data generation and augmentation challenges, GANs continue to push the boundaries of what is possible with artificial intelligence, driving progress and innovation across multiple domains [1-4].

2. Motivation:

There are various image based datasets are present for machine learning applications [8-13]. Autonomous vehicles are increasingly regarded as a promising solution to a myriad of transportation challenges. The primary motivation for developing these vehicles stems from their potential to significantly enhance road safety by reducing the number of accidents caused by human error. Human factors, such as distraction, fatigue, and impaired driving, contribute to a substantial proportion of traffic accidents. Autonomous vehicles, with their

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ability to operate without these limitations, can help in minimizing such incidents, thereby saving lives and reducing injuries. Additionally, autonomous vehicles promise to improve traffic efficiency. By optimizing routes and managing traffic flow more effectively than human drivers, these vehicles can reduce congestion in urban areas. The ability of autonomous systems to communicate with each other and with traffic infrastructure enables smoother traffic patterns and less stop-and-go movement, which in turn leads to reduced travel times and less fuel consumption. This optimization not only benefits individual drivers but also has broader economic and environmental impacts, as reduced congestion translates into lower emissions and fuel savings. Another significant advantage of autonomous vehicles is their potential to increase accessibility for individuals who are unable to drive, such as the elderly and disabled. By providing a reliable means of transportation, autonomous vehicles can enhance mobility for these populations, thereby improving their quality of life and independence. This increased accessibility also extends to regions where public transportation options are limited, offering a viable alternative for those who rely on others for transportation. Environmental benefits are another crucial motivator for the development of autonomous vehicles. These vehicles can contribute to reducing fuel consumption and emissions through more efficient driving practices. Autonomous systems can optimize acceleration and braking patterns to conserve fuel and reduce pollution. Furthermore, the integration of electric autonomous vehicles can further diminish the environmental footprint of transportation, supporting global efforts to combat climate change. From an economic perspective, autonomous vehicles hold the promise of cost savings associated with fewer accidents and more efficient transportation systems. The reduction in accidents can lead to lower insurance premiums and healthcare costs related to traffic injuries. Additionally, the ability of passengers to use travel time more productively—such as working, reading, or relaxing—adds an economic benefit by transforming commuting time into valuable personal or professional time. Despite these promising benefits, the widespread adoption of autonomous vehicles faces several challenges. Legal and regulatory frameworks need to be developed to address the unique aspects of autonomous driving, including liability issues in the event of accidents. Ethical concerns, such as decision-making in unavoidable crash scenarios and data privacy, must also be carefully considered. Moreover, extensive testing and validation are required to ensure the safety and reliability of autonomous systems before they can be integrated into public transportation networks. The motivation for developing autonomous vehicles encompasses a range of safety, efficiency, accessibility, environmental, and economic benefits. These vehicles have the potential to revolutionize urban design, influence land use, and provide crucial transit options for various demographics. However, addressing the accompanying legal, ethical, and technical challenges is essential to realize their full potential and ensure their safe and effective integration into our transportation systems.

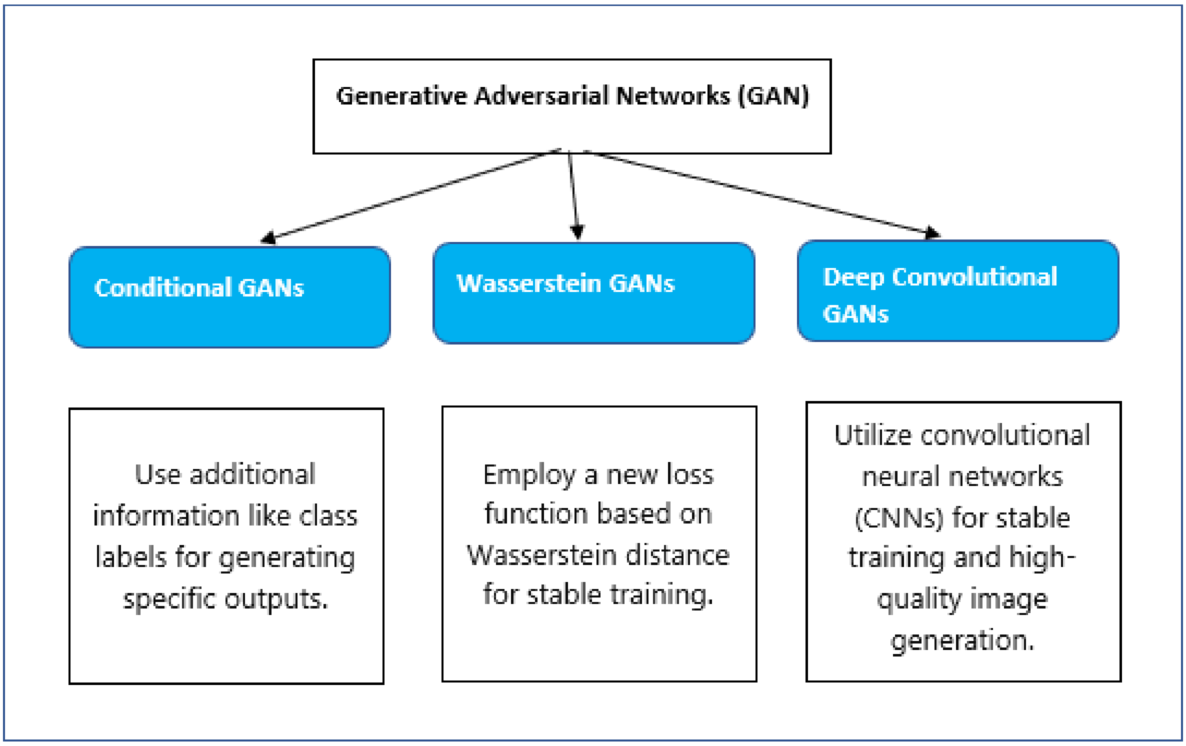

Figure 1. Types of GAN network

3. Review Literature

The literature surrounding the use of Generative Adversarial Networks (GANs) in autonomous vehicles and related fields is extensive and reveals the significant impact of these technologies on enhancing safety and functionality. One notable study addresses the necessity for advanced monitoring systems in shared autonomous vehicles (SAVs). This research introduces the application of Generative Adversarial Networks, specifically utilizing the BigGAN architecture, which is enhanced through consistency regularization and differential augmentation. The findings from this study, conducted using the expanded MoLa-VI dataset, demonstrate that the combination of CR+BigGAN yields superior performance, achieving a Frechet Inception Distance (FID) of 28.23 and an Inception Score (IS) of 17.19 [5]. These results highlight the efficacy of GANs in developing robust monitoring systems for SAVs, overcoming data limitations in training deep learning algorithms for object detection and classification in diverse vehicle environments .Another critical area of research focuses on the safety of self-driving cars, particularly their ability to navigate safely around pedestrians. Testing autonomous vehicles in real-world scenarios is challenging due to the scarcity of diverse, real-world data. To address this, researchers have developed a solution known as Ped-Cross GAN, a specialized GAN model that generates realistic images of pedestrians crossing streets. Trained on a comprehensive dataset featuring various pedestrian scenarios, Ped-Cross GAN produces lifelike images that are crucial for testing and validating the accuracy of self-driving cars in recognizing and responding to pedestrians [6]. This advancement is vital for enhancing the safety of pedestrians and ensuring the reliability of autonomous vehicle systems on public roads. Further research introduces innovative methods to improve the prediction accuracy of how vehicles and pedestrians move in traffic, considering that human behavior often deviates from established traffic rules. This study explores the integration of generative adversarial networks with signal temporal logic and syntax trees to model realistic traffic behaviors. By incorporating these elements, the research enhances the prediction capabilities of autonomous systems without biasing towards rule-abiding behavior. Testing these models with real driving data demonstrates their superior performance compared to standard models, contributing to more accurate and reliable predictions of human behavior in traffic scenarios, which is crucial for the safe operation of autonomous vehicles .In another study, researchers focus on developing autonomous driving capabilities through the creation of a computerized model of traffic situations using both real and simulated data. This method employs a Generative Adversarial Network to simulate the appearance and dynamics of traffic over time. The autonomous system learns to drive by practicing with this simulated data, which combines real-world and computer-generated information. This comprehensive approach ensures that the autonomous driving system can effectively navigate real-world conditions, providing a more robust training environment that enhances its ability to operate safely and efficiently on public roads .Collectively, these studies underscore the transformative potential of GANs and other generative AI technologies in advancing the development and safety of autonomous vehicles. By addressing the limitations in data diversity and enhancing the predictive accuracy of vehicle and pedestrian behaviors, these technologies pave the way for more reliable, efficient, and safe autonomous transportation systems. As research in this field continues to evolve, it holds promise for significant advancements in the integration and functionality of autonomous vehicles within our transportation infrastructure.

4. Objectives:

This research endeavor seeks to explore the evolution of generative AI as a prominent and extensively discussed domain.

1. Additionally, the research aims to identify key advancements and state-of-the-art developments in the field, along with gathering pertinent information.
2. Furthermore, the study seeks to explore potential challenges and limitations associated with the implementation of generative AI in real-world scenarios.
3. The primary goal is to dissect the factors driving the widespread interest in generative AI.
4. The secondary objective involves scrutinizing the manifold applications of generative AI across diverse domains, including projects like ChatGPT, BERT AI, and its integration into autonomous vehicles.
5. The third aim is to delve into the scientific principles underlying the integration of generative AI in autonomous vehicle technologies.
6. It aims to propose recommendations for future research directions and applications of generative AI in various industries.

5. Methodology:

For the methodology, the software setup included Windows or Linux as the operating system and Python 3.6 or higher. Key libraries and packages utilized were scipy, numpy, tensorflow, keras, matplotlib, PIL, and pickle to support various scientific computing, machine learning, and data visualization tasks. GPU support was enabled by the CUDA Toolkit, specifically version 10.1 or another version compatible with the installed TensorFlow. Development was conducted using IDEs and code editors such as PyCharm, VS Code, and Jupyter Notebook. The system required a minimum of 8GB RAM, though 16GB or higher was recommended for optimal performance. Additionally, the latest GPU drivers compatible with the CUDA Toolkit and cuDNN were installed to ensure proper GPU functionality and performance (Table 1).

Table 1: Software and System Requirements.

Requirement	Description
Operating System	Windows or Linux
Python Version	Python 3.6 or higher
Libraries and Packages	scipy, numpy, tensorflow, keras, matplotlib, PIL, pickle
CUDA Toolkit	Required for GPU support, version 10.1 or compatible with installed TensorFlow
IDE/Code Editor	PyCharm, VS Code, Jupyter Notebook
Memory	Minimum 8GB RAM, recommended 16GB or higher
GPU Drivers	Latest GPU drivers compatible with CUDA Toolkit and cuDNN

To address the challenge of limited real-time data availability, particularly in varying weather conditions such as fog, rain, sun, and wind, a data generation approach utilizing Generative Adversarial Networks (GANs) is proposed. GANs comprise two neural network components: the generator and the discriminator [7]. The generator network creates multiple images from a single image, introducing subtle variations to produce synthetic data that mimic different weather conditions. Meanwhile, the discriminator network distinguishes between real and generated images by comparing them with real-world counterparts, ensuring the authenticity of the synthetic data. This GAN-based data generation process allows for the creation of synthetic datasets that closely resemble real-world conditions, facilitating robust training and testing of models under diverse environmental scenarios.

6. Result:

The code implements a Generative Adversarial Network (GAN) to generate high-resolution images. This setup includes a discriminator, a generator, and a combined GAN model. The discriminator, a convolutional neural network with LeakyReLU activations and dropout layers, classifies images as real or fake. The generator transforms latent vectors (random noise) into images using dense and transposed convolutional layers. Both networks are optimized using the Adam optimizer and binary cross-entropy loss function. During training, the GAN model combines these networks, with the discriminator set to non-trainable to focus on training the generator.

The training process alternates between updating the discriminator and the generator. In each

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epoch, the discriminator is trained on batches of real images and fake images produced by the generator. Simultaneously, the generator is trained to produce images that can deceive the discriminator. The training routine involves loading real samples from a .pkl file, generating fake samples, and periodically saving generated images and model weights. After 25,000 epochs, the trained GAN can generate realistic, high-resolution images from latent vectors, with checkpoints saved for evaluation and further use.

Figure 2. Output of Image Samples in Real World.

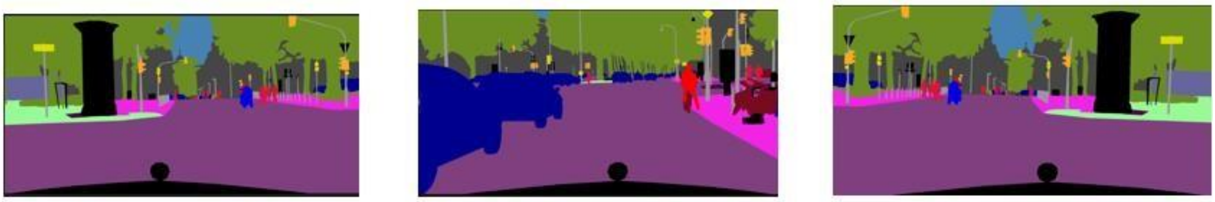

Figure 3. Output of Image Samples in Simulation.

7. Conclusion

The project was successfully completed by utilizing GAN networks to create an augmented dataset. By implementing and training the generator and discriminator networks, realistic high-resolution fake samples were generated. The GAN model effectively learned to produce these images from latent vectors, with the trained model and generated samples saved for further evaluation and application. This project demonstrates the powerful capabilities of GANs in data augmentation and synthetic image generation.

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