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USING A NEW HYBRID SEGMENTATION TECHNIQUE TO SEGMENT LUNAR CRATERS AND DETERMINE ITS DIAMETER

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Abstract

Segmentation method is the process of partition digital image into parts depending to color, texture, and intensity. There are many segmentation methods used in different fields according to the purpose of application. In this study the global thresholding and proposed hybrid method were used to segment lunar craters. Craters on Moon's surface caused by collision between Moon and celestial objects as comet, meteorite, asteroids and others. Due to the Moon has no atmosphere, the lunar surface covered by a huge number of craters different in their size and depth depending on velocity and size of collided objects. The study of lunar craters provide information about the age and geology of a Moon's surface. So, we proposed a novel hybrid segmentation method to segment Moon's images and isolate lunar craters from other surface features and then determine the diameter of lunar craters. The proposed hybrid method combine the performance of K-Means and SFFNN together. The results shown that, the proposed method gives very acceptable outcome, where the boundaries of lunar craters were delineate in professional way that lead to accurate determination of its diameters.
Keywords: Hybrid Segmentation, Lunar Craters, Craters Diameters.

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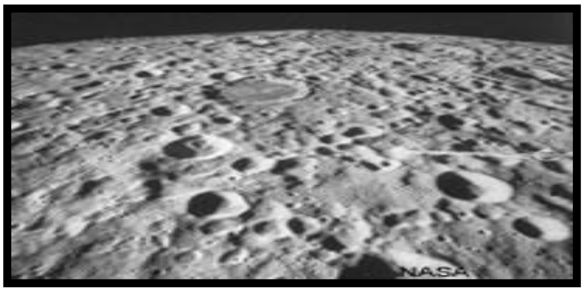
1. Introduction

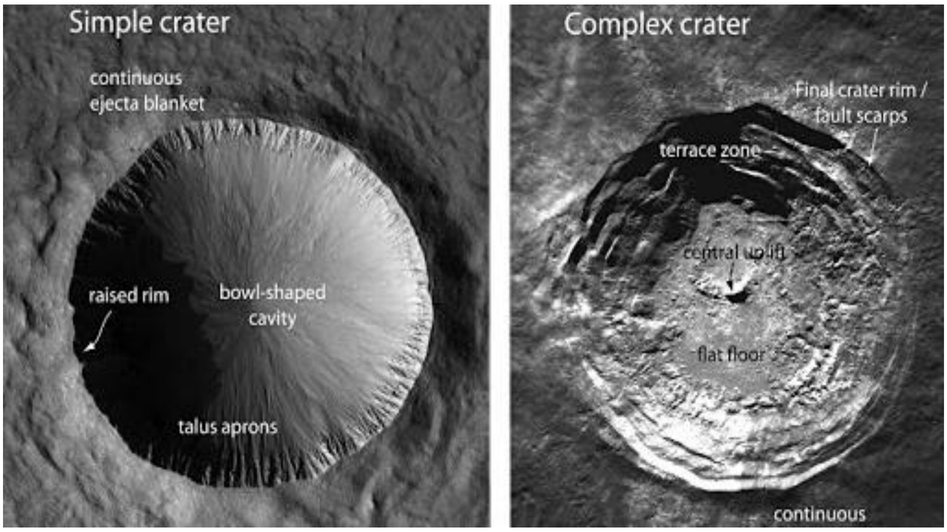
Moon is the nearest celestial object to the Earth and its a unique natural satellite. Moon does not have atmosphere, so its surface covered by a large number of craters different in their type, shape, depth, and size depending on the size and speed of collided objects with the lunar surface. Craters is the most natural features can be seen on the surface of Moon by naked eyes, it caused by the collision between many celestial objects like: Asteroids, comets, rocks and others. These types of craters called impact craters. As the Moon does not have water or oceans or other geological phenomena, the impact craters still on the lunar surface without any changes until other impact occurs, Research concerning the lunar geomorphology, especially the study of impact craters, has always been important topic of the Moon exploration. So, the study of the morphological characteristics of impact craters is important for furthering our understanding of both the impact cratering process and target properties [1]. Figure (1) shows craters on the lunar surface.



Figure(1):- The craters on the Moon's surface
[https://www.lpi.usra.edu/education/explore/shaping_the_planets/impact-cratering/].

Types of Lunar Craters

The types of lunar craters depend on collided objects with lunar surface. collided objects form craters in a near circular shape, this is the main basis for the identification of lunar craters, Where the size, mass, speed, and angle of the collided object with Moon's surface specified the size, shape, and complexity of resultant craters. Small and slow objects with a low energy cause a small and simple craters. While, large and fast objects form the large and complex lunar craters. Most craters on the Moons' surface are simple craters, that have diameters less than 15 kilometer (km), while the complex craters have diameter range from 20 to 175 km. The crater of diameter greater than 300 km called impact basin craters. The time of formation and long term alteration lead to craters having different complex morphology [2]. Figure (2) shows the main types of lunar craters.



Figure(2):- Types of lunar craters[http://www.ianmorison.com/observing-the-moon-the-first-six-lunar-days/].

Segmentation of Lunar Craters

Segmentation process can be define as the process of subdivided images into different parts according to intensity, color, texture, and homogeneous regions. Segmentation of lunar craters is not easy, due to the craters features overlap with each other. In this work the traditional threshold segmentation, and hybrid segmentation were used to segment lunar craters.

1. Thresholding Segmentation Method:- Thresholding is the simplest and useful segmentation method. This method partition the input image's pixels with respect to their intensity level. Thresholding method is used over images having lighter objects than background. The selection of threshold (T) can be manually or automaticaly (based on a prior knowledge or information about features of image). There are basically three types of thresholding methods, these are: Global Thresholding; Variable Thresholding; and Multiple Thresholding [3]. To segment lunar craters, the global thresholding method was used. Global Thresholding is done by using a appropriate T value. The value of T will be constant for whole image. On the basis of T the output image q(x,y) can be obtained from original image p(x,y) as expressed in equation (1), [4].

$$q(x,y) = \{1 , \quad if\ p(x,y) \quad > \ T\ 0 , \ if \quad p(x,y) \ \leq \ \ T \tag{1}$$

2. Hybrid Segmentation Methods: hybrid method uses the concepts of two or more segmentation methods together in order to achieve a specific propose and give more accurate results [5]. In this study, a novel hybrid method was proposed, that combine the clustering segmentation and artificial neural network. K-Means clustering method with three clustering and Feed Forward Neural Network (FFNN) were combined to produce the proposed method.

(i) K-Means, is one of the clustering segmentation techniques, in this method data is divided into a number of unique clusters, where each data component belongs to exactly in one cluster [6]. In this technique, at first, all the clusters centroids are selected randomly, then each pixel is assigned to nearest center. It emphasizes on maximizing the intra cluster similarity and also minimizing the inter cluster equality [4]. After all image pixels are clustered, the mean of each cluster is re-calculated again. Then, repeated This process until no major changes result for each cluster mean [7]. Let the feature vectors derived from l clustered dataset be:

X = (x_i | i=1,2,3,....... l) (2)

The generalized algorithm initiates (k) cluster centroids (C) is given by equation (3):

C = (c_j | j=1,2,3,....... k) (3)

By randomly selecting (k) feature vectors from (X). Then, the feature vectors are grouped into (k) clusters using the Euclidean distance as shown in equation (4):

d = | | x_i - c_j | | (4)

(ii) FFNN, FFNN is one type of Artificial Neural Network (ANN), A Neural Network (NN) is an artificial representation of human brain which is used to simulate the learning strategies of brain for decision making process. NN that simulate the human brain's learning procedures constitutes a large number of parallel nodes. Each node can perform some basic computing. The learning process can be achieved through the transferring the connections among nodes and connection weight. The network called FFNN when no feedback from the outputs of the neurons towards the inputs throughout the network. There are two types of FFNN depending on the number of hidden layer, Single FFNN (SFFNN) or multi- FFNN. Generally, there are two types of learning either supervised or unsupervised. In supervised learning type, the network is presented to input samples with known outputs during the training phase. Once trained, a ANN can classify, with some level of error, any sample (set of inputs) consistent with any of the patterns to which it has been exposed during the training process [6]. All types of ANN applies the following mathematical operations in the inputs (x_i) to calculate the output (y):

y = $\varphi\ (\sum_{i=1}^{m} \quad (\omega_i x_i) +\ b)$ (5)

where (ω_i) are the synaptic weights, (b) is the bias, which serves to increase or decrease the activation function input, (m) is the number of input features, and (φ) represent the activation function, that limits the neuron output. There are different types of activation function, among most of them is the hard limit (expressed by equation(6)).

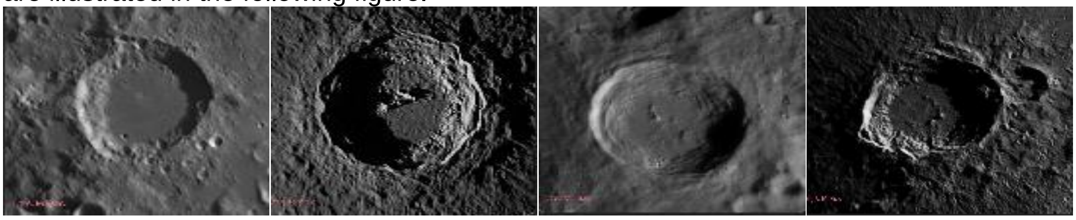
$$Hard\ limit(n) = \begin{cases} 1 & if\ n \geq 0 \\ 0 & otherwise \end{cases} \quad (6)$$

where (n) is the neuron output.

Methodology

1.Material

Thresholding and hybrid segmentation methods were implemented using MATLAB software (2019a). These segmentation methods were applied to segment Moon's images and isolate the boundaries of lunar craters in order to determine their diameters. Thirteen images of lunar craters were used in this work, obtained from internet Website (https://www.visit-the-moon.com/), all datasets are shown in Appendix, some of these data are illustrated in the following figure.



1 2 3 4

Figure(3):- Some of craters images used in this study.

2.Method

The algorithm of global thresholding and the proposed hybrid segmentation method were described in this section in a briefly steps as:

Algorithm(1): Thresholding method.

Input: Original images.

Output: Segmented images

Step1: Read the craters images of size 256×256.

Step2: Convert original images to gray.

Step3: Use the different T value (50,100, and 200).

Step4: Using equation (1) to apply thresholding segmentation.

Step5: Display all original and segmented images resultant from step4.

Algorithm(2): The proposed hybrid method.

Input: Original images.

Output: Segmented images.

Training the network:- To training SFFNN, lunar craters images were separated into train/test, splits of 80%/20%. 10 images of lunar craters were used to train network. The SFFNN initialized with masks (weights) pre-trained for images was trained for up to 100 epochs or more until reach target. These masks were created based on network targets and features of craters.

Step1: Read input images of size 256×256.

Step2: Convert original images to gray.

Step3: Input the target.

Step4: Creating masks, depending on the features of used images and targets, then it were used as an inputs weights to SFFNN.

Step5: Lunar craters images were enhanced using adaptive histogram equalization.

Step6: Butterworth High Pass Filter was used to increase the sharpening of craters images.

Step7: K-means segmentation method was applied with three clusters. Choose the maximum thresholding images between them to used in SFFNN. Centroid of each clusters are chosen randomly, then the distances between data points and cluster centroids are calculated using equation (4). Each data point is assigned to the cluster whose centroid closest to it. If no data point is assigned to a new cluster the run of algorithm is stopped, otherwise the this step is repeated for probable movements of data points between the clusters.

Step8: Using hard limit activation function (equation6) to switch neuron ON/OFF.

Step9: Compute the output using equation (5).

Step10: Display all original and segmented resultant images depending on the maximum correlation between masks and image results from step7.

Step11: Measure loss function, if the value of loss function greater than 0.9, then masks are adjusted and re-implemented the algorithm again.

Testing the network:- To test the performance of SFFNN, four Moon images (approximately 20% of all images) were used and display the results.

3. Determine Craters Diameters

After identify the boundary of lunar craters the diameters of lunar craters were measured by the equation (7), [8].

$$D = C_f \times d \quad (7)$$

Where:

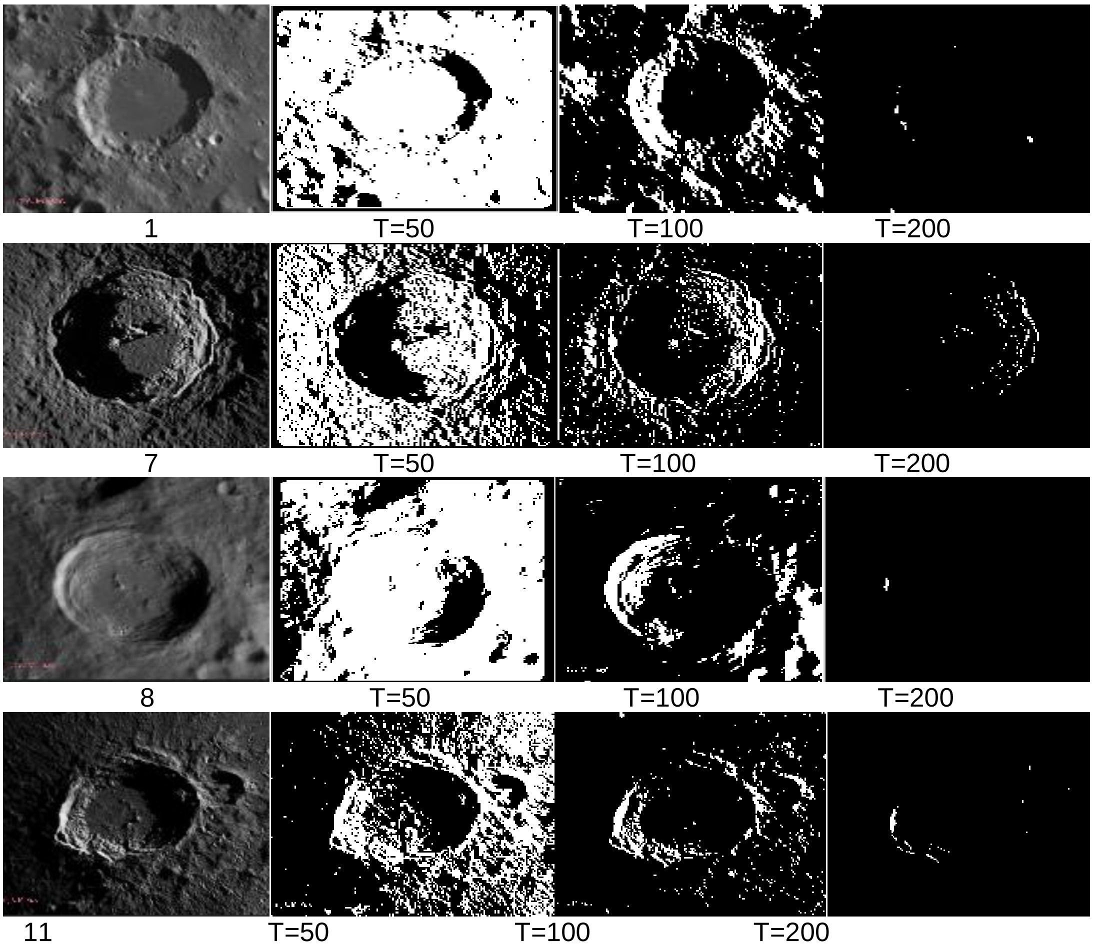
D : is the diameter of lunar craters in km.

C_f : is the conversion factor ($C_f = 1.3775\ \frac{km}{pixel}$), and

d : is the Equivalent Diameter of crater measured in pixel, that measured based on region properties by MATLAB software.

Results and Discussion

The resultant images from applied the global thresholding method with different T values illustrated in figure(4).



Figure(4):- Segmented lunar craters with different T values.

The first column in figure(4) contains original craters images in different region on the Moon's surface. Second column contains the segmented images using T=50, the results shown noisy images and does not show the contours of the Moon's craters. Third column includes the resultant segmented images when using T=100, it give results somewhat better than T=50. The last column contains the results of T=200, that show very bad results. Finally, we can conclude that, T=100 give results better than other T values. But, in general global thresholding method with different T values did not succeed to segment and isolate the craters boundaries. Figure (5) shows results of applied the proposed hybrid segmentation method.

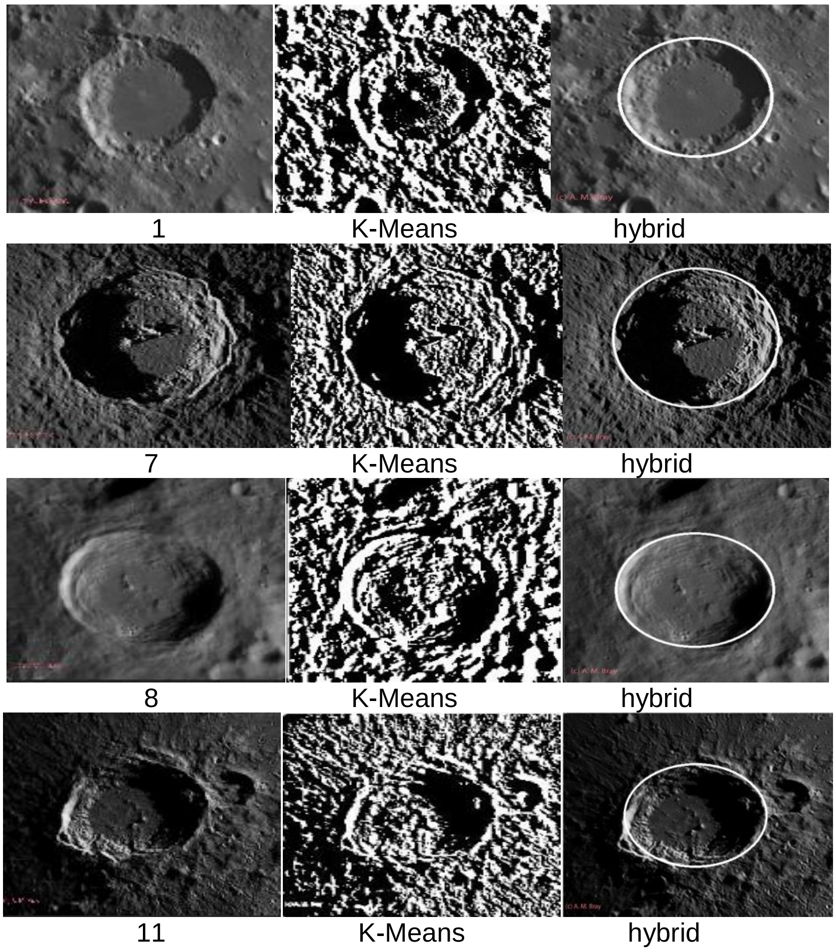


Figure (5):- The results of implementing hybrid method.

First column in figure (5) shown the original images. Second column contains the resultant images from applied K-Means with three number of clusters and select the maximum threshold of them as an output result. The last column represent the resultant images obtained from applied the proposed hybrid segmentation method, which combine K-Means with SFFNN method. From the results shown in figure(5), it clear that, the proposed hybrid method was succeeded in segment and isolate the boundaries of lunar craters perfectly. So, these results were used to determine the diameters of lunar craters. using MATLAB software and equation (7), the diameters of lunar craters were measured and results shown in table (1); also error between reference and measured diameters was computed using equation (8).

$$\text{Error} = \left| \frac{The\ oretical - Expeirmental}{Theoretical} \right| \times 100\% \qquad (8)$$

Table (1):- The diameters of lunar craters.

Image	Equivalent diameter(pixel)	Measured crater diameter (km)	Reference crater diameter (km)	Percentage error (%)
1	45.2774	62.3696	62	0.5
7	67.5427	93.0401	93	0.04
8	50.9751	70.182	70	0.2
11	63.3100	87.2095	87	0.2

The equivalent diameter (pixel) in table(1) represent the values computed using MATLAB properties, then were converted to km using equation (8) and displayed results in the measured crater diameter column in table(1). The percentage of error between references and measured craters diameters were very small values, that supports the validity and accuracy of the results.

Conclusion

Impact craters are the most common natural phenomena on the Moon's surface, formed after collision between celestial objects and surface of Moon . The study of lunar craters is an important in determining the geological age of the Moon. In this study thresholding and the proposed hybrid segmentation method, that combine both K-Means and SFFNN methods together, were used to segment lunar craters and isolate its boundaries, then determine its diameters. From results shown in figure(4) its clear that, the thresholding method did not succeed to do this, while hybrid method succeed to segment and identified the boundaries of craters in perfect way as shown in figure (5), that lead to accurate measurement of the diameters of craters as shown in table (1).

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Appendix

This section contains all lunar images that used in this work.

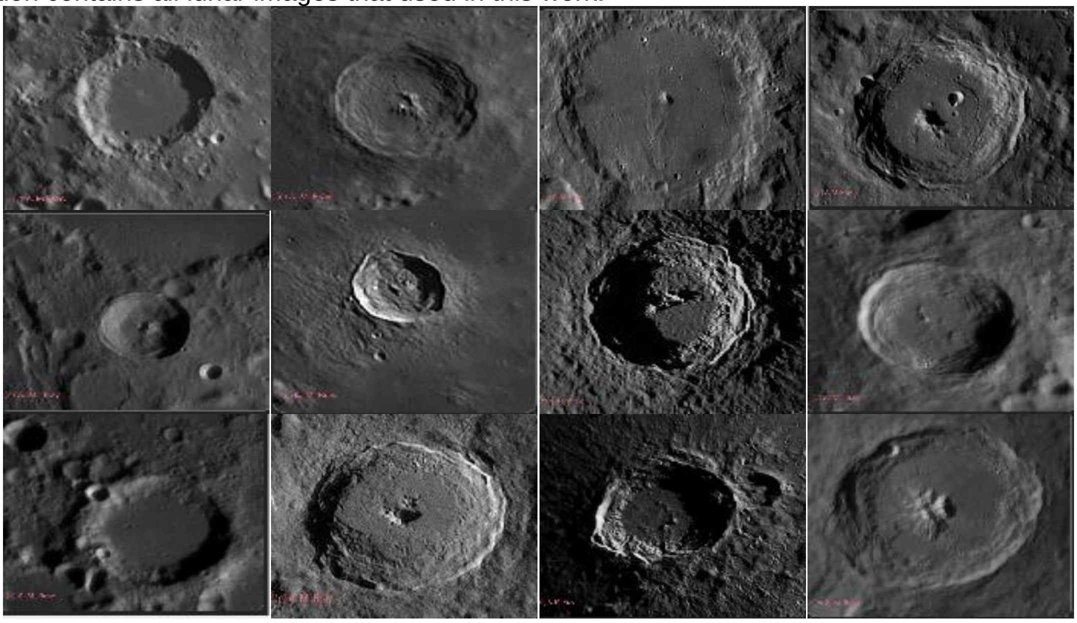

Figure (A.1):- Shows the Moon craters images used in this work.