Real-time haze removal and object detection for vehicle surveillance

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Introduction

Reduced visibility due to haze in adverse weather conditions is a major cause for road accidents.
Objective: To propose a system, C-Thru that removes the haze and improves visibility for the drivers in real-time.

Highlights of C-Thru system

- Reduces the presence of haze in every frame of a video.
- Detects vehicles and other barriers present on the road.

Challenges in existing work:

- High quality output comes at a heavy processing complexity cost. Light weight models produce low quality output.
- Loss of colour in images after dehazing.

Proposed System for Dehazing and Object Detection

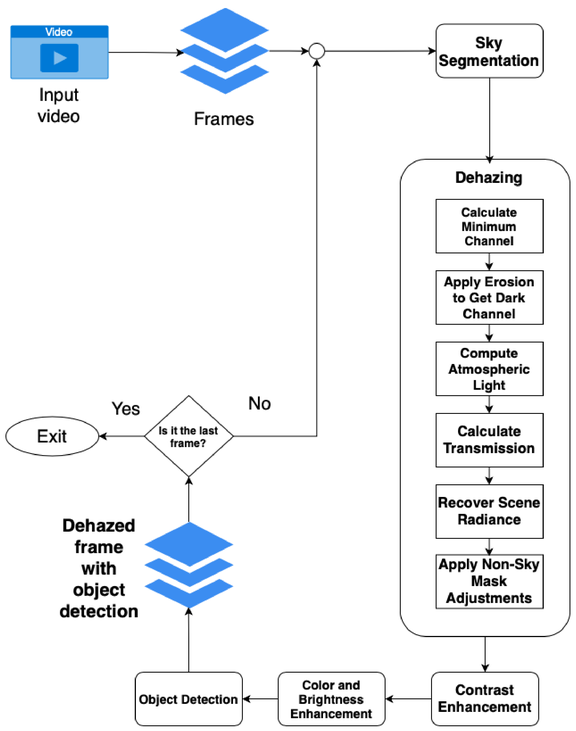

Figure 1. C-Thru Architecture

Dataset Description

- **RESIDE (REalistic Single Image DEhazing)**
  - A large-scale benchmark consisting of both synthetic and real-world hazy images.
  - Used to evaluate PSNR and SSIM of the dehazing module.

Table 1. RESIDE

Synthetic outdoor	Synthetic Indoor	Real Outdoor
72,135	14,490	9,129

- **NuImages**
  - A total of 93,000 images with instance masks and 2d boxes for 800k foreground objects on roadsides.
  - Used to train the object detection module.
- **DAWN**
  - A collection of 1000 images from real-traffic environments, divided into four sets of weather conditions: fog, snow, rain and sandstorms.
  - Is annotated with object bounding boxes for autonomous driving and video surveillance scenarios.
  - Used to analyse the mAP50 performance of the object detection module.

Performance Analysis of C-Thru

- **Impact on haze density**
  This is a score representing the predicted density of haze in an image. The value ranges between 0 and 1.

Table 2. EDN-GTM Haze density

Video	Before	After	Reduction(%)
1	0.543	0.492	9.3
2	0.735	0.628	14.5
3	0.612	0.547	10.6
4	0.549	0.461	16.2

Table 3. C-Thru(Proposed System) Haze density

Video	Before	After	Reduction (%)
1	0.543	0.454	16
2	0.735	0.471	35.85
3	0.612	0.418	31.65
4	0.549	0.4	27.05

- **Impact on latency**
  This is an important metric to consider for real-time applications. The proposed system gives good frame rate.

Table 4. EDN-GTM performance (in fps)

Video Resolution	Intel Core i5	Intel Core i7
1280 x 720	1.8	3.2
854 x 480	3.9	5.9
640 x 360	7.8	11.5
426 x 240	10.5	14.2

Table 5. C-Thru (Proposed system) performance (in fps)

Video Resolution	Intel Core i5	Intel Core i7
1280 x 720	7.5	16.1
854 x 480	13.35	21.4
640 x 360	24.9	31.2
426 x 240	36.39	**61.62**

- **Impact on PSNR and SSIM**
  - **Peak Signal to Noise Ratio (PSNR):** This ratio is used as a quality measurement between the original and processed image. The higher the PSNR, better the quality of the output image
  - **Structural Similarity Index (SSIM):** It is an image quality metric that shows the similarity between the original and processed image.

Table 6. Evaluation on RESIDE dataset.

Models	PSNR	SSIM
Deep Learning		
MFID-NET	**34.21**	0.9844
MA-MFC Net	33.6	**0.9869**
DehazeFormer	32.36	0.9736
LD-Net	26.98	0.9477
EDN-GTM	23.46	0.8198
C2PNET	20.09	0.8281
MSBDN	24.36	0.749
Unsupervised		
Depth Aware Unpaired Video Dehaze	**21.96**	**0.909**
CycleGAN	21.18	0.77
GAN and self supervised	15.62	0.781
Prior Based		
DCP	19.37	0.8431
C-Thru	**20.29**	**0.857**

- **Impact on mAP50**
  Images from the DAWN dataset were used to evaluate the object detection module in terms of the mAP50 metric.

Table 7. Evaluation using mAP50 metric

Method	Before dehazing	After dehazing
DCP	0.734	0.752
EDN-GTM	0.734	0.745
MSBDN	0.734	0.755
C2PNET	0.734	0.753
C-Thru	0.734	0.761

Dehazed and object detected

A Hazy image taken from the *Real Outdoor* subdivision of the RESIDE dataset and the corresponding output image from our proposed system.

Figure 2. Input frame

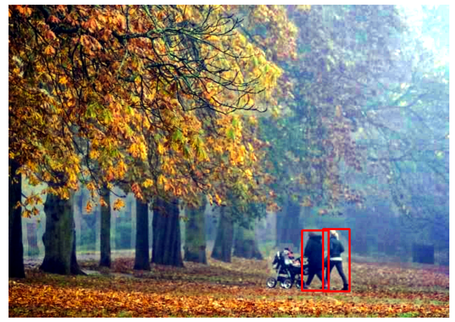

Figure 3. Output frame from C-Thru system

Inferences

- The proposed C-Thru system shows a better haze density reduction percentage as compared to the other machine learning based models.
- It shows 0.19% improvement in PSNR and 8.34% improvement in SSIM than the other prior based models.
- It reaches upto 60 fps for videos of 240p resolution and provides real-time support upto 480p.

Future Scope

- The sky segmentation algorithm is not perfect. It fails in creating a perfect mask at areas close to the horizon.
- The system cannot handle HD and Full-HD videos in real-time speeds.