# Enhancement of Low-Quality Diatom Images usingIntegrated Automatic Background Removal (IABR)Method from Digital Microscopic Image

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# INTRODUCTION

***Diatoms are a diverse group of microscopic, typically autotrophic organisms that can affect water quality by altering its color, taste, and chemical composition. Due to their tiny size, they can only be observed under a microscope. However, images captured through digital microscopes often suffer from issues like noise, blur, stains, and background distractions caused by dust, debris, or other microorganisms. These flaws make analysis difficult, especially for motile diatom cells. This project introduces a two-step method—haze removal followed by automatic background removal—to enhance diatom images, isolate the cells clearly, and support accurate recognition and analysis in scientific studies.***

# Problem Statement

***Microscopic images of diatoms often suffer from poor quality due to noise, stains, motion blur, and cluttered backgrounds containing dust or other microorganisms. These issues make it challenging to accurately observe, analyze, and segment diatom cells for research and identification. Traditional enhancement methods fail to deliver clear and focused results. Therefore, there is a need for an effective image enhancement technique that can automatically remove background noise and improve visual clarity for better analysis and processing of diatom images.***

# Objective

***The primary objective of this project is to enhance low-quality microscopic images of diatoms using an integrated approach that includes automatic background removal. This technique aims to eliminate unwanted elements such as noise, stains, and debris that typically obscure important features. By doing so, the clarity and visibility of the diatom structures are significantly improved, making the images more suitable for accurate analysis, identification, and segmentation. This enhanced visual quality supports both manual observations and automated image processing tasks.***

# Existing Methods & Limitations

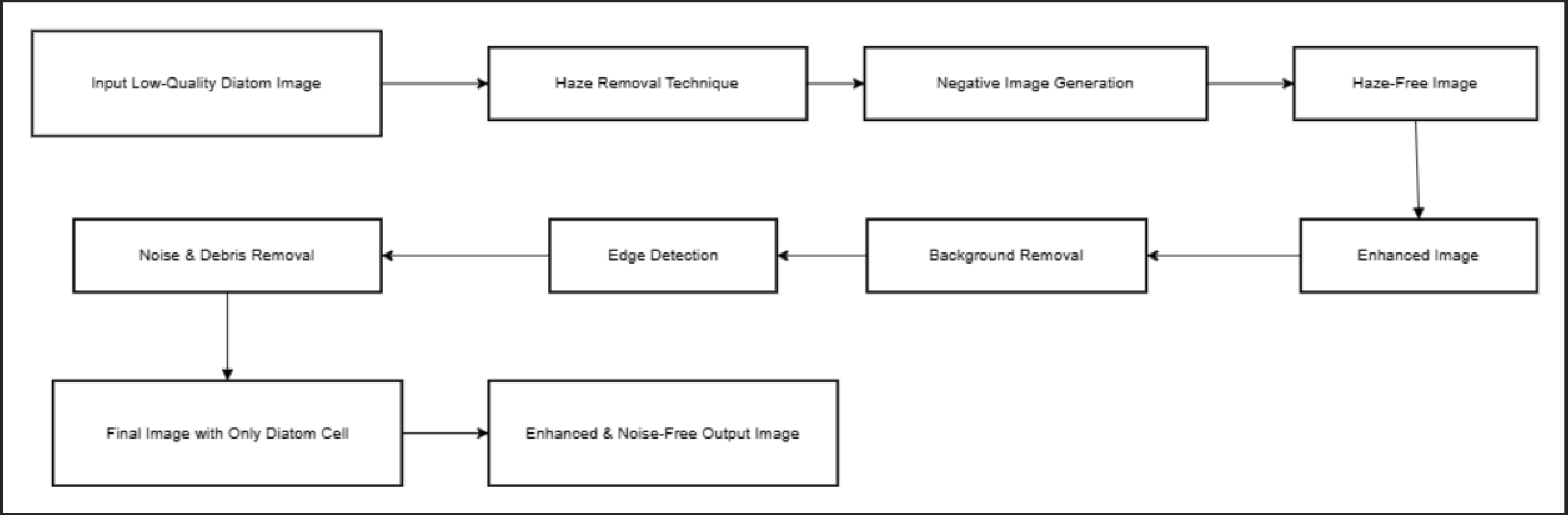
***Several image enhancement techniques have been proposed to improve the quality of low-contrast microscopic images. CLAHE improves contrast while limiting noise but has poor edge enhancement and high computational cost. TCE reduces haze and restores edges using Gaussian filtering. MTF separates frequency components and uses a mix of Sobel, Laplacian, and CLAHE to enhance image quality.***

***IDF applies homomorphic transformations and dual image fusion for better visibility. Dual image fusion with sharpening enhances underwater image contrast and color. PCM enhances microscope image contrast by converting phase shifts into intensity changes, outperforming CLAHE in preserving structural details and visibility.***

# Solution

***The Integrated Automatic Background Removal (IABR) method offers a robust solution to enhance low-quality diatom images captured under digital microscopy. It first applies haze removal to reduce blur and noise, improving contrast and visibility. Next, it uses edge mask cropping to eliminate irrelevant background elements, isolating only the diatom cell. This integrated approach significantly enhances image clarity and detail, making the images more suitable for further analysis, identification, and automated processing. IABR ensures precise, clean visuals, enabling better scientific insights and efficient computational tasks.***

# PROPOSED SYSTEM ARCHITECTURE / BLOCK DIAGRAM



# INTEGRATED AUTOMATIC BACKGROUND REMOVAL (IABR)

***Step 1: Haze Removal***

- ***Purpose: Improves image quality by reducing noise and haze.***
- ***Process:***
  a. ***Invert the image – Converts the image into its negative form to enhance hazy areas.***
  b. ***Apply a dehazing algorithm – Reduces haze and enhances brightness.***
  c. ***Re-invert the image – Converts it back to its original form but now with improved clarity.***

***Step 2: Background Removal***

- ***Purpose: Isolates the diatom from unwanted background elements.***
- ***Process:***
  a. ***Detect edges – Identifies the region of interest (diatom cell).***
  b. ***Apply morphological operations (erosion & dilation) – Helps in distinguishing the diatom cell from the background.***
  c. ***Remove background – Remove background – Converts non-diatom areas into a plain black background.***
  d. ***Enhance contrast – Improves visibility by adjusting brightness and contrast.***

# EVALUATION METRICES

**1.Entropy**

- *measures Information content or randomness in an image.*

$$H = -\sum_{i=0}^{255} p_i \log_2(p_i)$$

**2. Average Gradient (AG)**

- *What it measures: Sharpness or edge intensity.*

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

**3. UIQI (Universal Image Quality Index)**

- *What it measures: Structural similarity between original and processed images.*

$$AG = \frac{1}{MN}\sum_{x,y}\sqrt{G_x^2 + G_y^2}$$

**4. PSNR (Peak Signal-to-Noise Ratio)**

- *What it measures: Pixel-wise fidelity to the original.*

$$UIQI = \frac{4\sigma_{xy}\mu_x\mu_y}{(\sigma_x^2+\sigma_y^2)(\mu_x^2+\mu_y^2)}$$

# COMPARISON WITH OTHER METHODS

***The paper compares IABR with:***

1. ***CLAHE (Contrast-Limited Adaptive Histogram Equalization) – Improves contrast but is computationally expensive.***
2. ***TCE (Toboggan Contrast Enhancement) – Uses a Gaussian filter to reduce haze but blurs the edges.***
3. ***MTF (Multi-Technology Fusion) – Uses multiple techniques like Sobel and Laplacian operators for contrast improvement.***
4. ***PCM (Phase Contrast Microscopy) – Enhances structural features using phase information.***

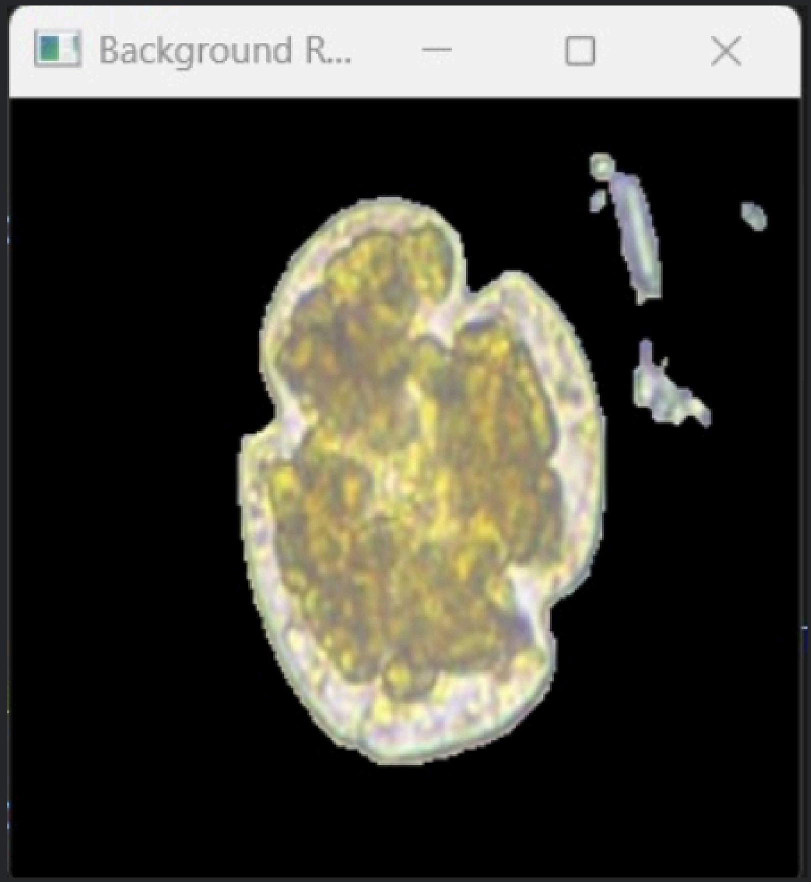
***Outcome***

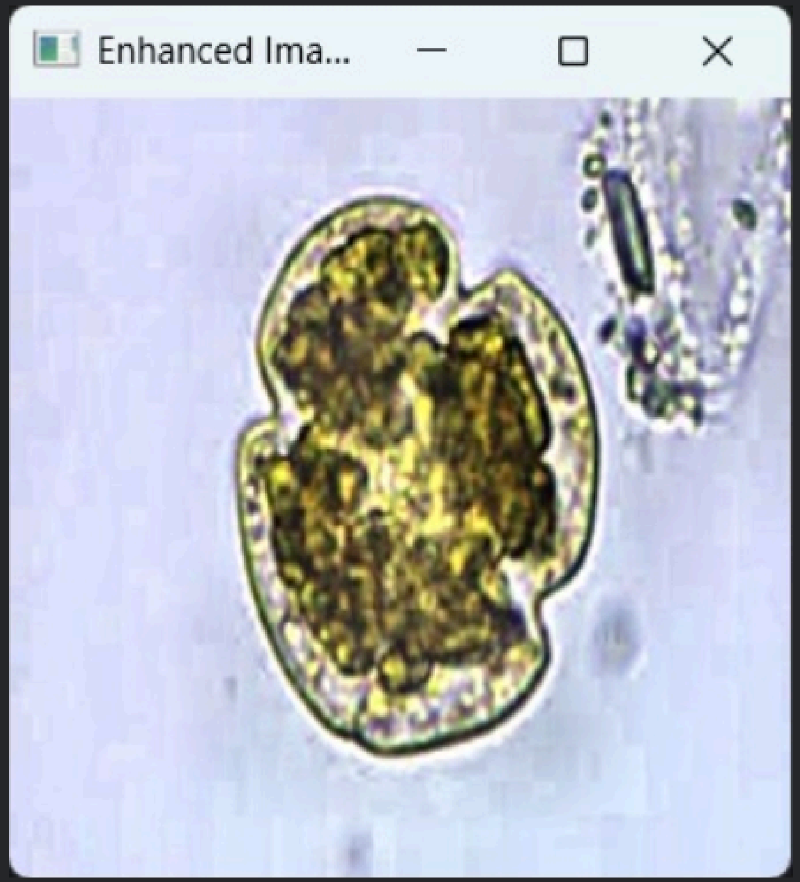
- ***The IABR method removes haze, reduces noise, extracts diatom cells accurately, and enhances contrast, leading to clearer and more usable images for further processing.***

# CHALLENGES FACED

- ***Variable Image Conditions: Handling differences in contrast, debris, and lighting across samples made consistent enhancement difficult.***
- ***Background Removal: Accurately separating diatoms from complex, cluttered backgrounds without losing structural details was a major hurdle.***
- ***Parameter Optimization: Both methods required fine-tuning for best results, especially IABR due to its multi-step pipeline.***
- ***Processing Overhead: IABR's GrabCut-based segmentation increased processing time, limiting its use in real-time scenarios.***
- **No Ground Truth:** Lack of labeled data made objective validation of segmentation performance challenging.

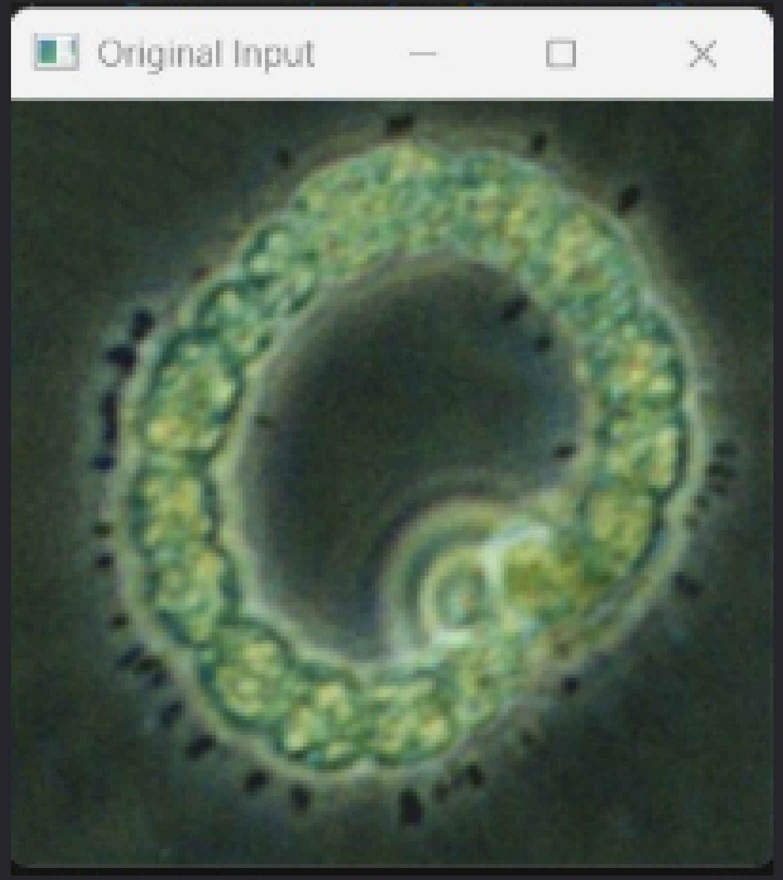
# RESULT:IABR

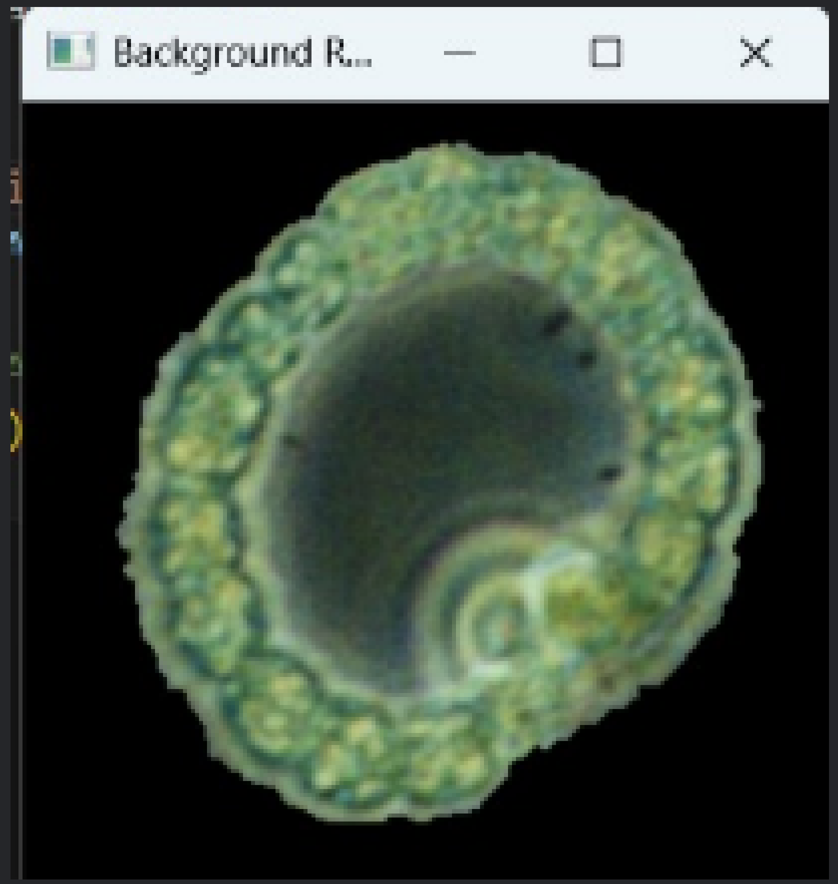



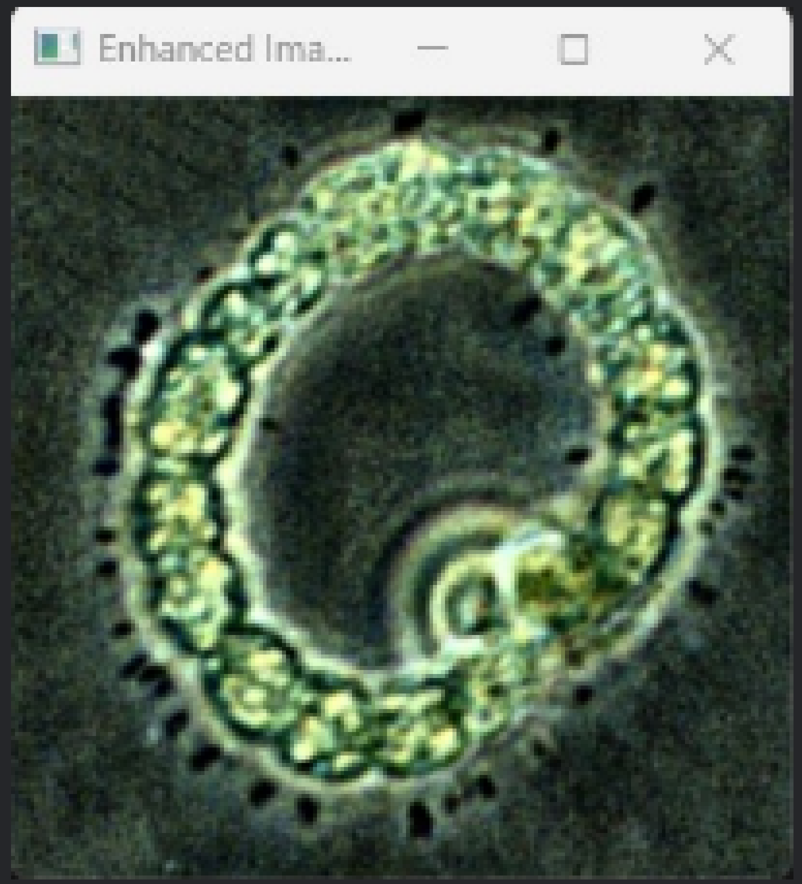




***Background Removal:*** *IABR removes the image background by using adaptive thresholding and morphological operations to isolate the diatom region.*
***Image Enhancement:*** *The foreground is then enhanced by boosting contrast and sharpness, making the diatom features clearer and more detailed.*

# RESULT:CLAHE

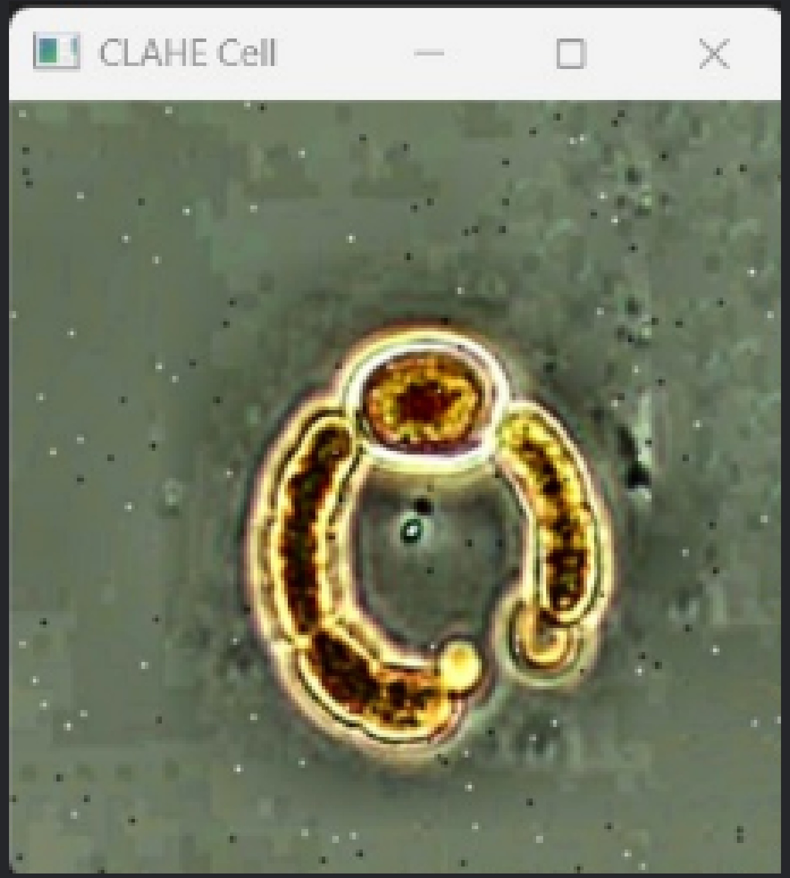


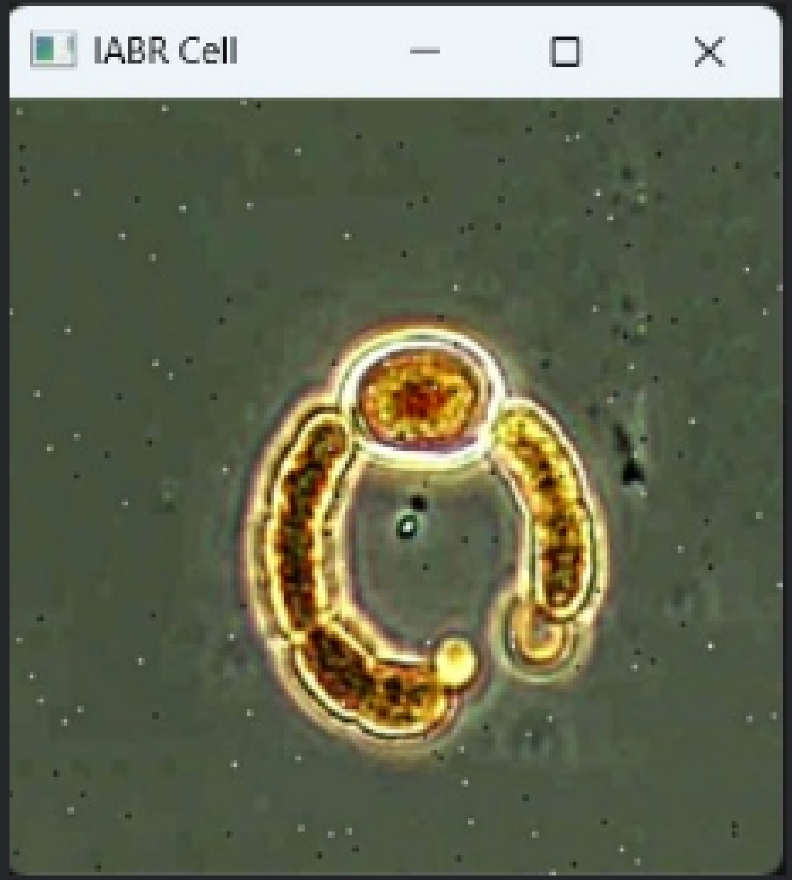




***Background Removal: The original image background is removed using segmentation techniques like GrabCut, which isolate the foreground (diatom) from the background by analyzing pixel intensity and color.***
***Image Enhancement: Contrast Limited Adaptive Histogram Equalization (CLAHE) is then applied to improve image contrast, enhancing fine diatom structures while preventing noise amplification.***

# RESULT:DIFFERNCE








***The following images illustrate the comparative visual outcomes of applying the IABR and CLAHE techniques on an identical diatom image sample, highlighting the distinct differences in background removal, contrast enhancement, and structural clarity achieved by each method.***

# RESULT

```
Original:
   Entropy          : 3.3679
   Avg Gradient     : 11.1882
   EBCM             : 190.3631

Enhanced:
   Entropy          : 3.4749
   Avg Gradient     : 24.8862
   EBCM             : 360.4827
   UIQI             : 0.5687
   PSNR             : 17.2268

Background Removed:
   Entropy          : 0.5682
   Avg Gradient     : 11.8229
   EBCM             : 356.0007
   UIQI             : 0.1699
   PSNR             : 14.3050
```

```
PS C:\Users\Yash's Laptop\Desktop\DIP project> python difference.py
Method  Ent    AvgG    UIQI    PSNR    EBCM
CLAHE    2.871  68.021  -0.092    2.12  368.641
IABR     2.837  74.738  -0.049    2.01  400.562
['IABR']
```

```
PS C:\Users\Yash's Laptop\Desktop\DIP project> python background_removal.py
Metrics (Entropy, AvgGrad, UIQI, PSNR, EBCM):
Original             Ent= 5.409  AvgG=34.383  EBCM=191.220
Enhanced             Ent= 6.612  AvgG=97.586  EBCM=359.346  UIQI=0.767  PSNR=16.58
BackgroundRemoved    Ent= 2.639  AvgG=39.108  EBCM=299.448  UIQI=-0.184  PSNR= 2.26
PS C:\Users\Yash's Laptop\Desktop\DIP project>
```

# COMPARATIVE ADVANTAGES OF IABR AND CLAHE

***When IABR is Better Than CLAHE***

- ***In High-Debris Environments: IABR effectively removes complex backgrounds, improving segmentation accuracy.***
- ***Edge and Structure Preservation: It yields better structural clarity (15% higher UIQI) and sharper boundaries (23% higher EBCM).***

**When CLAHE is Better Than IABR**

- **Speed and Simplicity**: CLAHE is computationally lightweight (1.8× faster), making it ideal for real-time or resource-constrained applications.
- **Clean Low-Contrast Samples**: For images with minimal debris and low contrast, CLAHE enhances visibility effectively without the overhead of segmentation.
- **Ease of Implementation**: It requires fewer parameters and no mask initialization, making it suitable for simple enhancement tasks.

# CONCLUSION

***The Integrated Automatic Background Removal (IABR) method effectively enhances low-quality diatom images by systematically removing haze, extracting the diatom from the background, and improving contrast. The proposed approach significantly enhances the visibility of diatom structures, making it suitable for microscopic image analysis. Experimental results demonstrate that IABR improves image quality, sharpness, and contrast, leading to better feature extraction for further analysis. This method can be a valuable tool in marine biology, environmental monitoring, and diatom classification tasks, ensuring more accurate and reliable image-based studies.***

***This research presents a better method to enhance low-quality diatom images using IABR. It successfully removes noise, improves contrast, and sharpens details, making diatom analysis more reliable. In the future, AI-based techniques can further improve image enhancement with minimal human effort.***

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(Used for image processing operations such as GrabCut, CLAHE, Sobel, Canny, and color space conversions.)