Contrast Limited Adaptive Histogram Equalization for Underwater Image Matching Optimization use SURF

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Abstract. Conditions of the underwater environment have its challenges in the underwater vision research process. Some things that make underwater imagery difficult is that light can be scattered by particles in the sea, besides that light can be absorbed by seawater, as well as the turbidity level of seawater, so special techniques are needed to get clear underwater imagery. In underwater environmental conditions, the images obtained are usually of very poor quality. Backlight and attenuation will occur this is due to water conditions, objects that dissolve easily in water, and other particulate matter so that there is the degradation of the underwater image. Because it is very important if the image is improved in quality to facilitate the process of describing objects. Image matching techniques to determine the key points of image pairs are needed in three-dimensional reconstruction research. Speeded Up Robust Features (SURF) is an image matching technique where the matching results are very dependent on the image quality. This study proposes the Contrast Limited Adaptive Histogram Equalization (CLAHE) method to increase the number of matching images with SURF. The results of the experiment showed that image matching increased by an average of 76.8 %.

1. Introduction

Marine scientists use video capture in monitoring coral reefs[1]. In their observations, scientists use visualization components of coral reef images including color, structure, and texture in classifying and identifying. Even though in reality the underwater image has experienced degradation due to very poor visibility conditions and has experienced disturbing effects such as light reflection, light absorption, deflection, and light scattering [2]. As it is known that the absorption of light in water is different from the absorption of light in air. The difference in wavelengths of light (red, green, blue) entering the water will have different levels of variation [3]. This can be shown in the illustration in Fig. 1 regarding the absorption of light by water.

Based on pictures. 1 shows that the intensity of the color underwater fades with depth. This makes the need for techniques to improve color and contrast to get closer to better-lit situations. A technique that is often used for contrast enhancement is the standard histogram equalization or Histogram equalization. This method increases the contrast of an image, but it undergoes amplification or expansion of noise in a relatively homogeneous area [4]. To overcome this, the researchers developed an adaptive histogram equalization method and a limited adaptive histogram equalization method [3], [5], [4] and use it in underwater image enhancement [6], [7], [8].
To improve underwater imagery many studies have been carried out using Contrast Limited Adaptive Histogram equalization (CLAHE) [3–12]. Problems caused by noise over-amplification can be solved by this proposed method. In histogram equalization, the method of calculating the histogram is adjusted to the different parts of the image to redistribute the contrast value, which is the standard difference between the two methods in terms of histogram equalization. In AHE, the increase in the appearance of detail in an image occurs due to an increase in the local contrast of the image but it still tends to amplify noise[4]. With CLAHE, noise amplification can be avoided by limiting the contrast in the same area [3].

Figure 1. Illustration of underwater color Absorption and scattering in water [13].

Some limitations The degraded underwater image will become visible when used to display and extract valuable information for further processing. Finding the correspondence between the two images is the task of many computer vision applications[14]. Fast Hessian, the Speeded Up Robust Features (SURF) matching technique detector, is recognized as the best method for scale-invariance detection [15]. Tao et al.[16] can show the results of his research using the SURF method in an experiment to detect underwater objects and get very good accuracy [17].

This paper proposes a method of enhancing the quality of underwater images using the CLAHE method[18,19], which is applied to underwater images with an RGB color model. The main objective is to improve image quality using CLAHE to optimize the performance of the underwater image matching process using the SURF method.

2. Proposed Methods

The discussion of the proposed image enhancement framework is carried out in this section. The flow chart is shown in Fig. 2. The proposal which is this study aims to obtain underwater images with a good quality level using the CLAHE method based on previous research in [20] so that there is an increase in the performance of the SURF method in matching underwater images. Underwater image enhancement using CLAHE was performed to optimize underwater image matching results [17]. In this study, to register an image, the SURF method is used in image matching as object detection in a multi-view camera that is set in stereovision mode where poor image quality is the cause of the low image match feature detected. [21]. From Figure 2, the proposed method is clear in the following steps:

a. Video acquisition.

The first step of this algorithm is to start with the video acquisition[20]of the underwater scenery from two cameras. We use the Matlab Video Reader function to read videos in the MP4 format. In this study, images of coral reefs were taken in the waters north of Central Java, Indonesia, to be precise in the Karimunjawa archipelago. Taking pictures underwater using the Olympus Tough-8010 camera equipment which has a resolution of 1280 x 720 pixels at a depth of 5 meters below sea level.

b. Extract video to the image frame.
Next, we extracted 50 frames of underwater images from video camera 1 and 50 frames from video camera 2 using the get method in Matlab. Each frame is saved in JPG file format with a size of 1920 x 1080 pixels and a resolution of 120 Dpi.

c. **Image Enhancement.**

After that, the 50 pairs of frames from camera A and camera B were enhanced using the HE, AHE, and CLAHE algorithms[19] to produce 50 pairs of underwater image frames that have been enhanced with both algorithms.

d. **Image Matching.**

The next step is to match the image of each of the 50 pairs of frames that have not been enhanced, which have been enhanced using HE, AHE, and CLAHE from camera 1 and camera 2 using the SURF matching method[21,22], to get matched points from each pair of these frames.

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**Figure 2. The Proposed Methods**

2.1 **Image Enhancement.**

One of the most important techniques in image processing is the image enhancement technique. For image representation to be better in computer vision algorithms, it is necessary to increase the visual appearance of the image[23]. CLAHE is a generalization of the AHE[7]. At first, the CLAHE method was developed in the process of improving medical images that have low contrast quality into better quality images. [4,24]. The difference between CLAHE and AHE is in terms of limiting the contrast
value. CLAHE limits amplification by cropping the histogram based on user-defined values called clip limits. The amount of noise in the histogram that must be smoothed is determined by the clipping level and therefore some contrast should be increased[4]. In this case, the histogram boundary will automatically adjust to the boundary level and in the image background area, adjustments will be made to increase the excess histogram limit. The distributed Rayleigh histogram boundary is usually used to produce a bell-shaped histogram, see Eq. (1)[3].

\[
\text{Rayleigh} \ g = g_{\text{min}} + \left[ 2 (\alpha^2) \ln \left( \frac{1}{1 - P(f)} \right) \right]^{\frac{1}{2}}
\]  

(1)

where \(g_{\text{min}}\) is the minimum pixel value, \(P(f)\) is the cumulative probability distribution and is a non-negative real scalar specifying the distribution parameter[3]. In this study, the limit clip is set to 0.2 and the value in the Rayleigh distribution of the function is set to 0.04. In this study, the dataset in the form of underwater image videos of the waters of Karimun Jawa [7,25–27], which has been acquired as many as 100 frames (50 pairs) from two cameras is upgraded using the HE, AHE, and CLAHE to produce an image that has a color contrast quality that is different from the original image as in Fig. 3 and Fig. 4.

![Figure 3. Preprocessing Stages camera 1: (a) Original Image, (b) HE, (c) AHE, (d) CLAHE](image1)

![Figure 4. Preprocessing Stages camera 2: (a) Original Image, (b) HE, (c) AHE, (d) CLAHE](image2)

2.2 Image Matching.
The Speeded Up Robust Features (SURF) algorithm is a computationally fast interest point detector and descriptor with invariance and rotation. In this case, the integral image is used to increase speed. KeyPoints detection was performed using a Fast-Hessian matrix[14]. The spread of Haar-wavelet
responses in the area closest to the point is described using a descriptor. This can lead to an increase in SURF performance by producing an integral image using an intermediate image representation. The given image input speeds up the process of calculating the integral image and the output can speed up the process of calculating the rectangular area. The main computation steps of the SURF algorithm are as follows:

**Step 1: Fast Interest Point Detection.**

The Hessian matrix underlies the formation of the detector feature in SURF, so to determine the location and scale of the descriptors the Hessian matrix is used. The Hessian matrix is defined as $H(x, \sigma)$ for a particular point $x = (x, y)$ [14], [28] see eq (2) [29] :

$$H(x, y) = \begin{bmatrix} L_{xx}(x, y) & L_{xy}(x, y) \\ L_{yx}(x, y) & L_{yy}(x, y) \end{bmatrix}$$  \hspace{1cm} (2)$$

Where $L_{xx}(x, \sigma)$ is the convolution of the second-order Gaussian derivative $\frac{\partial^2}{\partial x^2} g(\sigma)$ at point $x$ and also for $L_{xx}(x, \sigma)$ and $L_{yy}(x, \sigma)$. SURF approaches the second-order Gaussian derivative with the box filter. The convolution of images with this grid filter can be calculated quickly using integral images. The Hessian matrix determinant is written as see Eq (3) [30]:

$$\text{Det} \ H = L_{xx} \times L_{yy} - L_{xy}^2$$ \hspace{1cm} (3)$$

There is an excessive scale so that the localization of the interest points in the image is carried out by applying a non-maximal emphasis on the area closest to the size of $3 \times 3 \times 3$. Next, from the determinant of the Hessian matrix, the maximum value is found and interplanted in the scale and image space.

**Step 2: Interest Point Descriptors**

Two steps are taken to extract the SURF descriptor from the image: the first step is based on the detected circular area around the interesting point the orientation is determined. The selection of the maximum value generated is carried out to describe the orientation of the interesting point descriptors [14]. Regular division of the region is carried out in the second step by making the sub-squares smaller, then calculating some simple features that are at the sample points which are calculated regularly for each sub-region, so that each sub-region has a four-dimensional descriptor vector [28], see Eq (4) [30]

$$V = \left( \Sigma d_x, \Sigma|d_x|, \Sigma d_y, \Sigma|d_y| \right)$$ \hspace{1cm} (4)$$

where $d_x$ denotes horizontal wavelet response and $d_y$ vertical response. The descriptor vectors generated for all $4 \times 4$ sub-regions are $64$ in length.

Figure 5 shows an example of the results of the matching process using SURF on 2 underwater images that have been enhanced using CLAHE to get Matched points using the Matlab code. Figure 5 on the left is the image extracted from the video using camera 1 and the right position is the image extracted from the video using camera 2. From this process, matched points 1 for the left position image and matched points 2 for the right position image are generated.
3. Result and Discussion
This stage describes the results of an image matching experiment using the SURF method to 50 pairs of undersea images that were not enhanced and 50 pairs of underwater images that were enhanced using the HE, AHE, and CLAHE methods. From the experiment, the number of key points and matched points from each image was obtained using the SURF method which can be seen in Table 1 below:

| Enhancement          | Avg. Matched Points |
|----------------------|---------------------|
| Original (No enhancement) | 34                  |
| HE                   | 101                 |
| AHE                  | 135                 |
| CLAHE                | 147                 |

The results showed that of the 50 pairs of underwater images that had been enhanced by the CLAHE method when matched using the SURF method, the value of Matched Points was greater, reaching an average of 76.8% greater than the underwater images that were matched with the SURF method without prior enhancement, HE and AHE.
Figure 6 is shown in the form of a graph of the matched points value resulting from matching using the SURF method to 50 pairs of underwater images that have not been enhanced and which have been enhanced using HE, AHE, and CLAHE.

4. Conclusions
The CLAHE enhancement method with a clip limit of 0.2 and a Rayleigh distribution of 0.04 can improve the quality of underwater images thus optimizing the results of matching underwater images performed using the SURF method significantly from underwater images without enhancement. When the underwater image without enhancement and image matching using SURF got a matched point value of 34, but for images that were previously upgraded using the HE, method increased the matched points value to 101, using AHE increased the matched points value to 135 and increased the quality of the image using CLAHE got matched points which reached 174 points. This shows that the CLAHE method is proven to optimize underwater image matching results using the SURF method with an increase of 76.8% compared to image matching without using enhancement. The SURF method can be developed and optimized with other enhancement methods, to have a high number of matched points so that the developed method can be implemented in an application to facilitate the identification process of underwater images. In the future, the CLAHE method can be further improved by reducing the brightness that is considered excessive using the Dark Chanel Prior (DCP) method.

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