Literature Review and Proposal

Image Enhancement (Haze and Fog)

Fog Removal from Hazy Images to Improve Object Detection

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Recent Developments in Image Dehazing and Fog Removal for Object Detection

1. Introduction

Haze and fog, caused by light scattering in the atmosphere, significantly degrade image quality and impair the performance of vision-based systems such as object detection. Recent research has focused on improving dehazing algorithms, not only to restore visual quality but also to enhance downstream tasks such as detection and segmentation. This chapter reviews major advancements from top-tier venues—CVPR, ICCV, and NeurIPS—between 2020 and 2024, highlighting how modern dehazing approaches affect detection accuracy in hazy conditions [1–3].

2. Classical Deep-Learning Dehazing Methods

Classical CNN-based models estimate transmission and atmospheric light using encoder–decoder architectures. Morales et al. [4] proposed an efficient multi-scale U-Net (FastNet) achieving PSNR≈30.4 dB on NYU-Depth and PSNR≈22.1 dB on O-HAZE. These models improved restoration while maintaining real-time efficiency, crucial for autonomous systems.

3. Transformer-Based Dehazing Models

Recent methods employ Transformers for global context modeling. Guo et al. [5] introduced DehazeFormer (CVPR 2022), which embeds transmission-aware 3D positional encoding. Qiu et al. [6] presented MB-TaylorFormer (ICCV 2023), achieving state-of-the-art PSNR/SSIM with linear computational complexity.

4. Physics-Informed and Hybrid Models

Xie et al. [7] proposed SynFog (CVPR 2024), a photo-realistic synthetic fog dataset generated via end-to-end rendering. SynFog-trained models yielded higher PSNR (15.43 dB) and SSIM (0.612) on real fog, and improved YOLOv8 detection mAP (71.5%) compared to models trained on Foggy Cityscapes (69.7%).

5. Joint Dehazing–Detection Pipelines

Joint pipelines optimize dehazing and detection simultaneously. Zhang et al. [8] developed UDnD (ACCV 2020) with a haze-density classifier guiding both networks. AlHindaassi et al. [9] proposed ADAM-Dehaze (2025), which improves PSNR by +2.1 dB and detection mAP by +13 points over baselines.

6. Benchmark Datasets and Metrics

Common datasets include RESIDE, DNH-HAZE, SynFog, and Foggy Cityscapes. Metrics like PSNR, SSIM, and mAP evaluate image restoration and detection quality [7,9]. SynFog's physically-based rendering pipeline reduces the domain gap between synthetic and real fog images.

Method	*Year (Venue)*	*Main Contribution*	*Datasets Used*	*PSNR / SSIM (if reported)*	*Detection mAP (if reported)*	*Joint (Dehaze–Det)*
FastNet (Morales et al.)	2019 (CVPRW)	Efficient CNN dehazing (small/large variants); feature-forwarding architecture	NYU Depth (synthetic haze), O-HAZE, I-HAZE	NYU-Depth: PSNR≈30.4, SSIM≈0.97; O-HAZE: PSNR≈22.1, SSIM≈0.746	–	No
DCMPNet (Zhang et al.)	2024 (CVPR)	**Depth-assisted dehazing** via dual-task learning; mutual enhancement of dehazing & depth	RESIDE-ITS/OTS, SOTS (synthetic)	SOTS indoor: PSNR up to ~40.4, SSIM ~0.995	–	No (dehaze+depth)
SynFog (Xie et al.)	2024 (CVPR)	Photo-realistic synthetic fog dataset (500 scenes, 3 densities, realistic camera)	SynFog (proposed), plus FoggyCityscapes/VK for comparison	Real-fog test: PSNR≈15.43, SSIM≈0.6116 when trained on SynFog	On Foggy Zurich: 71.5% (SynFog-trained) vs 69.7% (Cityscapes)	No
DeHamer (Guo et al.)	2022 (CVPR)	Transformer dehazing with **transmission-aware 3D position embedding**	RESIDE, O/I-HAZE	SOTA on RESIDE benchmarks (e.g. SSIM, PSNR not given here)	–	No
MB-TaylorFormer (Qiu et al.)	2023 (ICCV)	Efficient multi-branch Transformer (Taylor expansion) for large-image dehazing	RESIDE (SOTS), others	SOTA PSNR/SSIM on benchmarks (no numeric here)	–	No
UDnD (Zhang et al.)	2020 (ACCV)	**Joint dehazing–detection** framework using haze-density classifier to guide both tasks	RTTS (foggy KITTI)	HRDN dehazing: PSNR/SSIM ≫ baselines	Improves detection mAP on real fog (not quoted)	Yes

ADAM-Dehaze (AlHindaassi et al.)	2025 (ArXiv)	Adaptive multi-stage dehazing (light/med/heavy branches) + fog-density–weighted loss	Cityscapes (synth), RTTS (real)	+2.1 dB PSNR over baseline	+13 pts mAP (IOU0.5) on RTTS	Yes

7. Open Challenges and Future Directions

Key challenges include reducing the synthetic–real domain gap, creating efficient multi-condition models, and integrating physics-based priors into learning frameworks. Future research should focus on realistic datasets, dynamic architectures, and unified dehazing–detection training [3,7,9].

References

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