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# GRAYSCALE IMAGE ENHANCEMENT FOR ENHANCING FEATURES DETECTION IN MARKER-LESS AUGMENTED REALITY TECHNOLOGY

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## ABSTRACT

Tracking is a fundamental task in Augmented Reality (AR) technology which requires robust real-time to properly adjust real and virtual objects in a single alignment, so that, both objects appear to coexist in the same world. Marker-less tracking has been explored to overcome the limitations of conventional marker-based tracking in AR. By capturing real surroundings to produce the features, the marker-less tracking will recognize these features to overlay the virtual objects on the top of the captured features. The features have been tracked in real-time by the display device, based on the real environment. Therefore, this article aimed to explain the features detection using Features Accelerated Segment Test (FAST) to detect corner features. Related works were reviewed and the features extraction for AR framework using Grayscale Image Generation (GIG) were presented. In addition, to enhance details of grayscale images, a comprehensive study was performed on the three techniques of Contrast Enhancement (CE), namely, Colormap, HE and CLAHE to determine the best method for robust features detection. The findings showed Colormap to be the best technique, compared to HE and CLAHE, in terms of noise, the accuracy of the corner, distributed histogram and amount of features.

**Keywords:** *Augmented Reality, Contrast Enhancement, Template Matching, FAST Corner Detector, GIG*

## 1. INTRODUCTION

Augmented Reality (AR) is a technology which blends virtual contents into the real environment [1]. In other words, it displays digital data in the real world. In addition, a variety of data can be displayed, such as image, text, audio and video [2]. Marker-based tracking and marker-less tracking are two tracking systems that are commonly used in AR [3]. Marker-based tracking uses a black and white marker, for example, ARToolkit and a fiducial marker, including ARTag or ARToolkitplus [4]. A fiducial marker is a point of reference of the real location. A marker is designed with the aim of being accurate and robust tracking by camera [5]. Fiducial markers basically use frames or other landmarks to recognize an object and pose estimation of features for displaying virtual objects.

In marker-less tracking, Natural Feature Tracking (NFT) approaches, such as SIFT, SURF, Ferns and FAST use natural features, for example, corners, edges, and blobs that exist in the real world [6]. NFT requires a vision-based tracking technique which applies image processing to use features on the captured images to calculate the camera's pose [6]. The images become unseen or hidden from user when it uses natural features as a marker. Users

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cannot see the features through their naked eyes. This condition has turned this features-based tracking to become marker-less. Besides features-based tracking, the location-based tracking is also commonly known as marker-less tracking. It uses the GPS to register the 3D content. With marker-less tracking, user does not need to worry about the location of the virtual objects. It does not require an anchor to the real world [7].

Markers are defined as a sign or image that can be detected by a camera, using pattern recognition, image processing, and computer vision techniques [8]. According to [9], there are five types of marker in AR, namely, template marker, circular marker, imperceptible marker, features marker, and infrared marker. Feature is a natural marker type, which uses natural features. Imperceptible marker and infrared marker are sensor marker types. Template marker and circular marker are fiducial marker types [9]. Features marker typically uses templates or features matching for its recognition. Implementations of features marker have an advantage in AR application, because it can work without changing the environment in an existing real environment [9]. The marker must have a different feature to distinguish one another. Some features tracking uses four corners of a square image as features to recognize the images in AR.

Based on Figure 1, there are five types of trackers, namely, magnetic tracker, inertial tracker, optical tracker, ultrasonic tracker and mechanical tracker [10]. This study focused only on the optical tracker. A tracker is a device used to track or capture images. There are two divisions in AR, namely, marker-based tracking and marker-less tracking. In general, the marker-less tracking is further divided into three categories, edge-based, keypoint-based and interest point-based. Edge-based tracking uses edges as features or known as points sampled. Interest point-based tracking uses keyframe from camera pose, while keypoint-based tracking uses natural features, such as corners. Keypoint-based tracking is also known as features-based tracking. Based on the principles of features tracking, there are three approaches highlighted which can affect tracking.

First is the black and white ratio on fiducial marker, and this approach can be considered as an easy detection in various lighting conditions. This ratio can affect a detection in marker-based tracking [11]. Along with black and white markers, the use of fiducial markers is a common practice in AR, where it can be divided into two types, the template marker and the circular marker. Meanwhile in the grayscale approach, such as FAST, ORB, and BRISK, the intensity pixel of grayscale images is used to detect features. Grayscale Image Generation (GIG) method is used in marker-less AR framework [16-17], where it enables the intensity of the grayscale image to affect features detection. The features marker, also known as natural marker is derived from the grayscale approach. The combination of marker-based and marker-less tracking is known as hybrid tracking, which usually uses the sensor output as a marker [14], for example, imperceptible marker and infrared marker. Edge-based and interest point-based tracking use the last calculated pose as an estimate for the current pose (recursive), while the keypoint-based tracking uses the current frame to estimate the pose (non-recursive) [15].

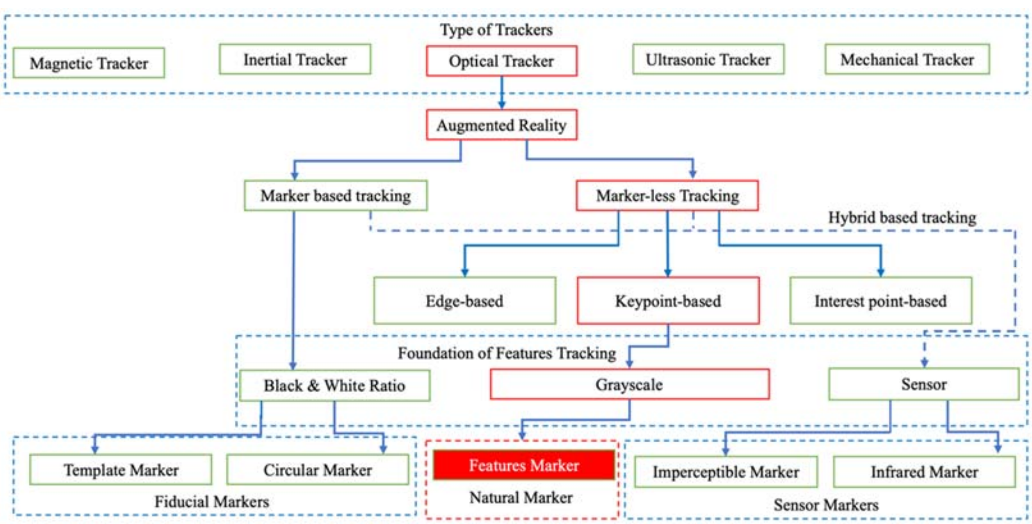


*Figure 1. Tracking system based on type of trackers, features tracking techniques, and type of markers*

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Features detection mainly aims to produce features for robust object detection. With certain features in the images, hidden information can be added, such as steganography techniques [16] and watermarking techniques [17]. During features extraction process, the process cannot extract features precisely, due to the noise and image quality. The more features can be detected much robust the markers can be tracked and recognized [18]. Therefore, to identify and recognize the object or marker on a digital image, image processing is necessary [19]. Sometimes, the marker used does not have enough features, such as the lack of a good texture and noise and lighting problems, especially if it is directly captured using a camera. This makes the features difficult to detect or encounter mismatches [18].

To improve features tracking, such as problems that occur in [18], the tracking accuracy will be increased with the more features which have been detected. In this research, GIG was used as the method to extract features from a natural marker in AR. According to [20] and [21] features extraction in AR can use GIG method to convert the RGB images into grayscale images before producing the features. Converting RGB images into grayscale images can cause a loss of some details [18-19]. A method was proposed in this study to improve the details on grayscale images for a precise detection of the features. It was revealed that, the details of grayscale images could be enhanced using Contrast Enhancement (CE) method, such as CLAHE, HE and Colormap [22]. Experiments were carried out to compare the three techniques in terms of features tracking, noise, the accuracy of the corner, distributed histogram and the amount of features.

## 2. RELATED WORKS

Several researchers have studied the reliability of marker recognition. A previous work by [23] developed a tracking technique to detect the features of fiducial marker underwater, using generated synthetic images for robust detection in these environments, while [24] developed a new marker detection known as mono-spectrum marker which can accurately detect blurred and defocused images in real time. A black and white fiducial marker which can positively affect detection is used to increase the robustness of the marker recognition[11]. Designing highly reliable fiducial markers can solve interest point detection and matching problems, as agreed by [25]. Fiducial Marker Optimization (FMO) method has been developed using image processing techniques, which are edge sharpness and noise removal [26] to design high quality markers. Tracking a marker in AR has three problems, namely, inter-marker confusion, true detection, and false detection. The severity of these problems depend on the available extraction features and matching features [27]. Certain images do not have many detectable features, and according to [28], contrast value, brightness and colour image manipulation can affect the quality of image marker in AR.

Features detection using natural features have the same problems. As such, good extraction features and matching features are needed to resolve the inter-marker confusion, true detection, and false detection problems. To detect the natural features, two software libraries have been compared between ARToolkit and Vuforia. Based on the findings in [18], Vuforia detects fewer features, compared to ARToolkit, and the amount of features detected can increase tracking accuracy and robustness of the marker recognition.

Based on related works, researchers have attempted to produce features detection in template matching better and to recognize features in objects more quickly and accurately. However, our study focused only on natural features marker for marker-less AR.

## 3. FUNDAMENTAL OF TRACKING FEATURES

There are five types of tracking system as mentioned above. The magnetic tracker uses the magnetic field as a source to estimate orientation, while an ultrasonic tracker, also known as an acoustic tracking system, uses sound wave to determine the position and orientation. Inertial tracker uses Inertial measurement units (IMU) with a combination of multi-sensors, such as accelerometer, gyroscope, and magnetometer to get orientation. Mechanical tracking systems rely on physical connections between targets and fixed reference points. The last fifth type of the tracking system, namely, optical tracker, also known as Optical Tracking System (OTS), depends on two components, light source and optical sensor [10]. Virtual Reality (VR) and AR are included in the optical trackers category [29].

Corner is a characteristic of the image for a robust detection [30], and it carries an extensive data about picture composition and invariant characteristics under many geometric transformations into pictures [31]. The corner detector has been widely used as a

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feature point detectors, because each corner in the image can distinguish information from the image [32]. Features detection algorithms try to identify features directly, based on the intensity patterns in the marker. The selection of features detection can affect the overall system performance [33]. Some techniques, such as SUSAN (Smallest Univalue Segment Assimilating Nucleus), Harris corner, and FAST corner (Features from Accelerated Segment Test) are used for tracking corners. Among these, FAST corner is the most stable [8]. FAST corner uses grayscale images to find features [34]. The ratio of darker and brighter areas in a grayscale image, is very important to find a candidate corner using FAST corner detector. FAST corner with rotated BRIEF or known as ORB is also suitable to be used in AR mobile device, because it is fast, with no heavy computational load needed [35] and mobile phones and tablets are increasingly becoming common media for AR, which provide a significant growth, because they are oriented towards consumer experiences [36].

There are eight important qualities which must be had for ideal features, namely, distinctiveness, locality, quantity, accuracy, efficiency, repeatability, invariance, and robustness [37]. Distinctiveness is the condition where detected features must have variations which can be used to differentiate each feature and match. Locality means, the features should be local to reduce the chances of getting occluded and allow simple estimations of geometric and photometric deformations. Quantity is the total amount of detected features which must be enough to reflect the object. Accuracy is the detected features which must also be located accurately from the various locations of pixels, shapes, and scales. Efficiency means, the features detected do not take much time to be identified and are suitable for real-time applications. Repeatability is the feature detected in the same object, which must have similarity features when tested in different display conditions. Invariance means, each feature detected is always matched if the image is transformed. Robustness is the deformation resistance from image noise, discretization effects, artifact compression, blur, etc.

According to these ideal features, improvements were made on the details of grayscale images for benchmarking purposes, in terms of noise for robustness, accuracy, quantity, and distributed histogram. The shape of the histogram of an image gives information about the possibility for a contrast enhancement. A histogram of a narrow shape indicates a little dynamic range which corresponds to an image having a low contrast [38] and Vuforia transforms the images into grayscale. When the images do not have enough contrast, the marker will produce very less or small amount of features, and the histogram looks narrow and spiky [39]. Non-maximum suppression is used for smaller patterns to better preserve the locality constraint of a corner [40]. Distinctiveness, repeatability, efficiency, and invariance tests are the next experiment to be carried out for real-time tracking to improve the features extraction in marker-less AR. This study proposed CE method to improve grayscale images for enhancing features detection in marker-less AR.

## 4. CONTRAST ENHACEMENT METHOD

According to [22], CE method can enhance low contrast grayscale images to improve the details of images. An experiment has been conducted before, using Image Adjust Intensity Values or Colormap [41] to enhance old pictures in a museum as marker in AR. In this section, the three types of CE method which can be used to increase the details of grayscale images, are described. The following subsections explain the three types of CE method, namely, Histogram Equalization, Contrast Limited Adaptive Histogram Equalization and Colormap.

### 6.1 Histogram Equalization

Histogram equalization is the act of modifying the intensity distribution that adjusts the contrast of an image-based on a histogram to provide a linear trend to the cumulative probability function associated with the image to produce an image with an even histogram. The even histogram will increase the details of the image achieved, as agreed by [42]. The histogram of an image is a discrete function formed by counting the number of pixels in an image that has a certain grey value, so that, the histogram of the output image approximately matches the specified histogram. Even distribution of regional histograms in images can increase the visibility of local details in images [22].

### 6.2 Contrast Limited Adaptive Histogram

CLAHE is widely used in medical image processing. The CLAHE algorithm divides the image into rectangular areas, applying several thresholds and equality locally in each region. After setting a threshold for the grey level, as in the above event, this threshold is truncated to minimize saturation, followed by a uniform and recursive redistribution throughout the local histogram [43].

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### 6.3 Colormap

Colormap, also known as the Image Adjust Intensity Values, is a colour transformation, from the colours of one source image to another target image [44]. Colormap is also known as an algorithm which can change the colour of an image or an algorithm that creates and produces an image mapping. Colormap is a merger of 3 matrices (m-by-3) real numbers between 0.0 and 1.0. The RGB colour in each row determines the colour transformed from the image having the RGB to grayscale image. Colour kith is defined in kith lines, with the specific intensity of the colours in red, green and blue, map (k, :) = [r (k) g (k) b (k)]) [44].

Image enhancement techniques are used to improve an image [45]. Intensity adjustment is an image enhancement technique that can be used to map and modify image values using the `imadjust` method in MATLAB. This is a method to increase the contrast of the output image, where the range of intensity values can be defined in the output image [46]. Colormap can strengthen the quality of images which will improve and increase the contrast in low-contrast grayscale image by remapping data values. By definition, 1 percent of data is saturated with a low and high output data strength [22].

## 5. DATASET

An appropriate dataset is needed to get an accurate corner position result. This experiment used a grayscale dataset to prove that, enhancing details can affect corner detection. Experiments were carried out by using a dataset from Guo Chengung, usually used to test detection of corner accuracy [47]. The dataset from Guo Chengung is as shown in Figure 2.

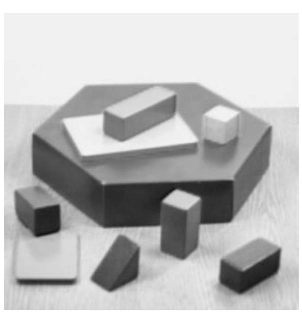

*Figure 2. The dataset used for keypoint detection*

## 6. RESEARCH FRAMEWORK

Figure 3 shows the proposed research framework. The original image is compared against the target image in each CE method used. The original image was acquired, followed by the tracking of the features using a FAST corner detector to get the result of the original image. In the second and third steps, the acquisition of the image applied image enhancement technique, using each of the three types of CE method to get the results, which relied on image noise, accuracy corner, distributed histogram and features amount.

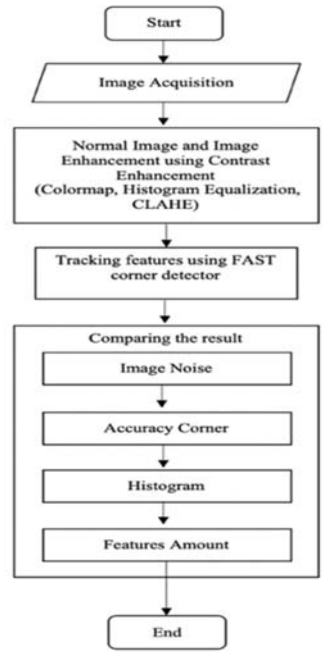


*Figure 3. Research Framework*

## 7. TOOLS AND HARDWARE

The tools used to enhance grayscale images and develop AR, based on mobile platform (Android) in our experiment were as follows:

- MATLAB as image processing tools, using CE method and OpenCV to accelerate machine perception for features tracking and matching.
- Unity 3D and Vuforia SDK as a media for designing and building AR applications.

  The quality of marker in Vuforia SDK was compared with that of our code using OpenCV.

  The hardware required for AR is as presented in Table 1, which lists the standard requirement and specification for RAM, Processor and VGA.

*Table 1. Hardware Specification*

| Hardware | Specification |
|---|---|
| Processor | Intel Core i7 2670QM @ 2.20GHz |
| RAM | 8.00GB Dual-Channel DDR3 797MHz |
| VGA | 3071MB NVIDIA GeForce GT 555M |

## 8. ENHANCE GRAYSCALE IMAGE USING CONTRAST ENHANCEMENT METHOD

Grayscale image is a variant form of black and white. Grayscale is a scale of black and white in digital image technology. It measures the intensity of light, reflected on an area or point of surface area and subsequently defines each pixel as a computer byte value. Grayscale image is included in the Histogram Stretching (HS) category. The operations will cause the pixels to be rounded to the highest or lowest grayscale values, causing the image to lose some details [12]. To enhance the grayscale images in this experiment, CE method comprising three techniques stated in the previous section was used in this study. The marker quality was improved in each of the three techniques used, which results were later compared against each other. The three types of CE algorithm can be seen in Algorithm 1, Algorithm 2, and Algorithm 3.

**Algorithm 1** Histogram Equalization (HE)
**Input : Original image**
**Output : Enhance image with HE**
1: Read image
Image ← imread("Location image")
2: Grayscale Image
Image ← rgb2gray (Image)
3: Enhance image using HE technique
Image ←histeq(Image)

*Algorithm 1. Histogram Equalization Algorithm*

**Algorithm 2** Contrast-limited Adaptive Histogram Equalization (CLAHE)
**Input : Original image**
**Output : Enhance dataset with CLAHE**
1: Read image
Image ← imread("Location image")
2: Grayscale Image
Image ← rgb2gray (Image)
3: Enhance image using CLAHE technique
Image ← adapthisteq (Image)

*Algorithm 2. CLAHE Algorithm*

**Algorithm 3** Color Map (Image Adjust Intensity Values)
**Input: Original image**
**Output: Enhance dataset with Color Map**
1: Read image
Image ← imread("Location image")
2: Grayscale Image
Image ← rgb2gray (Image)
3: Enhance using Color Map technique
Image ← imadjust (Image)

*Algorithm 3. Colormap Algorithm*

## 9. FEATURES DETECTION

Some AR SDK use corner as the features to recognize the marker in AR, such as Vuforia, which has applied FAST corner detection [48] and which has been patented by Qualcomm [49]. To recognize objects on the camera, features on objects or markers are stored first in the database as a template or references. Following this, the features stored do the matching with the object or marker tracked by the camera. If the features match with the marker, the virtual object will be shown.

Based on the review on features tracking with the FAST corner technique, the ratio of the darker pixels to the brighter pixels in grayscale image is very important. FAST tracking comparing 16 pixels with darker and brighter pixels to determine features corner and the intensity is very influential. FAST corner is ten times faster than the SIFT and SURF algorithms and until now, it is still used as the fastest detector [50]. Feature matching based on ORB (Oriented FAST and Rotated BRIEF) is better than other feature matching methods, such as SIFT, SURF, KAZE, AKAZE, and BRISK [51]. ORB is suitable for real-time recognition in mobile devices, based on accuracy and time [35]. Summary of a features extraction method for feature detectors and descriptors is as presented in Table 2. The intensity of image pixel is the foundation of the FAST, BRIEF, ORB, BRISK and FREAK methods, which all use intensity pixel of candidate corner as the centroid to measure orientation [52]. It shows that, the intensity of images strongly influences the detection of features. Different from Harris corner, SIFT and SURF use histograms of gradient computations to find the candidate corner [52].

*Table 2. Features Extraction Method* [53].

| 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 |

FAST was developed by Edward Rosten and Tom Drummond [54], known for its high-speed algorithm for corner detection [55]. This algorithm detects the

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pixel value on the circle formed around the candidate point, as shown in Figure 4. Neighbours of pixel must have at least nine pixels to be identified as corner, all brighter or darker than the threshold. Decision trees are trained to test several pixels to classify prospective pixels as interest points or otherwise.

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

$S_+$ is the subset of pixels on the circle that are brighter than $p$ (by threshold) and $S_-$ is the subset of pixels that are darker than $p$ (by threshold). The point of candidate $p$ is a black point. The discretized approximation of the circle around $p$ is used by 16 grey points $p$ [55]. Figure 4 shows how FAST determines a candidate corner.

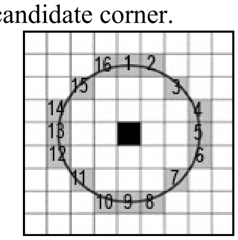



*Figure 4. FAST Corner Technique*

FAST corner detector will get more threshold responses in highly contrasted areas and even more in the homogeneous region of the image to count the total amount of corners and matching corners. To detect corners using FAST with a fixed threshold $\tau = 25$ [56]. This study also uses Vuforia to measure the quality of the marker and to compare with FAST corner tracking on OpenCV. The FAST algorithm is defined in Algorithm 4.

**Algorithm 4** FAST Corner (FAST)

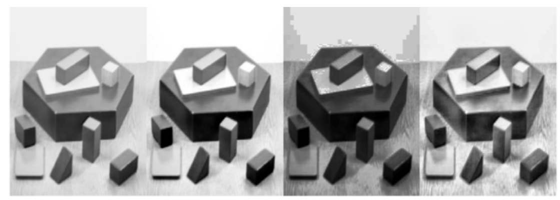
**Input: Original & Enhance dataset using CE method**
**Output: Features detection**
1: Read image
   Image ← imread ("Location image")
2: Initiate FAST object with default values
   fast ← cv2.FastFeatureDetector_create (threshold=25)
3: Find keypoints
   kp ← fast.detect(img,None)
4: Draw keypoints
   lmg ← cv2.drawKeypoints(img, kp, None,color=(255,0,0))
5: Show image
   plt.imshow(img2)

*Algorithm 4. FAST Corner Algorithm*

## 10. RESULTS AND DISCUSSION

The dataset from Guo Chengung [47] applied all the three techniques of CE method. Each technique was performed to get the best method for enhancing the quality of marker and also to compare the marker with the original images. Comparisons were made based on image noise, accuracy corner, histogram and features amount.

Noise comparison of the three techniques can be seen in the following Figure 5.



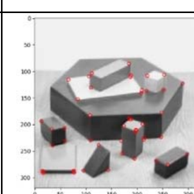
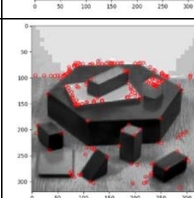
(a) (b) (c) (d)

*Figure 5. Comparison of original image with grayscale image obtained using the three techniques of CE Method*

The results of enhancement on grayscale images using CE method can be seen in Figure 5. The first image is the original image (as in Figure 5 (a)), while Figure 5 (b) is the original grayscale image, using Colormap technique, which shows more details , compared to Figure 5 (a). The image that uses HE technique (as in Figure 5 (c)) can be seen with noise in the image , and Figure 5 (d) shows the image using CLAHE technique. The details of image that uses the Colormap technique are much better, compared to those using the other techniques, namely HE and CLAHE, which recorded more noise.

For accuracy of the corner features, FAST corner detector algorithm was used for features tracking in the markers, which can be seen in Table 3.

*Table 3. FAST corner tracking for features tracking*

| Marker | Tracking Corner | Type Image |
|---|---|---|
|  |  | Original Image |
|  |  | Histogram Equalization |

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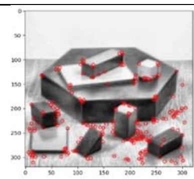
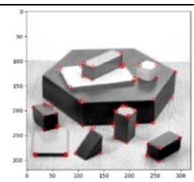
| | | |
|---|---|---|
|  |  | Contrast-limited Adaptive Histogram Equalization / CLAHE |
|  |  | Colormap |

Table 3 shows the images using HE technique and the CLAHE technique, where more mismatched positions of the corner are found. Obviously, Colormap is the best technique to detect the position of the corner.

To prove the accuracy of features detection, features in Vuforia were also compared, using FAST corner which has been improved to measure features of corners.


*Figure 6. Testing using Vuforia SDK*

Marker rating using Vuforia SDK can be seen in Figure 6. The results showed that, the marker rating increased using the colormap technique. The technique doubles the original image rating in Vuforia SDK database from two stars to four stars. Vuforia has a rating range between 0 to 5 stars. 1 and 2 stars indicate a low rating, while 4 or 5 stars indicate the best results.

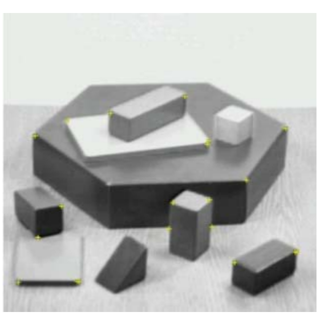


*Figure 7. Image marker before using Colormap*

The Colormap technique enables the number of corners previously not detectable to be seen. The marker which uses the Colormap technique as in Figure 8 improves the corner accuracy, comparedto the original image shown in Figure 7.

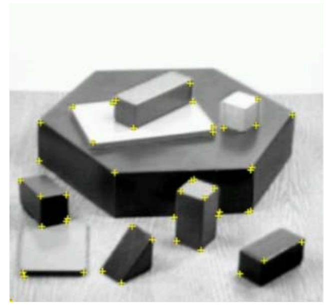


*Figure 8. Image marker using Colormap*

The high speed test of FAST corner can be performed by eliminating a candidate point which does not have the values of intensities pixel 3 by 4 greater or less than the candidate point, where the number of intensities of pixel is 1,5,9 and 13 [54].

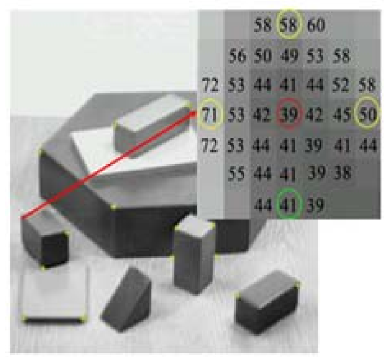



*Figure 9. Values of grayscale pixel before using Colormap*

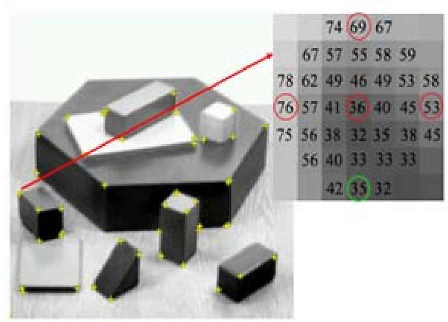



*Figure 10. Values of grayscale pixel using Colormap*

Figure 9 presents the original image and Figure 10 shows the results after the Colormap technique has been applied. It can be seen in Figure 9 that, the point marked by the arrow detected was not a corner, because there were 4 pixels greater than the candidate pixel. Figure 10 shows that, the point marked by the arrow is a corner, because 3 out of 4 pixels are greater than the candidate pixel.

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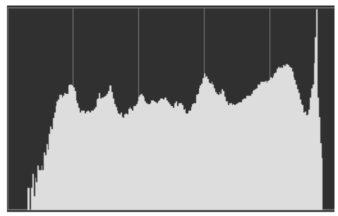
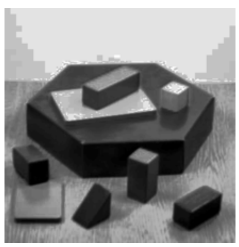
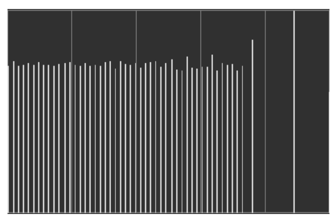
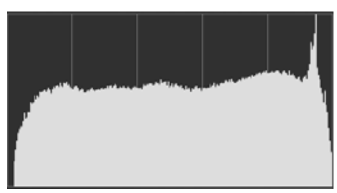
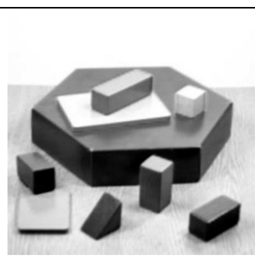
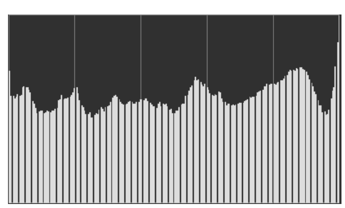
Marker quality can also be measured through a histogram on the image, as listed in the Vuforia website [49]. According to [42], the image details can be seen from the histogram taken. The more evenly distributed the histogram, the better the quality of the image details. Table 4 shows a histogram of each image using CE method and the original image. The evenly distributed histogram can be seen on the type of image using colormap technique.

*Table 4. Histogram images before and after using Contrast Enhancement Method*

| Marker | Tracking Corner | Type Image |
|---|---|---|
|  |  | Original Image |
|  |  | Histogram Equalization |
|  |  | Contrast-limited Adaptive Histogram Equalization / CLAHE |
|  |  | Colormap |

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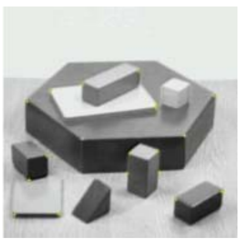
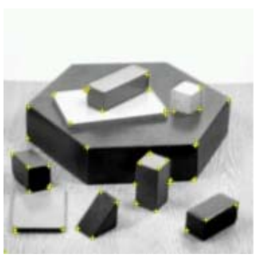
In the next experiment carried out to count the features amount, a problem was encountered in detecting multiple corner points on different locations. Non maximum suppression remove corners which have an adjacent corner [54].

The amounts of features using non maximum suppression and without non maximum suppression are as shown in Table 5, and it can be seen that, image with the colormap technique detects more corners.

*Table 5. Tracking corner using FAST corner Algorithm*

| Marker | Type of marker | Non maximum suppression | Without non maximum suppression |
|---|---|---|---|
|  | Original image | 49 Corner | 337 Corner |
|  | Using Colormap | 66 Corner | 492 Corner |

Upon completion of the features tracking and the corner counting process, feature matching was carried out, aimed to test whether each corner detected matches what is in the initial database or initial tracking.

The brute-force-matcher approach was used for the feature matching [57]. It was used to match corners, before and after enhancement with threshold=25. Figure 11 shows that, the features matching using colormap technique are better.

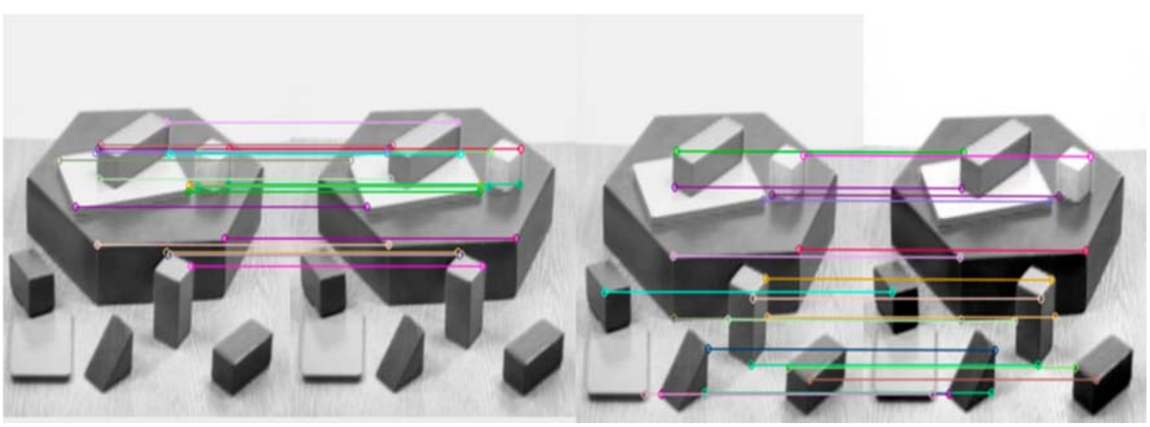


*Figure 11. Matching original image & enhanced image using Colormap*

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## 11. CONCLUSION & FUTURE WORK

Enhanced grayscale images help features detector to detect features corner better. CE method can be used to enhance grayscale images, and out of the three techniques used, Colormap technique was found to be the best. The results obtained using HE and CLAHE from Guo Chenguang dataset showed many mismatches of the corner positions, while more noise was recorded. These mismatches proved that CLAHE and HE are not suitable to be used for enhancing the details of grayscale images to improve the detection of features corner, based on FAST corner detector. The accuracy of corner using image adjust intensity values or Colormap was found to be better, compared to that using HE and CLAHE, with more evenly distributed histograms being produced. The amount of features also increased using Colormap, and the matching was found to be a lot better.

The matching keypoint is usually used as ID marker in AR. Colormap method is suitable for improving details of images to find keypoint or features corner using FAST corner tracking. The overall results showed Colormap to be better than HE and CLAHE, in terms of noise, the accuracy of the corner, the distributed histogram and the amount of features.

As for future works, this method can be used during features extraction before the features are stored in databases. In addition, this method can enhance features extraction in AR based template matching.

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