INTUITIONISTIC FUZZY GENERATOR-BASED RETINEX FRAMEWORK FOR ADVANCED LOW-LIGHT IMAGE ENHANCEMENT

ABSTRACT

Low-light image enhancement plays a critical role in improving visual perception and detail recovery from images captured under poor illumination. Insufficient lighting conditions often result in significant information loss, low contrast, and increased noise, making downstream tasks such as object detection, surveillance, and medical analysis challenging. This study introduces an advanced framework that integrates an Intuitionistic Fuzzy Generator (IFG) with the Retinex model to enhance image clarity and illumination balance. The proposed system, termed the Intuitionistic Fuzzy Image–Histogram Equalization Retinex (IFI–HER), converts the input image into an intuitionistic fuzzy domain, addressing uncertainty and ambiguity between pixel intensities while preserving natural color tones. The Retinex component ensures illumination correction and edge preservation, whereas histogram equalization restores global contrast. Experimental evaluations on low-light image datasets demonstrate that the proposed model surpasses existing algorithms in both qualitative and quantitative measures, including entropy, spatial frequency, mutual information, and brightness error. This hybrid fusion of fuzzy logic and Retinex principles establishes a new benchmark in low-light enhancement by achieving improved visual consistency, reduced distortion, and enhanced image detail without compromising natural appearance.

Keywords: Retinex, Intuitionistic Fuzzy Logic, Image Enhancement, Low-Light Images, Illumination Correction.

EXISTING SYSTEM

Existing low-light image enhancement systems predominantly rely on conventional histogram equalization, gamma correction, or deep learning-based enhancement. These models improve brightness but often fail to preserve fine textures and color balance, leading to over-enhanced or distorted outputs. Histogram-based methods lack the ability to handle spatially varying illumination, while neural approaches, despite their accuracy, require heavy computation and extensive training data. Retinex-based algorithms achieve good color constancy but may amplify noise in darker regions and cause halo effects along object boundaries.

Existing methods also struggle to address uncertainty in pixel-level interpretation. Variations in illumination cause ambiguity in intensity mapping, which cannot be adequately modeled by deterministic algorithms. Consequently, enhanced images may exhibit visual inconsistencies across regions with different lighting conditions. Additionally, most traditional methods lack an adaptive optimization process for selecting enhancement parameters, resulting in performance variation across image datasets.

Disadvantages of the Existing System

1. **Over-Enhancement and Noise Amplification:**

Many existing algorithms increase overall brightness excessively, causing loss of natural color tones and amplification of background noise.

2. **Lack of Uncertainty Modeling:**

Conventional methods fail to capture the ambiguity between pixel regions under inconsistent illumination, leading to uneven brightness and degraded textures.

3. **High Computational Cost and Limited Adaptability:**

Deep learning-based and multi-scale Retinex approaches require extensive computational power and are unsuitable for real-time applications on low-resource devices.

PROPOSED SYSTEM

The proposed Intuitionistic Fuzzy Generator-based Retinex Framework (IFI–HER) introduces a hybrid enhancement model that integrates the interpretive strength of fuzzy logic with the perceptual reliability of Retinex theory. The system begins by transforming a low-light image into an Intuitionistic Fuzzy Image (IFI), where each pixel is represented by membership, non-membership, and hesitation degrees. This representation allows the algorithm to effectively manage uncertainty and ambiguity in illumination transitions across the image.

Following fuzzification, the Histogram Equalization Retinex (HER) module operates on the fuzzy domain, enhancing global contrast while preserving natural illumination gradients. By separating the illumination and reflectance components, HER adjusts brightness adaptively, ensuring color constancy and detail preservation. Entropy-based optimization is applied to determine the most visually balanced image among multiple enhanced versions, ensuring maximum information retention without distortion.

The framework is designed to be lightweight yet powerful, suitable for real-time and high-resolution applications. It maintains structural integrity by suppressing noise and preventing over-saturation in bright regions. Additionally, the use of Gaussian filtering during illumination estimation ensures smooth enhancement and mitigates artifacts commonly seen in other Retinex variants.

Advantages of the Proposed System

1. **Enhanced Detail Preservation and Natural Brightness:**

The integration of intuitionistic fuzzy logic with Retinex processing ensures that both global illumination and fine local details are effectively enhanced without overexposure.

2. **Adaptive Uncertainty Handling:**

By modeling pixel ambiguity through membership and hesitation functions, the system produces consistent enhancement across varying light intensities and regions.

3. **Low Computational Complexity and Robust Performance:**

The entropy-based optimization and hybrid design reduce processing overhead, making the framework efficient for practical implementations in medical imaging, surveillance, and vision systems.

SYSTEM REQUIREMENTS

- **H/W System Configuration:-**
- Processor - Pentium –IV
- RAM - 4 GB (min)
- Hard Disk - 20 GB
- Key Board - Standard Windows Keyboard
- Mouse - Two or Three Button Mouse
- Monitor - SVGA

SOFTWARE REQUIREMENTS:

- **Operating system** : Windows 7 Ultimate.
- **Coding Language** : Python.
- **Front-End** : Python.
- **Back-End** : Django-ORM
- **Designing** : Html, css, javascript.
- **Data Base** : MySQL (WAMP Server).