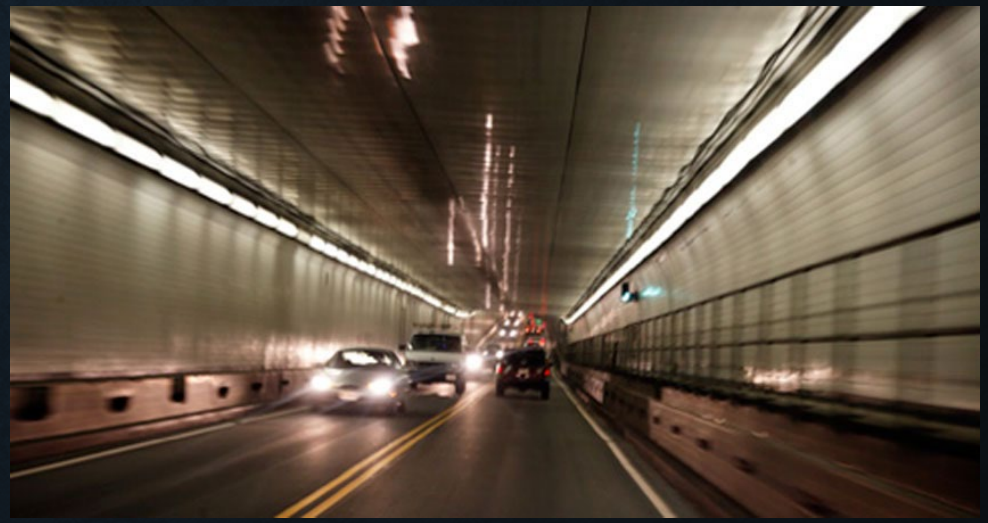
OPTIMIZED TUNNEL IMAGE ENHANCEMENT



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TITLE: TRAFFIC INCIDENT DETECTION AND ANALYSIS SYSTEM (TIDAS)

I want to thank Dr. Agaian, the Computer Science Department, and the College of Staten Island for opportunity to work on this project.

BACKGROUND

1. Recently, many tunneling projects were conducted to use the limited land surface area more efficiently. Such underground constructions are used for transportation such as for railways, subways and roads, to host equipment used for experiments like particle accelerators, as well as for pipelines and mines. Tunnels should be regularly inspected in order to avoid accidents resulting from structure failure and to simultaneously extend their lifetime by identifying deterioration at an early stage and perform the required maintenance.
2. Other challenges related to illegal drug trafficking via tunnels. Between 2007 and 2011, federal authorities have detected more than 75 cross-border smuggling tunnels, most of them in California and Arizona [1].
3. Tunnel fire detection and fighting application
4. Self-driving cars (Tunnel lane-positioning system for autonomous driving). Traditional methods of tunnel inspection and tunnel activity monitoring mostly rely on manual vision monitoring and sensing equipment that requires installation and contact with the tunnel surface, which is:
    - time consuming
    - tedious and expensive
    - highly dependent on human subjectivity
    - exposes inspection personnel to possible dangerous environments.

[1] L. Attard et al., Tunnel inspection using photogrammetric techniques and image processing: A review, Volume 144, October 2018
M. Dao et al., A Joint Sparsity Approach to Tunnel Activity Monitoring Using High Resolution Satellite Images

CHALLENGES

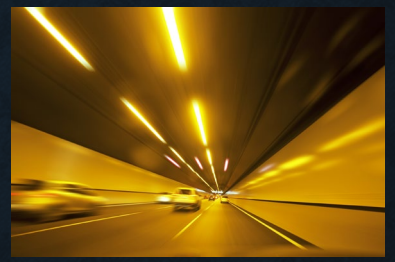
- Tunnel environment is unbalanced:
  - Low illumination
  - Reflected light
- Obtained images:
  - Hazy
  - Blurry
  - Noisy
  - Low contrast
  - Low brightness
  - Narrow dynamic range of colors
  - Limit computer vision systems

SOLUTION

Image enhancement could help computer vision systems to see and analyze better





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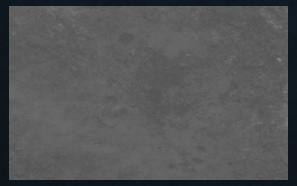
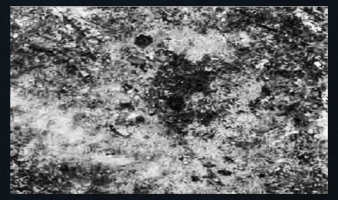
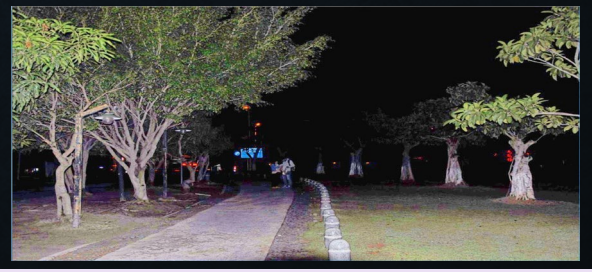
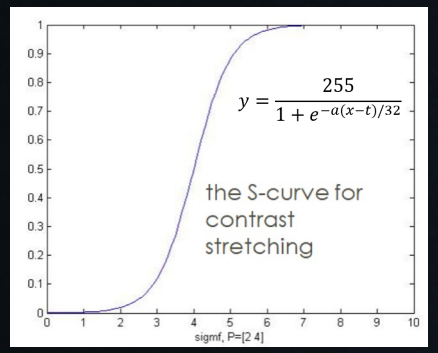
How to enhance tunnel image contrast/quality automatically?

The objective of the study is to improve the perception of information for both human viewers and automated image processing systems by creating a system for optimized contrast enhancement of tunnel images

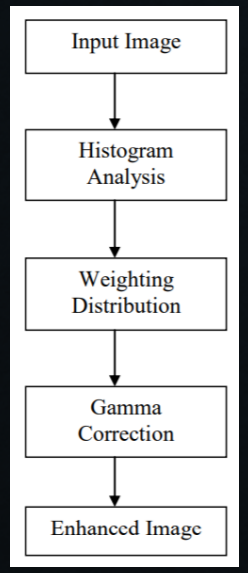





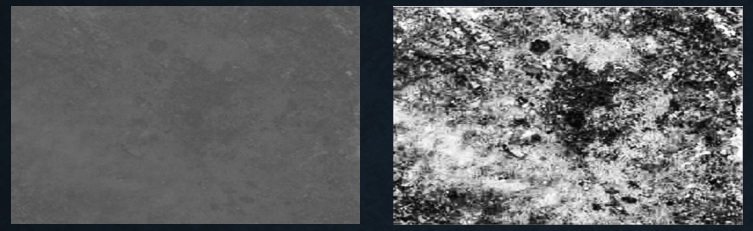
METHOD



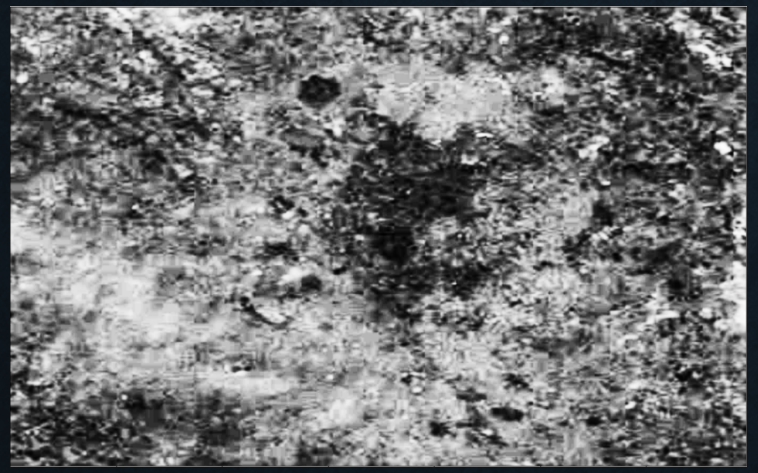
S-curve Stretching



Adaptive Gamma Correction Weighted Distribution



Contrast Limited Adaptive Histogram Equalization (CLAHE)



Alpha-Blending (α=0.3)

$$EME = \frac{1}{k_1 k_2} \sum_{l=1}^{k_2} \sum_{k=1}^{k_1} \frac{I^w_{\max;k,l}}{I^w_{\min;k,l} + c}$$

EME-score

1. S-curve contrast stretching to increase the dynamic range of gray levels using improved Otsu's thresholding algorithm
2. Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm to improve the contrast
3. Alpha-Blending (α=0.3) to restore image data that might be lost during the previous steps
4. Adaptive Gamma Correction algorithm to improve brightness
5. Adaptive Alpha-Blending that generates alpha based on the best EME-score (Measure of Contrast Enhancement)
6. (OPTIONAL) Restore color using Deep Learning Colorization model

RESULTS

RESULTS

Original - Gray

Enhanced - Gray

Original - RGB

Enhanced - RGB

RESULTS

Original - Gray

Enhanced - Gray

Original - RGB

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RESULTS

Original - Gray

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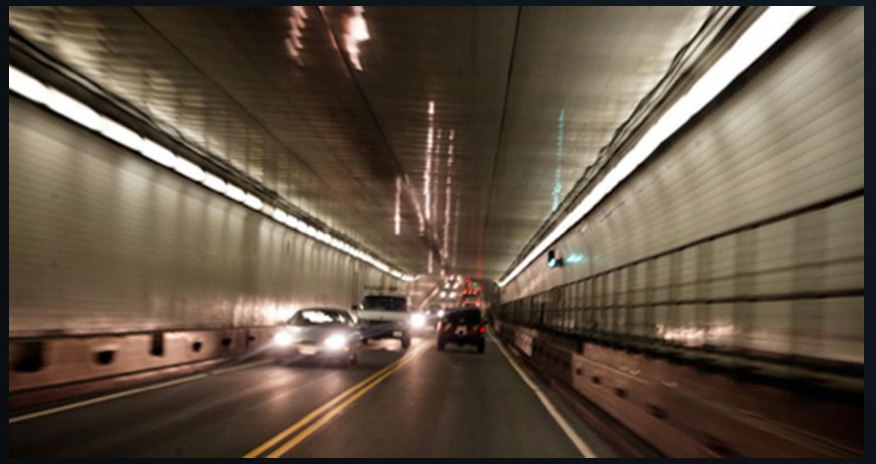
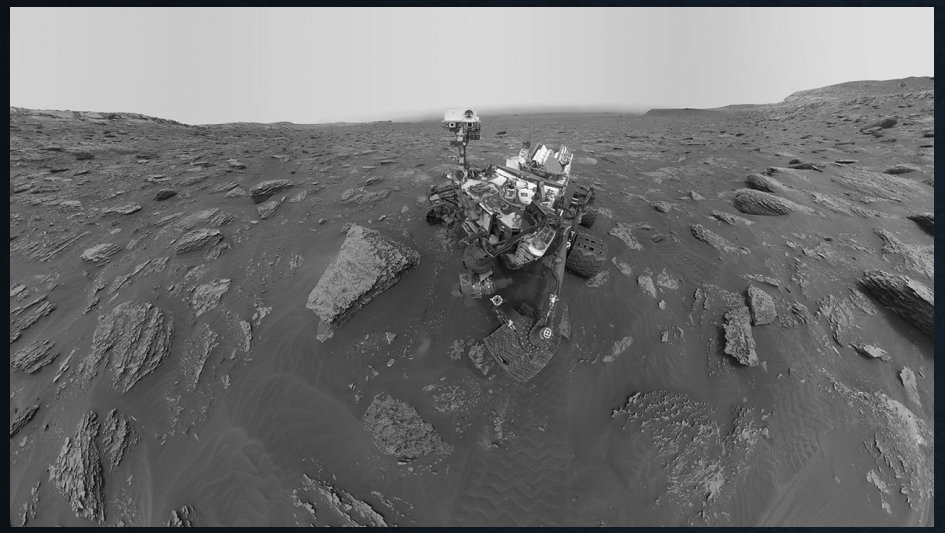


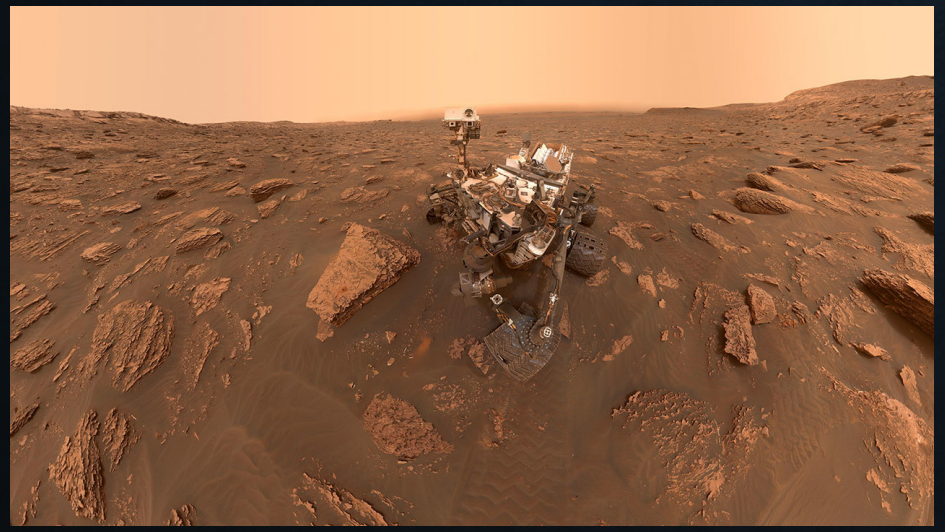
Enhanced - RGB

RESULTS



Original - Gray

Enhanced - Gray



Original - Gray

Enhanced - RGB

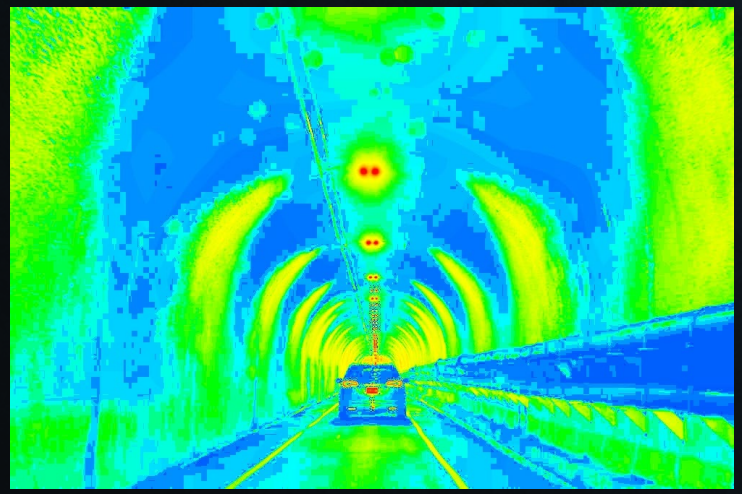
DISCUSSION

COLOR RESTORATION

Original - RGB

Enhanced - Gray

Enhanced - RGB



Pseudo-color Mapping

Deep Learning Color Restoration – SIGGRAPH17

Deep Learning Color Restoration – ECCV16

DISCUSSION

RUNNING ALGORITHM ON RGB CHANNELS

Original - RGB

Enhanced - RGB

DISCUSSION

RUNNING ALGORITHM ON RGB
CHANNELS SEPARATELY

Original - RGB

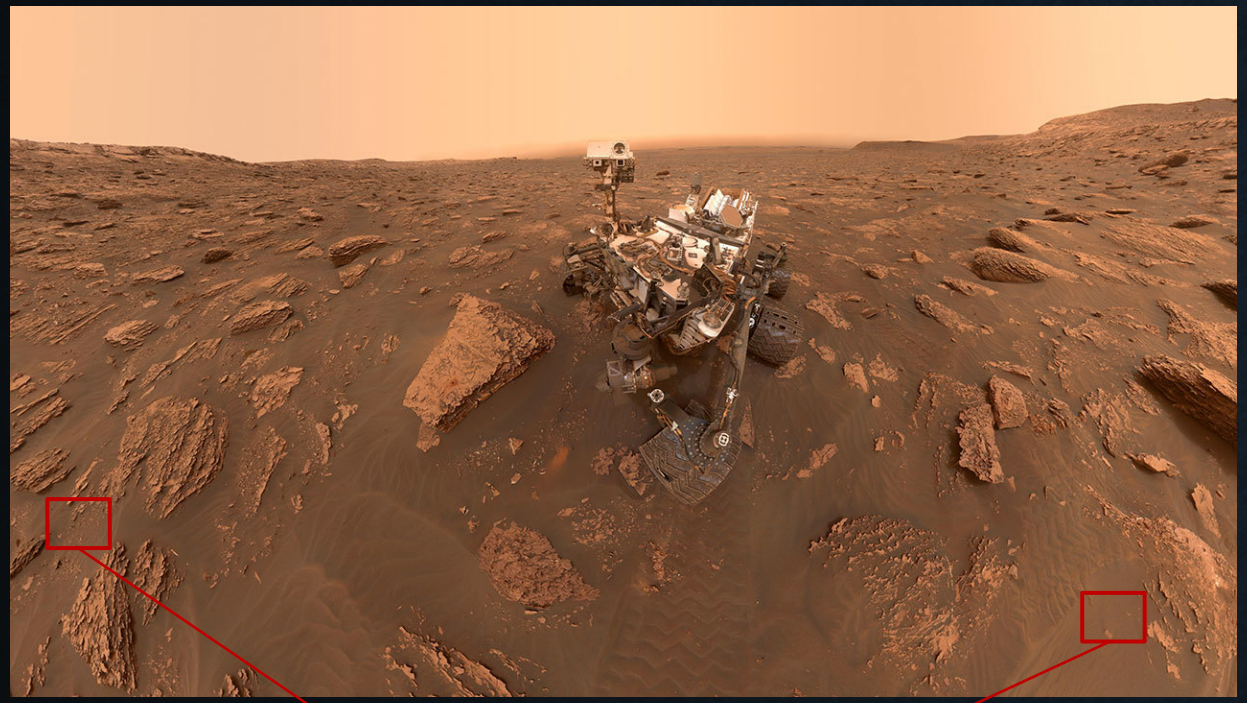
Enhanced - RGB

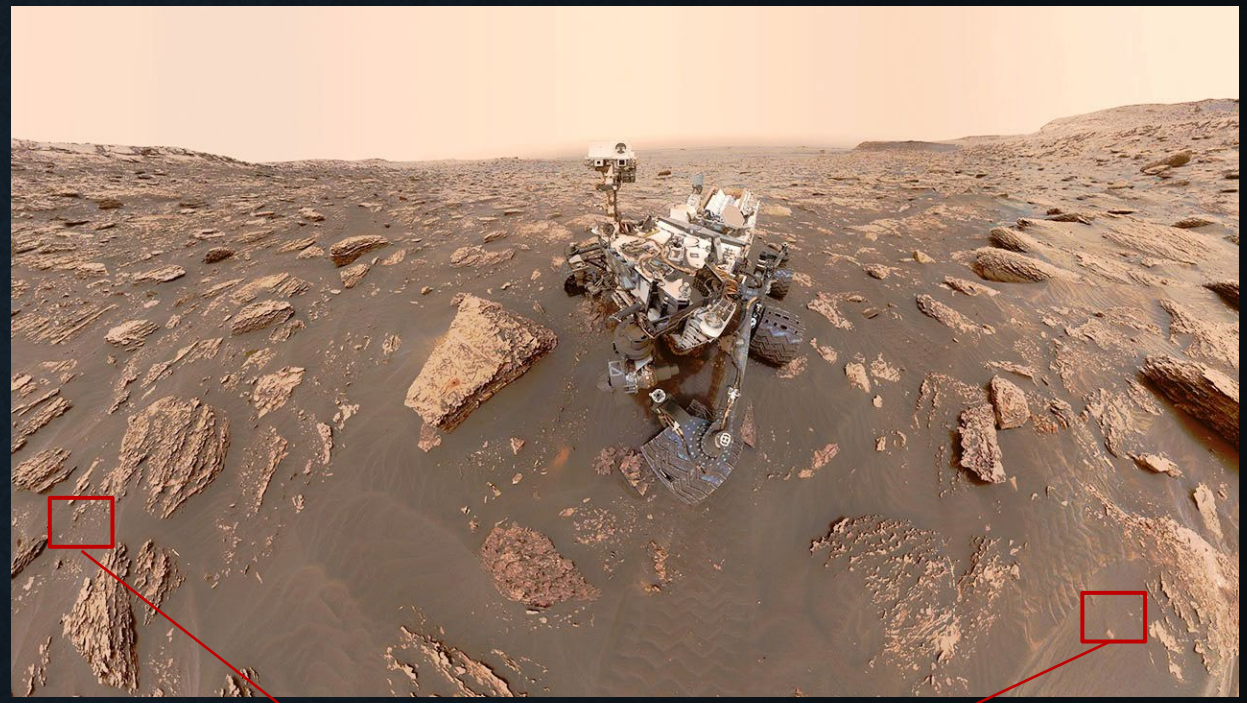
DISCUSSION

RUNNING ALGORITHM ON RGB CHANNELS

Original - RGB

Enhanced - RGB





CONCLUSION

- The results show improvements in contrast compared to the original image and the traditional state-of-the-art contrast stretching algorithms
- The system performs better in dark environments
- Contrast enhancement brings up compression artifacts

FUTURE WORK

- Separated enhancement of dark and bright regions
- Histogram equalization based on average value of color channel
- Reduce runtime by picking average alpha values for specific cases
- Denoising
- Image Restoration