

# Image Contrast Enhancement using Fuzzy Logic with Metaheuristics

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# What is Image Transformation?

- **Image Data** can be expressed as a tuple of all the pixel values
- A **mapping** can be done to map **one value of tuple** to another **possible value**. Therefore, **generating another image**

**An image transformation is such a mapping**

**A transformation can be expressed as a function**

# Contrast Enhancement

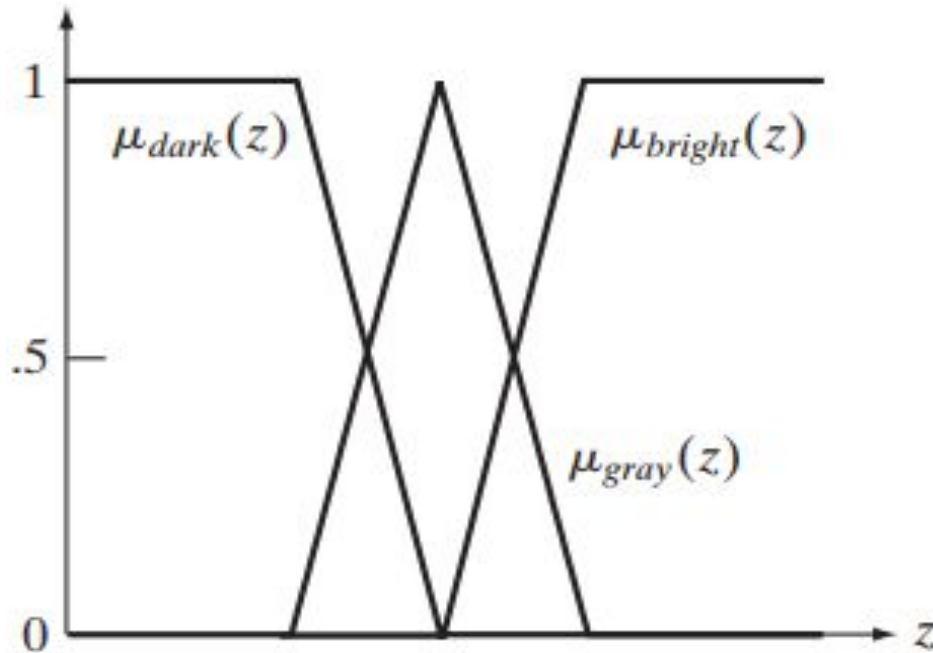
- Image contrast = |highest pixel value - lowest pixel value|
- Image has structure, we cannot arbitrarily change any pixel value
- Although defined mathematically, it is associated with subjective image quality
  - Increasing difference between pixels does not mean it will look good to human

# Contrast Enhancement: Fuzzy Workflow

A fuzzy description of image contrast enhancement workflow has three choice per pixel

1. IF a **pixel** is **dark**, THEN make it **darker**
  2. IF a **pixel** is **gray**, THEN make it **gray**
  3. IF a **pixel** is **bright**, THEN make it **brighter**
- How to define this human description quantitatively
    - How to define what is dark?
    - What is meant by making it gray?

# Contrast Enhancement: Fuzzy Membership of Pixel



$$v_0 = \frac{\sum_{i=1}^n \mu_i(z_0) * v}{\sum_{i=1}^n \mu_i(z_0)}; n = 3$$

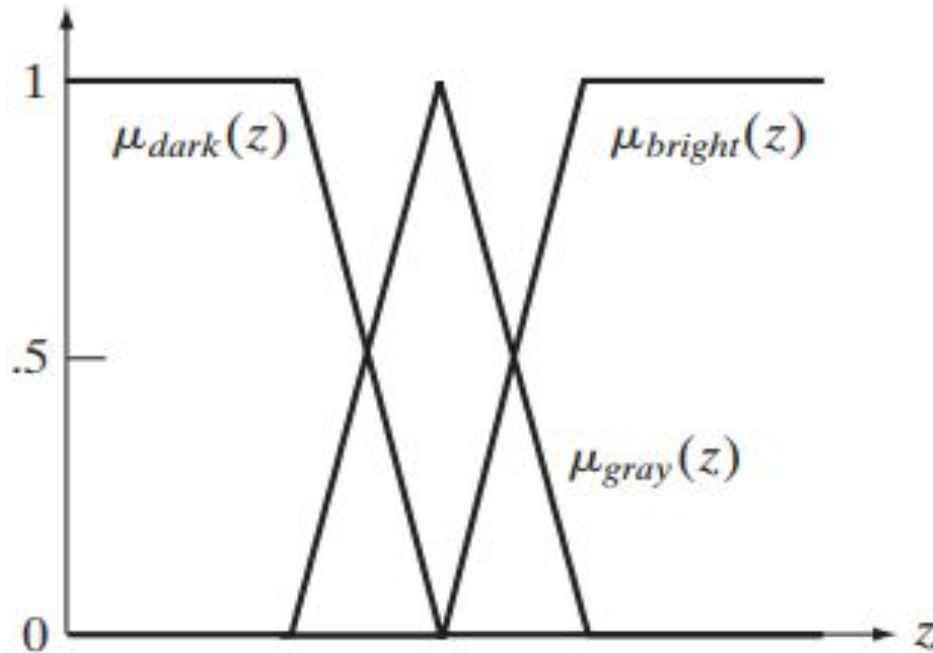
$z \in [0, 255]$ , pixel value

$\mu_i(z)$  : fuzzy membership of image pixel value  $z$  for in set  $i$

$u$ : value associated with each set

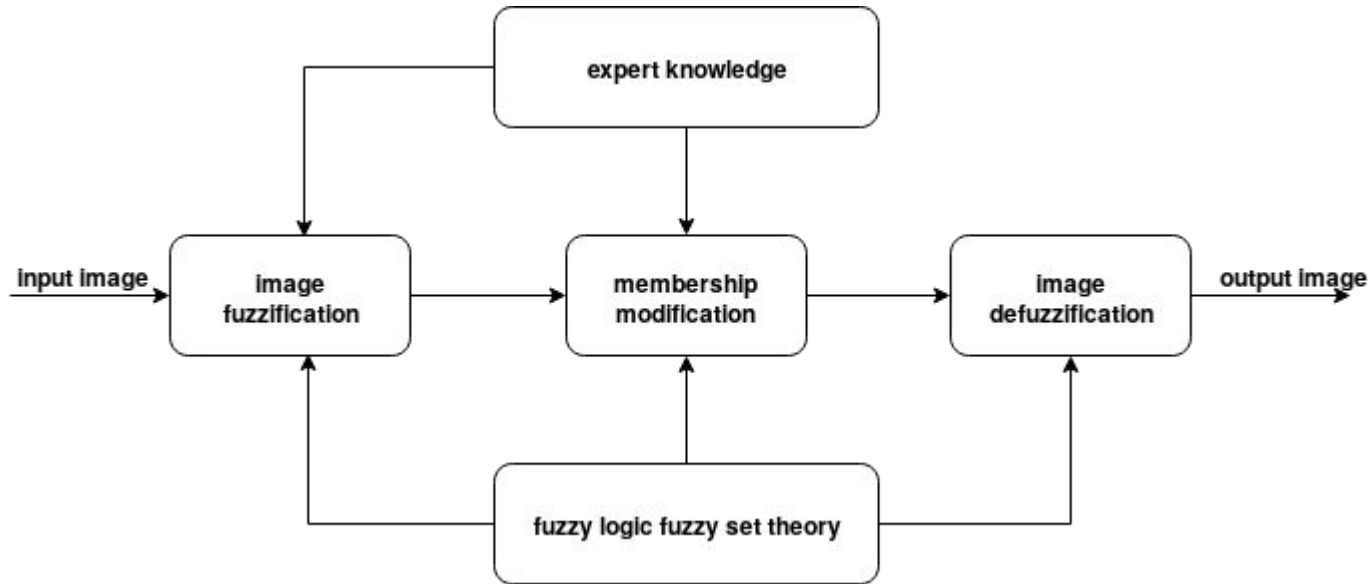
$u_0$ : defuzzified value

# Research Question



1. Is this the best membership set?
2. How to look for better membership set?

# Methodology: Fuzzy Image Enhancement



# Methodology: Membership Modification (Our method)

- We decide **Member function shape and number** through **evolutionary algorithm**
  - Hill Climbing Algorithm (HC)
  - Genetic Algorithm (GA)



# Methodology: Fitness Function

$$\text{Fitness}(I) = \log \log E(I_s) \times \frac{\text{ne}(I_s)}{M \times N} \times H(I_s)$$

$I_s$  = image after Applying *Sobel filter* on  $I$

$E(I)$  = sum of intensity of image  $I$

$\text{ne}(I)$  = number of edge pixel in  $I$

$H(I)$  = entropy of image  $I$

$M$  = width of  $I$

$N$  = height of  $I$

# Evaluation Result:

## Contrast Comparison Metrics

- Michelson Contrast
- PSNR

## Image Structure Similarity Comparison Metrics

- SSIM

## Compared Approaches

1. HE (Histogram Equalization)
2. ACGWD \* (Adaptive Gamma Correction with Weighting Distribution)
3. Dual \*\* (Dual Channel prior-based Nighttime Low Illumination Image Enhancement)

\*Shih-Chia Huang, Fan-Chieh Cheng, and Yi-Sheng Chiu. 2012. Efficient contrast enhancement using adaptive gamma correction with weighting distribution. IEEE Trans. on Image Processing 22, 3 (2012), 1032–1041.

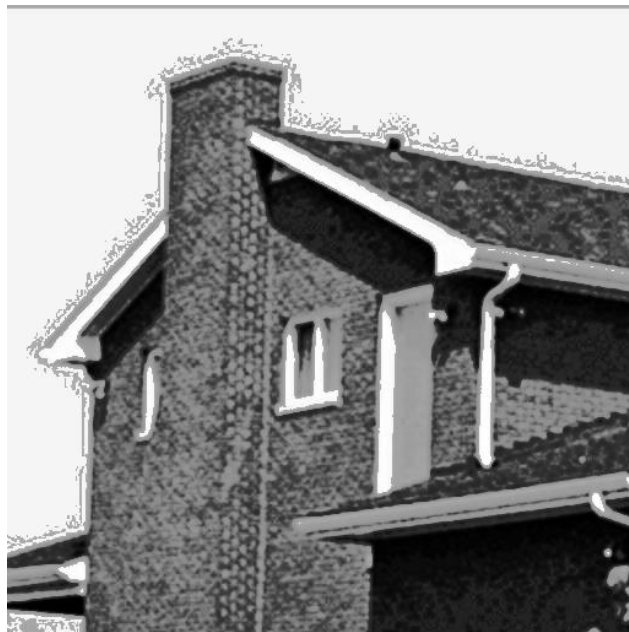
\*\*Zhenghao Shi, Mei Mei Zhu, Bin Guo, Minghua Zhao, and Changqing Zhang. 2018. Nighttime low illumination image enhancement with single image using bright/dark channel prior. EURASIP Journal on Image and Video Processing 2018 (2018), 1–15.

# Evaluation Result: Less Artifact

From SSIM value we can see our method has **greater SSIM** then SSIM of **HE** output



Original



HE



Ours

# Evaluation Result: Our Method helps in Overexposure

## Clarification

In the last edition of the "Catholic New World," an article on the annual conference hosted by the Respect Life Office did not fully reflect the context of Cardinal George's remarks.

During an informal question-and-answer session with the archdiocese's parish Respect Life Coordinators, the cardinal emphasized that the participation by any person in the promotion of abortion, including through his or her political position, is a grave matter. While the issue of withholding Communion from some of these individuals can be complex, Cardinal George said that when any person presents him or herself to receive the Eucharist, they "take their salvation into their own hands." For a more complete explanation of this matter, reference the cardinal's column "Catholic participation in political life, revisited" (CNW, Oct. 10, 2004) online at [www.catholicnewworld.com/cnw/issue/2004/cardinal\\_101004.html](http://www.catholicnewworld.com/cnw/issue/2004/cardinal_101004.html).

Original

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HE

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ACGWD

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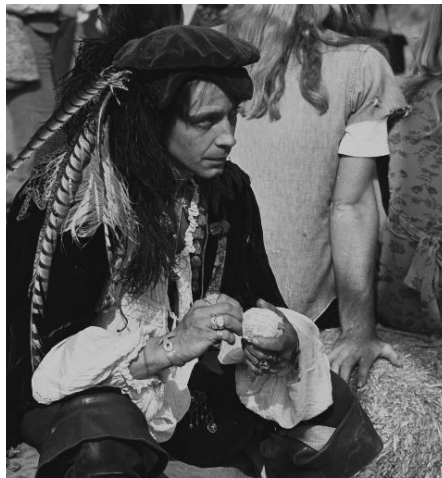
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Ours

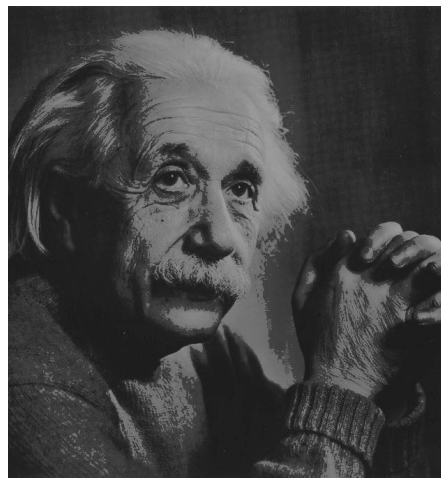
# Evaluation Result: GA is Better Than HC



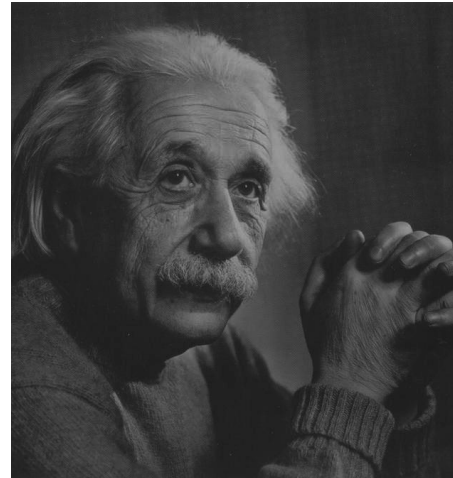
HC



GA

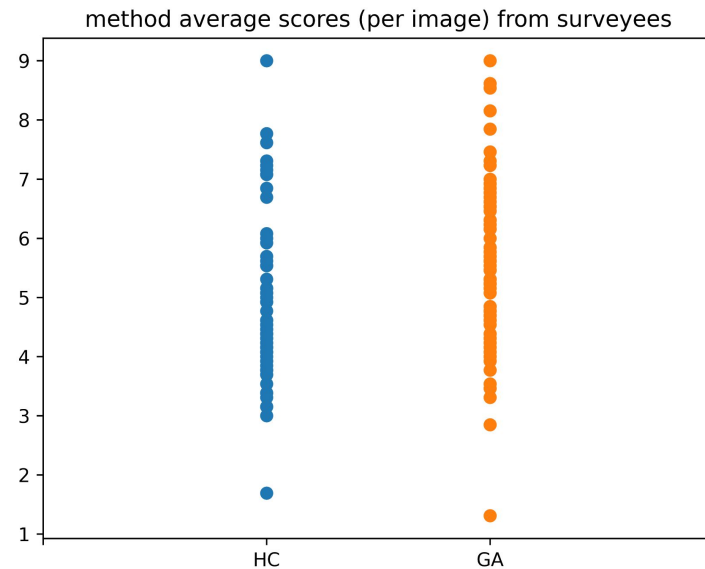
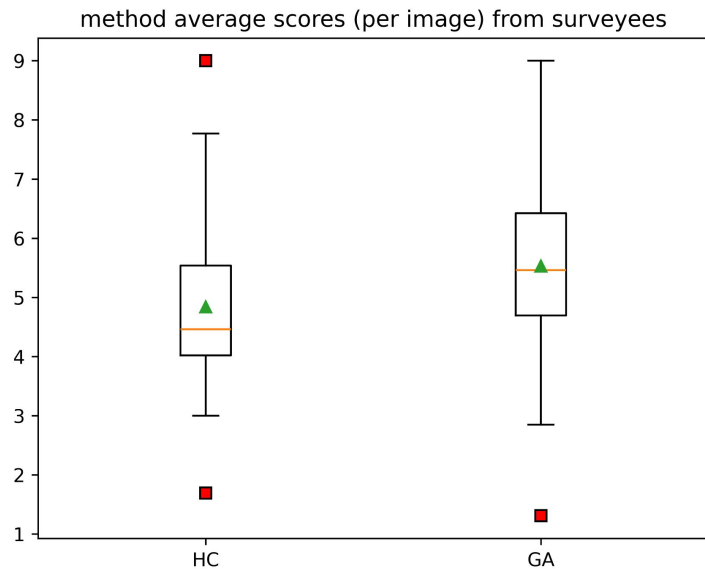


HC



GA

# Survey: Assessment of 65 People of Our Method



# Conclusion

- We propose a Fuzzy contrast enhancement with image specific optimization using evolutionary algorithm
- Our method shows to be capable to achieve better contrast and PSNR compared to original
- Some properties of our method is introducing less artifact, helping reducing overexposure
- Survey shows that proposed method although small has achieved subjective improvement on average in image enhancement