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The Comparison of Grayscale Image Enhancement Techniques for Improving the Quality of Marker in Augmented Reality

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Abstract—**Natural Feature Tracking (NFT) in Augmented Reality (AR) applications use feature detection and a feature matching approach to aligning virtual objects in a real environment. Thus, this tracking detects and compares features that are naturally found in the image (query of image) with the visible feature in the real environment. Therefore, the query of an image must contain good features to track. One of the representing natural features that is easily found in the image is in the corner, and a feature from Accelerated Segment Test (FAST) is one of the fastest corner detectors. However, the FAST corner uses the intensity of the grayscale pixel to determine the candidate corner. Hence, the intensity greatly affects the detection result. Therefore, FAST corner uses the grayscale conversion process to changes the color image into a grayscale image. Thus, the conversion process can lose some details of the images, such as sharpness, shadow, and color image structure. Hence, this process will affect the result of FAST corner to find the feature corner. Besides, Contrast Enhancement also can improve the quality of low contrast grayscale image. In this paper, there are three techniques of the Contrast Enhancement (CE) method were compared, which are Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE), and Colormap. As a result, Colormap is better than HE and CLAHE to extract conner and others feature accurately.**

Keywords— **Augmented reality; FAST corner detector; contrast enhancement; natural feature tracking; feature matching.**

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I. INTRODUCTION

Augmented Reality (AR) is recently one of the latest technologies that offer a new way to educate. There is an interactive technology between the real and the virtual worlds [1]. AR applications employ computer graphics, image processing, and computer vision approaches to develop interactive applications, augmenting the real world with digital content [2]. However, need a unique pattern which could be taken by the camera and recognized by AR application to align virtual object into the real world, this pattern called marker [3]. Thus, the image recognition approach is important in the AR application and the calibration process helps to align the marker with the virtual object correctly in real environment. The marker was defined in Image Recognition field were used for barcode, and followed by Quick Response (QR) code [3], [4]. The evolution shows natural markers were defined by printed AR marker, natural printed AR marker and real-life marker. Figure 1 shows the evolution of markers used in various applications.

The barcode is a one-dimensional (1D) marker representing data by varying the width and spacing of parallel lines [5]. However, the pattern in a 1D barcode is easy to translate and only has 20-25 characters limitation. Then, two-dimensional (2D) marker, commonly known as QR code, aims to solve limitations and privacy. At the same time, QR code represents data using rectangles, dots, hexagons, and other geometric patterns [5]. QR code has more 20,000-character limitation than a 1D barcode, and the QR code is difficult to decode without tools. Then it appears the printed AR marker has shown the fiducial markers.

This was the beginning of AR markers. AR technology is an optical tracker system that has two tracking methods to track the marker. These are the Marker-based tracking method and the Marker-less tracking method [6]. Real-world objects are recognized by tracking less and tracking-based techniques [7]. The printed AR marker in Figure 1 is an example of

Fiducial markers such as template marker and circular marker [8]. Fiducial markers use the black and white ratio region as a pattern to display information [9]. This aims to make a marker robust and easily detected by the scanner. So, the fiducial marker was created to ensure the camera can track it for recognizing the object [9]. The weakness of fiducial markers must be set the ratio black and white region before changed to a binary number. Arrangement of binary numbers used as an Marker Identifier (Marker ID) in fiducial markers [10]. An illustration of the translation Marker ID on the fiducial marker can see in Figure 2.

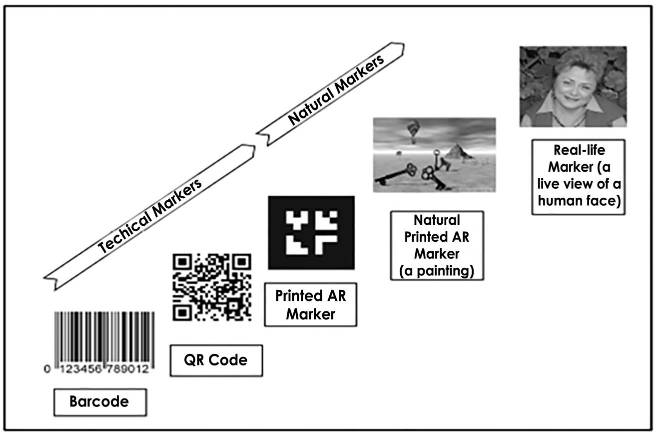


Fig. 1 Evolution of Marker in Image Recognition [4]

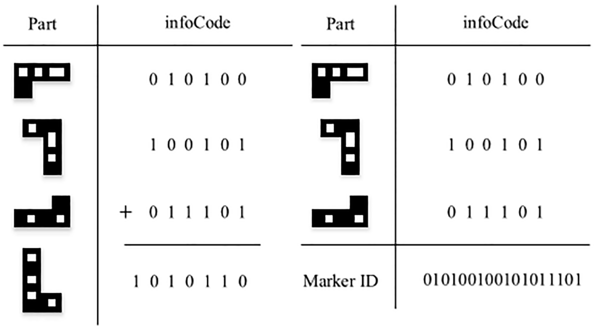


Fig. 2 Illustration of translation Marker ID [10]

The natural printed AR marker and Real-life marker are used in the current AR application that uses natural features like a pattern. For that purpose, the representation of natural features will be used, such as corners, edges, and blobs, to extract from the real world [11]. These called a feature marker, it has the advantage not to design specific Marker ID to be recognized by the camera and are obtainable from the real environment [12]. Implementations of feature markers have an advantage in the AR application because they can work without changing the environment in an existing real environment.

The feature matching method is used to track features in the query of image and feature in the real environment. Some query of the images does not have many detectable features in terms quality of the images, that need enough matching features to enable pose estimation and tracking [13]. Cause, recognize the natural feature is required the unique patterns recognition. During the recognition process, if the marker used does not have enough features, the pattern will lack robustness. For example, it does not have a good texture, noise, and lightning, especially if the marker is taken directly using a camera to be difficult to detect. The natural feature such as the leaf, trees, or human hands can be represented as a marker, and this marker has gone through a marker identification process for the computer to recognize the marker. Marker recognition is important in AR tracking. Tracking is commonly divided into two types of tracking, marker-based, and marker-less tracking. To track natural features, some researchers use marker-based tracking such as Vuforia tools [14] and use Natural Feature Tracking (NFT) method [13]. While for marker less tracking, some researchers using sensors with networking approaches [15]. NFT method uses the textured surface, and the surfaces were in printed material. Vuforia also used the printed material. These marker-based systems have captured the marker by storing unique features; neither requires any visual tracking markers. Multiple features of tracked surfaces are extracted, allowing partial occlusion and degradation of the tracked surface.

The corner is an example to represent the natural feature used in AR. So, it is a vital characteristic of pictures that carries extensive data on the composition and an invariant attribute under several geometric transformations of pictures [16]. The corner detector has been widely used as a feature detector due to the ability of each corner to distinguish information from an image [17]. Several techniques such as Smallest Univalue Segment Assimilating Nucleus (SUSAN), Harris corner, and Features from Accelerated Segment Test (FAST) corner have been applied to track corners, and FAST corners were discovered to be the most stable [2].

FAST corner using grayscale pixels intensity in images is subject to find features corner [18]. The foundation of feature extraction methods presents in Table 1 [19]. From Table 1, it can be seen that the intensity of images strongly influences detected features, especially on FAST, Binary Robust Independent Elementary Features (BRIEF), Oriented FAST and Rotated BRIEF (ORB), Binary Robust Invariant Scalable Keypoint (BRISK), and Fast Retina Keypoint (FREAK).

TABLE I
SUMMARY OF FEATURES EXTRACTION METHOD

Algorithm	**Detector**	**Descriptor**	**Foundation of the Method**
Harris Corner	Harris Corner	-	Gradient
SIFT	DoG	SURF	Gradient
SURF	Fast Hessian	SURF	Gradient
FAST	FAST	-	Intensity
BRIEF	-	BRIEF	Intensity
ORB	oFAST	rBRIEF	Intensity
BRISK	FAST	BRISK	Intensity
FREAK	-	FREAK	Intensity

The FAST corner is ten times faster than the SIFT and SURF algorithms and is currently being used as the quicker detector [20]. Feature extraction-based Oriented FAST and Rotated BRIEF (ORB) is better than another feature extractor like Scale-Invariant Feature Transform (SIFT), Speeded-Up Robust Features (SURF), KAZE, AKAZE, and BRISK [21]. In the FAST corner technique, the ratio darker and brighter in the grayscale pixel is very important in determining candidate features. The conversion process from color image may lose some details of images such as sharpness, shadow, and structure of the color image [22]. The three techniques of CE method are used to enhance the grayscale image, and compare which techniques are suitable with FAST corner detector.

II. MATERIALS AND METHOD

A previous study on the tracking of markers in Augmented Reality [23] has three important things that need to be considered that will affect the detection results, which are inter-marker confusion, true detection, and false detection. The inter-marker confusion was due to multiple markers with almost the same feature patterns, thereby making it difficult for the detector in the library to recognize each feature. Meanwhile, several detectable features are required to increase the true detection marker, and this is expected to subsequently and automatically reduce false detection.

The study by Saipullah *et al.* [20] compared two Software development kits in AR, ARtoolkit, and Vuforia to detect rock art, and the results showed the number of features detected could influence the recognition and robustness of the marker tracking. In this case, every marker has problems in detection and matching features. Meanwhile, the function of the feature extractions is to extract all data inside the image after which they are processed and become useful information to be recognized by the machine [24]. It is, however, challenging to recognize enough features in a real-time environment to estimate the position and orientation of a real-time camera in the AR application [13].

Edward Rosten and Tom Drummond developed FAST corner detector [25] and reputable for their high-speed algorithm in detecting corners [26]. This technique detects the pixel value on the circle formed around the candidate point, as shown in Figure 3. The neighbors of the pixel are required to have at least nine pixels to be identified as a corner, all brighter or darker than the threshold.

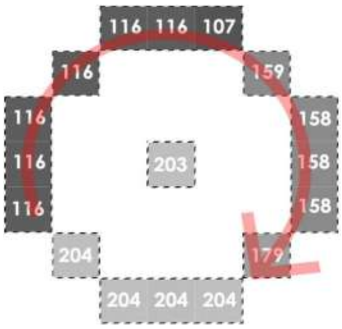


Fig. 3 FAST Corner Technique

Moreover, the decision trees are trained to test several pixels in order to classify prospective ones as interest points or not. Detection of multiple interest points adjacent to one another is one of the other problems in FAST corner, with applying non-maximum suppression in Equation (1), it can remove corners that have an adjacent corner [27].

$$c(p) = \max\left\{ \sum_{q \epsilon S_+} |I_q - I_p| - t, \sum_{q \epsilon S_-} |I_q - I_p| - t \right\} \quad (1)$$

S_+ is the subset of the pixels in the circle which are brighter than p by the threshold, while S_- the subset of pixels darker than p by the threshold (t). The point of candidate p is a black point. Meanwhile, the discretized approximation of the circle around p was used by the 16 gray points p [26].

FAST corner uses darker and brighter pixels from grayscale images to find a corner [17], [18]. Meanwhile, it is possible for oriented images which are changed from RGB to grayscale to lose some details [22]. The grayscale image is also included in the Histogram Stretching (HS) category, and this means the pixels are rounded to the highest or lowest grayscale values. Therefore, the Histogram Equalization method has been applied by several researchers to minimize the lack of Histogram Stretching [28]. This is different from the enhancement method, which is mostly used to enhance grayscale images [29]. Another image manipulation tool is contrast enhancement, which can improve the perceived contrast of an image [30]. The enhancement of grayscale images using CE method requires three techniques which involve Colormap technique, Contrast-limited Adaptive Histogram Equalization (CLAHE) technique, and Histogram Equalization (HE) technique [31].

Image enhancement techniques are usually applied to improve the details of an image [32]. Meanwhile, the AR marker's best quality should be easily detected and reliable in all situations [2]. It also needs to be different from the surrounding environment, unique from the library database, passive and not coated with electronic substances, quickly detectable, and efficient in low light and noisy environments using a powerful image processing algorithm [33].

Fiducial Marker Optimizer (FMO) method is usually used to optimize and increase marker detection [23]. It indicates the possibility of improving marker visibility through noise removal and edge sharpness [23]. Moreover, the black and white ratio also can increase robust marker recognition [34].

Unlike fiducial markers, a marker in NFT method uses natural features, and the images are changed to grayscale to detect the corner. Grayscale is a series of shades of gray with no visible color, and a total absence of visible or reflected light indicates a darker color which is black [35]. These techniques aim to increase the speed and independence of local features [36]. Therefore, the visibility of features marker using natural features was increased in this research through a comparison of three types of CE method used in enhancing details of grayscale images. This research focused on assessing the intensity indicated through the existence of a corner directly from the gray image values.

Figure 4 shows the proposed research framework. There are three main steps, Image Acquisition, image enhancement using CE method, and last step find features using FAST corner technique. The original image is compared with the target image in each CE method used. First, the original image was acquired, followed by tracking the features using a FAST corner detector to get the result of the original image. In the second, the image acquisition was applying an image enhancement technique, using each of the three types of CE method to get the results. Then compare the result based on image noise, the accuracy of a corner, histogram distribution, number of features detected and matched.

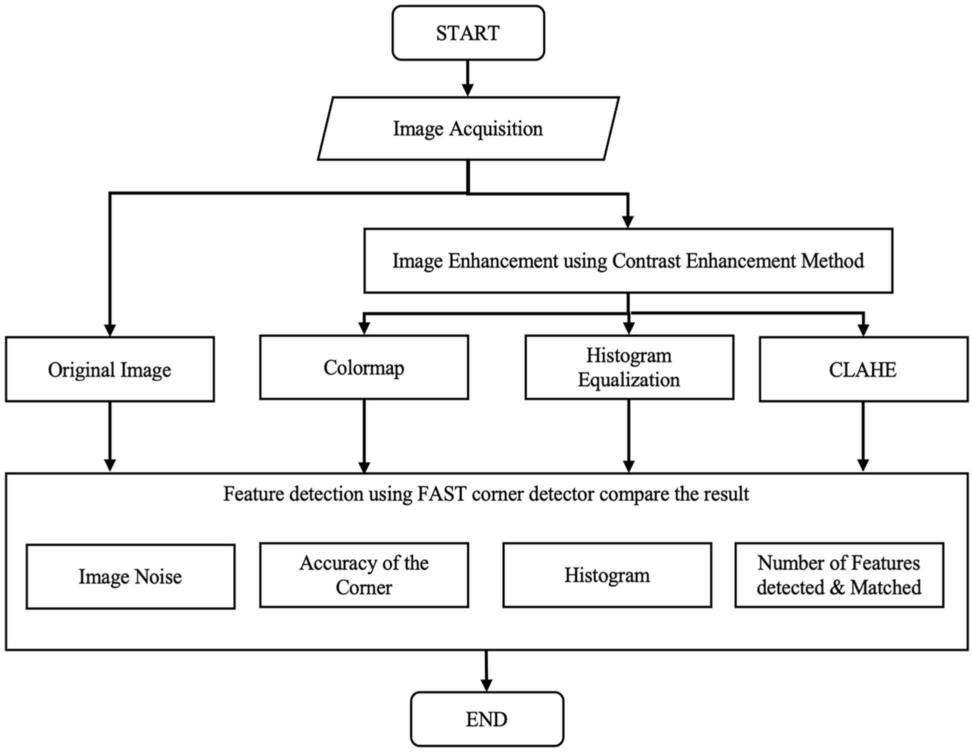


Fig. 4 The proposed Research Framework

That has two image acquisitions in the feature matching method. The first is the acquisition of query of images, and the second is acquisition testing image. Then the feature detected in both acquisitions is compared to get a matching result. Many factors can affect detection in tracking features, such as light intensity, Light Marker Camera (LMC) angel, surface smoothness, and physical movement camera in real-time tracking. This factor is a part of the marker placement-related factor affecting the marker's quality [9].

Experiments were carried out by enhancing the query of the image using each CE method, then performing feature tracking using the FAST corner algorithm. First, the original image has been tracked by FAST corner detector and get the result in terms of noise, accuracy of the corner, histogram and number of features detected and matches. Second, the enhanced grayscale image using three types of CE method. The three types of contrast enhancement algorithm (HE, CLAHE, and Colormap) can be seen in algorithm 1, algorithm 2, algorithm 3.

Algorithm 1. Histogram Equalization (HE)

1: Read image
    Image ←imread ("Location image")
2: Grayscale Image
    Image ← rgb2gray (Image)
3: Enhance image using HE technique
    Image ←histeq (Image)

Algorithm 2. Contrast-limited Adaptive Histogram Equalization (CLAHE)

1: Read image
    Image ←imread ("Location image")
2: Grayscale Image
    Image ← rgb2gray (Image)
3: Enhance image using CLAHE technique
    Image ←adapthisteq (Image)

Algorithm 3. Colormap

1: Read image
    Image ←imread ("Location image")
2: Grayscale Image
    Image ← rgb2gray (Image)
3: Enhance using Color Map technique
    Image ←imadjust (Image)

After enhancing images using three CE technique types, each marker does the features detection using FAST corner. Then the result of image noise, the accuracy of a corner, histogram distribution, number of features detected and matched compared. Based on FAST corner threshold [37], in this experiment using same FAST threshold $\tau = 25$. The FAST corner algorithm is shown in Algorithm 4.

Algorithm 4. FAST Corner (FAST)

1: Read image
    Image ←imread("Location image")
2: Initiate FAST object with default values
    fast ← cv2.FastFeatureDetector_create(threshold=25)
3: Find keypoints
kp←fast.detect(img,None)
4: Draw keypoints
lmg← cv2.drawKeypoints(img, kp, None,color=(255,0,0))
5: Show image
plt.imshow(image)

III. Result and Discussion

The dataset Mapleget called "*Image Database and Corner Detection*" is usually used for corner detection assessment

[38]. This involves applying three contrast enhancement techniques to determine which is best for enhancing the quality of the marker, as shown in Figure 5.

Fig. 5 Comparison three types of Contrast Enhancement, from the left: Original image, Colormap, HE, CLAHE

The original image and three techniques of CE method were compared to determine the exact position of the corner in the image using FAST Corner, and the results are presented in Figure 6 – Figure 9.

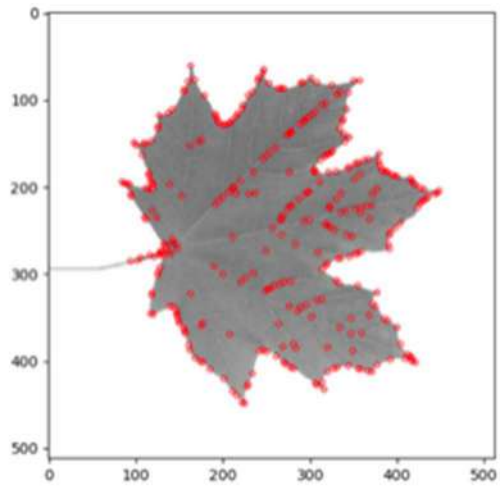


Fig. 6 Result of corner tracking the original image

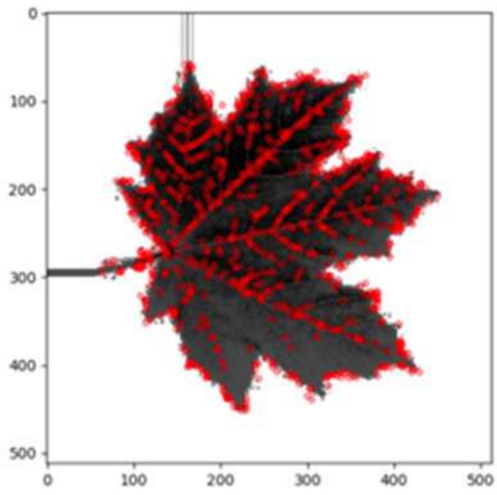


Fig. 7 Result of corner tracking Histogram Equalization

Figure 6 shows the result of corner tracking; the original image has fewer features detected. The HE technique has noise at the edge of the image, it can be seen in Figure 7. CLAHE has inaccurate and overlapping the corners indicated in Figure 8, while Colormap does not have too many overlapping corners as presented in Figure 9.

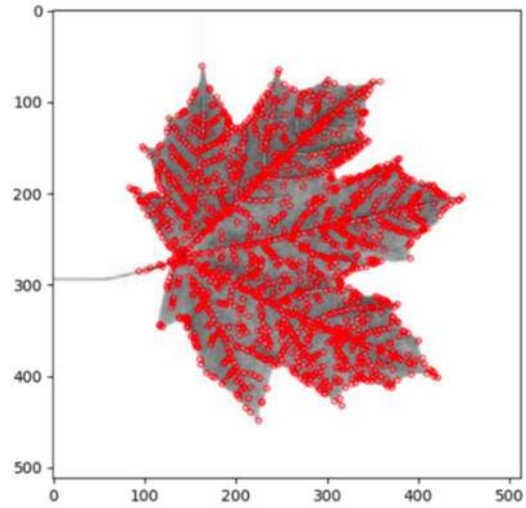


Fig. 8 Result of corner tracking using CLAHE

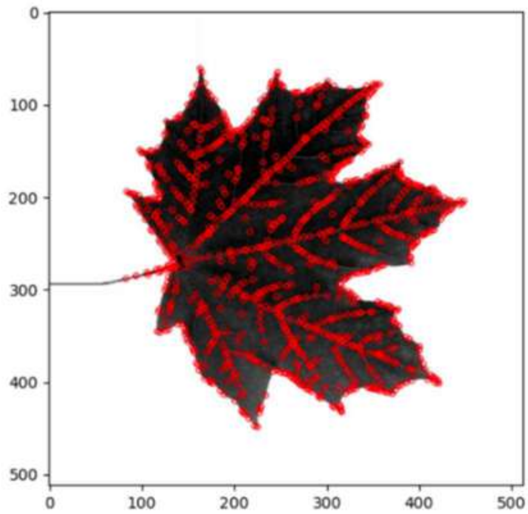
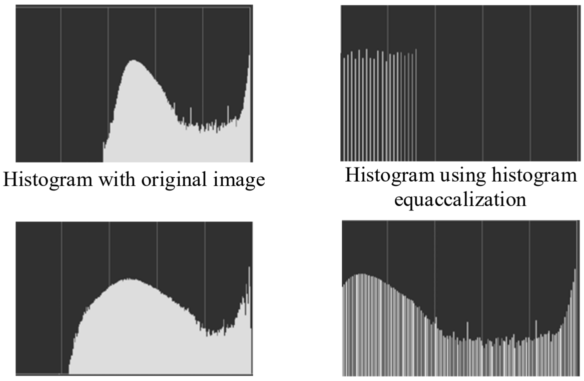


Fig. 9 Result of tracking using Colormap

Rating quality marker from Vuforia SDK is used to benchmark this experiment result. Vuforia uses the FAST corner as Feature Detector [39]. Marker quality can also be measured through a histogram on the image, and this is also listed on the Vuforia SDK website [40]. The image details can be seen from the histogram obtained, and a more evenly distributed histogram is considered to have better image quality details [41]. As can be seen in Figure 10, an original marker that has four stars in the Vuforia SDK database become five stars, although HE has the same rating but has more noise better than Colormap.

Fig. 10 Vuforia rating quality marker



Histogram with original image

Histogram using histogram equaccalization

Histogram using contrast-limited adaptive histogram equalization

Histogram using colormap

Fig. 11 Histogram of Marker

The histogram result shows in Figure 11, Colormap has a more distributed histogram than HE and CLAHE. The shape of the Histogram of an image gives information about the possibility of a contrast enhancement. A histogram of a narrow shape indicates a little dynamic range which corresponds to an image having a low contrast [42].

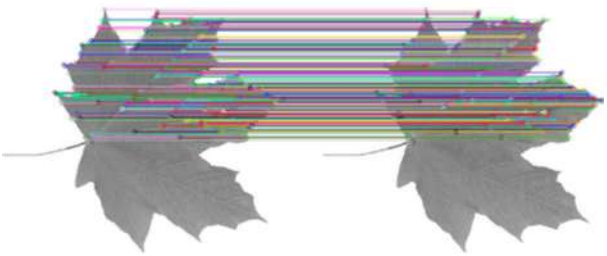
Detecting multiple corner points that have different locations is another problem. Non-maximum suppression can remove corners that have an adjacent corner. The number of features using non-maximum suppression and without non-maximum suppression can be seen in Table II.

TABLE II
CORNER TRACKING USING FAST CORNER ALGORITHM

Type of marker	non maximum suppression	Without non-maximum suppression
Original Image	328 corner	738 corner
Using HE	909 corner	2808 corner
Using CLAHE	1607 corner	2999 corner
Using Colormap	922 corner	1966 corner

Based on the corner tracking result in Table 2. The highest amount of feature detected using CLAHE technique, based on non-maximum suppression result CLAHE has detected 1607 corner and without non-maximum suppression has detected 2999 corner. While the second highest is Colormap and the lowest is HE. The number of features detected does not indicate accurate tracking. The number of features detected must also suitable for the result of matching.

After tracking was done and the corner counting process has been carried out, the next step is to do a feature matching. Feature matching aims to test whether each corner detected matches what is in the initial database or reference image. The brute-force matcher was applied in this research for this purpose [43] and implemented FAST threshold=25 and preset the first 50 detected features.



(a) Matching Original Image

(b) Matching Original Image with HE image

(c) Matching Original Image with CLAHE image

(d) Matching Original Image with Colormap image

Fig. 12 Image Matching Result

The matching result present in Figure 12 (a-d), can be seen in Figure 12 (a) the matching result of the original image has less spread feature matched. Figure 12 (b) indicate the HE technique has a mismatch matching, and Figure 12 (c) shows CLAHE has the highest features, but they are mismatched. Meanwhile, Colormap in Figure 12 (d) is discovered to be better because it does not have mismatched features.

IV. CONCLUSION

In feature matching based, feature detection can affect the feature matching result. However, the feature matching determines whether each pair of the image is similar. Thus, the more accurate feature detected and matched signify the tracking is robust. Robust tracking will make it easier to recognize the objects and also images with watermarking [44]. Some feature detectors like FAST corner influenced by the intensity of a grayscale pixel in the marker. To improve the quality of the marker we suggest using the Contrast Enhancement Method to enhance the detail of the grayscale image. As a result, Colormap is better at reducing noise, fewer mismatches' features, evenly distributed. Histogram and better features detected and matched.

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