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Crescent Moon Segmentation via Histogram Percentiles and Simplified K-Means Algorithm

(Segmentasi Bulan Sabit melalui Persentil Histogram dan Algoritma K-Means Ringkas)

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ABSTRACT

Detection of crescent moon in digital images is of interest to researchers and practitioners involved in crescent moon sighting activities. The ability to detect the crescent moon shape, if it exists, will contribute to the decision making related to the local Islamic calendar based on the observation method and support the expected visibility of the crescent moon using the calculation method. However, under the syariah (Islamic law) consideration, any crescent moon detection procedure on the original image should not 'create what is not' during the image processing. Hence, in this paper, we propose a new crescent moon shape detection procedure by increasing the contrast of the image without changing its original feature. This is done by segregating the ordered pixel intensity values of the image according to their quartiles and maximizing the contrast in each quartile. Next, another procedure is proposed to segment the crescent moon from the background. These procedures are applied on selected crescent moon images taken at Teluk Kemang Observatory Station, Negeri Sembilan, Malaysia. We found that the procedures are able to detect the crescent moon shape if it exists in the image, and segment it from the background. More importantly, false detection is also avoided. The results are very important to support the local Islamic religious authority in making the final decision on the beginning of important Islamic events that depends on the visibility of the crescent moon in Malaysia.

Keywords: Feature extraction; image contrast; Islamic calendar; object segmentation; quartile plots

ABSTRAK

Pengesanan anak bulan dalam imej digital adalah perkara yang menarik minat para penyelidik dan pengamal yang terlibat dalam aktiviti cerapan anak bulan. Keupayaan untuk mengesan bentuk anak bulan, sekiranya wujud akan menyumbang kepada proses membuat keputusan berkaitan dengan kalendar Islam tempatan berdasarkan kaedah cerapan serta menyokong jangkaan kebolehnampakan anak bulan menggunakan kaedah pengiraan. Namun, dari sudut pertimbangan syariah, sebarang prosedur pengesanan anak bulan pada imej asal tidak seharusnya 'mencipta sesuatu yang tiada' semasa pemprosesan imej. Oleh itu, dalam kertas ini kami mencadangkan satu prosedur baharu untuk mengesan bentuk anak bulan dengan meningkatkan kontras imej tanpa mengubah ciri asalnya. Kaedah ini dilakukan dengan memisahkan nilai keamatan piksel imej mengikut kuartil dan memaksimumkan kontras dalam setiap kuartil. Seterusnya, satu lagi prosedur dicadangkan untuk mengasingkan anak bulan daripada latar belakang. Prosedur ini diaplikasikan pada imej anak bulan terpilih yang diambil di Balai Cerap Teluk Kemang, Negeri Sembilan, Malaysia. Kami mendapati bahawa prosedur ini berupaya mengesan bentuk anak bulan sekiranya ia wujud dalam imej, serta mengasingkannya daripada latar belakang. Lebih penting lagi, kesalahan dalam pengesanan juga dapat dielakkan. Hasil kajian ini sangat penting untuk menyokong pihak berkuasa agama Islam tempatan dalam membuat keputusan muktamad mengenai permulaan peristiwa penting Islam yang bergantung kepada kebolehnampakan anak bulan di Malaysia.

Kata kunci: Ciri pengekstrakan; kalendar Islam; kontras imej; plot kuartil; segmentasi objek

INTRODUCTION

Image processing has been associated with either correcting the errors during image acquisition or to enhance the weakness in the image for human visual system (Awcock & Thomas 1995). It also covers the work on the digitisation and segmentation of pictures for early stage in Machine Vision (Petrou & Petrou 2010). Just as the human is able to see, integrate, and interpret the visual surround us, so does a machine is able to understand an image through visual information analysis technique (Acharya & Ray 2005). For feature extraction in image analysis, Marion (1991) discussed point and algebraic operation techniques on histogram of the pixel intensity to analyse shapes, contours, and textures of the image. The technique chosen should provide useful information on the feature of interest in the image.

In order to extract features of an image, one can use *k*-means clustering. *k*-means clustering is a method to identify and partition *n* observations into an optimum number of clusters based on the squared Euclidean distance. A paper by Caponetti, Castellano and Corsini (2017) uses different clustering methods to compare and evaluate the effectivity of clustering in segmenting Magnetic Resonance (MR) brain images that was done on 60 images from the Internet Brain Segmentation Repository available by the Centre for Morphometric Analysis, Massachusetts General Hospital. The result from this paper shows that the optimum number of clusters is 4, based on the desired number of tissue regions in the brain images, which is 3. It is only logical to have a higher number of clusters than the desired region to be segmented, where among the 4 clusters, 3 of them are the desired tissue regions, and the remaining 1 cluster is the background.

Image enhancement methods can help in extracting image features too. Hummel (1977) developed the histogram equalization (HE) method based on the histogram of the pixel intensities to enhance the image. This is achieved by transforming the original histogram to be approximately uniformly distributed, hence increasing the contrast of the image. In addition, another approach is also available using gamma correction (GC) method. Here, GC enhances the images by using pre-specified gamma correction curve with parameter γ. Adjusting the gamma parameter value to be less than 1, then the resulting image will be darker. If the value is greater than 1, then the processed image will be brighter. A gamma parameter value of 1 gives out the same original image. Fakhar, Moalem and Badri (2014) used HE as part of a new image processing algorithm to detect crescent moon shape in selected images while Sejzei and Jamzad (2016) illustrated the use of these methods in enhancing the crescent moon shape in selected images and consequently proposed a new toolbox for critical crescent moon detection.

Even though HE and GC methods are successful in enhancing the image and able to extract the features, it involves an image enhancement which might distort the original feature of the image. This becomes an issue when we work with the crescent mood image for the determination of important events in the Islamic calendar according to the guideline adopted in Malaysia (JAKIM 2021). When enhancing the image, the concept of 'create what is not' is vital to ensure the confidence in the crescent moon visibility result under the syariah consideration and avoid false identification of crescent moon shape from the processed image. This is in line with hadith no 1909, page 26-27, Sahih Al-Bukhary (Al-Bukhary 2000) where, for the purpose of determining the new month in the Islamic calendar using *Al-Rukyah* method, the only information required is whether the crescent moon shape is sighted or not. Even if the crescent moon is known to be shielded by the cloud or pollution, then it is considered not visible. In other word, we need a procedure that can identify the shape, if it exists, without removing the feature of the original image and then used it to support the findings in the sighting process. A new procedure which takes into account the issue is proposed in this paper called Crescent Moon quartile (CMq). Next, by using the same idea from the CMq and the classical *k*-means clustering method, we extend the idea for image segmentation, referred to as Crescent Moon *k*-means (CMkmeans). In CMkmeans, we intend to approach the problem by pre-defining the desired number of clusters and see whether the chosen centres can segment the image optimally.

The paper is arranged as follows: Next section discusses the materials and methods used in this paper, including the layout of the proposed procedures, i.e., CMq and CMkmeans. Then, we present the results when the proposed methods are applied on selected images. In the following section, we discuss the finding and contribution of the study followed by the conclusion.

MATERIALS AND METHODS

DIGITAL IMAGE

Digital image uses digital representation to show its intensity or grey level. Each element in the digital image is called pixel and the digit representing the intensity of the image on each particular pixel is called pixel intensity. For greyscale image, the value of pixel intensity ranges from 0 to 255, with 0 being the darkest and 255 being the brightest intensity. For instance, from Figure 1(a), region at the bottom will have pixel values closer to 0 as the colour is darker while those on the middle will have pixel values closer to 255 as the colour is brighter. It is clearly reflected on the histogram given in Figure 1(b). The darker pixels are on the left-hand side of the horizontal axis, while the brighter pixels are on the right-hand side of the histogram.

A standard high-definition image featured in the photography and film is with size 1920 width and 1080 height. This means that it is made up of over 2 million pixels in defining the image. When taking the image of the crescent moon, it is necessary to get high resolution image so that it can capture every detail of the scene to its best potential. Such images can be obtained using the digital single lens reflects cameras (DSLRs). The use of DSLR in astrophotography has been used widely to capture night sky images. In this study, we are using the images taken with DSLR camera.-

DATABASE

Every image is taken during the beginning of the cycle of the moon. This moon sighting activity was carried out by a group of researchers from Space Physics Laboratory University of Malaya. The images from moon sighting are taken in the duration from the sun sets until the moon sets. This duration acts as a control in this sighting activity.

The date of the moon sighting activity follows the local lunar/Islamic calendar. It will fall on either the 29th day or 30th day of the month. A set of criteria called *Imkanur Rukyah* (possibility of sighting) is used in Malaysia to help the observer in predicting the visibility of the crescent moon. The criteria are, namely, the altitude of the moon should not be less than 3° and the elongation not less than 6.4° during sunset, or the age of the crescent moon not less than 8 h during moonset (SSFC 2021). In this paper, we will illustrate the results for selected images as listed in Table 1. -

METHODOLOGY

INTENSITY AND IMAGE DIMENSION

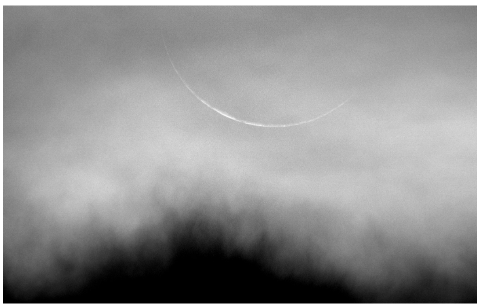
Consider a digital image with the dimension *m rows* × *n columns*. Each cell is called a pixel. The pixel intensity in an image is the value stored in the pixel and is calculated based on the RGB colour values. The pixel intensity is denoted as $x_{i,j}$, $i = 1, 2, 3, \dots m$, $j = 1, 2, 3, \dots, n$ and can be represented by a histogram to show the distribution of the pixel intensities of the image. The mean pixel intensity value is given by

$$\bar{x} = \sum_{j=1}^{m} \sum_{i=1}^{n} \frac{x_{i,j}}{m \times n}. \tag{1}$$

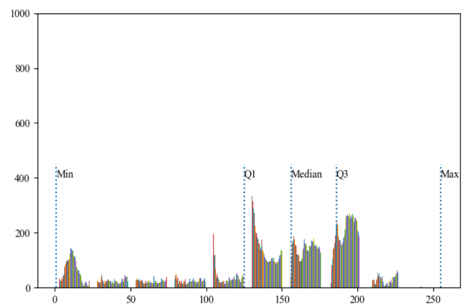
and since the total pixel intensities from the image is used, the population variance is given by

$$\sigma^2 = \sum_{j=1}^{m} \sum_{i=1}^{n} \frac{\left(x_{i,j} - \bar{x}_{..}\right)^2}{m \times n}, \tag{2}$$

where $\bar{x}_{..}$ is the global mean. The value of variance can be taken as the value of contrast of the image. Smaller value of contrast close to zero indicates the pixel intensities are largely concentrated toward the mean value. For images with size 6000 width and 4000 heights, there



(a)



(b)

FIGURE 1. A sample of crescent moon image with histogram of pixel intensities

TABLE 1. Detail of selected crescent moon images

No.	Image	Month
1	IMG_0032	Rabiul awal 1443
2	IMG_0032	Rejab 1443
3	IMG_0109	Rejab 1443
4	IMG_0109	Syaaban 1443
5	IMG_0033	Rabiul Akhir 1443
6	Syaaban1441j	Syaaban1441

will be twenty-four million pixels and, hence, we expect to have large value of contrast depending on the level of contrasting brightness and darkness seen in the image.

ORDER STATISTICS

From a given image, the pixel intensity values $x_{i,j}$ are ordered from the lowest value to the highest value giving the order statistics, X_p, $p = 1, 2, ..., m \times n$. Hence, we have X_1 as the minimum value and $X_{m \times n}$ as the maximum value. We can split X_p into four parts of almost equal size and obtain the first quartile Q_1, the second quartile/median Q_2 and the third quartile Q_3. Here, Q_1, Q_2 and Q_3 are the values where 25%, 50%, and 75% of the ordered data falls below the values, respectively.

METHOD 1 (CMq)

In this section, we propose a new crescent moon detection procedure based on the improvised quartile plots or CMq using descriptive statistics. The steps are described herewith. For a given digital image,

Step 1: Use the original dimension of the image and obtain the pixel intensity values of the image using *OpenCV* library in *Python*

Step 2: Plot the histogram of the pixel intensity values

Step 3: Sort the pixel intensity values in an ascending order and calculate the quartile values, namely, Q_1, Q_2, Q_3 and Q_4

Step 4: Use the quartile values to separate the pixel intensity values into 4 quarters, that is, the k-th quartile, $k = 1, 2, 3, 4$

Step 5: Set new pixel intensity values, $x'_{i,j,k}$ for each quartile as follows:

$$x'_{i,j,k} = \begin{cases} x_{i,j}, & x_{i,j} \in k - \text{th quartile}, \\ 0, & \text{otherwise.} \end{cases} \tag{3}$$

That is, pixel values that fall in the k-th quartile will take the original pixel intensity values, whereas others are replaced by zero.

Step 6: Plot the processed image with $x'_{i,j,k}$ values giving 1st, 2nd, 3rd and 4th quartile plots for crescent moon shape detection, if it exists, in the image.

By implementing the transformation in Step 4, we maximize the contrast of the image in each quarter and expect to improve the possibility of detecting crescent shape, if it exists, in the image.

k-MEANS CLUSTERING

The k-means clustering is proven to be useful in clustering tabular and raster data. However, it still has its limitations in our context. Finding the optimum number of clusters is quite straightforward for some images, but some might take some time to figure out by trial and error. Images with vague visibility of the crescent moon will need a greater number of clusters to optimally segment the crescent moon, while images with clear visibility can take as minimum as 3 - 4 clusters. One of the ways to automatically find the optimum number of clusters is by calculating the silhouette score for each number of clusters proposed (4). Silhouette score works by finding which clusters can give the maximum number of average inter-clusters and the minimum number of average intra-clusters. The formula for calculating the silhouette score is as follows:

$$silhouette\ score = \frac{(b - a)}{max(a, b)} \tag{4}$$

where b is the average inter-cluster and a is the average intra-cluster. Having mentioned that the digital images used are high definition, one image will consist of millions of pixel intensities. Calculating these pixel intensities as our data points for the silhouette score is very time-consuming. In some situations, this is not practical. Hence, we propose a new clustering method that can easily cluster the digital crescent moon images using a pre-defined number of clusters and values for the centre of the clusters, called CMkmeans. The idea of obtaining the pre-defined number of clusters and centre values is similar to CMq, in which the image will be segmented into 4 clusters, using the quartile values as the centre.

METHOD 2 (Cmkmeans)

CMq works by segregating the image into four quartile plots. The values used to separate the quartiles are the Q_1, Q_2, Q_3 and Q_4. Meanwhile, k-means clustering partition the data by finding the minimum squared distance between the data points and the centre. By using the idea from both methods, the centre is decided from the quartile values, and the data is partitioned by finding the minimum squared distance between the data and the centre. Before running this proposed method on the image, the images are resized to reduce any noise, and to make every image used in this study in a uniform size. However, this downscaling makes this method no longer satisfy the syariah requirement, since resizing will alter the original feature of the image.

Step 1: The cluster centres, $\bar{x}_c$ are pre-defined from the CMq procedure where c is the respective quartiles (i.e., 25%, 50%, 75%, 100%)

Step 2: For an image with m *rows* × n *columns* , the pixel values $x_{i,j,}$ $i = 1, 2, 3, \ldots m$, $j = 1, 2, 3, \ldots n$ is transformed into a one-dimensional array of $m \times n$ rows and 1 column $[m \times n, 1]$

Step 3: Each pixel value is then used to find the distance from the pre-defined centres,

$$diff_{k,c} = (x_k - \bar{x}_c)^2, \text{ where } k = m \times n. \tag{5}$$

Step 4: Identify the minimum value for each $dif\,f_{k,c}$, min ($diff_{k,1}$, $diff_{k,2}$, $diff_{k,3}$, $diff_{k,4}$) for each k

Step 5: The minimum value for $dif\,f_{k,c}$ will go into the respective $\bar{x}_c$ to form a new cluster

Step 6: The results of each cluster are reshaped into the original image size and then plotted for visualization

In summary, we will use the proposed method 1 CMq to identify if there are presence of crescent moon in the digital image. Then we will use the proposed method 2 CMkmeans to try to segment the crescent moon shape from the background using the images that had been confirmed to have visibility of crescent moon. The results are compared with the classical *k*-means clustering and CMq.

RESULTS

CMq

Figure 2(a) and 2(b) are the original image of Image 5 and 6. Figure (c) and (d) are the results from CMq procedure for image (a) and (b), respectively. The crescent moon is hardly visible in these 2 images, making it difficult on the decision-making process. Both image (c) and (d) are from the 3rd quartile of the CMq procedure. Based on the resulting image, the crescent moon is believed to be visible which are indicated by the bounding box in red. In the bounding box, there is a partial crescent shape seen in the image (c) and full crescent shape seen in image (d). After evaluation from expert, it is concluded that the object segmented is indeed the crescent moon. Knowing that the 3rd quartile is taken from the pixel intensity with values from 51% to 75% of the histogram, we can say that the crescent moon is not the brightest object in the image. With bright surrounding, it could make the contrast of the image lower and making it more difficult to identify the crescent moon in the image. However, the proposed CMq method had successfully identify the crescent moon shape without changing the original features of the image.

CMkmeans

While CMq had successfully detect the crescent moon in the image by showing some part of the border of the crescent moon, we are also interested in segmenting the crescent moon from the background for images that had been confirmed to have crescent moon. We will group the results into image with clear visibility (first 2 images) and vague visibility (last 2 images).

Figure 3 shows the original and resulting images from the mentioned processes. The result from CMq (b) shows that the crescent moon is segmented along with some areas from the background. Meanwhile, (c) and (d) are the results from *k*-means clustering and CMkmeans, respectively, showing that the crescent moon is successfully segmented from the background. However, we noticed that there are differences in the pixels left between these two images. More pixels that are allegedly the crescent moon's intensity seem to fall into the cluster from the *k*-means clustering method compared to CMkmeans.

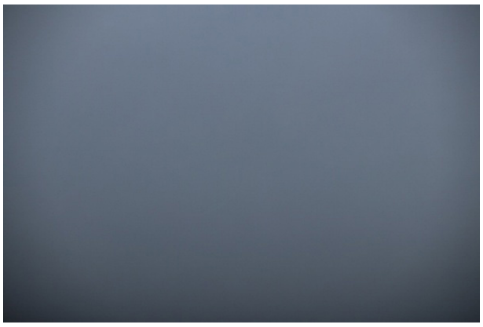
Figure 4 shows the original and resulting images from the mentioned processes. The result from CMq (b), and *k*-means clustering (c) show that the crescent moon is segmented along with some area from the background. Meanwhile, (d), the result from CMkmeans shows that the crescent moon is successfully segmented from the background.

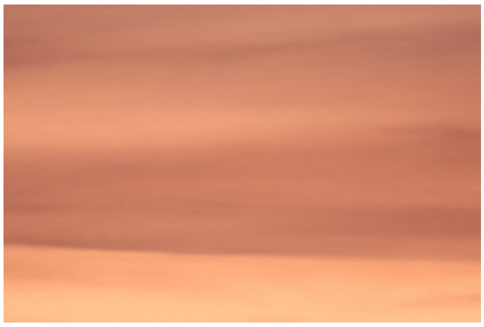
Figure 5 shows the original and resulting images from the mentioned processes. The result from CMq (b) and *k*-means clustering (c) show that the segmentation of the crescent moon fails as it is still surrounded by the background pixels. Meanwhile (d), the result from CMkmeans shows that the crescent moon is successfully segmented from the background, even though there are pixels belonging to the background that fall together in this cluster (in the lower region).

Figure 6 shows the original and resulting images from the mentioned processes. The result from CMq (b), and *k*-means clustering (c) show that the segmentation of the crescent moon fails as it is still surrounded by the background pixels. Meanwhile (d), the result from CMkmeans shows that the crescent moon is successfully segmented from the background, even though only a partial of the crescent moon shape is visible in this cluster (indicated in green bounding box).

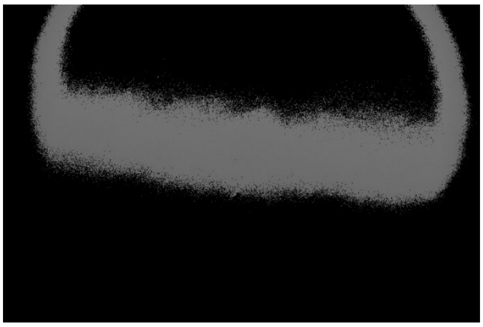
DISCUSSION

The monthly crescent moon sighting activities forms a very important role in making decision on the visibility of crescent moon based on *Al-Rukyah* method in Malaysia (JAKIM 2019). Using optical aid such as telescope does improve the possibility of sighting the crescent moon instead of via the naked eye. The result will complement the visibility prediction that follows the *Imkanur Rukyah* criteria based on the *Al-Hisab* method (Ahmad et al. 2020; Faid et al. 2022; SSFC 2021). Both methods have been used by the local religious authority, namely the Department of Islamic Development Malaysia (JAKIM) together with the State Mufti Departments, to decide on the first day of the





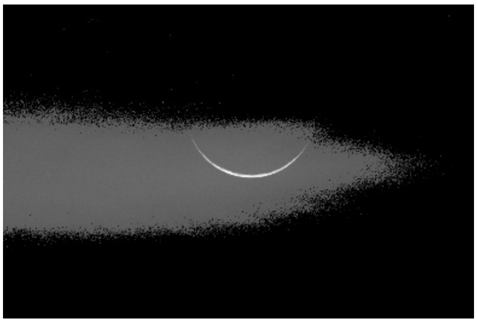
(a) (b)



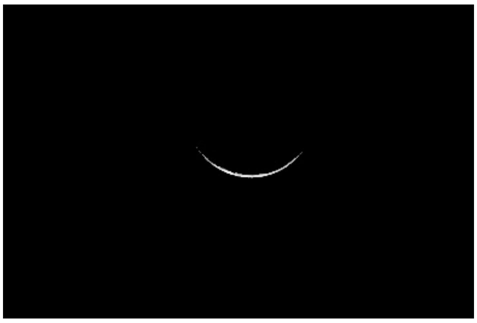
(c) (d)

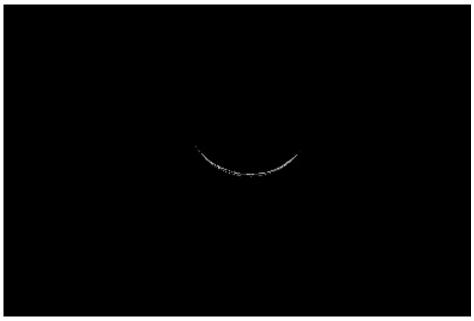
FIGURE 2. The original image (a) image 5 and (b) image 6 with (c) (d) the resulting image from CMq, respectively

Image 3 – Clear visibility



a) Original image b) CMq



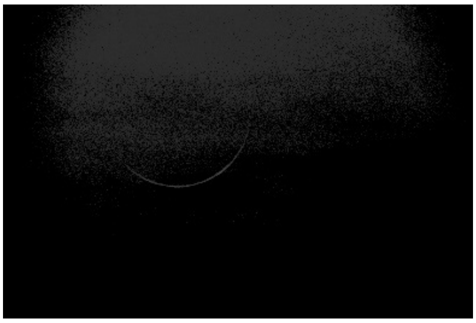


c) Clustering d) CMkmeans

FIGURE 3. The a) original image 3 and the resulting images from b) CMq, c) *k*-means clustering, and d) CMkmeans

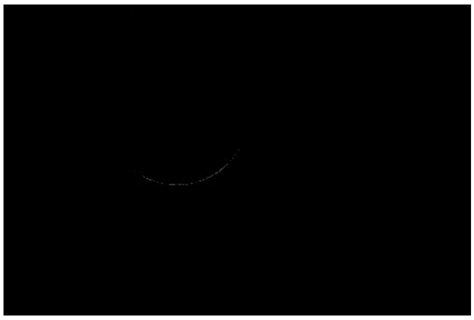
Image 1 – Clear visibility

a) Original image



b) CMq

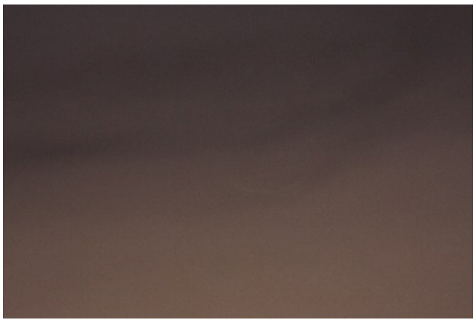
c) Clustering



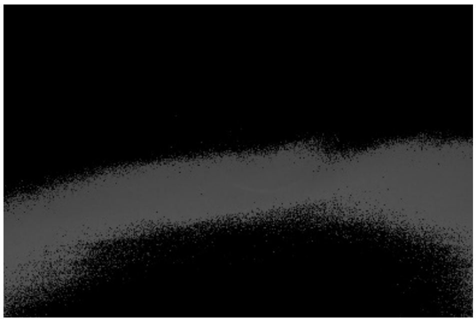
d) CMkmeans

FIGURE 4. The a) original image 1 and the resulting images from b) CMq, c) *k*-means clustering, and d) CMkmeans

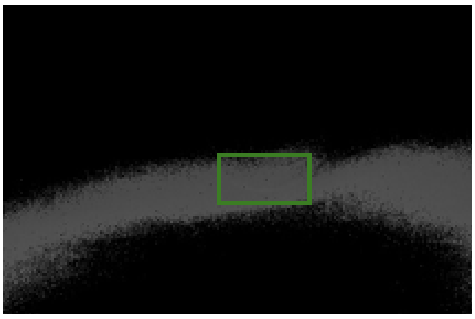
Image 2 – Vague visibility



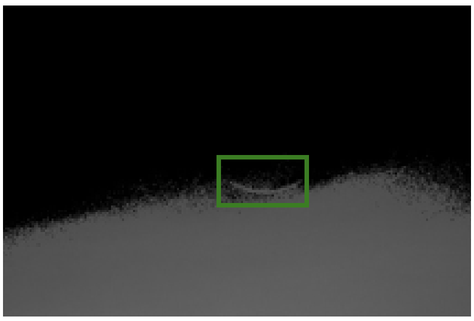
a) Original image



b) CMq



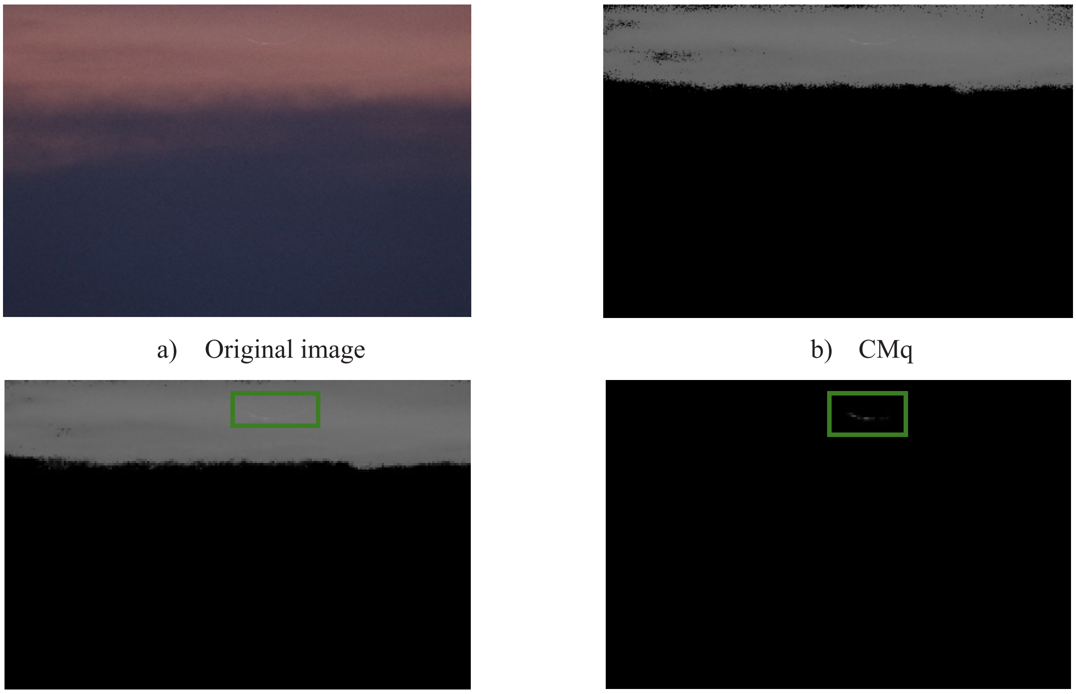
c) Clustering



d) CMkmeans

FIGURE 5. The a) original image 2 and the resulting images from b) CMq, c) *k*-means clustering, and d) CMkmeans

Image 4 – Vague visibility



a) Original image

b) CMq

c) Clustering

d) CMkmeans

FIGURE 6. The a) original image 4 and the resulting images from b) CMq, c) *k*-means clustering, and d) CMkmeans

month in the Islamic Calendar and hence the date of important events for the Muslim community in Malaysia (JAKIM 2021).

It is known that the outcome of the crescent moon sighting activities is influenced by the sky condition which might obscure the visibility of the crescent moon via naked eye (Crumey 2014). At the same time, via modern camera technology, images of the sky can also be taken before being processed to detect any crescent moon shape if it exists (Zulkeflee et al. 2022). However, ethical issue related to the use of image enhancement methods that may change the feature of the original image has been raised (MacDonald 1996; Sohn 2013). The proposed CMq procedure has no such issue as it only maximises the contrast of the image so that any crescent moon shape in the image can be revealed.

Understanding the features of the digital image helps in detecting the crescent moon for future reference. Here, we highlight some additional features observed in the study. Firstly, based on Image 5, the background is smooth, with no obvious sudden changes in brightness throughout the image. The partial crescent moon shape is detected in the 3rd quartile with the range (107, 116) and high contrast of 2420. Secondly, Image 6 shows a mix of bright and dark region throughout the image. From the image, no clear sign of the crescent moon is detected. After CMq procedure, we can see the shape of the crescent moon in the 3rd quartile, along with the other pixels that is believed to be the cloud.

Next, understanding the features of the crescent moon image helps researchers in investigating the crescent moon pre and post the sighting activity. This is an excellent example of integrating multiple knowledge fields i.e., societal activity, photography, astronomy, and image processing, into one research activity to understand the implication of each and every limitation imposed by every field involved.

Image segmentation can be regarded as a step to simplify the representation of the object in an image so that it is easier to analyze. Specifically, segmented objects are easier to locate, to find their borders or edges, or to identify which group of pixels share a common characteristic so that we can assign a label on each or the targeted group.

Based on Table 2, the results show that the crescent moon is visible on either cluster 1 or cluster 2, with cluster 1 having the highest value for center. For Image 3, both clusters have the crescent moon visibly segmented from the background. The cluster 1 and 2 with center 255px and 191px, respectively, indicate that the crescent moon has a wide range of values of pixel intensity, and we can deduce that the difference in value of pixel intensity between the crescent moon and the background is large. This is obviously true since the

TABLE 2. Clusters in which the crescent moon is visible and the center of the clusters' values

Image	Cluster crescent moon visibly segmented	Cluster center (px)	Remarks
3	1, 2	255, 191	Both these clusters contain only the crescent moon
1	2	65	This cluster has the crescent moon partially, while the rest of the crescent moon is in the next cluster, i.e., cluster 3
2	2	94	This cluster managed to segment the crescent moon, however, together along with some part from the background
4	1	139	This cluster has the crescent moon partially, while the rest of the crescent moon is in the next cluster, i.e., cluster 2

original image shows a very clear visibility of the crescent moon suggesting that the contrast between the crescent moon and the background should be big. For Image 1, the crescent moon is visible on cluster 2 with a center of 65px. Only partial shape of the crescent moon is seen in this cluster, specifically the center of the crescent, with the rest of the crescent moon is in cluster 3, along with some part from the background. Similar case for Image 4, where the center of the crescent is visible in cluster 1, and the rest in cluster 2. Meanwhile, for Image 2, cluster 1 shows little to no visible pixel intensity. This shows that the maximum value is too far apart from the rest of the pixel intensity, hence, the crescent moon falls in cluster 2. However, cluster 2 contains not just the crescent moon, but also some parts of the background as well. Even though we can see clear segmentation of the crescent moon and the background, due to these two components having close value of pixel intensities, results in them grouping in the same cluster. From discussion based on Figures 2 - 6, we can conclude that the center of the crescent is relatively brighter compared to the edges of the crescent or the background.

Since we use the minimum distance of each pixel intensity from the centers to cluster the image, we can say that, from the results, the crescent moon will tend to fall on the upper half side of the pixel distribution. This is another key value in understanding the nature of these images. The upper half side, which is greater than 50% of the pixel distributions, suggests that the crescent moon is relatively brighter than at least 50% of the area in the image.

Based on Figures 3-6, we can see the improvement of segmentation of the crescent moon from the background using CMkmeans compared with CMq and classical *k*-means clustering methods with the only exception in Figure 3. In Figure 3 (Image 3), even though CMkmeans managed to segment the crescent moon from the background, the result from *k*-means clustering performs better since we can see more part of the crescent moon falls in that cluster. On the other hand, for Figures 4-6, CMkmeans performs better in segmenting the crescent moon from the background. For CMq, while it can increase the overall contrast of the image, the segmentation is not accurate. All the images have some part of the background fall in the cluster along with the crescent moon. However, this is expected since we allow 25% of the pixel intensities to be grouped into one cluster. As for *k*-means clustering, since we do not pre-determine the centre of the clusters' values, it was calculated by the clustering method, and hence it may not be favourable compared to what we aimed for. *k*-means clustering and CMkmeans also differ in a way that CMkmeans do not update the center of the clusters. It will only compute once to cluster all the pixel intensities. Meanwhile, *k*-means clustering will start at random when choosing the cluster's centre and keep on updating the value until the smallest value of distance for intra-cluster and biggest value for inter-clusters are obtained. That is why *k*-means clustering is more flexible, but when it comes to computational cost, CMkmeans performs better, provided that by intuition, we can target the pixel intensities of the object of interest so that we can pre-determine the centres of the clusters before running the process.

CONCLUSION

In this paper, we have proposed a new way to detect the crescent moon in digital images that complies with the syariah requirements by segregating the pixel intensities into equal quartiles, called CMq. From the results, the segregation managed to segment some parts of the crescent moon, hence increasing the contrast between the object of interest and the background. Plus, this was successfully done without changing any feature of the original image, specifically the brightness of the crescent moon. The result is very important to assist the Islamic Religious Authority in Malaysia in making decision on the start of important event that depends on the visibility of the crescent moon. The procedure can also be used in other countries which adopted both *Al-Hisab* and *Al-Rukyah* method in the determination of the Islamic calendar.

Next, we can see that the CMkmeans outperforms both CMq and *k*-means clustering in image segmentation. However, this conclusion is true for these selected images only, and more images need to be explored to make a more generalized conclusion. This is due to the variety of possible features and characteristics in an image that could lead to different results and interpretations. Image features depend on many attributes such as the brightness of natural light, the camera setup, and the objects surrounding the object of interest. Different combinations of these attributes could lead to the image taken having different features portrayed. While we cannot have the best method to segment the crescent moon for every image that we have, it is a good practice knowing that we do have other alternatives available. Finally, we can conclude that CMq is best to detect the crescent moon because it works without changing the original features of the image, making it syariah compliant. Meanwhile CMkmeans can segment the crescent moon in the image from the background optimally, better than CMq and *k*-means clustering in terms or results obtained and computation time.

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