Comparison of Various Machine Learning Algorithms on Color Quantization Techniques

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***Abstract*— Color image quantization is used to lower the range of colors of an image in an effort to decrease the size of the image and trying to keep the quantized image visibly similar to the input image. Color quantization is performed to reduce the color information while trying to maintain the quality. The technique is used in various fields like computer graphics and image processing. In this paper, comparison of various algorithms is carried out to calculate the mean absolute error and mean squared error and determine the accuracy for each algorithm. The algorithms used in this paper are K-means, median cut, Lloyd max and fast octree.**

Keywords— K-means, Median-cut, Color Quantization, max, image

I. INTRODUCTION

In this paper the technique of color image quantization has been analyzed. This is followed by discussion and a comparative study on the different algorithms applicable for this quantization technique. In order to represent a high resolution colored digital image, a large number of colors are used, sometimes even extending to a million colors. In the study conducted, an inference was derived that the usage of a huge quantities of colors to represent an image increases the size of the image. This increase in size leads to increased difficulty in the process of storing, displaying, transmitting, and processing of the concerned image. Color quantization is performed in two steps. The first step involves making a decision concerning the reduced number of palette colors that should be used to represent the image. The second step is referred to as is pixel mapping. Pixel mapping is the process of assigning a color to each pixel from the decided color palette. Even though the process of reducing the number of colors in the image may destroy some details of the image, but the basic principle of this technique is to transform the image to a form that is easy to be displayed, stored, transmitted, processed and is also visually similar to the original image. Previously, the display hardware that was being used in the industry could not support storage of 24-bit image, thus giving rise to the need of color quantization. As the technology grew, display hardware's became compatible for storing huge sizes of image. However, color quantization still has a lot of advantages and applications in graphics and image processing. These applications range from compression, segmentation, color-texture analysis to content-based retrieval.

Color quantization techniques are sub divided into image dependent and image independent. Image independent as the name suggests is the same regardless of the image on which it is applied. These types of methods just fix the color palette which remains same for every image. In contrast, image dependent also known as adaptive method determines a unique color palette for every image. The palette is decided according to the color distribution of the image. Even though image independent methods have an advantage of being fast but usually give poor results as compared to image dependent methods.

The image dependent algorithms can be categorized into two classes: splitting algorithms and clustering algorithms. In the splitting algorithms the color area of the image is divided into two disjoint cells. If the image has not acquired the required number of cells the spitting continues. From each cell a color is chosen to represent the cell in the color map. The basic idea behind the clustering is to group objects with similar properties which can be used in color quantization to perform grouping based on colors. The disadvantage of splitting methods when compared to clustering methods is that generally global optima is not obtained in splitting as a decision to split at lower level cannot be undone at a higher level. The clustering algorithms are further divided into pre-clustering and post-clustering method [8]. In pre-clustering each color is scanned and decided if the current color will merge with the already formed clusters or start a new cluster. This way the color space is divided into set of various clusters. On the other hand, post-clustering methods follow an iterative approach, different from pre-clustering to determine the color palette. As post-clustering involves iterative optimization, they give better results as compared to pre-clustering but also ends up increasing the computational time.

In this paper a comparative study of four popular algorithms of color quantization is conducted. The algorithms that are studied and experimentally evaluated are median-cut, octree, k-means and Lloyd-max. The comparison is done both on the basis of performance and computational time. To compare the performance, mean absolute error and mean squared error is calculated for every algorithm.

II. Related Work

The authors of this research Mohammed Alzaber et. al.[1] explore the effects of the colors used and the size of the image in order to choose an approach to perform color reduction(color quantization). The researchers conducted experiments on images using different methods of color quantization like Median Cut, Centre Cut, Octree, K-means and Color Cut algorithms and compared their results. Twenty-Five images were selected for conducting this study, each image consisted of a variety of color gradients, edges and a high level of detail along with visually conspicuous objects. All images were of the dimensions 512 by 512 pixels and were quantized into three levels, 64,128,256 respectively. The scholars proposed three different methods to perform color Quantization: by increasing the colors with the usage of properties of the median cut algorithm, by using Super-resolution technologies or by applying Neural Networks. The application of Neural Networks to the images improves the speed of the process and generates the output faster than the other approaches.

In the work proposed by the authors Guojian Cheng and Junjie Wei [2] signal that the different types of RGB which would be four in number have remote sensing photographs which have been processed using a color quantization method which is based on K-means. The K-Means technique, an unsupervised clustering algorithm that automatically groups data points based on their similarity, is known to the authors. Despite being uncomplicated and easy to use, the K-Means technique generates robust clustering and great processing performance for large data sets. The results of the studies demonstrate that the K-Means-based color quantization technique can more precisely depict the color properties of remote sensing photos and has a minimal perceptual error. In addition, color quantization reduces the size of an image from what it was initially.

The author Dan S. Bloomberg [3] discusses the different methods for performing color quantization on RGB Images using the Octree data structure. The usage of Octree is beneficial for performing this operation as it provides a simple method for generating a good partition for the color space and a fast inverse color table to find colors' for each pixel. For testing this algorithm an image with a vast variety of flesh colors has to be selected as it challenges the octree model due to its difficulty level in representation. This approach was compared to the median cut approach for color quantization. It was found that the octree approach and the best median cut method produce comparable results when done with 256 colors.

The authors Navjot Kaur and Sukhkirandeep Kaur[4] in their paper mainly discusses the different splitting and clustering algorithms for image quantization using many different approaches. In splitting algorithms, the author talks about a few of them where the Octree algorithm proves itself to be the best splitting algorithm as there is a distinct color at every depth 8. After this, it can be seen that the clustering algorithms are to be focused on where it can be found that the post-clustering algorithm has one advantage compared to the pre-clustering one as post-clustering algorithms work with arbitrary-shaped clusters. From the research, it can also be defined that clustering algorithms take up less space compared to other ones. When images are quantized, it can be easily seen that pre-clustering algorithms are preferred over other algorithms as they do not require any sort of complicated relationship between color clusters whereas for quantization within window systems, post-clustering methods are utilized because they maintain image quality even when multiple images can be displayed at once, use little memory, and generate few errors. Splitting algorithms, on the other hand, take a lot of time and result in discontinuities many times.

This research conducted by the authors Rajinder Kaur et. al. [5] introduces the Bacteria Foraging Optimization technique, which is primarily made for picture compression because it tends to change the distribution and structure of image colors. The findings shown are preliminary, and much work needs to be done to perfect this algorithm. The Lab color space is used by the BFOCIQ. Although the Lab color model does away with the shortcomings of the RGB model. Equal distances in the RGB color space could not equate to equal distances in color perception, which is one of the shortcomings of RGB. The LAB color model has device independence over the RGB color model as a benefit. In other words, this paradigm allows you to control colors without relying on any particular equipment (such as monitors, printers, or computers). BFO has been used in this research on a variety of images, including phantom images. This supports the validity of the suggested algorithm, which, when applied to the phantom photos, produces results that are optimized.

The authors Hyun Jun Park et. al. [7] present an octree-based SOM color quantization approach in this paper. Particularly when K, the number of colors, is low, it performs better than other methods. It complements the drawbacks of SOM color quantization, one of the most effective approaches, by using an octree color quantization technique. The octree color quantization method's palette has a variety of colors because it does not take color distribution into account. Processing time, MSE, and MAE are measured for comparison. The experimental findings demonstrate that the suggested method is superior than other methods when it quantizes the colors in the image using fewer colors. Lower MAE and MSE are produced. As a result, the proposed technique runs in 71.73% the time of the traditional SOM method. However, even if the suggested technique performs similarly to conventional SOM in terms of MAE and MSE when using a lot of colors, it is still quicker.

In this paper, the authors M. Emre Celebi et. al.[10] propose an accelerated k-means algorithm for color quantization. The authors introduced a new method called coremeans. This method involves careful initialization using the k-means++ algorithm, deterministic data sub-sampling using decimation, coreset construction using importance sampling, and k-means clustering. Coremeans is relatively easy to implement and highly efficient. Experiments on publicly available test mages demonstrated that coremeans is typically an order of magnitude faster than k-means while producing virtually identical results.

III. Methodology

As discussed earlier the two categories of image independent methods are splitting and clustering. To effectively carry out the comparative analysis of various color quantization algorithms two algorithm from each splitting and clustering were picked and executed. The two common splitting algorithms that were chosen are median-cut and octree. For the clustering algorithms k-means and Lloyd-max were selected.

A. Splitting Algorithms

a) Median cut

In this algorithm the whole image is divided into small set of regions having almost the same number of pixels. Then the algorithm selects the region with the highest number of pixels and finds the longest axis in that region to arrange the colors along that axis, then break the box into two at the median point of the arranged set. The quantized palette is made from each of the final region. Each region is represented by it's respective centroids.

b) FastOctree

In this algorithm a tree structure is used to perform color quantization. Each leaf of the tree represents a color in the image. The octree can have upto 8 children per node and maximum of 8 levels [6] i.e., 8^8 =16777216 colors can be stored. To reduce the number of colors in an image to K, a leaf is chosen that represents the color very close to that in the color space and is replaced by a node representing the leaves' average colors. This has been further modified to speed up the whole process of splitting into child nodes, hence reducing processing time.

B. Clustering Algorithms

a) K-Means

In this algorithm, the dataset is divided into K number of non-overlapping clusters where each point corresponds to one cluster[9]. The aim of the algorithm is to make the inter cluster points as similar as possible while also keeping the clusters different from one another to inaccurate predictions. The data points are allotted to a cluster using each points distance from the centroid as a metric. There are three types of distances that are used for the same; Euclidean Distance, Manhattan Distance, City Block Distance. Euclidean Distance which is the sum of the squares is the most popular form of distance used in the algorithm. If a point is near to a centroid of a cluster, the arithmetic mean of all the points in the cluster is defined as the new centroid in order to keep the centroid at minimum. When the datapoints in a cluster have very less variations, the homogeneity of inter cluster points increases.

b) Lloyd-Max

This algorithm is a popular implementation of K means clustering. In this algorithm, K arbitrary datapoints are selected to be the centroids of the clusters. Then the distances between the datapoints and the centroids are calculated and the nearest datapoint to the centroid is added to the cluster. Then the centroid of the cluster is recalculated by calculating the arithmetic mean of all the datapoints. This will ensure that the points within the cluster are similar and have no variation amongst them. This is an iterative process which will continue until all the datapoints have been added to clusters

C. Performance Metrics

The results of the experiments are computed and compared on the basis of the following performance metrics

a. Mean Absolute Error (MAE) – It is the average of all the absolute errors. It is the absolute difference between the prediction of an observation and the true value of that observation.

MAE = Sum of Absolute Errors / Total number of Errors

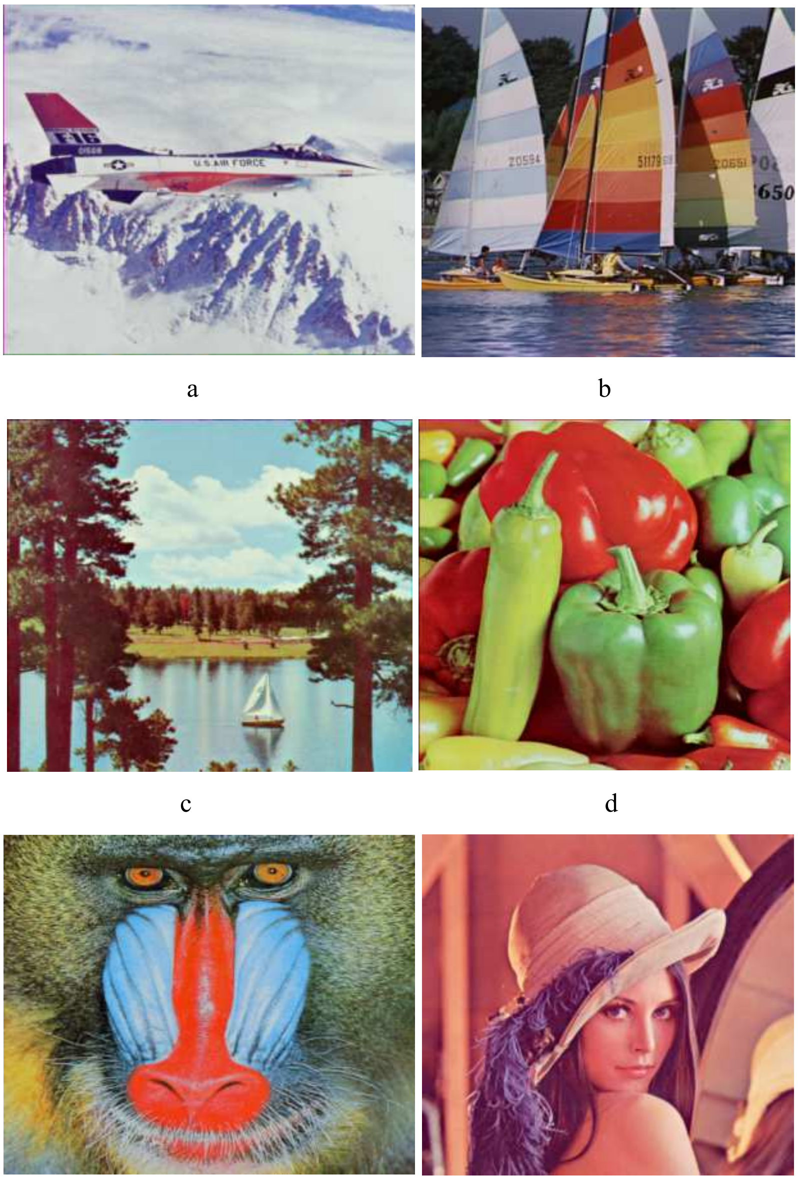
b. Mean Squared Error (MSE) – The definition of Mean Squared Error (MSE) is Mean or Average of the square of the deviation between actual and estimated values. It is more sensitive to outliners and punishes larger errors more.

MSE = Sum Square of Absolute Errors / Total number of Errors

c. Total Time – This is the total time required for computation for each algorithm.

IV. Results and Discussion

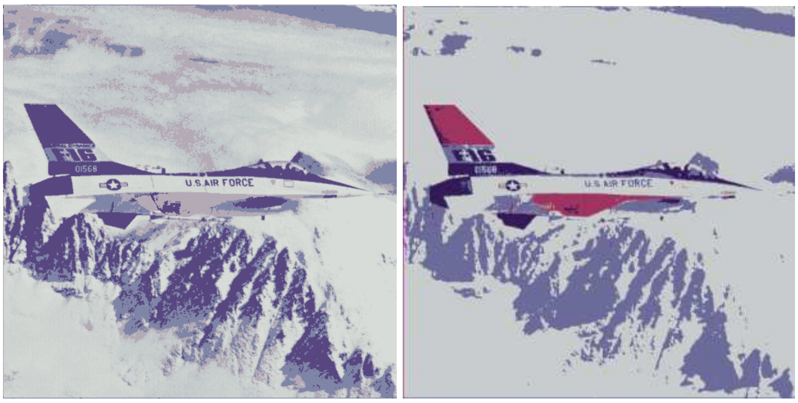
The data set used for experimentation consisted of 6 images that have been the standard for color quantization experiments: airplane, lenna, mandril, pepper, sailboat and yacht. All the images were quantized into 6 color palates and the results were calculated based on the MSE, MAE and time taken to perform the task. Figure 1 shows all the images of the dataset used for experimentation



a b c d e f

Fig. 1. Dataset of images used a) Airplane b) yacth c) sailboat d)pepper e) mandril f)lenna

All images being different in consistency and complexity had different results with algorithms. The image airplane quantized to the color plate of 8 bits revealed the mae is best for median cut algorithm, the mse is lowest for K-mean algorithm, and the time to compute and quantize the image was fastest for fast octree algorithm. For 16 bits, 32 bits, 64 bits, 128 bits AND 256 bits the mae was lowest for median cut but the mse was lowest for K-means and the fastest algorithm was fast octree.



a **b**

Fig. 2. 8 bit color palate images airplane for a) median cut b) K-means

a b

Fig, 3, 256 bits color palate images of airplane for a) median cut b) K-means

Fig. 2 and Fig. 3 is the experimentation result of the best performing algorithms for airplane image for 8 bits and 256 bits color palate.

For lenna, while quantizing the image to 8 bits, 16 bits, 32 bits, 64 bits, 128 bits AND 256 bits the lowest mae was for the median cut algorithm. While the lowest mse at 8 bits, , 16 bits, 32 bits, 64 bits, 128 bits AND 256 was also for the median cut algorithm. The fastest algorithm for lenna for all color palates was fastoct.

a b

c

d

e

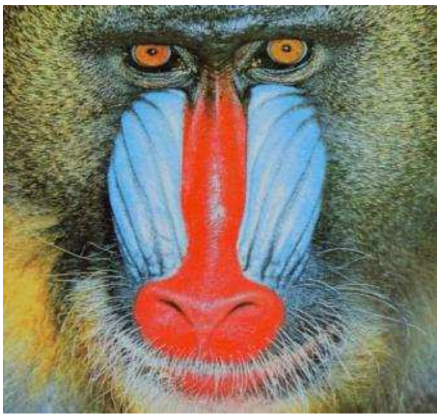
f

Fig. 4. Color Quantized image of lenna of a) 8 bits b) 16 bits c) 32 bits d) 64 bits e) 128 bits f) 256 bits for median- cut algorithm

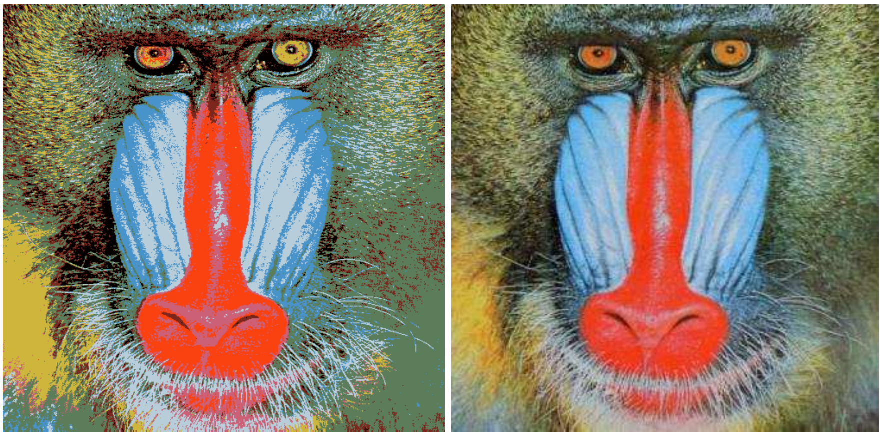
Figure 4 is the result of the median –cut algorithm for the color quantized image of lenna for 8 bits, 16 bits, 32 bits, 64 bits, 128 bits and 256 bits.

For the image mandrail, for the color palatte 8 bits, 16 bits, 32 bits, and 64 bits had the lowest mae for median cut and for the remaining two mae is lowest for maximum algorithm. Similar results were seen for mse. The fastest was yet again the fastoct algorithm.

a



b



c d

Fig. 5. Color quantization of mandril images for median-cut a) 8 bits b) 256 bits and for Lloyd-Max c) 8 bits and d) 256 bits

Figure 5 displays the best performing algorithms for mandril image for 8 bits and 256 bits color palate.

For pepper, sailboat, yacht the best algorithm for all color palate turns out to be the median cut algorithm with the lowest mae and mse. The fastest algorithm is the Fastoct algorithm.

a b

c d

e f

Fig. 6. Final results of pepper image in a) 8 bits b) 256 bits, sailboat image in c) 8 bits d) 256 bits and finally yacth image in e) 8 bits and f)256 bits.

Fig. 6 shows the quantized images in 8 bits and 256 bits of pepper, yacht and sailboats.

IMAGE	METHOD	Size of Palette					
		8	16	32	64	128	256
LENNA	FASTOCTREE	36.86	30.53	28.93	19.97	13.61	10.79
	K-MEANS	61.90	45.11	35.17	29.62	24.02	19.87
	MAXIMUM	71.16	52.14	32.74	24.54	18.74	13.87
	MEDIAN CUT	**32.34**	**24.69**	**19.13**	**14.65**	**11.36**	**9.04**
AIRPLANE	FASTOCTREE	34.98	23.98	21.99	12.89	9.68	8.87
	K-MEANS	43.09	33.08	22.95	18.36	16.17	11.57
	MAXIMUM	74.61	55.78	35.99	22.39	18.76	12.83
	MEDIAN CUT	**24.96**	**19.67**	**15.68**	**10.87**	**8.45**	**6.56**
MANDRILL	FASTOCTREE	74.75	48.24	31.74	24.29	16.30	7.95
	K-MEANS	96.59	71.12	54.12	38.85	27.86	21.84
	MAXIMUM	71.64	48.24	34.65	22.95	**12.68**	**6.96**
	MEDIAN CUT	**50.71**	**37.54**	**28.67**	**21.61**	15.16	10.26
PEPPER	FASTOCTREE	55.97	37.86	34.00	26.55	19.89	14.10
	K-MEANS	76.73	59.74	44.61	36.85	30.88	26.16
	MAXIMUM	104.71	67.88	47.14	33.68	23.60	18.89
	MEDIAN CUT	**42.67**	**30.98**	**25.68**	**20.89**	**16.95**	**12.98**
SAILBOAT	FASTOCTREE	54.76	36.36	29.80	25.83	17.33	13.55

	K-MEANS	67.15	52.97	43.99	36.97	28.68	22.83
	MAXIMUM	107.31	61.83	49.72	37.98	24.95	19.75
	MEDIAN CUT	**39.91**	**29.86**	**21.67**	**17.92**	**14.68**	**11.82**
YACHT	FASTOCTREE	68.60	37.57	29.80	23.88	17.53	12.58
	K-MEANS	78.61	56.68	42.85	33.68	27.49	22.78
	MAXIMUM	94.41	62.64	40.65	33.40	23.75	17.43
	MEDIAN CUT	**43.60**	**31.87**	**24.90**	**18.43**	**14.54**	**11.67**

TABLE I. MAE FOR DIFFERENT IMAGES AND COLOR PALATES

IMAGE	**METHOD**	**Size of Palette**					
		8	**16**	**32**	**64**	**128**	**256**
LENNA	FASTOCTREE	989.65	547.32	460.46	295.21	162.62	68.95
	K-MEANS	921.88	464.05	368.85	270.29	151.08	131.00
	MAXIMUM	2283.19	1673.66	597.05	292.80	190.82	89.74
	MEDIAN CUT	**630.96**	**399.09**	**284.57**	**170.24**	**85.13**	**57.72**
AIRPLANE	FASTOCTREE	1937.09	595.31	299.58	150.95	89.25	72.80
	K-MEANS	**583.42**	**268.63**	**174.44**	**119.31**	**85.53**	**67.73**
	MAXIMUM	2474.37	1416.23	558.39	228.78	164.85	75.22
	MEDIAN CUT	765.16	541.59	364.63	171.62	127.84	72.50
MANDRILL	FASTOCTREE	4321.89	1784.17	586.35	474.42	214.95	32.59
	K-MEANS	2273.65	1186.34	633.52	362.64	205.81	143.77
	MAXIMUM	2674.93	1138.41	598.52	299.65	**90.50**	**24.49**
	MEDIAN CUT	**1321.51**	**759.34**	**470.04**	**275.08**	166.67	76.67
PEPPER	FASTOCTREE	2414.58	918.65	526.52	421.40	261.57	**147.32**
	K-MEANS	1593.64	908.24	532.07	331.38	235.43	174.55
	MAXIMUM	5518.01	2363.77	1121.70	543.61	282.80	159.28
	MEDIAN CUT	**1181.08**	**640.87**	**459.76**	**326.85**	**225.61**	**144.02**
SAILBOAT	FASTOCTREE	3596.12	1383.01	487.09	396.79	217.35	116.95

	K-MEANS	1171.15	723.93	487.26	336.99	221.70	147.32
	MAXIMUM	5763.44	1739.15	1134.58	654.31	294.97	174.13
	MEDIAN CUT	**1141.98**	**660.84**	**359.15**	**243.69**	**165.43**	**113.92**
YACHT	FASTOCTREE	3938.63	993.25	523.91	385.00	225.65	126.62
	K-MEANS	1543.41	847.28	477.49	289.89	211.67	146.92
	MAXIMUM	3983.17	1769.83	836.95	550.81	282.50	156.50
	MEDIAN CUT	**1061.80**	**651.85**	**431.96**	**259.71**	**166.03**	**112.07**

TABLE II. MSE FOR DIFFERENT IMAGES WITH DIFFERENT ALGORITHMS AND SIZE PALATES

Tables I and II display the MAE and MSE for The results clearly display that the Median Cut algorithm is the best for color quantization compared to K-mean, Maximum and fastoct as it has the lowest mean absolute error (mae) and mean square error (mse). The result also shows that the fastest algorithm is the Fastoct algorithm when compared by the speed of evaluation. The median-cut algorithm stands out dimensionally, for airplane image is as low as 6.56. In all the images even if some other algorithm is the lowest, the second lowest is median-cut. In majority of the results the median-cut is the best algorithm to preserve the color palate and has the closest semblance to the original image.

V. CONCLUSION

The purpose of this paper is to compare various machine learning algorithms and to compare their efficiency and accuracy while reducing a colorful image with a huge color palate to one that has been restricted to a specific number of colors. The process of color quantization was carried out and the performance was calculated on the basis of three parameters: Mean Absolute Error, Mean Square Error and Time taken for computation. The results demonstrate that for major images and color palates the Median-cut algorithm proved to be the best as it has the lowest MAE and MSE while compared to the remaining 4 algorithms While the fastest algorithm was the Fastoctree algorithm. While the paper compares the algorithm and consolidates the result into one, the scope for future work is tremendous, The improving of accuracy for the fastoctree algorithm by combining it with other known methodologies to improve performance while leveraging the improved speed of the algorithm will prove highly essential.

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