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Feature extraction from high resolution satellite images using K-means and colour threshold approach

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Abstract. In recent year developments in satellite sensors tend to the availability of high spatial and spectral resolution images. The motivation of this research paper is to obtain maximum benefits of different bands from high resolution satellite images in order to put into practice an image processing algorithm solution for extraction and classification of land cover and manmade objects can be used by non-professionals. In this research paper a novel approach for image classification is presented by applying k-means algorithm and colour threshold approach onto high resolution World View 2 (WV2) image. K-means algorithm is applied on a reflectance image to extract land cover classes and manmade objects based on a colour-based segmentation method. The proposed technique is applied through MATLAB environment. The user is asked to select few points of the desired classes and the algorithm do the rest and produce vector layers of the selected classes. The experimental results prove the effectiveness of our framework to enhance the quality of classification in aspects of computational time and precision. The preliminary results are considered promising.

Keywords: Classification; K-means; Radiometric Calibration

1. Introduction
Remote sensing images are a vital source in providing geographical information for different applications such as mapping land cover and give high accuracy. Urban area objects and features can be detected from satellite image by performing supervised or unsupervised classification methods [1]. Segmentation is one of important process of image processing to obtain information from an image to create uniform areas by classifying pixels into groups thus creating homogenous regions. Segmentation denotes to the process of dividing a satellite image into various regions (clusters of pixels). Image segmentation is mainly used to simplify and adjustment the depiction of an image into something that is more significant and easier to investigate. Image segmentation is typically used to detect objects and boundaries (lines, curves, etc.) in images[2]. Segmentation output is a group of areas that mutually cover the entire image, or a group of delineations extracted from the image. Each of the pixels in region are similar with respect to some characteristic or computed property, such as intensity, texture, or color [3, 4].There are different techniques for image segmentation such as color threshold, edge detection, clustering, neural network [2]. clustering methods were one of the first techniques used for the segmentation of natural images due to its simplicity and efficiency[5]. Other methods of clustering are distance based according to which if two or more objects belonging to the same cluster are close according to a certain distance, then it called distance is based clustering. In this research K-means

clustering approach is applied to performing image segmentation. The most common approach for segmentation is k-means [6, 7]. Optimum clustering technique will produce good result with low inter-class similarity and high intra-class similarity. The quality of segmentation result based on both the similarity measure used by the method and its implementation. K-means is commonly clustering algorithm that has been used in a different branches, such as information retrieval [8] and image segmentation [7]. K-means is common algorithm used to automatically divided a data set into k clusters[9]. It works by choosing k initial cluster centres and then iteratively refining them. Although k-means has the great benefits of being easy to implement, it has some problems. The accuracy of the final k-mean outputs is based on the arbitrary choice of initial centroid. So, if the initial centroid is randomly selected, it will provide undesired result for different initial centers. So, the initial center will be sensibly selected so that desired segmentation is obtained. In addition to computational complexity is another side which take in consideration while applying the K-means clustering. It depends on the number of data elements, number of clusters and number of iterations. High resolution World View 2 (WV2) satellite sensor provides images with multispectral data. The spectral bands are used in separating land use features by detecting spectral signatures of specific feature [10]. The electromagnetic radiation obtained by sensors in the solar spectrum is altered from scattering and absorption by gases and aerosols while received through the atmosphere from the Earth surface to sensors. The effects of radiometric correction plays an important role to reduce the fault in calculating reflectance to set of multi temporal data which is very important factors in application of classification and change detection for remotely sensed data[11, 12]. The quality of classification gives better results by a calibrated, high radiometric resolution sensor such as WV2 which permits greater classification automation with reduced manual editing. WV2 satellite remote sensing data compared with aerial photographs for the purpose of discrimination features using object-based image analysis method and SVM algorithm give good results[13].The proposed approach starts first by radiometric calibration which involved a conversion to radiance then to reflectance. The   next step in our proposal   is that applying K-means clustering algorithm on image which dividing a digital image into several areas (groups of pixels). After that, select each of classes (water, buildings, vegetation and roads) automatically from viewer which displayed original image. Then applying color thresholding on water region to reduce inters class with shadow and buffering filter to separate and extract manmade objects (ships, buildings). Finally, the research algorithm is robustness and automated to extract objects.

2. Area of study

2.1. Input image:
The available data of an image of residential areas was provided by Digital Globe from (WV2) satellite sensor. The image was captured on MAY 2th, 2011 which is land cover area in a residential area of Presidio of San Francisco, California of area equals to 16 hectares approximately. The area of study is an urban area contains different features, buildings, roads, vegetation areas and. The projection of this image is UTM, with datum of WGS84 zone 10N. The area of study is bounded by coordinates as upper left corner coordinates are (lat 80° $13^{\backslash}$ $56.3251^{\backslash\backslash}$ W, lon 25° $47^{\backslash}$ $27.8616^{\backslash\backslash}$ N) and lower right corner coordinates of the image are (lat 80° $13^{\backslash}$ $40.9419^{\backslash\backslash}$ W, lon 25° $47^{\backslash}$ $26.1779^{\backslash\backslash}$ N).

2.2. WV2 satellite image:
In 2009 Digital Globe launched the WorldView-2 satellite. Figure (4) is showing the advantages of WV-2, WV-3 satellite comparing with other satellites, Quick Bird and WorldView-1[9].

2.3. Multispectral bands of WV2:
WorldView-2 satellite gives four new distinctive spectral bands that provide extra information for different objects, Coastal blue, Yellow, Red edge and NIR-2 [14] [15].

3. Research methodology

This frame work focused on segmented dataset of MS bands from WV2 imagery using k-means algorithm. Figure (5) illustrates the steps that were used in experiment.

Raw imagery (DNs) is converted to atmosphere reflectance in order to take in consideration condition of capturing such as positions between the sun, the earth and the satellite and to obtain an absolute value for the normalized band ratios or any indices which used to any remote sensing imagery [13]. The methodology of Converting the Digital Numbers (DN) to top of atmosphere (ToA) reflectance applied on two main stages: First, the DNs are converted to ToA radiance values. Second, these radiance values are converted to reflectance values

Figure 1. Presidio of San Francisco, California,
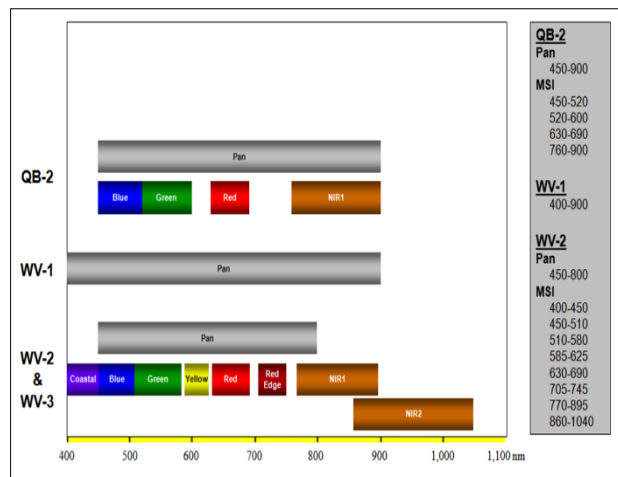WV-2 satellite image
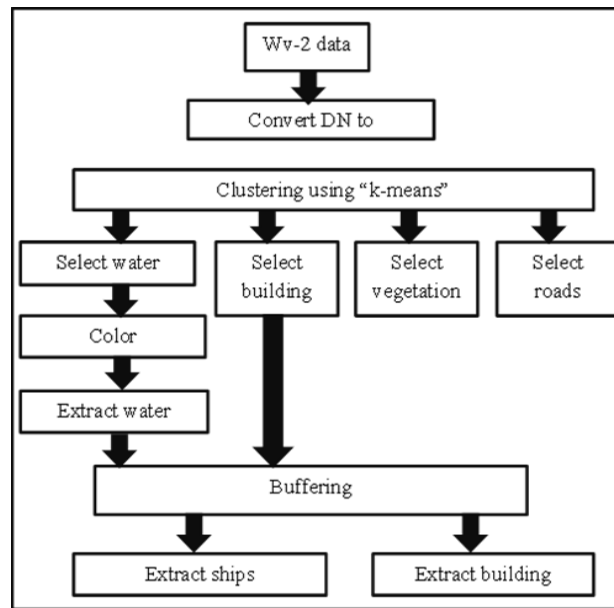

Figure 2. Spectrum band width of satellites

Figure 3. Research methodology algorithms

3.1. Conversion to top-of-atmosphere spectral radiance

WV2 imagery is supplied to the user as radiometrically corrected image pixels. The values of these pixels are calculated as a function of the amount of the spectral radiance enters the telescope aperture and the equipment conversion of that radiation into a digital signal[16]. The conversion from DN to spectral radiance according Eq. (1) for each band of a WV2 image [13]:

$$L_{\lambda_{pixel,band}} = \frac{k_{band} \cdot q_{pixel,band}}{\Delta\lambda_{band}} \tag{1}$$

where, $L_{\lambda_{pixel,band}}$ are the top of atmosphere spectral radiance image pixels, K_{band} is the absolute radiometric calibration factor for a each band; $q_{pixel,band}$ are the given radiometrically corrected image pixels; $\Delta\lambda_{band}$ is the effective bandwidth for a given band.

3.2. Conversion to top of-atmosphere spectral reflectance

There are different parameters (solar zenith angle, Earth-Sun distance, topography, bi-directional reflectance distribution function, and atmospheric effects) affect on top of atmosphere spectral radiance [17]. So that MS band must be converted into reflectance to applying spectral analysis techniques such as band ratios, Normalized Difference Indices. There are several factors that must be known for each image: the distance between the sun and earth in astronomical units, the day of the year (Julian date) as in Eq.2, and solar zenith angle. Earth-Sun distance is calculated using Eq. 3 will be in Astronomical Units (AU) [13].

$$JD = int\ [356.25.(year+4716)] + int[30.6001.(\ month+1)] + day + \frac{ut}{24} + B - 1524.5 \tag{2}$$

Solar zenith angle is calculated for the whole image at the time of capturing using Eq. 4:

$$d_{ES} = 1.00014 - 0.01671.\cos(g) - 0.00014.\cos(2g) \tag{3}$$

$$\theta s = 90.0 - sunEL \tag{4}$$

The sunEl value can be found in file *.IDM. Finally, the process of converting the radiance values to reflectance values is performed according Eq.5

$$\rho_{\lambda_{pixel,band}} = \frac{L_{pixel,band} \cdot d_{ES}^2 \cdot \pi}{E_{SUN\,\lambda_{band}} \cdot \cos(\theta s)} \tag{5}$$

where

$\rho_{\lambda_{pixel,band}}$	ToA reflectance,
$L_{pixel,band}$.	ToA radiance,
$\mathbf{d_{ES}}$	Distance between Earth-Sun ,
$E_{SUN\,\lambda_{band}}$	WV2 band-Averaged Solar Spectral Irradiance,
θ_s	Average solar Zenith angle,

3.3. K-means algorithm

Clustering is a technique to partitioning dataset into a certain number of groups. In k-means clustering, it divides a set of information into a k number group of data [18, 19]. K-means applied by two phases. In the first phase it calculates the k centroid and in the second phase it takes each point to the group which has adjacent centroid from the respective data point. There are various approaches to describe the distance of the adjacent centroid and one of the most popular approaches is Euclidean distance. Once the clustering is achieved it recalculates the new centroid of each group and depends on that centroid, Euclidean distance is calculated between each data point and each center and allocates the points in the group which have minimum Euclidean distance. Each group in the segmentation is described by its associate objects and by its centroid as in figure 4. The centroid for each group is the point to which the sum of distances from all the items in that group is minimized. So, K-means is an iterative algorithm in which it minimizes the sum of distances from each item to its group centroid, over all groups. For example, Image with resolution of (x×y) can be cluster into k number of clusters. Let p(x, y) be an input pixels to be cluster and c_k be the cluster centers. The k-means algorithm [20] is applied according steps:

1. Initialize number of cluster k and center.

2. Euclidean distance (d) is calculated between each pixels the and center in image by the Equation (6).

$$d = \|p(x,y) - c_k\| \tag{6}$$

3. Label all the pixels to the adjacent center depend on distance (d).

4. Recalculate new position of the center by applying Equation (7) after all pixels have been assigned.

$$c_k = \frac{1}{k} \sum_{y \in c_k} \sum_{x \in c_k} p(x,y) \tag{7}$$

5. Repeat the procedures until it achieves the tolerance or error value.

6. Reshape the group of pixels into image.

3.4. Color thresholding

Using color information of raster images is one the robust methods to select the suitable values of the threshold. The color thresholding method was used to extract only desired objects from the background and other objects in images. Color thresholding detects the value of RGB intensities for desired objects. The objects haven't desired range will be rejected or removed. so, it is very essential to define the most suitable value of threshold because if this threshold cannot get a optimum value, the thresholding the threshold method will extract pixels other than the desired object [21].

The careful study of RGB intensity is applied to extract water class., the color thresholding value should be able to extract the pixels of water and reject pixels of undesired objects (shadow) [22]. Figure 5 illustrates steps.
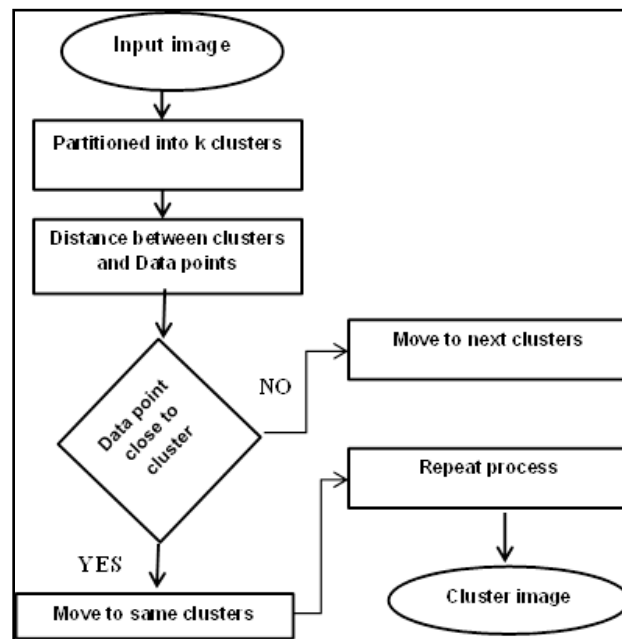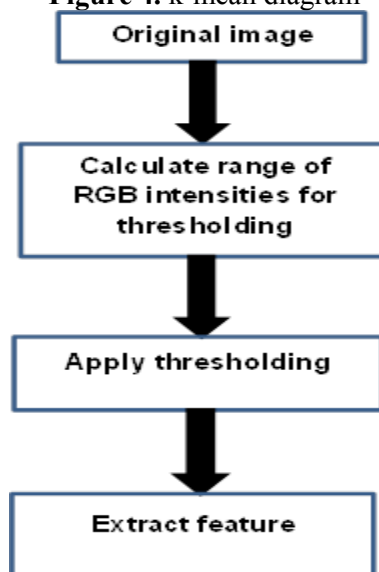
Figure 4. k-mean diagram

Figure 5. Steps for RGB Thresholding algorithm

RGB intensities are calculated for water class, and then thresholding algorithm is applied. The information is being gathered in a Table.1. The color thresholding algorithm is applied to extract the pixels of water and remove pixels of shadow. RGB intensities are calculated for water class, and then the thresholding algorithm is applied. The maximum and minimum values for the RGB components are calculated for water class in corrected image, Table.1. The reflectance image gives benefit to select better RGB intensities of water class and remove the overlaps between shadows in image. The reflectance image gives benefit to select better RGB intensities of water class and remove the interference between shadows in image

Table 1. RGB intensities

channel	min	max
RED	0.08	0.45
GREEN	0.07	0.09
BLUE	0. 13	0.15

3.5. Buffering filter

Spatial analysis is used to extract new information from GIS data .GIS applications are applied by spatial analysis tools for feature statistics such as relation between vertices and polylines or feature buffering [23]. management analysts are used analytical functions to study environment point locations and their relationship to the environment [24]. In this research buffering is used as useful spatial analysis tool that can be applied with vector data. Buffering contained two regions one region that is within a specified distance to selected real world features and the other area that is beyond[25]. The region that is within the specified distance is called the buffer zone. In a GIS Application, buffer zones are always represented as vector polygons enclosing other polygon, point or line features as in following figures:
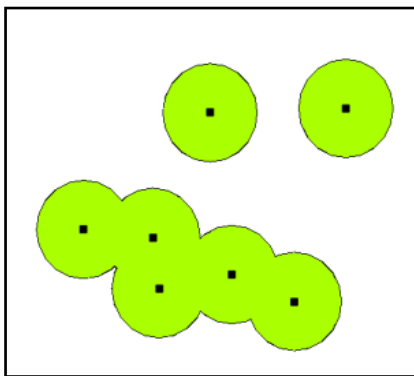

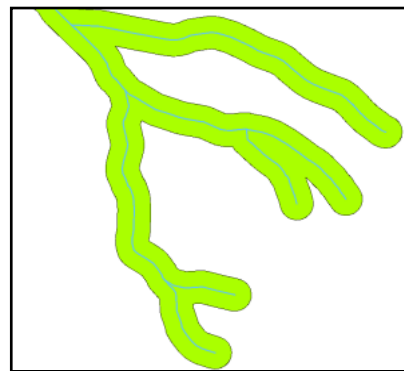**Figure 6.** A buffer zone around vector points

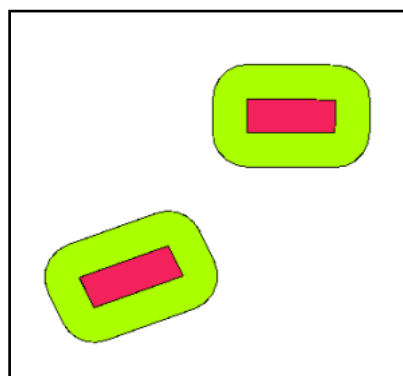**Figure 7.** A buffer zone around vector polylines

Figure 8. A buffer zone around vector polygons

Figure 9. K-means output images

Buffer in GIS is a zone around a map feature measured in units of distance or time. A buffer is useful for proximity analysis the size of a buffer zone is distinct by a buffer distance. A buffer distance usually has to be defined as integer number or a decimal number (floating point value). This value is well-defined in map units (decimal degrees, meters and feet) according to the Coordinate Reference System (CRS) of the vector layer[23]. Buffer zones around polygon features are usually extended outward from a polygon boundary but it is also possible to create a buffer zone inward from a polygon boundary. Finally, buffer is an area defined by the bounding area defined by a set of points at a specified maximum distance from all nodes along segments of an object.in research buffering applied extended outward water vector polygons with buffer distance in pixels unit (111 pixels) in MATLAB. Buffer zone involved ships.

4. Discussion and analysis results

K-means is applied on original image and select number of clusters (k = 5). Figure 9 shows the output image of K-means algorithm. Colored k-means output image to illustrate the interference between different classes such as shadow with respect to water aspect to ships with respect to buildings in figure 9.
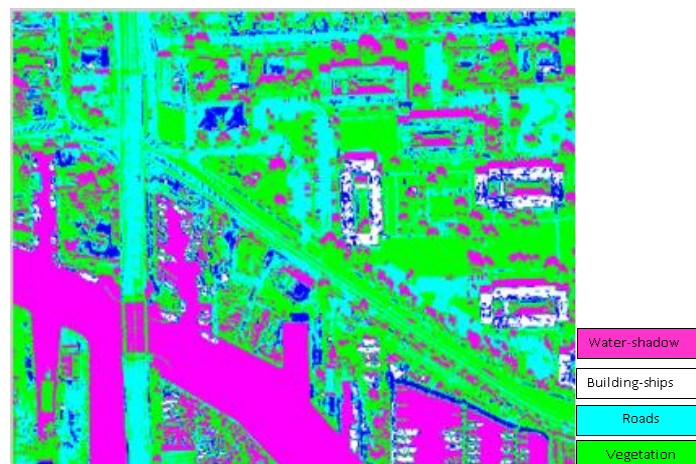

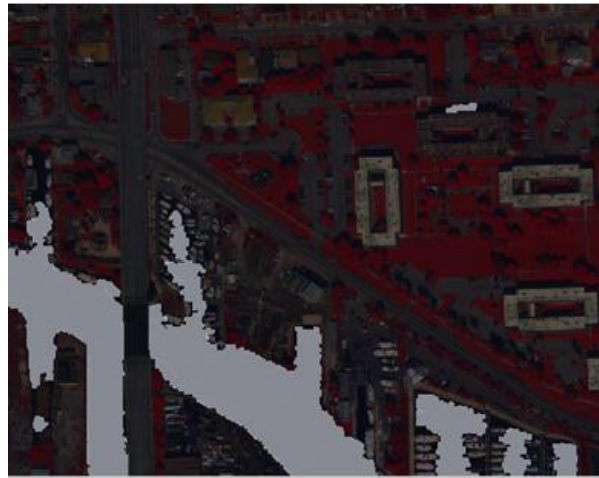**Figure 10**. Colored k-mean output images

Figure 11. Water vector overly on original image

Then selecting suitable thresholding value which is in RGB channel (0.45<red<0.08 & 0.07< green <0.09 & 0.15>blue>0.13) to extract pixels for water only as shown in figure 10.

Building mask is produced automatically by selection any point from required building in original images. This process created building layer but contained ships as in figure 12. Buffering filter is applied with buffer distance (dis) =111 pixels from water vector layer. Buffer zones around polygon features are extended outward from water polygon boundary. This Buffering zone involved ships so we applied condition which performed the objects that lie inside the desired range will be rejected or removed. Therefore, it is very important to determine the selection range because if this buffer distance cannot acquire a suitable value, the condition will extract pixels other than the expected object. Buffering process with condition are produced building vector layer only and ships as in figure13 Building vector overlay on original image and figure 14 Ships vector layer respectively.
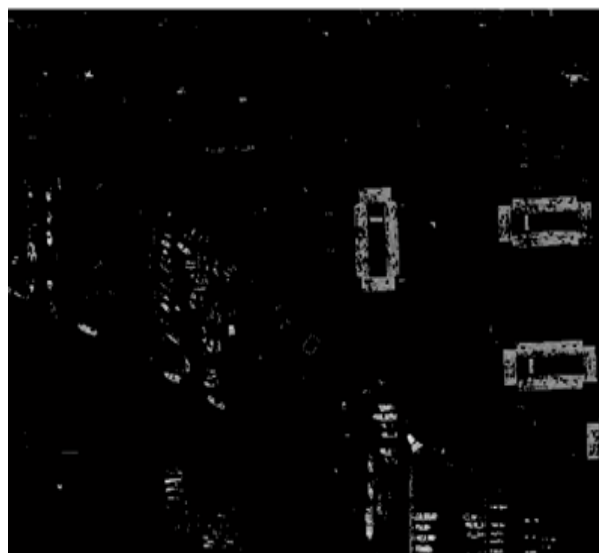

Figure 12. Building mask

Figure 13. Building vector overlay on original image

Figure 14. Ships vector layer
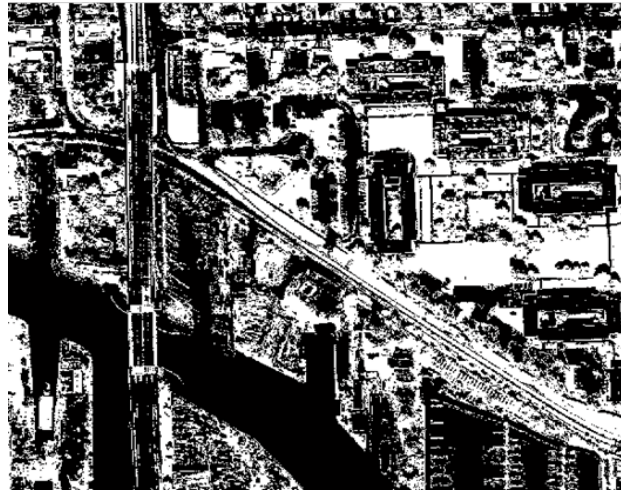

Figure 15. Roads vector layer

Figure 16. Vegetation vector layer

Vegetation and roads classes are produced in vector layers automatically when select any points contain these classes (Vegetation and roads) from viewer which display original image. Selection point from viewer give ability to define p(x,y) of this classes. Figure15 and figure16 illustrate output.

5. Conclusion

We have classified an image by using k-mean clustering algorithm, at the same time radiometric calibration is used to improve the quality of original image and colour thresholding is used to improve segmented image which allows the elimination of a great amount of unwanted pixels, and retained only those pixels in object we are interested in study area. The resulted images satisfactorily showed that by using the selected threshold values, the image segmentation method has been able to segment out image. And the final, we can conclude that the proposed clustering algorithm has better segmentation. Classical K-means algorithm and it is found that the proposed method has better performance result. In the future, we can improve the quality of the output image more by using the morphological operation and get better performance Measurement. And lastly, we can implement and analyse in different areas of image segmentation.

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