Improving Lane Detection in Autonomous Vehicles under Adverse Weather Conditions Using CycleGAN

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Background of Study

With the advancement of autonomous driving technology, ensuring stable perception performance in various environments has become essential.
In adverse weather conditions, such as rain, snow, and fog, sensor perception performance deteriorates, threatening the safety of autonomous driving.
Previous research has employed data augmentation and filtering techniques to improve performance in such weather; however, issues with image distortion remain unresolved.

Research Objective

The objective of this study is to enhance lane detection accuracy by using CycleGAN to convert adverse weather images into images that resemble clear-weather conditions.
CycleGAN, an unsupervised learning model that can translate images between two domains, is suitable for correcting image distortions in adverse weather conditions while preserving data characteristics.

Data

We collected 64,800 road images taken in both clear and adverse weather conditions to create a dataset that reflects various weather scenarios.
It is challenging to capture identical scenes in both clear and adverse weather, making it difficult to obtain paired data.
Therefore, this study employs CycleGAN to train the model on unpaired data, transforming adverse weather images into clear-day images and vice versa.
The collected images are categorized into two domains (clear and adverse weather), with clear-day images used as target images in the CycleGAN model, enabling the conversion of adverse weather images into clear-day-like images.

CycleGAN Model

CycleGAN (Generative Adversarial Networks) is an unsupervised learning model that enables image translation between two different domains and is effective in enhancing the perception performance of autonomous vehicles.
CycleGAN consists of two networks, Generator and Discriminator, which improve each other's performance through adversarial training.

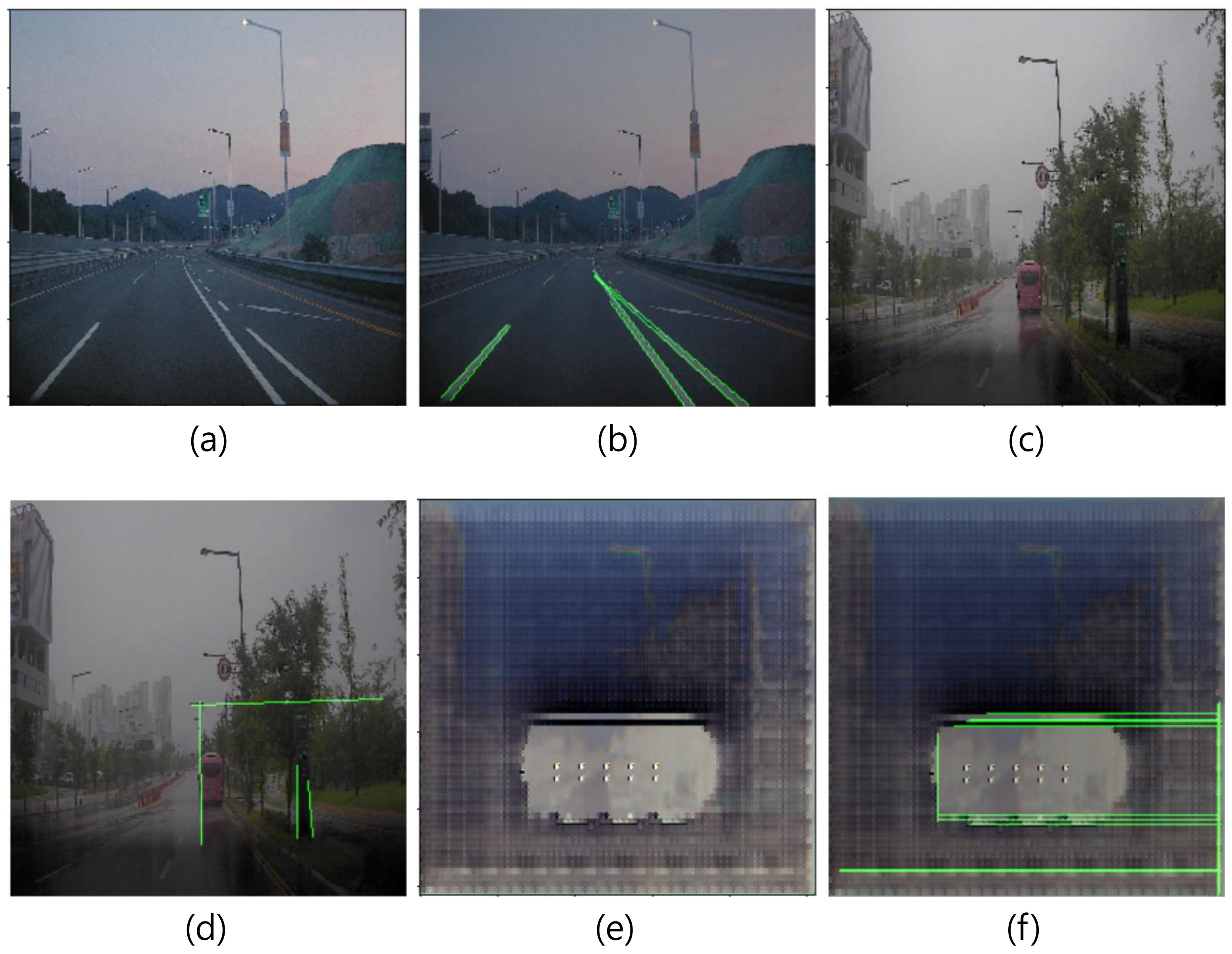
A major advantage of CycleGAN is its ability to learn without paired data, which is particularly useful in road environments where it is challenging to collect the same scenes under various weather conditions.
Once trained, the CycleGAN model transforms road images taken in adverse weather into clear-day-like images.
In this process, the Generator reduces or removes weather elements, such as rain, snow, and fog, creating images that resemble clear-day conditions.
The converted images exhibit visual characteristics similar to clear-day images, allowing the lane detection algorithms of autonomous vehicles to interpret road information more accurately and clearly.

Lane Detection Algorithm

In this study, lane detection is performed using a Hough Transform-based approach.
By setting a Region of Interest (ROI) focused on the lower area containing the lanes, unnecessary sections are excluded, enhancing detection accuracy.
Canny edge detection emphasizes the boundaries of lanes and roads, providing a basis for the Hough Line Transform to detect lane-forming lines.
The detected lines are filtered based on length and slope, and are post-processed to resemble actual lane structures.
This approach allows for lane recognition in both pre- and post-transformation images, enabling the analysis of whether transformed images can effectively detect lanes under adverse weather conditions.

Results

Using CycleGAN, adverse weather road images were converted into clear-day-like images, followed by Hough Transform-based lane detection on both the transformed and original images.



<Figure 1 Lane detection under various conditions>

(a) Clear-day image

(b) Lane detection on clear-day image

(c) Adverse weather image

(d) Lane detection on adverse weather image

(e) Transformed image

(f) Lane detection on transformed image

In this study, the number of epochs for CycleGAN was set to 30 for efficient training, but this resulted in lower image quality in the transformed images.

The converted images did not achieve a sufficient level of visual clarity comparable to clear-day images, and lane visibility was limited, yielding minimal improvement in lane detection performance.

Conclusion

This study attempted to enhance lane detection performance by using a CycleGAN trained on a lower epoch count to convert adverse weather images into clear-day-like images.

However, the limited quality of transformed images led to restricted improvements in lane detection.

Due to insufficient training iterations, weather elements were not fully removed in the transformation process, preventing the transformed images from reaching the clarity level of clear-day images.

Future research will focus on improving image quality by training with a higher number of epochs.
Additionally, a variety of lane detection algorithms beyond Hough Transform will be applied to compare performance on the transformed images.
Through optimized real-time transformation and detection, this model aims to enable autonomous vehicles to reliably detect lanes in diverse weather conditions.