# Hybrid Contrast-Aware Fog Detection for Automotive Vision Systems

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**Abstract**

*Modern vehicles are equipped with a wide range of Advanced Driver Assistance Systems (ADAS) that rely heavily on camera-based perception. Reliable visibility estimation – particularly under fog condition – remains a significant challenge. Accurate fog detection can enable proactive system responses, such as automatic activation of fog lights, and enhance operational safety. We present a contrast-aware anomaly detection framework for image-based fog detection. Our algorithm combines multi-scale Difference of Gaussians responses and Gaussian-weighted local Root Mean Squared contrast with a convolutional autoencoder. The model is trained exclusively on clear-weather imagery to learn the nominal scene distribution, and visibility degradation is detected as a reconstruction deviation from this learned representation. Evaluation on a separate test set containing clear and fog conditions demonstrates an AUC of 0.91, achieved without using fog samples during training. The framework provides a practical basis for camera-based visibility monitoring in automotive environments.*

**CCS Concepts**

• ***Computing methodologies*** → ***Computer vision;*** *Neural networks;*

## 1. Introduction

Reliable perception under adverse weather conditions remains a major challenge for camera-based systems in real-world environments. Fog is particularly critical, as atmospheric scattering reduces contrast and suppresses fine-scale structure, directly affecting safety-relevant perception and system behavior in automotive applications. Despite the widespread deployment of camera-based driver assistance systems, explicit visibility assessment is not commonly implemented. This motivates image-based visibility estimation methods operating directly on camera data and remaining robust across heterogeneous driving environments.

To address these challenges, we propose a hybrid visibility estimation method combining contrast analysis with a contrast-regularized convolutional autoencoder (CAE). The approach uses multi-scale Difference of Gaussians (DoG) and Gaussian-weighted local Root Mean Square (RMS) contrast to capture visibility degradation. The CAE is trained on clear imagery to model the nominal scene distribution. The objective minimizes both reconstruction error and discrepancies in contrast descriptors. Fog is detected as an increased deviation from the learned clear distribution.

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## 2. Related Work

Most prior work addresses recognition under fog or haze, typically using learning-based approaches [AEE*25]. Two dominant strategies can be identified: image restoration (dehazing) as preprocessing, and training recognition models directly on fog-affected data to improve robustness. Direct fog detection has received less attention. Existing methods rely either on contrast-based descriptors derived only from atmospheric scattering principles [PBRI12], or on supervised classifiers trained to categorize visibility conditions, often based on object-detection backbones such as YOL O [WXH*22]. Hybrid method based on combination of edge detector with multitask network cascade and overview of recent methods is in [YZL*23]. However, contrast-based methods are sensitive to illumination changes and generalize poorly across diverse scenes, while supervised approaches require extensive labeled data. These limitations motivate the proposed hybrid approach.

## 3. Methodology

For the initial training of the framework, datasets were prepared with various conditions, including brightness, clouds, and day-time/nighttime period. Multi-scale DoG and local RMS contrast capture structural and radiometric visibility degradation. The CAE was designed with four hidden convolutional layers, and the number of training parameters is 1.3 mil. , latent layer has 256 channels. Scheme of proposed framework is in Fig. 1. The training data



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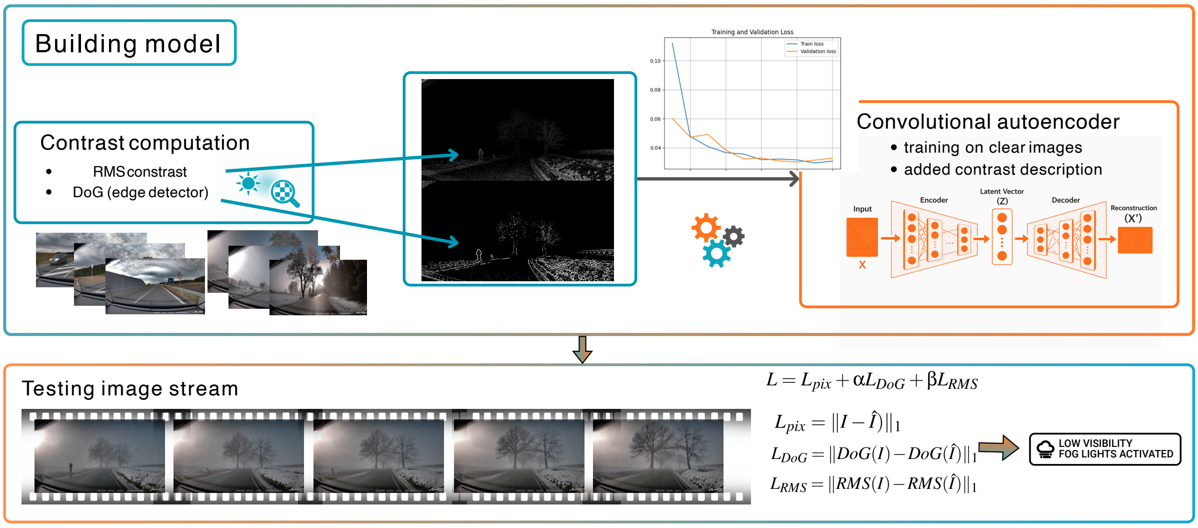


**Figure 1:** *Hybrid visibility assessment framework combining contrast statistics and latent feature analysis.*

comprise eight internally collected driving datasets acquired during controlled test drives using instrumented vehicles. After preprocessing and temporal subsampling, approximately 5,000 clear-weather frames were retained for training. No fog images were used during training.

The CAE is trained exclusively on clear imagery to learn the nominal appearance of scenes, minimizing both pixel-wise reconstruction error $L_{pix}$ and differences between contrast descriptors computed from the original and reconstructed images $L_{DoG}, L_{RMS}$. The model is optimized using L1loss (MAE): $L_{pix} = \|(I - \hat{I})\|_1$

$$L_{DoG} = \|DoG(I) - DoG(\hat{I})\|_1, \qquad L_{RMS} = \|RMS(I) - RMS(\hat{I})\|_1,$$

leading to the hybrid objective $L = L_{pix} + \alpha L_{DoG} + \beta L_{RMS}$.

Two inference strategies can be considered. The first relies solely on the pixel-wise reconstruction error, $S = L_{pix} = \|I - \hat{I}\|_1$, where the influence of DoG and RMS is implicit through the hybrid training process. This approach is computationally efficient and suitable for real-time applications, but it does not explicitly evaluate structural and contrast deviations during inference. The second strategy mirrors the hybrid training objective by combining pixel and descriptor-based errors, $S = L_{pix} + \lambda_2 L_{DoG} + \lambda_3 L_{RMS}$.

This formulation explicitly accounts for structural and contrast discrepancies and can better capture visibility-related degradation, although it requires higher computational cost and additional weighting calibration.

## 4. Results and Conclusion

The proposed hybrid contrast-aware framework enables visibility degradation detection using a one-class training paradigm. By combining structural contrast descriptors with a contrast-regularized CAE, the method models nominal clear-weather appearance and detects fog as a deviation from this learned distribution. Experimental evaluation on real-world automotive data achieved an AUC of 0.91 despite the absence of fog samples during training, indicating strong discriminative capability for visibility degradation detection. The framework is suitable for integration into camera-based ADAS visibility monitoring. Future work will focus on expanding evaluation datasets and investigating multimodal sensor fusion for enhanced robustness under adverse weather conditions.A representative subset of the dataset is publicly available at [PŠ26].

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