**UNIVERSITI TEKNOLOGI MARA**

# A DEEP LEARNING AUTONOMOUS VEHICLE MACHINE VISION SYSTEM FOR ROAD CLASSIFICATION USING LGAN-BASED SYNTHETIC IPM DATA AND CNN

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# ABSTRACT

Despite significant advances in autonomous vehicle (AV) technology, reliable lane detection remains a critical challenge, particularly in complex urban environments. Traditional image processing techniques often fail under poor lighting, occlusions, and irregular lane conditions, while deep learning approaches suffer from data scarcity, class imbalance, and insufficiently calibrated vision systems. This study addresses these issues by developing an integrated framework to enhance road curvature classification using deep learning, synthetic data generation, and accurate camera calibration. The primary objectives are threefold: (1) to establish an optimal camera calibration methodology for accurate inverse perspective mapping (IPM); (2) to design and implement a lightweight Generative Adversarial Network (LGAN) for generating realistic synthetic IPM images; and (3) to develop a robust Convolutional Neural Network (CNN) model for classifying road types straight, left curve, and right curve. The methodology begins with precise calibration of a Point Grey camera (CM3-U3-31S4C-CS) to generate distortion free bird's-eye view (BEV) images essential for lane feature extraction. An LGAN, enhanced with an Exponential Moving Average (EMA) strategy, is then trained to generate high-fidelity synthetic BEV images that augment limited real-world datasets and address class imbalance. Quantitative evaluations using PSNR, SSIM, FID, and Inception Score validate the realism of the generated images. The final stage involves training CNN architectures (AlexNet, MobileNetV2, EfficientNet-B0) on the combined dataset, using SGD and ADAM optimizers, to assess classification performance across various training. Experimental results demonstrate that EfficientNet-B0, when optimized with SGD and trained for 25 epochs, consistently achieves superior validation accuracy (up to 99.74%) and excellent AUC-ROC scores, outperforming baseline models in generalization and robustness. The study concludes that the combination of rigorous camera calibration, high-quality synthetic image generation via LGAN, and modern CNN architectures forms a scalable and effective solution for enhancing lane classification in AV systems.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Research Background

The evolution of autonomous vehicle (AV) technology represents a significant paradigm shift in transportation systems, fundamentally transforming how vehicles perceive and navigate their environment. This transformation is particularly timely given projections indicating that 68% of the global population will reside in urban areas by 2050 [1], creating unprecedented pressure on transportation infrastructure. At the core of this transformation lies the intricate integration of multiple sensor modalities including cameras, radar, sonar, Light Detection and Ranging (LiDAR), and Global Positioning System (GPS) that enable AVs to execute driving functions without human intervention [2]–[5]. This sensor fusion architecture forms the foundation for critical functionalities such as lane detection, road curvature estimation, and obstacle avoidance, tasks traditionally managed by human drivers.

The historical trajectory of AV development spans several decades, with its origins traced to 1977 at Japan's Tsukuba Mechanical Engineering Laboratory, where researchers achieved a breakthrough in machine vision-based navigation, demonstrating the first autonomous system capable of following white traffic markings at speeds exceeding 20 miles per hour [6]. A pivotal moment in AV evolution occurred in 2004 with the Defense Advanced Research Projects Agency (DARPA) Grand Challenge, which catalyzed extensive research and accelerated development in autonomous systems [7], [8]. In recent years, commercial entities like Waymo and Tesla have advanced the field significantly, with Waymo developing specialized systems Waymo One for ride-hailing and Waymo Via for commercial transport that integrate high-definition maps with real-time sensor data for precise road positioning [9]. Tesla's Autopilot system exemplifies modern AV technology, employing eight cameras, ultrasonic sensors, and forward-facing radar, processed by neural networks to enable self-driving capabilities [10], [11].

Central to the advancement of AV technology is the challenge of robust lane detection, particularly in complex environments where traditional image processing techniques such as line segmentation, Hough transform, and Canny edge detection often