Underwater Metal Selection Using Image Enhancement and Morphological Operations

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***Abstract*—This research paper focus on the underwater metal selection techniques. The underwater images usually appears with low contrast, color distortion, haziness due to scattering of light in the underwater these phenomenon makes it difficult to identify and sort the metal on the basis of corroded and no corroded metal. To address these problems, this technique is developed which uses DCT and wavelet transform for denoising and morphological operation for selection. This result enhanced image with accurate identification and selection of metals in underwater environment.**

Keywords— UIE, DCT, WT, db1, Morphological operation

I. INTRODUCTION

Underwater Image Enhancement (UIE) is a crucial aspect of marine exploration, engineering application, research and defence operation, but it often suffers challenges like blurred details, color distortion, low contrast, haziness like effects [1], due to the scattering and attenuation of light [2]. These limitations are problematic in applications requiring precision such as the selection of metals for underwater images, where the clarity of surface details and material properties is essential.

Among the many challenges in underwater imaging, material selection particularly the metal detection [3] stands out as a complex problem. Metals are widely used in underwater structures including pipelines, shipwrecks and marine equipment, without clear and detailed images, the task of identifying and selecting surfaces becomes extremely difficult, which can lead to inefficiencies and errors.

To address these problems advanced image enhancement techniques are required to improve the clarity and contrast of underwater images. Traditional methods of underwater Image Processing, such as simple contrast enhancement or reduction techniques are insufficient for addressing the degradation in underwater images. These methods often fail to enhance fine details or retain important structural information that is necessary for analysis [4]. Further, conventional techniques do not addressed the need for accurate separation of critical features from the background, that makes it difficult to analyse textures and boundaries of metal surfaces.

Therefore, this technique is developed that can enhance problems simultaneously like improving contrast, reducing noise, restoring color and preserving structural details. This development of robust image enhancement methods that can work with material analysis is crucial to overcoming these challenges and enabling more reliable underwater operations.

The proposed project aims to enhance underwater Images for metal selection by employing wavelet decomposition and morphological operations. Wavelet Decomposition is a mathematical technique used for multi resolution analysis of images. It allows the decomposition of an image into two parts say HF and LF component. By processing HF component and LF component separately, we can enhance features that are critical for material analysis, such as edges, textures and surface patterns.

Wavelet decomposition has been successfully applied in various image enhancement tasks due to its ability to preserve both global and local image characteristics.

On the other hand, morphological operations are the techniques that focuses on the geometric structure of objects within an image. These dilation, erosion are particularly effective in refining shapes, removing small noise, artifact's and enhancing object boundaries [5]. In UIE, morphological operations can be used to clean up noise, emphasize the structure of metal surfaces and improve the separation between different region of interest. It is useful for tasks such as identifying corrosion spots, scratches or other imperfections on metal surfaces. By integrating wavelet decomposition and morphological operations, the proposed project focuses on a correspondence approach to UIE. The wavelet decomposition process ensures that fine details are preserved and enhanced multiple scales, while the morphological operations correct these details and improve the overall structureal representation of the image.

This approach is highly relevant to the field of Underwater Image Enhancement and metal analysis. The combination of wavelet decomposition and morphological operation represents a novel contribution to the field, offering a robust and versatile solution for Inderwater image enhancement.

II. RELATED WORK

Underwater image enhancement is a crucial area of research with wide application in marine biology, underwater archaeology, mineral exploration and autonomous underwater vehicles [6].

The inherent challenges associated with underwater imaging, such as light absorption, scattering, colour distortion, and reduced visibility, have spurred extensive research into developing robust enhancement techniques. This section discusses the advancements in underwater image processing, focusing on wavelet decomposition, and morphological operations, while situating this work within the broader contet of the field.

A. WAVELET BASED TECHNIQUES IN UNDERWATER IMAGING

Wavelet decomposition has proven effective in many image enhancement tasks due to its ability to analyse both spatial and frequency components simultaneously. Early works, such as Mallat's foundational contributions to wavelet theory (Mallat,1989), laid the groundwork for applying wavelet transforms in image processing. Researchers leveraged this approach to address underwater imaging challenges, emphasizing its multi-resolution analysis capability for noise suppression and detail enhancement [7].

For instance, Zhou et al. (2005) utilized wavelet transforms to enhance underwater images by separating high-frequency noise components from low-frequency illumination variations. This approach provided an adaptive mechanism to suppress noise while preserving image details, significantly improving underwater object detection [8]. Similarly, Xu et al. (2012) demonstrated how wavelet-based techniques could mitigate scattering effects, enabling better visibility in turbid environments [9]. Despite their effectiveness, these methods often struggled to address color distortion and required complementary techniques for holistic enhancement.

B. MORPHOLOGICAL OPERATIONS IN IMAGE PROCESSING

Morphological operations, originally proposed for binary image analysis, have found applications in enhancing image structures such as edges, textures, and boundaries. Serra (1982) introduced morphological filters that could extract meaningful geometric structures from images, making them particularly relevant in underwater environments where edges of metallic objects need clear delineation [10].

In underwater imaging, researchers have employed morphological operations to enhance object features and reduce background noise. Prasanna et al. (2014) proposed a combined approach where morphological operations were used alongside histogram equalization to enhance underwater pipeline images [11]. Their work highlighted the role of morphological techniques in delineating object boundaries under challenging light conditions.

However, standalone morphological operations are often insufficient for dealing with color attenuation and scattering effects. Recent research trends have explored combining morphological operations with other techniques, such as wavelet transforms, to address these limitations comprehensively.

C. HYBRID APPROACHES COMBINING WAVELET AND MORPHOLOGICAL TECHNIQUES

The combination of wavelet decomposition and morphological operations has garnered attention as a promising hybrid approach for underwater image enhancement. Such methods aim to leverage the strengths of both techniques: wavelets for multi-resolution analysis and morphological operations for structural enhancement.

Wang et al. (2017) proposed a framework that integrated wavelet transforms with morphological reconstruction for underwater pipeline inspection [12]. Their approach decomposed the image into different frequency bands, enhanced the edges using morphological operations, and recombined the components to generate a clearer output. The results demonstrated improved clarity and structural preservation, making it suitable for identifying underwater metallic objects.

Similarly, Kumar and Singh (2020) developed an enhancement technique combining wavelet-based denoising and morphological filters to process underwater images of corroded metal structures [13]. This hybrid method effectively reduced noise and enhanced edge features, proving its utility in metal detection and classification tasks.

D. COLOR CORRECTION AND CONTRST ENHANCEMENT TECHNIQUES

Color distortion is a significant challenge in underwater imaging due to differential attenuation of light wavelengths. Various researchers have proposed color correction techniques to address this issue. The white balance algorithm (Tao et al., 2013) [14] and retinex-based methods (Jobson et al.,1997) have been widely used for color correction, often as preprocessing steps before applying wavelet or morphological techniques.

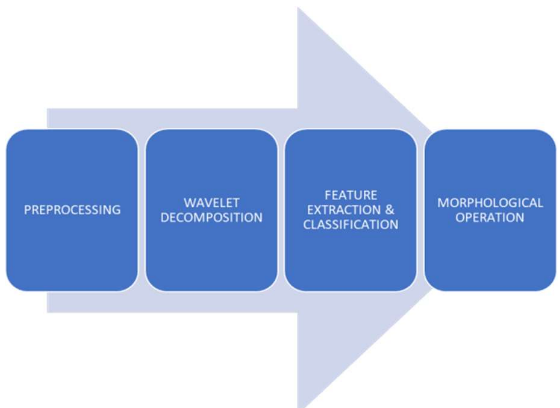
Contrast enhancement methods, such as histogram equalization and its variants (e.g., CLAHE), have also been employed to improve visibility in underwater images. Researchers have explored combining these methods with wavelet and morphological operations for comprehensive enhancement. For example, Li et al. (2018) [15]. Integrated retinex-based color correction with wavelet transforms and morphological operations to enhance images captured in deep-sea environments. Their approach demonstrated superior performance in retaining natural colors and enhancing object features.

III. METHODOLOGY

In this section, metal selection approach via wavelet transform and morphological operation is proposed as shown in figure 1.The proposed methodology for underwater image enhancement for metal selection involves four key steps preprocessing, wavelet decomposition, feature extraction and classification and morphological operation.

STEP(1). PREPROCESSSING

The preprocessing step is performed by addressing problems such as noise, low visibility and color distortion.



A. IMAGE ACQUISITION

We took the images from public datasets. This images typically exhibit significant degradation caused by attenuation, scattering and absorption of light in underwater.

B. COLOR SPACE CONVERSION

To improve the interpretability of the image, we converted the RGB color space to the YCbCr color space[16]. This transformation separates the luminance component (Y) from from chrominance Component (Cb and Cr), which allows targeted enhancement of brightness without affecting color information.

Fig. 2. RGB TO YcbCr Conversion

Fig. 3. Luminance component of image

STEP (2). WAVELET DECOMPOSITON

In this step wavelet decomposition is applied to enhance luminance component (Y) of the images. This step focuses on separating high frequency and low frequency component.

A. WAVELET TRANSFORM

A discrete wavelet transform was applied to the luminance component decomposing it into multiple levels of approximation and detail cofficient [17].

The haar wavelet or daubechies davelet (db1) was opted due to its efficiency in capturing edge information.

B. COFFICIENT THRESHOLDING

The wavelet coefficients were treated to soft thresholding to eliminate noise while retaining significant features. A threshold value was chosen empirically to balance noise suppression, while preserving detail.

C. RECONSTRUCTION

Using the modified wavelet coefficients, the luminance component was reconstructed through the inverse wavelet transform [IWT]. This reconstruction resulted in a denoised and enhanced image component.

D. DISCRETE COSINE TRANSFORM (DCT)

The denoised luminance component was further processed using the DCT. By thresholding the DCT coefficients, low-energy components were suppressed, enhancing the visibility of edges and fine detail[18].

STEP(3). FEATURE EXTRACTION & CLASSIFICATION

The enhanced luminance component was analyzed to extract features indicative of metallic regions.

A. THRESHOLDING

The enhanced luminance component underwent global thresholding to create a binary mask of potential metallic regions. The threshold value was determined using Otsu's method to account for varying illumination.

B. FREQUENCY COMPONENT ANALYSIS

The DCT coefficients were separated into high-frequency (HF) and low-frequency (LF) components. HF components, which contain edge and texture information, were segregated to highlight metallic surfaces, while LF components represented smooth regions.

C. REGION PROPERTY ANALYSIS

The connected components in the binary mask were labeled, and region properties such as area, centroid, eccentricity, and mean intensity were calculated. These properties were used to distinguish metallic objects from non-metallic objects.

D. CLASSIFICATION

A rule-based classification approach was implemented to categorize detected regions as "good metal" or "bad metal" based on criteria such as area, eccentricity, and mean intensity. Regions with large areas, low eccentricity, and high intensity were classified as good metals, while others were marked as bad metals [5].

STEP (4): MORPHOLOGICAL OPERATION

Morphological operations were employed to refine the binary mask and enhance the delineation of metallic regions.

A. NOISE REMOVAL

Morphological opening using a disk-shaped structuring element was performed to eliminate small, isolated regions and noise [19].

B. GAP FILLING

Morphological closing was applied to fill gaps in the detected regions, ensuring the continuity of metallic surfaces.

C. HOLE FILLING

The binary mask was subjected to hole-filling operations to ensure complete coverage of metallic objects.

D. EDGE REFINEMENT

Morphological gradients were used to refine the edges of detected regions, improving their accuracy and visual clarity.

IV. RESULT

This study presents an efficient approach for UIE tailored to the task of metal selection by leveraging wavelet decomposition and morphological operations. This experimental results demonstated that the proposed method effectively enhances image quality while accurately distinguishing good and bad metal regions based on defined characteristics.

A. TEST DATA TAKEN

As illustrated in Fig.4, the suggested approach assesses both challenging underwater photos [20] and real-world underwater images from the U45 dataset and several other pictures are taken. The test dataset is the U45 dataset, which consists of 240 realisticunderwater imagery taken from the seabed close to Zhangzi Island in China's Yellow Sea [21].

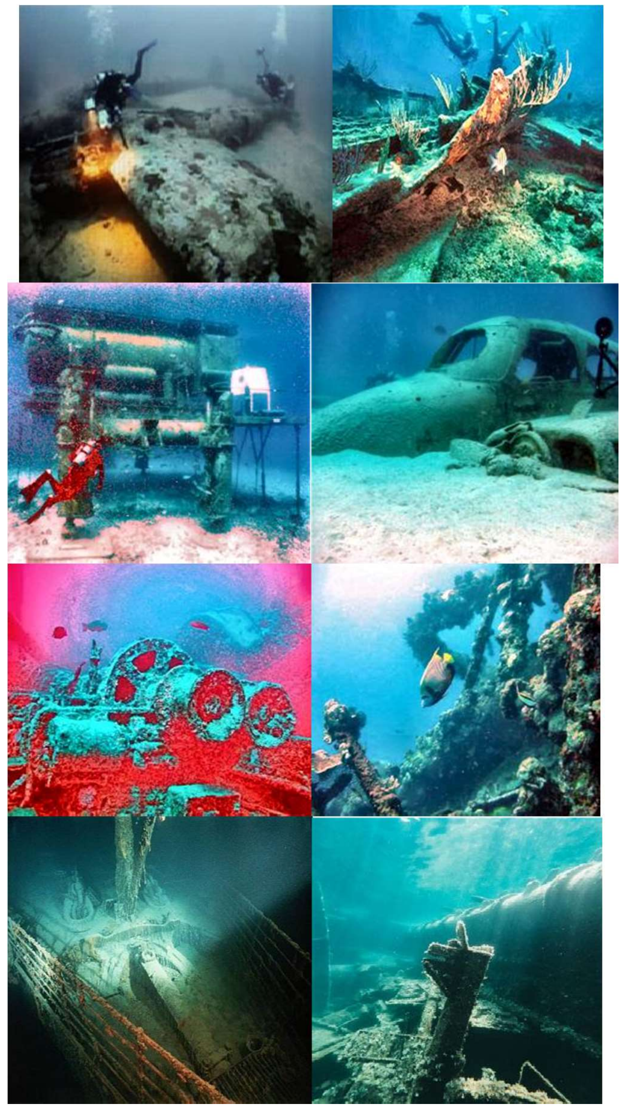


Fig.4. Collection of data set taken from U45 data set

B. ENHANCEMENT ANALYSIS

The enhancement is quantitatively validated using no reference image quality metrices namely BRISQUE, NIQE and PIQE.

1) BRISQUE (BLIND/ REFERENCELESS IMAGE SPATIAL QUALITY EVALUATOR)

It is a no reference image quality assessment metric that evaluates the perceptual quality of an image without requiring a reference image. It analyses spatial natural scene statistics (NSS) and measures deviation from naturalness caused by distortion like noise, blurring or compression artifacts.

2) NIQE (NATURAL IMAGE QUALITY EVALUATOR)

NIQE is another no reference quality metric that assesses image quality by comparing the statistical features of an image to a model of pristine, high quality natural image.

3) PIQE(PERCEPTION BASED IMAGE QUALITY EVALUATOR)

PIQE is a no reference metric designed to evaluate perceptual quality based on block wise distortion analysis. The lower BRISQUE and NIQE scores for enhanced images compared to the original images that confirms the improvement in image quality and naturalness.The reduction in PIQE scores further demonstrates the enhanced image suitability for metal detection Tasks, as artifacts and distortions are minimized.

Fig.5. Test image 1

TEST IMAGE	ORIGINAL	ENHANCED
TEST IMG 1	11.30	15.32
TEST IMG 2	10.29	20.92
TEST IMG 3	28.73	17.49

Table.1. Comparison between original and final value of BRISQUE

Fig.6. Test image 2

TEST IMAGE	ORIGINAL	ENHANCED
TEST IMG 1	2.77	3.06
TEST IMG 2	3.20	3.86
TEST IMG 3	2.72	3.96

Table.2. Comparison between original and final value of NIQUE

Fig.7. Test image

Table.3. Comparison between original and final value of NIQUE

TEST IMAGE	ORIGINAL	ENHANCED
TEST IMG 1	22.7	15.99
TEST IMG 2	16.39	15.68
TEST IMG 3	29.91	14.63

C. CLASSIFICATION ANALYSYIS

The labeled regions in the following teat images are analysed for area, eccentricity and mean intensity, enabling precise classification into good and bad metal categories.
Regions with high area, low eccentricity, and high mean intensity are consistently labelled as good metals and otherwise it will be labelled as bad metals

TEST IMAGES	No. OF GOOD REGION	No. OF BAD REGIONS
TEST IMG 1	2	8
TEST IMG 2	2	16
TEST IMG 3	0	1

Table.4. No. of regions for good and bad metal present in test image for metal selection

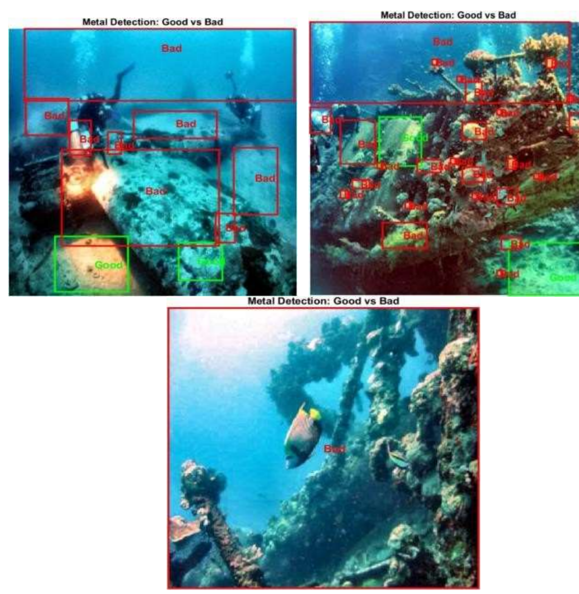


Fig.8. Labelled Region that are good or bad for metal selection

Fig.9. some other test images displaying dection of metal

V. DISCUSSION AND CONCLUSION

This paper presents an effective approach for underwater image enhancement and metal classification utilizing wavelet decomposition, discrete cosine transform (DCT) and morphological operations.

The proposed method enhances image quality by reducing noise through Wavelet denoising and DCT based thresholding, thereby preserving essential structure details.

Quality metrices such as NIQE and PIQE validate the improvement in visual perception of the enhanced images.

Whereas in BRISQUE, it was observed that the obtained values did not allign with expected outcomes.

Additionally, metal regions are identified and classified into “good” or “bad” categories based on morphological analysis, leveraging region properties such as area, eccentricity and mean intensity.

The results demonstrate that this methodology is robust in improving underwater image clarity and enabling reliable metal detection and classification, making it suitable for industrial and marine applications.

In future more attention will be paid on two things. One ,in some scenarios image enhancent is not up to the point with respect to BRISQUE, metal region identification and classification and secondly, further incorporating the deep learning based image enhancement models that are used to improve visibility and contrast of underwater images, particularly in challenging conditions.

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