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Underwater Image Enhancement

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ABSTRACT

Underwater images suffer from low contrast, color distortion and visibility degradation due to the light scattering and attenuation. Over the past few years, the importance of underwater image enhancement has increased because of ocean engineering and underwater robotics. Existing underwater image enhancement methods are based on various assumptions. However, it is almost impossible to define appropriate assumptions for underwater images due to the diversity of underwater images. Therefore, they are only effective for specific types of underwater images. Recently, underwater image enhancement algorisms using CNNs and GANS have been proposed, but they are not as advanced as other image processing methods due to the lack of suitable training data sets and the complexity of the issues. To solve the problems, we propose a novel underwater image enhancement method which combines the residual feature attention block and novel combination of multi-scale and multi-patch structure. Multi-patch network extracts local features to adjust to various underwater images which are often Non-homogeneous. In addition, our network includes multi-scale network which is often effective for image restoration. Experimental results show that our proposed method outperforms the conventional method for various types of images.

1. INTRODUCTION

Underwater imaging has gained significant importance in various fields, including marine biology, underwater exploration, and pipeline monitoring. However, capturing clear underwater images poses unique challenges. Factors like light scattering, color distortion, and low contrast severely affect the quality of underwater photographs, making it difficult to extract meaningful information. These limitations hinder many scientific and industrial applications that rely on accurate visual data.

High-quality underwater cameras with specialized optical equipment can address some of these issues, but they are prohibitively expensive for many organizations. Consequently, researchers and developers are increasingly focused on creating software-based solutions for image enhancement. These approaches aim to restore clarity and color fidelity to underwater images using advanced computational techniques without requiring costly hardware investments.

Several algorithms have been proposed for underwater image enhancement. Some of the most popular approaches are based on histogram equalization, contrast enhancement, and color restoration techniques. More recently, machine learning models, including convolutional neural networks (CNNs) and Generative Adversarial Networks (GANs), have shown potential for image enhancement tasks. Despite these advances, current methods have not achieved consistently high performance due to the complex nature of underwater environments and insufficiently trained models.

Underwater images are often plagued by blurriness and poor visibility, making it challenging to capture clear images from the ocean. Building specialized cameras for this purpose is expensive. As a result, many organizations focus on software solutions for

underwater image enhancement. Existing approaches like Color Restoration and GAN-based enhancement have limitations in performance. To overcome these challenges, a new Multi-Patch Residual Attention deep learning algorithm is proposed, which improves image quality significantly.

To address these challenges, a novel approach using a Multi-Patch Residual Attention Network has been developed. This method focuses on enhancing image quality through deep learning-based feature extraction and contrast adjustment, offering significant improvements over traditional algorithms. The new approach not only increases the clarity and realism of underwater images but also minimizes computational complexity.

Existing System

1. The existing methods for underwater image enhancement include both traditional image processing techniques and more recent machine learning-based approaches. A widely used method is Histogram Equalization, which improves the overall contrast of images by redistributing pixel intensities.

2. Machine learning approaches using CNNs and GANs have shown some promise, but their effectiveness is limited by the availability of high-quality training datasets. Many underwater images are characterized by complex and non-uniform degradation patterns, which traditional neural networks struggle to handle.

Proposed System

1. The proposed system uses a Multi-Patch Residual Attention Network to improve underwater images using deep learning. The system uses both multi-patch and multi- scale networks to extract local features and adjust contrast.

2. The multi-patch network breaks the image into smaller sections, which helps deal with varying lighting and contrast in different areas .The multi-scale network helps the system handle images with different levels of detail, processing them at different resolutions for better image restoration**.**

2. REQUIREMENT ANALYSIS

Functional Requirements:

Admin Module:

Role: The Admin is responsible for preparing the system to process images effectively by training the algorithm with a specific dataset

Functionality: Uploads and manages datasets required to train the image enhancement algorithm. Trains the algorithm using machine learning or deep learning techniques to optimize performance. Monitors and updates the model to improve its accuracy over time.

User Module:

Role: The User interacts with the system to upload images and check the results of the image enhancement process.

Functionality: Allows the user to upload an image through a user-friendly interface.

Processes the uploaded image using the trained algorithm to enhance its quality - Displays the enhanced image for the user to review or download.

Non-Functional Requirements:

- Performance: The application should process and enhance images within 2 seconds per image on average. Support GPU acceleration for faster processing.
- Scalability: Handle a variety of underwater image types, including those with severe distortions and varying water conditions.
- Accuracy: Achieve at least 86% SSIM and 23 PSNR for most processed images.
- Usability: Provide an intuitive and responsive graphical user interface (GUI). - Allow non-technical users to enhance images without requiring detailed knowledge of the underlying algorithm.

- Reliability: Ensure consistent results across different underwater image datasets. Provide fallback options for unexpected errors during processing**.**
- Portability: The application should run on Windows, MacOS, and Linux systems. Include dependencies and installation instructions for easy setup.

Hardware Requirments:

- RAM : 512 MB RAM
- Hard disk : 20 GB

Software Requirements:

- Operating System : Windows 11
- Script : python IDLE

2. DESIGN

Project architecture represents number of components we are using as a part of our project and the flow of request processing i.e. what components in processing the request and in which order. An architecture description is a formal description and representation of a system organized in a way that supports reasoning about the structure of the system.

Software Architecture

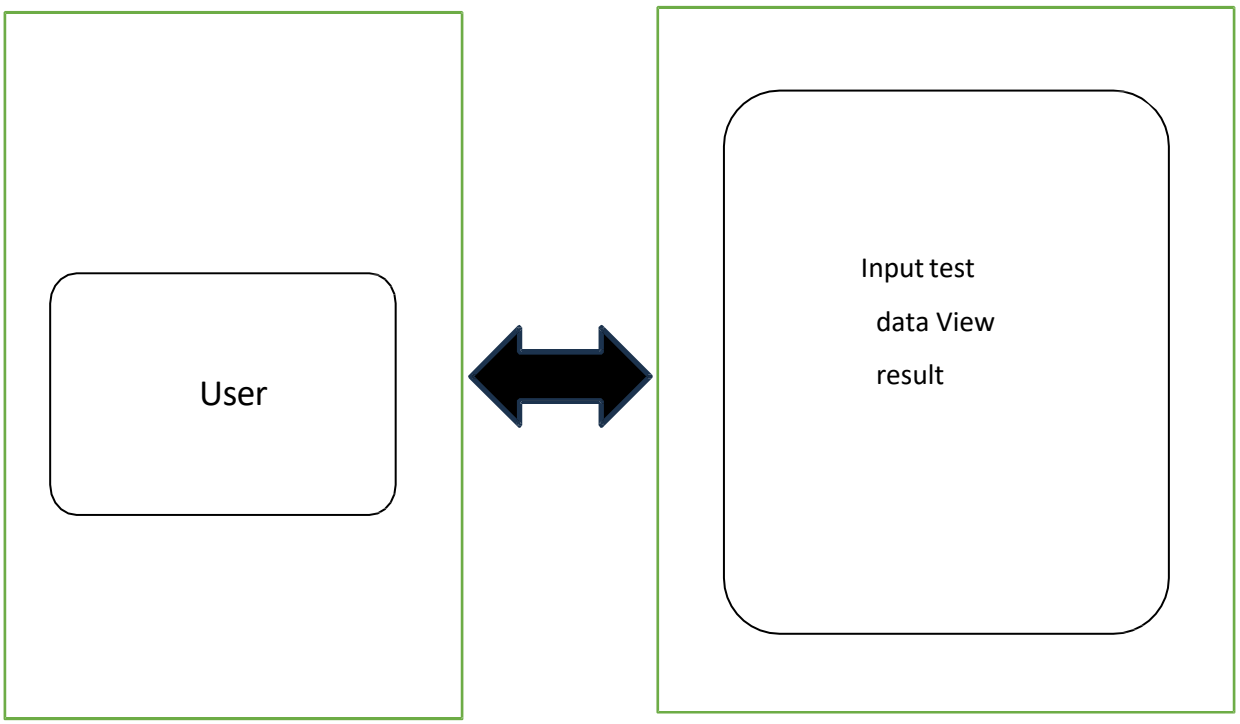


Fig. 3.1 Software Architecture

Technical Architecture

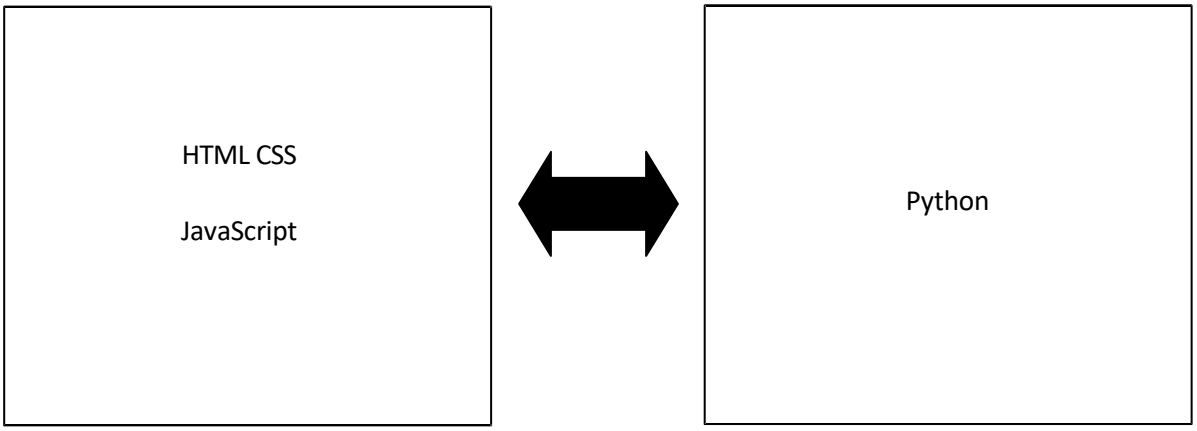


Fig. 3.2 Technical Architecture

3. IMPLEMENTATION

This system is developed using the Python programming language along with popular libraries for image processing and graphical interface development.

Python

Python is an easy-to-learn, high-level programming language. It is known for its clear and simple syntax, which makes it a popular choice for beginners as well as experienced developers. Python is widely used in various fields such as web development, data science, artificial intelligence, machine learning, and image processing.

In this project, Python is used because it has powerful libraries and tools for working with images and building applications quickly. Python makes it easier to handle images, perform operations like filtering, edge detection, and display the final output.

For writing and testing the Python code, IDLE (Integrated Development and Learning Environment) and VS Code (Visual Studio Code) are used as development tools. These IDEs provide useful features like:

- Syntax highlighting
- Smart indentation
- Autocompletion
- Easy debugging
- Running scripts directly

NumPy

NumPy is a powerful and essential Python library used for numerical and matrix operations. It makes working with large amounts of data and performing mathematical calculations much easier and faster.In this project, NumPy is mainly used to handle image pixel data in the form of arrays. It helps perform operations like reshaping, flattening pixel values, and supporting the mathematical calculations needed in algorithms like **K-Means Clustering** for color simplification.

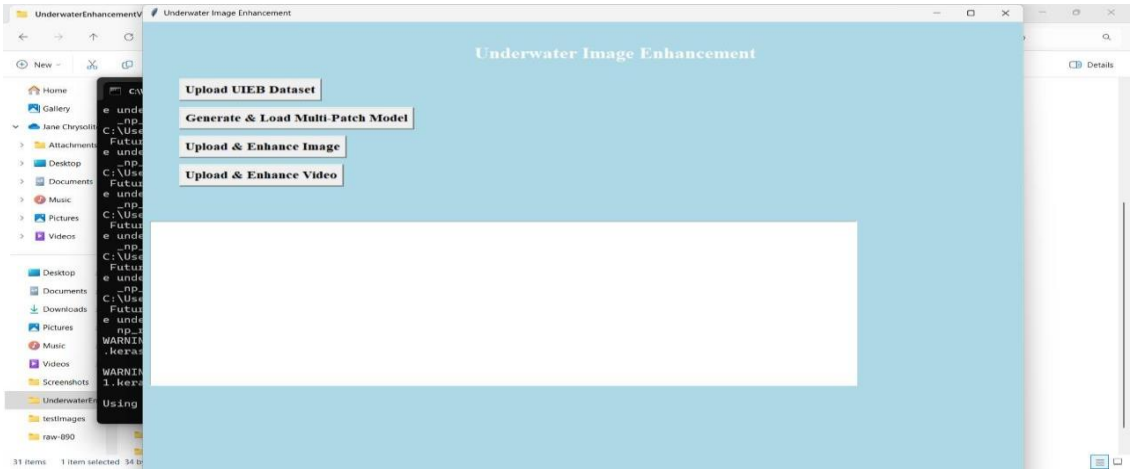
Tkinter

Tkinter is Python's built-in library for creating simple graphical user interfaces (GUI). It allows developers to easily design windows, buttons, labels, and other interface elements within a Python application.In this project, Tkinter can optionally be used to build a basic interface for users to load images, click a button to start the cartoonization process, and save the final cartoon image. It makes the application more interactive and user-friendly.

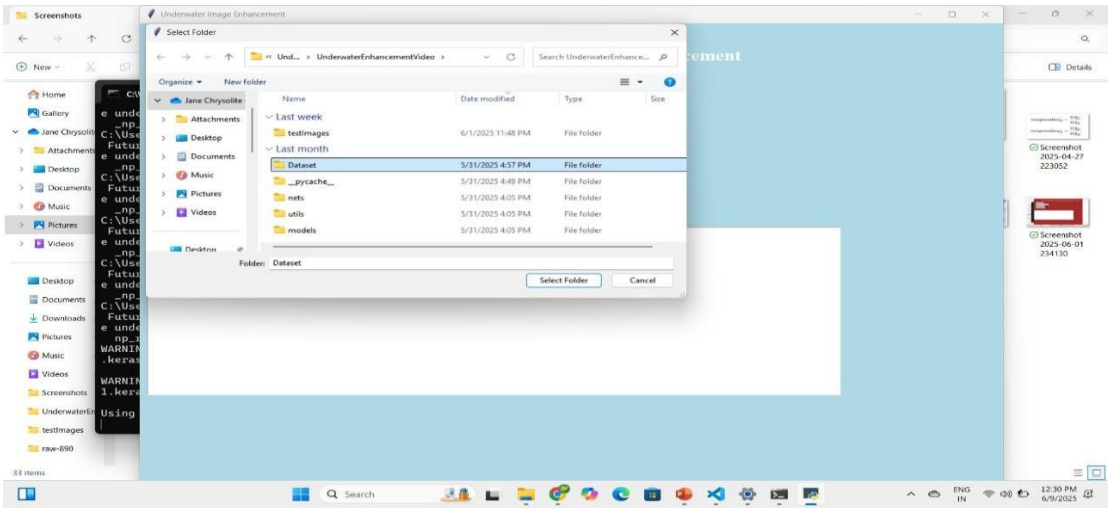
Scikit-learn (sklearn)

Scikit-learn is a popular machine learning library for Python. It provides easy-to-use tools for data analysis, clustering, classification, and more.In this project, Scikit-learn is used to implement the **K-Means Clustering** algorithm, which reduces the number of colors in an image by grouping similar colors together. This simplifies the image colors, giving it a clean, flat cartoon-like appearance.

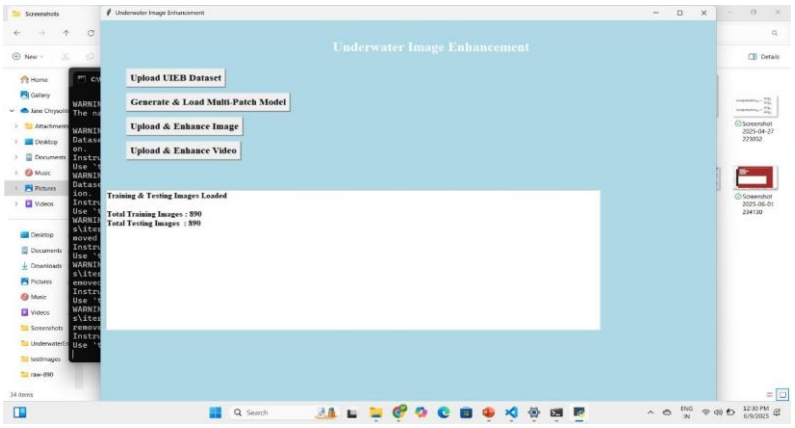
4. SCREENSHOTS



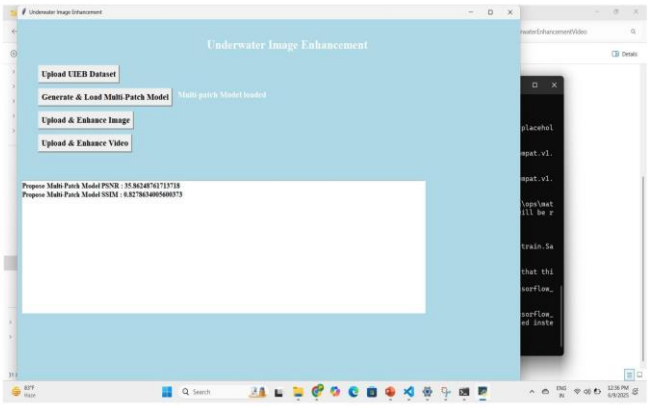
Screenshot 1: Run.bat file



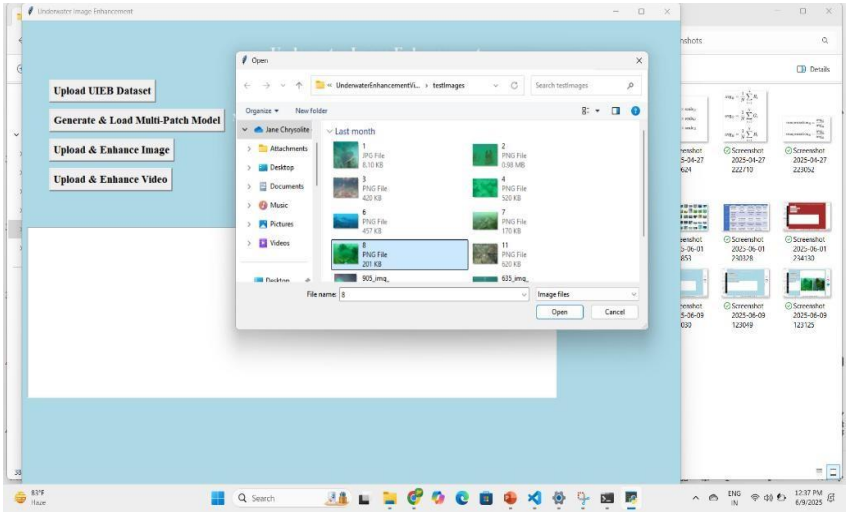
Screenshot 2: selecting and uploading ‘Dataset’ folder



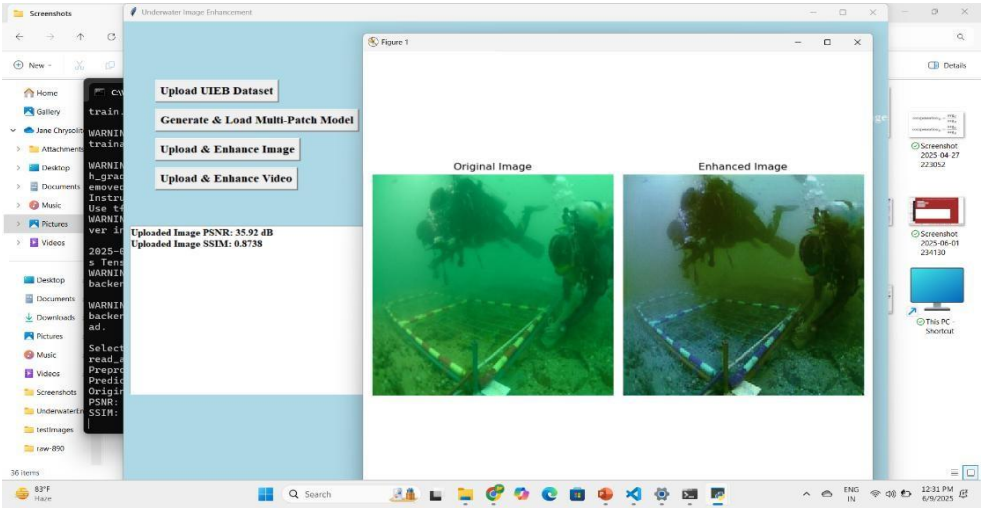
Screenshot 3: dataset is loaded



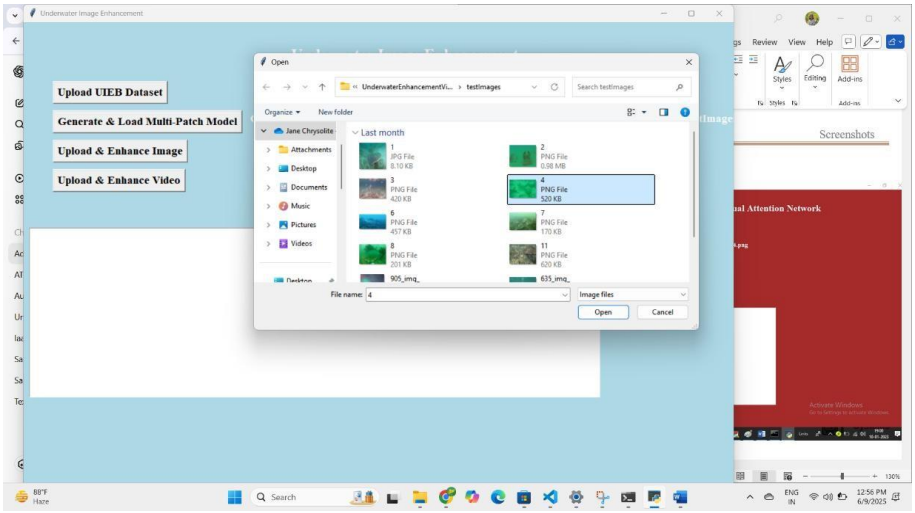
Screenshot 4**:** Generation of model SSIM as 82% and PSNR as 35%



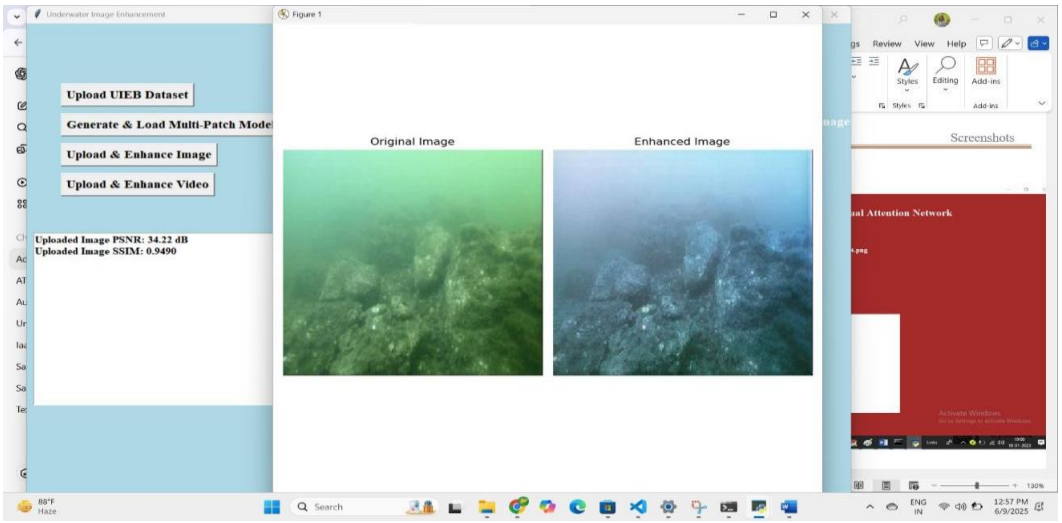
Screenshot 5: selecting and uploading '4.png'



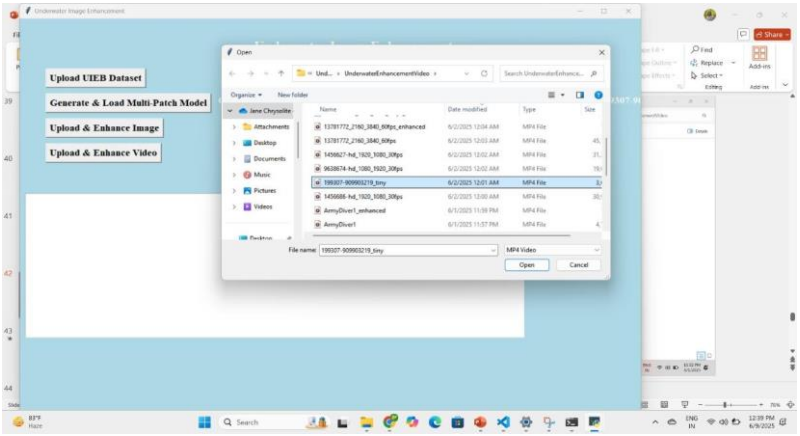
Screenshot 6: enhance image



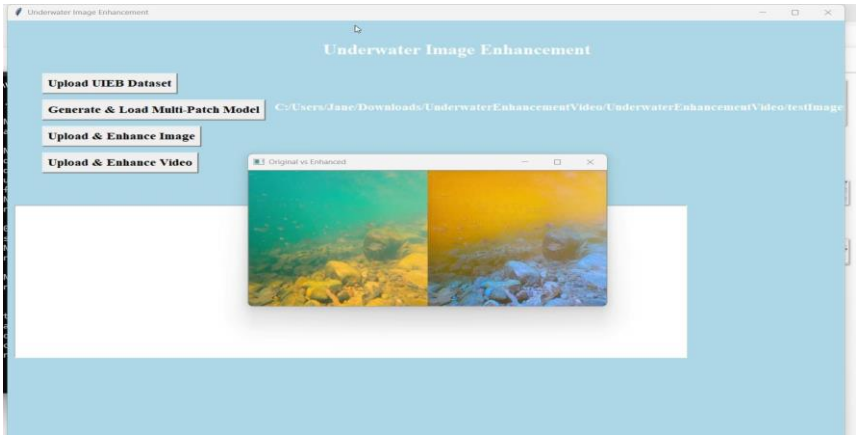
Screenshot7: uploading 8.png



Screenshot 8: Enhanced image



Screenshot 9: Uploading Video



Screenshot 10: Enhanced Video

5-CONCLUSION

Underwater image enhancement method combining residual feature attention with multi-scale and multi-patch structures. The multi-patch network captures local non-homogeneous features, while the multi-scale network improves restoration.

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