“A SINGLE BACKLIT IMAGE ENHANCEMENT METHOD FOR IMPROVEMENT OF VISIBILITY OF DARK PART”

by Masato Akai et al. (Published: IEEE ICIP, 2021)

Aniket Das (CS2407)
&
Soham Chakraborty (CS2432)

Course: Image Processing - I
Instructor: Pradipta Majhi
Indian Statistical Institute, Kolkata

Introduction : Backlit Image

An image where the primary light source is behind the subject, causing the foreground to appear dark or silhouetted.

Challenges:

- Loss of detail in shadows and highlights
- Poor contrast in key subject areas
- Glare or halo effects around object edges
- Difficulty in segmentation and object detection

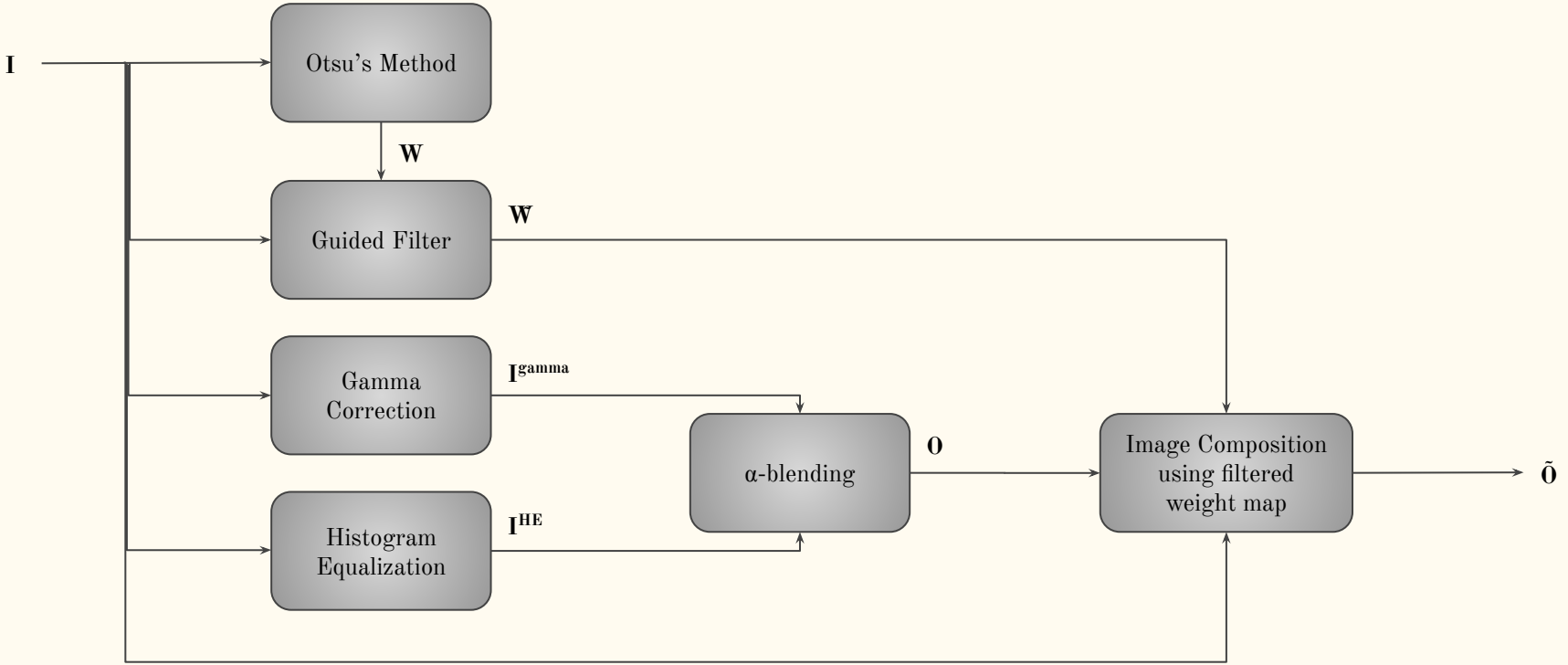
Objective of the Paper

- Propose a simple and fast method for enhancing backlit images
- Improve visibility in dark regions without introducing artifacts
- Avoid over-enhancement and color distortion common in other methods
- Develop an approach for real-time applications and low-resource devices

Proposed Method

- Generation of enhanced intensity image using Gamma Correction and Histogram Equalization
- Generation of weight map using Otsu's Thresholding and creating a guided weight filter
- Image composition using the filtered weight map

Flowchart


I
Otsu's Method
W
Guided Filter
W̃
Gamma Correction
I^gamma
Histogram Equalization
I^HE
α-blending
O
Image Composition using filtered weight map
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Proposed Method : Implementation

Original image

Proposed Method : Implementation

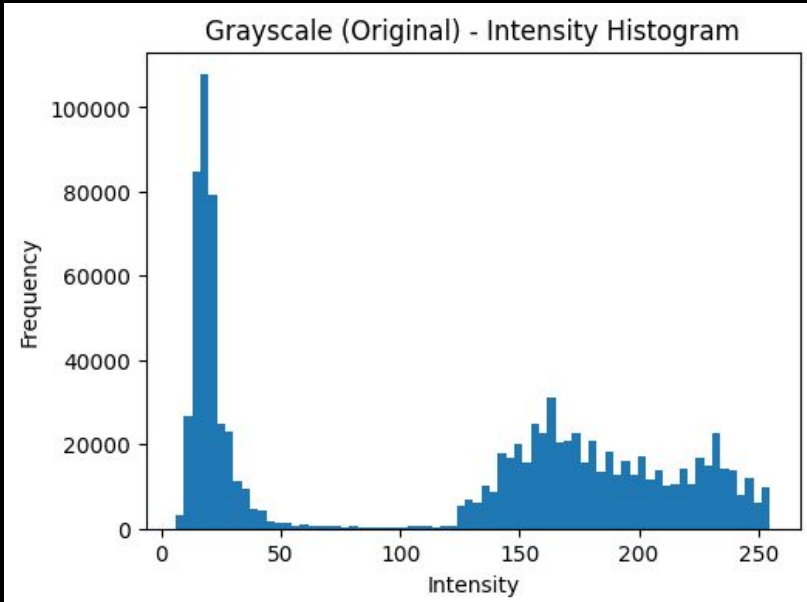
Let $\boldsymbol{I}_{ij}^{\boldsymbol{RGB}}$ be a pixel value of an input 24-bit RGB color backlit image.

The intensity image is first computed using the mean of all components (red, green, blue) for a particular pixel:

$$\boldsymbol{I}_{ij}^{RGB} = (I_{ij}^{R}, I_{ij}^{G}, I_{ij}^{B})^{\mathsf{T}} \; (i = 1, 2, \cdots, M; j = 1, 2, \cdots, N)$$

$$I_{ij} = (I_{ij}^{R} + I_{ij}^{G} + I_{ij}^{B})/3$$

Proposed Method : Implementation



Histogram of the image

Grayscale intensity image I

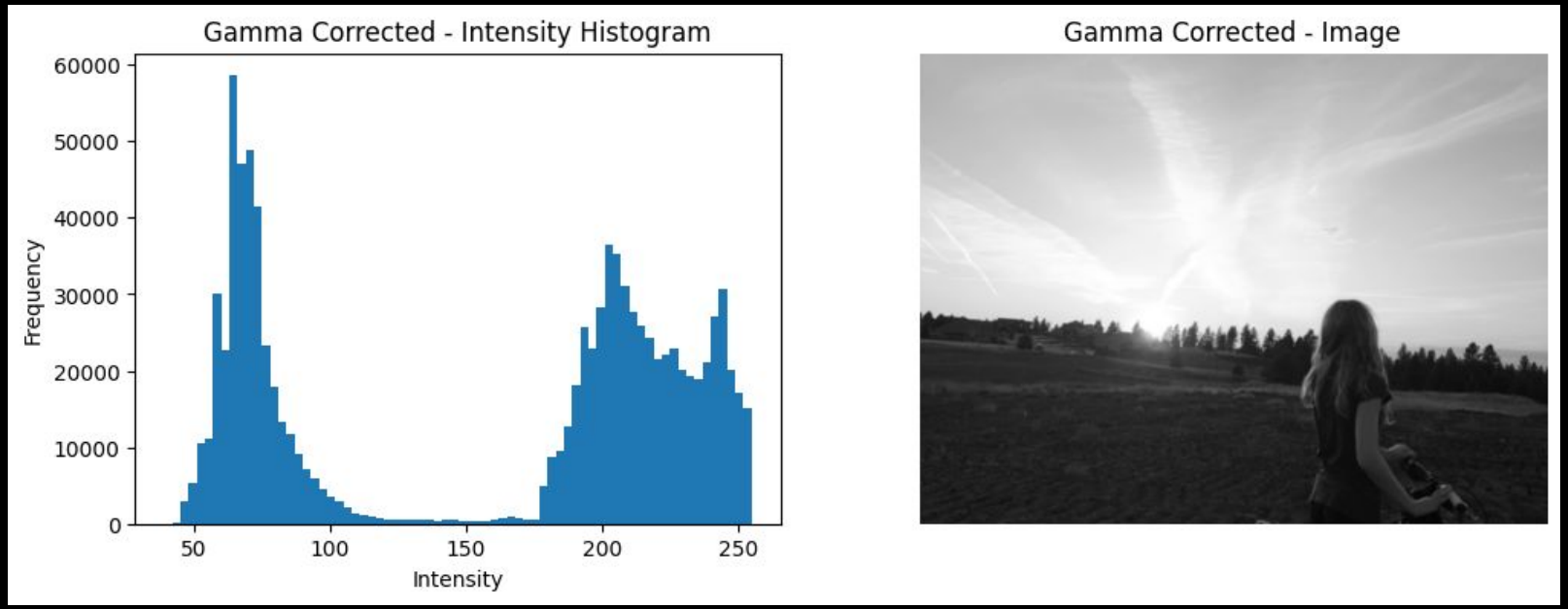
Proposed Method : Implementation

Gamma Correction : To improve the visibility of the image, gamma correction is applied to $\boldsymbol{I_{ij}}(\boldsymbol{\gamma} = 2)$.

$$I_{ij}^{gamma} = 255 \cdot (I_{ij}/255)^{\frac{1}{\gamma}}$$

Histogram Equalization : The contrast is further improved using histogram equalization.

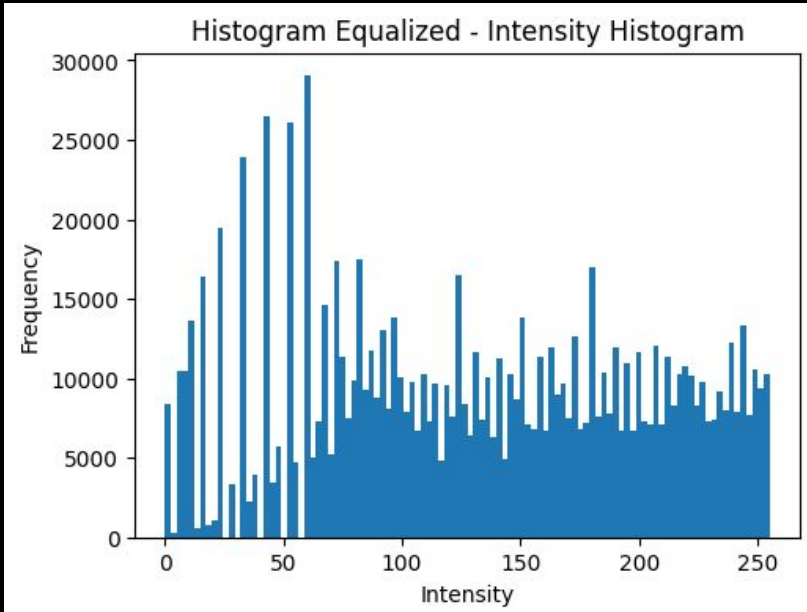
Proposed Method : Implementation



Histogram of the image

Result of gamma correction for I

Proposed Method : Implementation



Histogram of the image

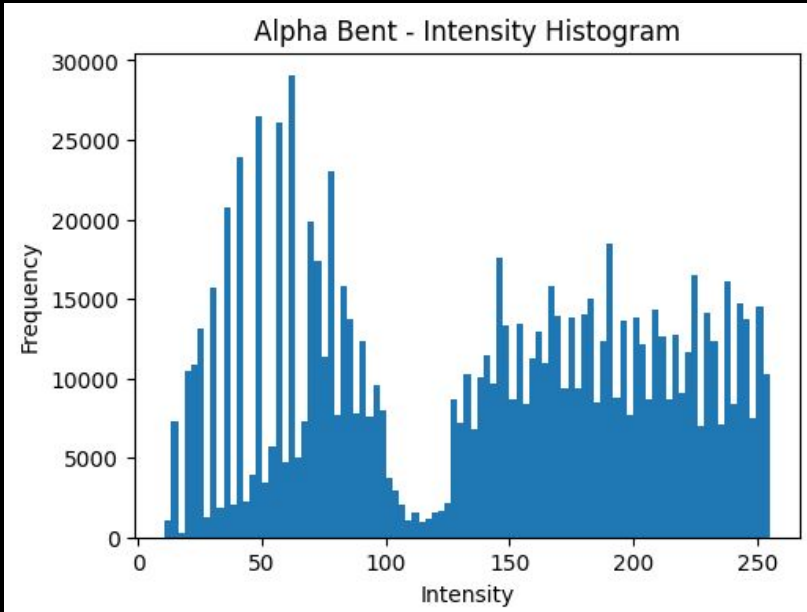
Result of histogram equalization for I

Proposed Method : Implementation

Alpha Blending : The pixel values of an enhanced intensity image $\boldsymbol{O}$ is calculated as follows ($\boldsymbol{\alpha} = 0.7$):

$$O_{ij} = (1 - \alpha) \cdot I_{ij}^{gamma} + \alpha \cdot I_{ij}^{HE}$$

Proposed Method : Implementation



Histogram of the image

Enhanced image obtained by alpha blending

Proposed Method : Implementation

Otsu's Method : It is used to divide the intensity image into dark and bright parts.

Obtaining the ideal threshold value t which maximizes the optimization function:

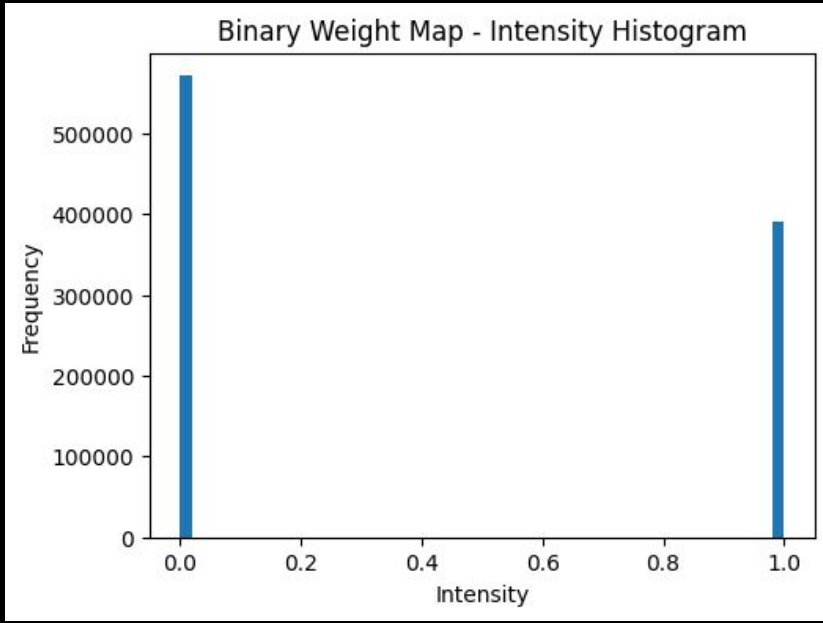
$$\omega_b \omega_w (m_b - m_w)^2$$

where:
ω_b : Number of pixels belonging to black class
ω_w : Number of pixels belonging to white class
m_b : Mean of pixels belonging to black class
m_w : Mean of pixels belonging to white class

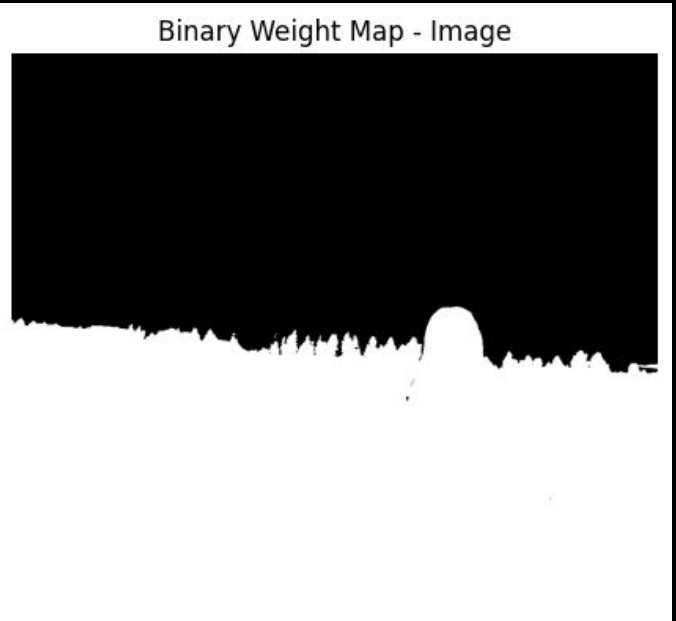
Using this threshold t, a binary image W is generated:

$$W_{ij} = \begin{cases} 1, & I_{ij} < t \\ 0, & \text{otherwise} \end{cases}$$

Proposed Method : Implementation



Histogram of the image



Binary weight map obtained from Otsu's Method

Proposed Method : Implementation

Guided Filter : Otsu's method determines the threshold value from the histogram distribution of the entire image and does not consider the local bright-dark pattern. To resolve this, a guided filter is applied to the weight map with ***I*** as a guide image.

$$\tilde{W}_{ij} = \overline{a}_{ij} \cdot I_{ij}^{nor} + \overline{b}_{ij}$$

$$I_{ij}^{nor} = \frac{1}{255} \cdot I_{ij}$$

$$a_{ij} = \frac{\frac{1}{(2r+1)^2} \sum_{(k,l)\in\Omega_{ij}} I_{kl}^{nor} \cdot W_{kl} - \overline{I}_{ij}^{nor} \cdot \overline{W}_{ij}}{\frac{1}{(2r+1)^2} \sum_{(k,l)\in\Omega_{ij}} \left(I_{kl}^{nor} - \overline{I}_{ij}^{nor}\right)^2 + \epsilon}$$

$$b_{ij} = \overline{W}_{ij} - a_{ij} \cdot \overline{I}_{ij}$$

where, $\boldsymbol{\Omega}_{ij}$ is a $(2\boldsymbol{r}+1)\times(2\boldsymbol{r}+1)$ square region centered at (i, j) ($\boldsymbol{r} = 1$)

Proposed Method : Implementation

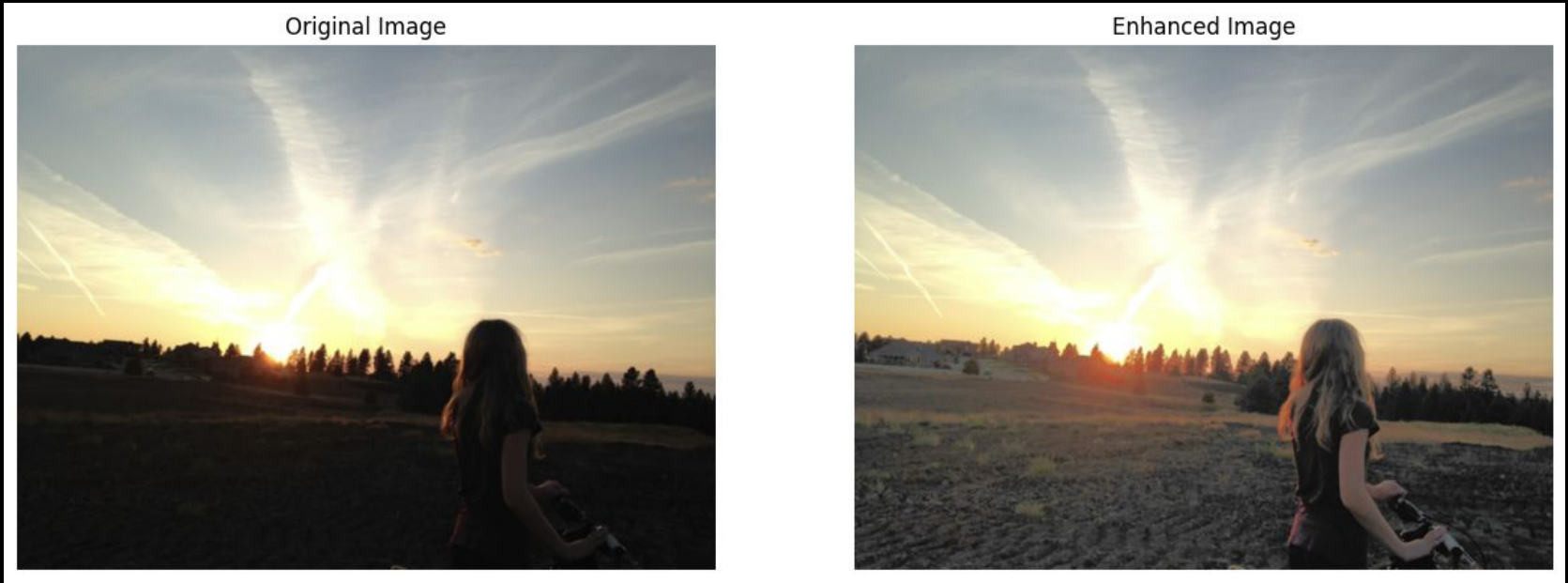
Image Composition using filtered weight map : Using $\tilde{\boldsymbol{W}}$, the final intensity image $\tilde{\boldsymbol{O}}$ is composed by the following equation:

$$\tilde{O}_{ij} = \tilde{W}_{ij} \cdot O_{ij} + (1 - \tilde{W}_{ij}) \cdot I_{ij}$$

Then $\tilde{\boldsymbol{O}}$ is colorized by the following equation:

$$\tilde{\boldsymbol{O}}_{ij}^{RGB} = \boldsymbol{I}_{ij}^{RGB} \cdot (\tilde{O}_{ij}/I_{ij})$$

Proposed Method : Implementation

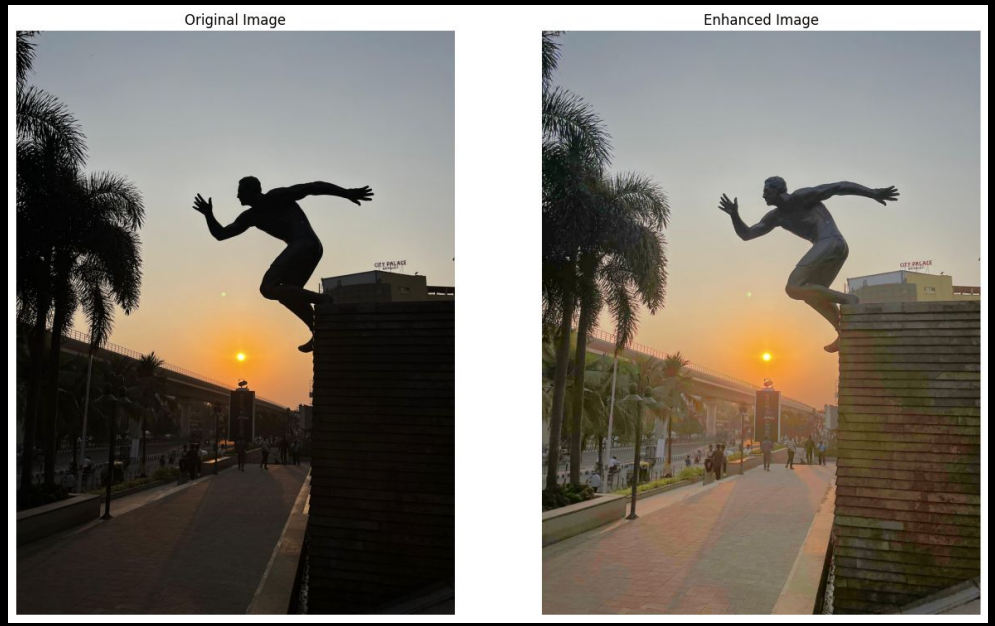


Original Backlit Image

Enhanced Image using the proposed method

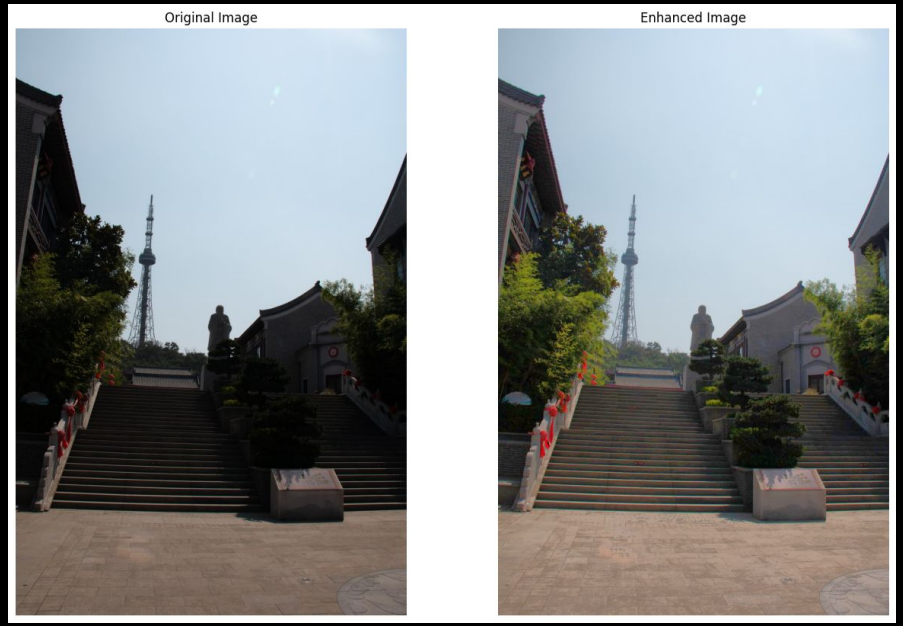
Implementation on Set of Backlit Images

Implementation on Set of Backlit Images



Implementation on Set of Backlit Images

Implementation on Set of Backlit Images



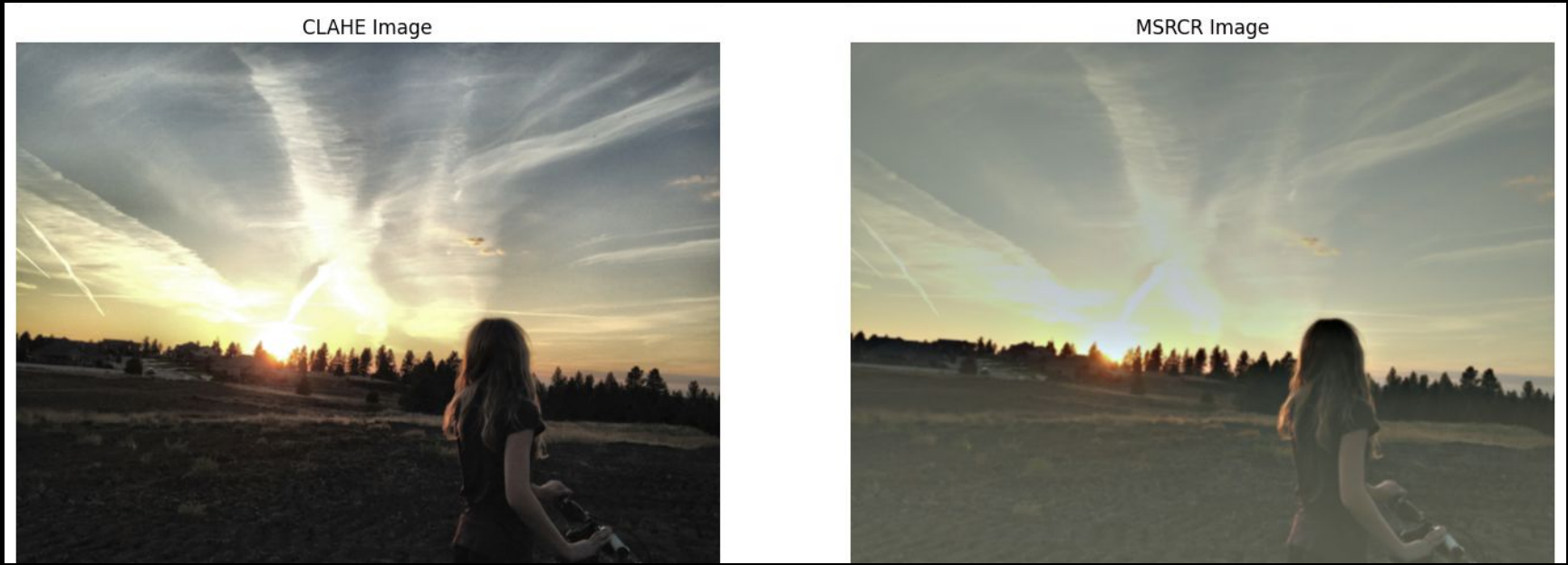
Proposed Algorithm vs Other Methods

The proposed algorithm is compared with Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE) and Multiscale Retinex with Color Restoration (MSRCR).

For comprehensive evaluation the following metrics have been used:

- LOE (Lightness Order Error): Measures the change in lightness order, lower LOE means better preservation
- Q Value: Assesses image quality, calculated separately for dark and bright regions using the binary image
- NIQE (Naturalness Image Quality Evaluator): A no-reference metric, lower scores indicate better quality

Proposed Algorithm vs Other Methods



Proposed Algorithm vs Other Methods

Proposed Algorithm vs Other Methods

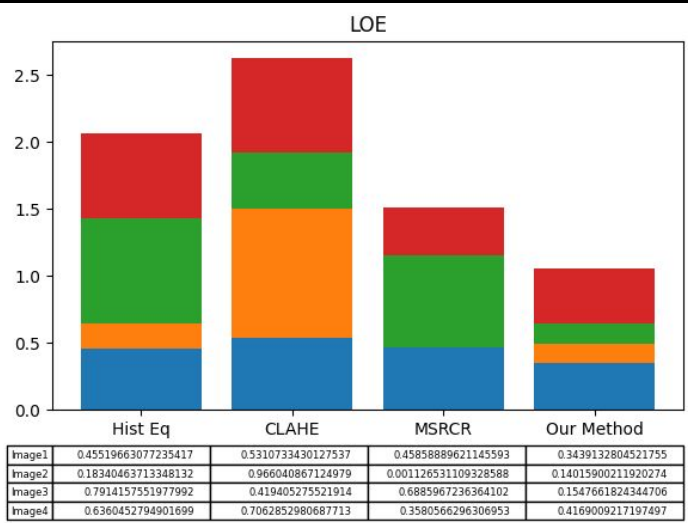


Image1	0.455196630772354 17	0.5310733430127537	0.4585888962114559 3	0.3439132804521755
Image2	0.183404637133481 32	0.9660408671249 79	0.0011265311093285 88	0.1401590021192027 4
Image3	0.7914157551977992	0.4194052755219 14	0.6885967236364102	0.1547661824344706
Image4	0.6360452794901699	0.7062852980687713	0.3580566296306953	0.4169009217197497

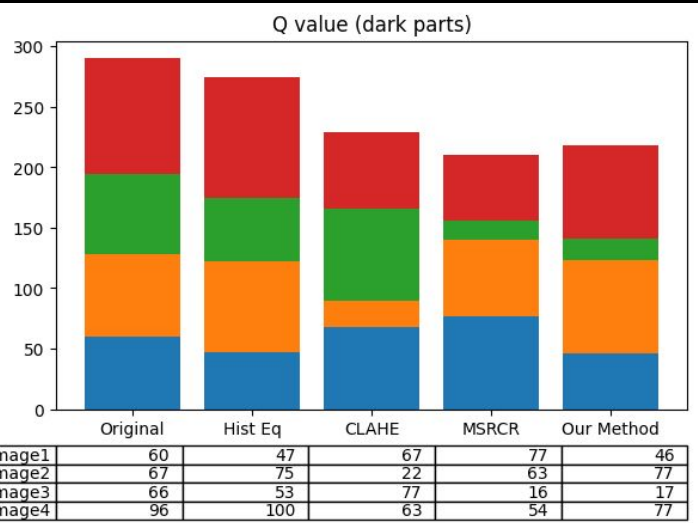
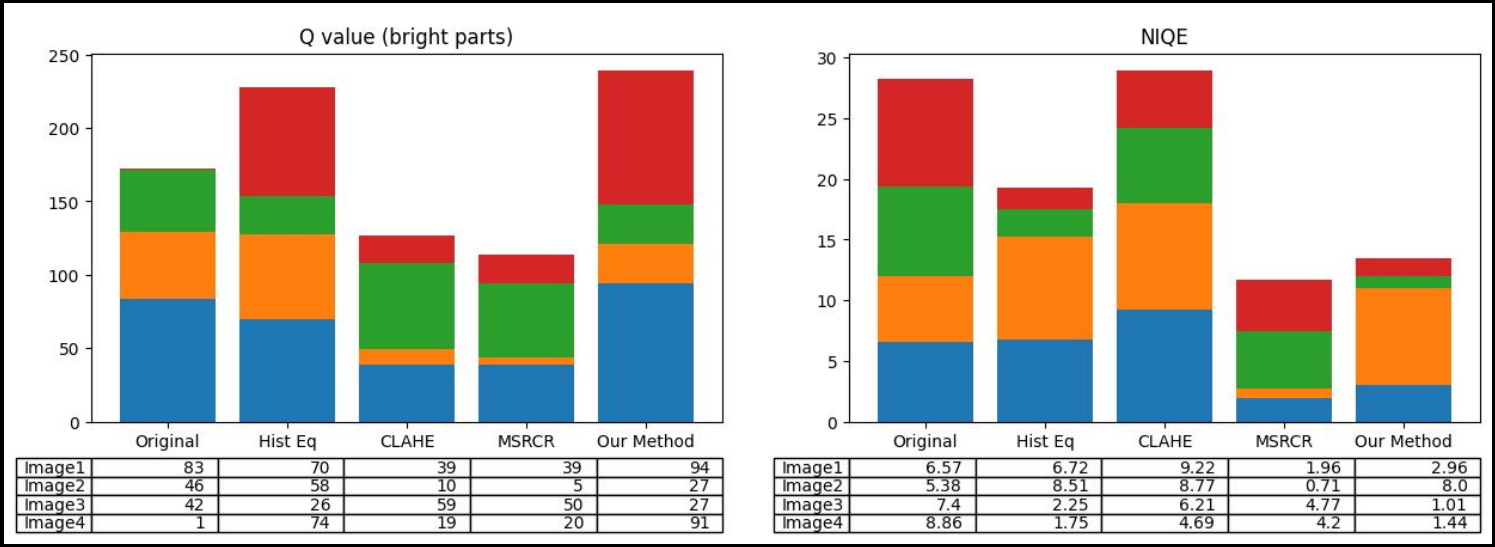


Image1	60	47	67	77	46
Image2	67	75	22	63	77
Image3	66	53	77	16	17
Image4	96	100	63	54	77

Proposed Algorithm vs Other Methods



	Original	Hist Eq	CLAHE	MSRCR	Our Method
Image1	83	70	39	39	94
Image2	46	58	10	5	27
Image3	42	26	59	50	27
Image4	1	74	19	20	91

	Original	Hist Eq	CLAHE	MSRCR	Our Method
Image1	6.57	6.72	9.22	1.96	2.96
Image2	5.38	8.51	8.77	0.71	8.0
Image3	7.4	2.25	6.21	4.77	1.01
Image4	8.86	1.75	4.69	4.2	1.44

Conclusion

- The proposed method consistently achieves lower LOE scores across all test images, indicating better preservation of intensity structure.
- It delivers superior Q values for dark regions in Image 2 and bright regions in Images 1 and 4, showcasing balanced enhancement.
- NIQE results demonstrate that the method outperforms both HE and CLAHE in perceptual quality for all images.

Overall, the method effectively enhances the visibility of dark areas while minimizing artifacts, ensuring visually pleasing results.

References

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