EUROGRAPHICS AACHEN 2026

HYBRID CONTRAST-AWARE DETECTION FOR AUTOMOTIVE VISION SYSTEMS

Procházková Jana[1], Mikuláček Pavel[1] and Štarha Pavel[1]
[1]Institute of Mathematics, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic

Contact: prochazkova.j@fme.vutbr.cz

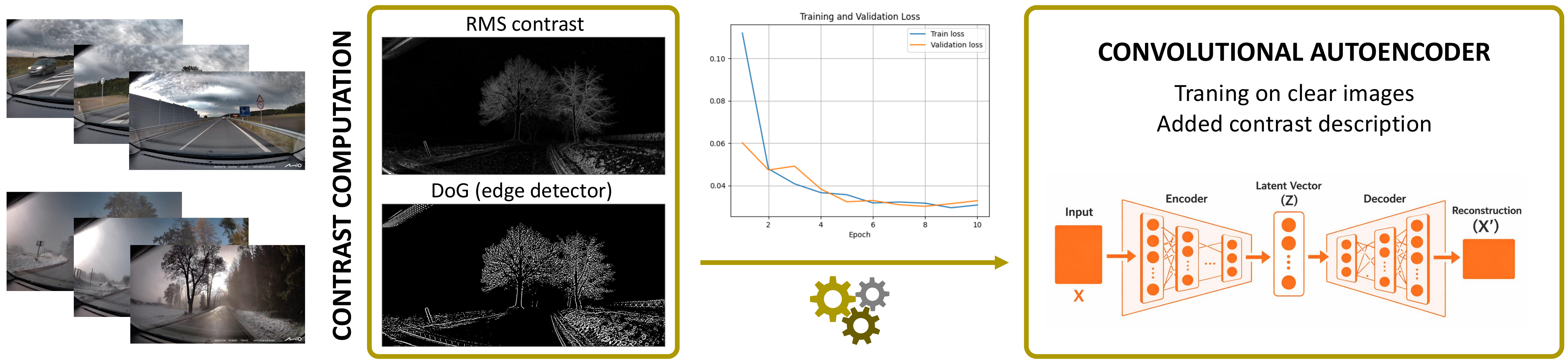
PROBLEM FORMULATION

Reliable perception under adverse weather remains a challenge for camera-based systems, especially in automotive environments. Fog degrades image contrast and suppresses fine structural details, leading to loss of important visual information. This reduced visibility affects safety-critical perception tasks such as object detection, lane estimation, and scene understanding. Despite widespread deployment of ADAS, explicit visibility assessment is rarely integrated. To address this, we formulate visibility degradation detection as a one-class learning problem trained on clear-weather data, enabling detection of deviations caused by adverse conditions without requiring labeled fog datasets.

METHODOLOGY

The proposed hybrid framework combines contrast-based descriptors with a convolutional autoencoder (CAE), where multi-scale Difference of Gaussian and local RMS contrast capture both structural and radiometric visibility degradation. The CAE consists of four convolutional layers with approximately 1.3M parameters and a 256-channel latent space. The model is trained exclusively on clear imagery using an L1 reconstruction loss applied in both pixel space and descriptor space. The training data include diverse conditions such as brightness variations, cloud cover, and both daytime and nighttime scenes, comprising eight internally collected datasets from controlled test drives, with approximately 5,000 clear-weather frames used for training.

BUILDING MODEL



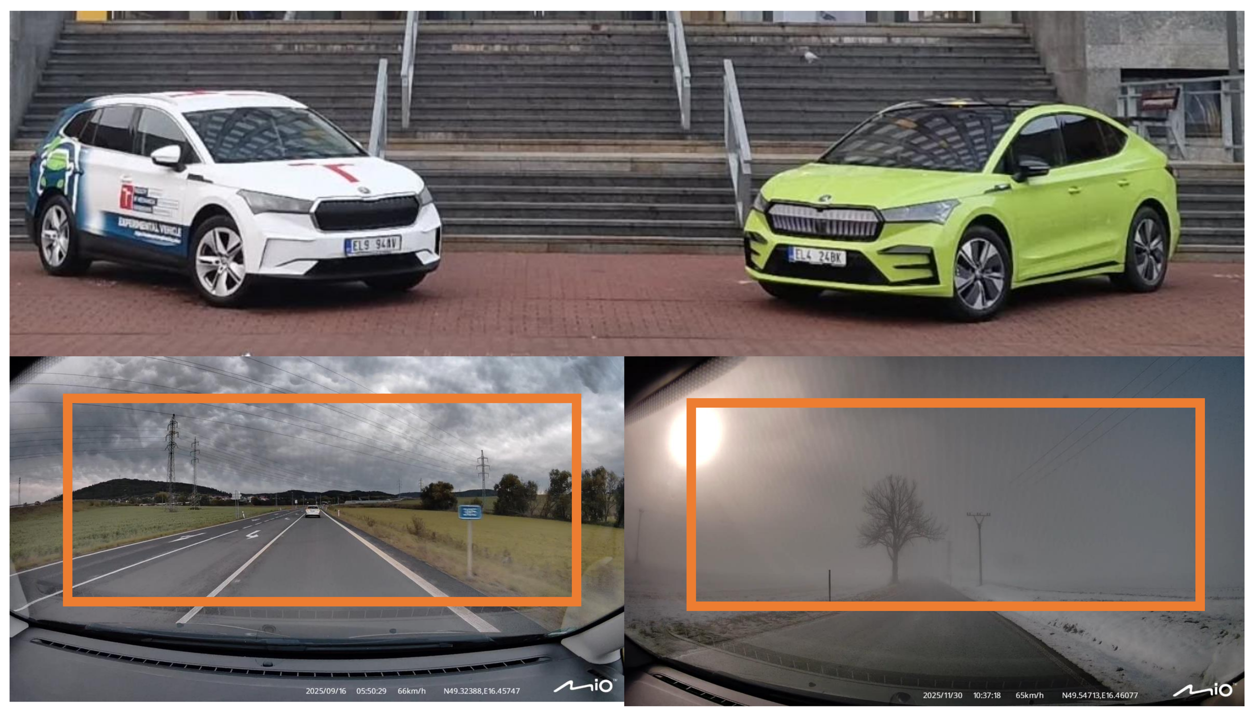
TESTING IMAGE STREAM

$$L = L_{pix} + \alpha L_{DoG} + \beta L_{RMS}$$
$$L_{pix} = \left\|I - \hat{I}\right\|_1$$
$$L_{DoG} = \left\|DoG(I) - DoG(\hat{I})\right\|_1$$
$$L_{RMS} = \left\|RMS(I) - RMS(\hat{I})\right\|_1$$

LOW VISIBILITY
FOG LIGHTS ACTIVATED

CASE STUDIES

1. Evaluation was conducted on a separate test set containing both clear and fog conditions.
2. Achieved an AUC of 0.91 in a one-class training setup (no fog samples used during training).
3. The results indicate strong discriminative capability for visibility degradation detection in automotive scenarios.
4. The framework is suitable for integration into camera-based ADAS visibility monitoring.



Data were acquired using our experimental vehicles (Škoda Enyaq iV and Škoda Enyaq Coupé RS iV). The cameras were mounted centrally behind the windscreen. To remove image borders and parts of the vehicle interior (e.g. the front section visible from the driver's perspective), a predefined region of interest (ROI), indicated by orange rectangles in the images, was used for further processing.

FUTURE WORK

Future work will focus on distinguishing fog from other adverse conditions such as rain or snow by analysing the spatial characteristics of degradation. We also plan to validate the method on larger and more diverse datasets. Further improvements will target robustness under varying illumination conditions. Finally, integration into real-time ADAS pipelines and multimodal extensions will be explored.

REFERENCES

[1] AYOUB A., EL-SHAFAI W., EL-SAMIE F. E. A., et al.: Review of Dehazing Techniques: Challenges and Future Trends. Multimedia Tools and Applications 84(1), 1103–1131, 2025.
[2] PAVLIĆ M., BELZNER H., RIGOLL G., ILIĆ S.: Image Based Fog Detection in Vehicles. In *Proc. IEEE Intelligent Vehicles Symposium (IVS)*, pp. 1132–1137, 2012.
[3] WANG H., XU Y., HE Y., CAI Y., CHEN L., LI Y., SOTELO M. A., LI Z.: YOLOv5-Fog: A Multi-objective Visual Detection Algorithm for Fog Driving Scenes Based on Improved YOLOv5. *IEEE Transactions on Instrumentation and Measurement* 71, 2022.
[4] YANG W., ZHAO Y., LI Q., ZHU F., SU Y.: Multi Visual Feature Fusion Based Fog Visibility Estimation for Expressway Surveillance Using Deep Learning Network. *Expert Systems with Applications* 234, 121151, 2023.

FACULTY OF MECHANICAL ENGINEERING institute of mathematics
iTEM
TRANSPORT RESEARCH CENTRE

ACKNOWLEDGMENT

This publication was supported by the project "Innovative Technologies for Smart Low Emission Mobilities", funded as project No. CZ.02.01.01/00/23_020/0008528 by Programme Johannes Amos Comenius, call Intersectoral cooperation.