Multiple Colour Detection of RGB Images Using Machine Learning Algorithm

Chapter *in* Communications in Computer and Information Science · October 2022

DOI: 10.1007/978-3-031-19647-8_5

4 authors:

Awotunde J. Bamidele
University of Ilorin

Sanjay Misra
Institute for Energy Technology

David Obagwu Obagwu
University of Ilorin

Hector Florez
District University of Bogotá

Multiple Colour Detection of RGB Images using Machine Learning Algorithm

Joseph Bamidele AWOTUNDE[1*][0000-0002-1020-4432], Sanjay MISRA[2][0000-0002-3556-9331], Hector Florez[3], Obagwu David OBAGWU[4]

[1, 4]Department of Computer Science, Faculty of Information and Communication Sciences, University of Ilorin, Ilorin, 240003, Kwara State, Nigeria
[2]Department of Computer Science and Communication, Østfold University College, Halden, Norway
[3]Universidad Distrital Francisco Jose de Caldas, Colombia

awotunde.jb@unilorin.edu.ng[1], ssopam@gmail.com[2], haflorezf@udistrital.edu.co[3], dobagwu@gmail.com[4]

Abstract. Colour detection is the act of identifying the name of any colour. Color detection is required for object recognition, and it is also utilized in a variety of picture editing and sketching programs. Machine Learning (ML) has been proof useful in this area, and lot of researches have been done. This has been utilized in fields of neural networks and digital image processing recently. RGB images multiple colour recognition are powerful tools for various images for images and sketches. There have been several suggested regression models that use crop image characteristics and image indices, however, they have not been properly tested for accuracy and adaptation effectiveness for multiple colors. Therefore, this paper proposes K- Nearest Neighbour (KNN) classifier for efficient colour detection of RGB images. The KNN algorithm is a prominent ML technique and neural network classification technique. The KNN classifier is utilized to segregate distinct colors in the RGB images. The paper utilized colour histogram for feature extraction to find the features that most relevant pattern that define certain colours. The feature extraction further improved the efficacy and accuracy of KNN classifier's in the classification of RGB images.

Keywords: Machine learning, Feature extraction, Colour histogram, RGB images, Colour detection, Object recognition.

1 Introduction

Within the actual world, the human eye is capable of detecting and distinguishing colours based on predetermined identification or conventional learning, after which the colour can be seen by the eyes and interpreted by the mind. The colour detection or colour sensation mechanism in computer vision is nearly identical to that in the eyes of humans, however, it must be designed with algorithms and logic processes that enable the CPU to take a piece of colour and do the necessary mathematical and logical operations to identify what colour that piece includes based on its recognition of all colour names. [1].

The method of detecting the name of any colour is known as colour detection. This is an exceedingly simple task for people, however, computers are not so straightforward. Humans' eyes and brains collaborate to transform light into colour. Light receptors in our eyes transmit the signal to the brain. The colour is then recognized by our brain. [2]. There has been the mapping of lights with their colour labels since we were children. To detect colour names, we'll use an approach that's similar to this one. Colour detection is used in a range of industries to help with the production and packaging process. Colour may be used as a quality control metric in the food industry, for example. Colour detecting sensors can be used in various sectors, such as the car, textile, and paint industries, to categorize goods or input materials based on their colours. Furthermore, during the bottling of items, Colour detection is employed to distinguish between those that have a bottle cap and those that do not.

Artificial Intelligence (AI) and Machine Learning (ML) are currently active research subjects with practical applicability [3]. ML is a method of generating predictions using computers based on a set of data or prior experience. Using supervised and unsupervised learning techniques from ML, these can manage massive volumes of data and solve classification issues [4-5]. ML now is not the same as machine learning in the past, thanks to advances in computer technology. Pattern recognition and the idea that computers could learn to execute tasks without being explicitly taught how to do so inspired AI researchers to investigate if computers could learn from data. ML's iterative feature is crucial since models can expand autonomously when exposed to new data. They use past computations to make dependable, repeatable judgments and results. It isn't a new science, but it is receiving renewed interest. Machine learning is a subset of AI that teaches a machine how to learn. AI is a general word for the study of simulating human abilities [6].

Over the years, colour images have taken over our lives through the medium of television, books, newspapers and photography [7]. With this technological breakthrough, colour televisions, colour scanners among others are now an integral part of our personal and professional environment. However, recognition of colour objects has evolved as a big challenge in computer vision [8]. Colour recognition, particularly in professional settings, colour management is required across all equipment in the manufacturing process, many of which use RGB [9-10]. During a normal production cycle, multiple transparent conversions between device-independent and device-dependent colour spaces emerge from colour management, ensuring colour consistency throughout the process. Therefore, this study use the K Nearest Neighbour classifier trained with the RGB Histogram to detect RGB images colours.

The paper develops a model to detect multiple colours in RGB images using ML algorithm. The specific contributions of this paper are to:

i. design a model that is able to detect colours in images using KNN classifier;
ii. Perform feature extraction to select relevant pattern for the detection of RGB colour in RGB images, before training and testing the model using a dataset; and
iii. evaluate the performance of the designed model.

The remaining part of this paper is organized as follows: section presents some relevant literature in multiple colour detection and prediction using machine learning. Section 3 discusses the methodology used in the paper. The results and discussion is presented in section 4 while section 5 conclude the study with future work and scope.

2 Related Work

ML aims to teach a computer how to learn. We'll also need to provide the machine the ability to react to user input. The main difference between traditional programming and machine learning is that instead of instructions, we must provide data. Machine learning algorithms also try to aid the machine in learning how to respond rather than presenting a predefined answer [11].

According to authors in [12], When dealing with large volumes of data, when dealing with big volumes of data, a basic model may function for short training sets but is less adaptive when dealing with large amounts of data. This is referred to as underfitting. If your model is underfitted to the data, it isn't capturing enough information and so delivers an incorrect forecast. On the other side, we may build a model that is flexible enough to operate with the dataset but is extremely complicated and difficult to comprehend. This is referred to as overfitting. Advanced techniques to solving the challenge of colour detection include machine learning algorithms.

Machine vision is a difficult field to work with. Neural network techniques are particularly beneficial for a number of challenges when compared to standard procedures. A traditional strategy for colour recognition is the K-Nearest Neighbors Machine Learning algorithm with feature extraction. In addition to feature extraction, other characteristics such as the Color Histogram, Color Correlogram, and Color Moments can be used [13]. The K-Means technique is a standard machine learning strategy for extracting colours from pictures and Colour space values are used to categorize each image in a collection. Any colour space can be utilized, including RGB, CYMK, HSV, and so on.

In [14], the authors suggested a colour recognition method using K-Nearest Neighbors Machine Learning classification algorithm trained on colour histogram features. They presented a colour recognition method using KNN classifier which is trained by RGB color histogram. The training dataset plays a very important role in classification accuracy. It can classify eight different colours namely White, Black, Orange, Green, Yellow, Red, Blue, and Violet. For classification of more colours and for increasing the accuracy large training dataset can be used. Authors in [15] suggested using Python and OpenCv for RGB image colour detection. The major goal of this application was to develop a mechanism for recognizing colour hues and making a precise forecast of their names. The OpenCv platform is used to implement many processes. The advantage of this approach is that it can differentiate monochromatic colors.

In [16], the authors study based on human facial recognition proposes one set of clever skin tone gathering methodologies. It starts with color photographs of the face and then uses FACE++ to determine the face's facial location in the image as a human facial recognition result. Based on the facial characteristics of the human face, it also determines the skin colour point for the human face collection. Programs that identify face colour have been developed as a result of this study. The clever approach allows it to calculate large amounts of data and even complex situations. This colour-selecting approach may be used to calculate large amounts of data. As a result, the gathered data may be used to construct a skin color trend.

Authors in [17] proposed colour identification using colour histogram feature extraction and the K-nearest neighbor classifier. Twelve distinct colours are distinguished using the KNN classifier. The colors utilized include blue, brown, green, navy, orange, forest green, pink, black, red, violet, yellow, and white. To extract characteristics that identify the colours, the colour histogram feature extraction approach is applied. With K=5, the most accurate colors are black and pink (90%). Violet and yellow, on the other hand, have the best ROC curve values. The findings suggest that a strong training dataset and well-chosen K values are crucial for classification accuracy, and that accuracy improves with them.

In [18], the authors published a paper called “Combing Colour Detection and Neural Networks for Gland Detection”, they developed a new method that blends a statistical colour identification model with a neural network. In a pre-processing stage, colours at gland borders are recognized and enhanced. A neural network model based on Faster R-CNN is then trained to detect glands using these colour pixels as input.

A color detection technique is implemented using fuzzy logic and a predetermined dataset that has a table of colour names that are related. The image's colours are compared to the table, and the comparison is successful if the table finds values for the image's colours that match the desired colour to be detected by providing the colour name. In addition, there are three more functions: most dominant color identification, conversion of HSV and HSI color models, and 3D histogram visualization.

In [19], the authors suggested employing digital image processing to determine soil colour. The procedure is coded in MATLAB. The database was created using photos from Munsell soil charts. To separate the soil part from the backdrop of a given input picture, the HSV segmentation technique is utilized. Images are categorized using KNN and annotated with Munsell soil notation depending on their RGB values. The Munsell soil notation is used to obtain the result.

The authors in [20] suggested a method for identifying 2-D pictures utilizing colour thresholds and the RGB colour model to detect colours. The colours identified here are red, green, blue, magenta, cyan, and yellow. The provided 3-D colour image is transformed to a Grey-Scale image, then the two pictures are subtracted to produce a two-dimensional black and white image. Unwanted noise is eliminated from the image using median filtering. Digital pictures are tagged in the connected region after being detected using a linked component. The measure for each marking area is determined by the bounding box and its properties. The RGB value of each pixel is used to determine the shade of each picture element.

In [21], the authors proposed multi-scale fuzzy colour recognition and colour image segmentation. This work proposes a multi-scale fuzzy colour detection and picture segmentation technique based on the HSV colour space in a visual environment. The method in this study allows it to quickly distinguish image color by classifying a wide range of multi-scale fuzzy colours in a visual scene picture into the nine colour ranges' subspace. The image's multi-scale segmentation is completed by obtaining picture edge information using the recognized colour information. A significant number of detail components were slowly segmented after the multi-scale fuzzy operation, resulting in a relatively good segmentation result. The recognition and segmentation result of this algorithm avoids colour duplication and improves desired recognition performance and delayed image response time, enabling convenience for sequential environment knowledge, navigating, planning, and behavioural patterns, as well as a novel notion for obtaining rapid and expanded automatic environmental awareness based on colour and edge information.

Colour Face Recognition Using KNN Classification Algorithm and PCA was proposed by authors in [22]. The KNN algorithm is used to classify colour face photos. Initially, the classification was done using a k-NN classifier. Later, characteristics of colour face photographs are extracted and the image data is simplified using a combination of Principal Component Analysis (PCA) and the k-NN classifier. Different colour space models and k values are evaluated in the apps. HSV, YCbCr, RGB, and YIQ are the colour space models. Finally, the outcomes of the experiments are compared. According to the classification accuracies of KNN and classification accuracies of PCA and KNN in the two tables provided, increasing the k value lowers the classification accuracies. Furthermore, in certain cases, changing the k value has little effect on categorization accuracy.

In [23], the authors proposed the segmentation of colour images using Feedforward Neural Networks with FCM. For color pictures, they presented a hybrid image segmentation approach. They employed feedforward networks and FCM (Fuzzy C-Means). They provided two innovative approaches for identifying the number of clusters, comprising a method for determining the number of clusters based on co-occurrence and validation of clusters using a silhouette index. This will be very beneficial for clustering algorithms. The FCM clustering approach to the CIE L*a*b* colour reduction image is a standout element of their work. The feed forward network is trained using the Levenberg-Marquardt back-propagation approach with the labels obtained from FCM.

The authors in [24] suggested a method for picture segmentation based on k-means and a subtractive clustering algorithm. They used the k-clustering technique to segment a picture and to create the initial centroid used a subtractive cluster. The segmented image is improved with the median filter, while the original image is improved by partially contrast stretching. We may establish that the recommended clustering approach gives superior segmentation after comparing the final segmented output to the k-means clustering technique. The output photos are also customizable by changing the hyper sphere cluster radius, and we can deduce that by changing the hyper sphere cluster radius, we can get a range of results.

A colour pattern identification of multiclass fruits using a histogram-based feature selection method was proposed by authors in [25], they proposed using chi-square feature selection to create a colour pattern for multiclass fruit photos. The colour pattern is made up of a variety of intensity values from the R, G, and B channels of RGB photographs. In [26], the authros proposed a technique for raw arecanut categorization.

Colour properties are used to classify objects. The raw arecanut is classified using colour moments and colour histograms, as well as the KNN method. To investigate the impact, this model employs a KNN classifier and four distance measurements. Using K closest neighbor with K value 3 and Euclidean distance metric for colour histogram characteristics, a result of 98.13 percent was obtained. Accuracy of 20% was achieved using a theoretical technique.

The authors in [27] published an article titled "An Image Processing Technique for Colour Detection and Distinguishing Patterns of Similar Colour: An Aid for Colour Blind People". The suggested approach of determining a given image's colour and edges achieves the work's goal. LabVIEW IMAQ vision and vision aid are used as a development tool to determine the colour and edge of a colour picture. The entire work setting is determined to be low-cost, practicable, adaptable, and efficient.

In [28], the authors presented novel real-time colour identification capabilities for vision-based human–computer interaction, such as extracting fundamental colours. They worked on colour-based picture segmentation and vision-based color identification in order to solve these problems. Colour detection was proposed by using a statistical technique. It starts with picture capture and object boundary detection to separate it from the backdrop [7]. The iterative procedure was used to acquire the binary values of various layers. A pixel-by-pixel Region of Interest (ROI) was employed to process the data. The threshold that aids in colour detection of an item is determined using a statistical technique. The threshold approach is applied to the ROI obtained, and the colour of the provided item is detected.

3 METHODOLOGY

3.1 Overall Framework

The major phases in the implementation of the colour detecting algorithm are depicted in figure 1.

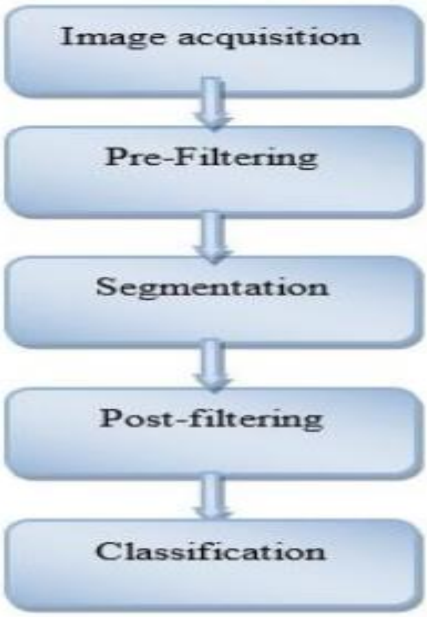


Fig. 1. Framework of colour detection

Image Acquisition.

Image acquisition is the process of capturing the photos that will be used in further processing. Because no processing can be done without a photo, this is the first step in the process. Various photos are gathered here. The images are unedited when they are taken.

Filtering.

Noise is an essential factor to consider when processing digital images. Whenever a picture is taken, it is possible that it will be filled with noise in some way. When an image has noise, it appears irregular, rough, uneven, or white. As a result, we need to employ appropriate filters to remove noise from the image. For filtering purposes, the median filter is utilized. It's a spatial nonlinear filter. For filtering, this filter employs a square window.

Segmentation.

Image segmentation is commonly used to remove a portion of an image that has similar qualities or properties, or dividing an image into many segments with similar qualities or properties. There are several methods for segmenting a photograph. Techniques for segmentation include edge-based, clustering, region-based, and thresholding. The threshold approach of segmentation may be further broken down into other ways. The picture is initially transformed from RGB to HSV in this step. The hue component's upper and lower limits are then set. The image is returned to its original RGB colour space and presented after the hue is thresholded to see the results.

Classification.

In image processing, machine learning techniques are becoming more popular. There are three types of machine learning techniques: Supervised, Unsupervised and Reinforcement. Supervised techniques use labeled inputs and outputs to train the algorithm. The system is educated using information that is neither categorized nor labeled in unsupervised learning. Reinforcement involves an agent capable of perceiving and interpreting its environment, acting on its findings, and learning through trial and error.

3.4 K-Nearest Neighbour (KNN)

K-Nearest Neighbor is a supervised machine learning algorithm (KNN) used to classify things. KNN is well-known for its speed and ease of usage. KNN compares the k most similar examples from an instance to find which class is the most common in the set (x). The instance class is assumed to be the one that appears the most frequently (x). In order to select the closest instance, the KNN system uses a distance metric. There are a variety of distance metrics that may be utilized, including Euclidean, which will be used in this research.

By comparing the test picture features to characteristics in the dataset, the Euclidean distance is determined. The identification rate is determined by the minimal distance between the test picture feature value and feature values contained in the dataset. The Euclidean distance is based on the following formula:

$$D = \sqrt{\sum_{i=1}^{n} (hist1_i - hist2_i)^2}$$

Pseudocode For KNN

1. Load the test and training data

2. Determine the value of K.

3. For each point in the test data, do the following:

- Calculate the Euclidean distance between all of the training data points.
- Create a list of Euclidean distances and sort it
- Pick the top k points
- depending on the majority of classes contained in the chosen points, assign a class to the test point

4. End

3.2 RGB Colour Histogram

In image processing, an image's histogram is a histogram of pixel intensity values. The histogram is a graph that shows how many pixels are in a picture at each different intensity value. For an 8-bit grayscale image, there are 256 distinct intensities, so the histogram will graphically display 256 numbers that represent the distribution of pixels among those grayscale values. Colour pictures may also be histogrammed, either as separate red, green, and blue channel histograms, or as a three-dimensional histogram with the three axes indicating the red, blue, and green channels, with intensity at each point reflecting the pixel count. The actual outcome of the operation is decided by the implementation. It may be a picture in a suitable image format showing the required histogram, or it could be a data file providing the required histogram statistics in some fashion. Figure 2 displayed the RGB colour Histogram samples.

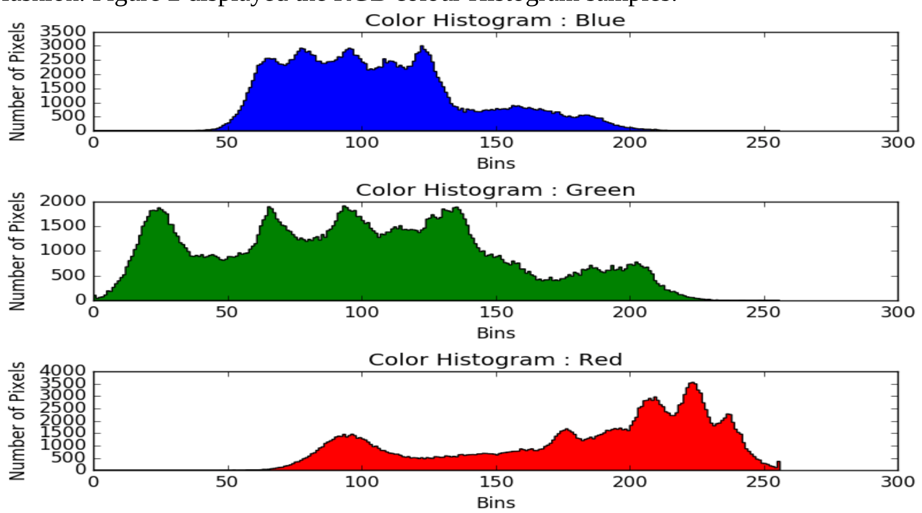


Fig. 2. Example of Colour Histogram

Pseudocode for RGB Colour Histogram

1. Load the source image.
2. Separate the source image in its three R,G and B planes. For this we use the OpenCV function cv2.split().
3. Establish the number of bins.
4. Set the range of values (between 0 and 255).
5. Proceed to calculate the histogram by using the OpenCV function cv2.calcHist().
6. Create an image to display the histogram.
7. Display the histogram.

3.3 Colour Classification using KNN

Colour classification is done by applying K-Nearest Neighbor algorithm. The general steps involved are stated in figure 3:

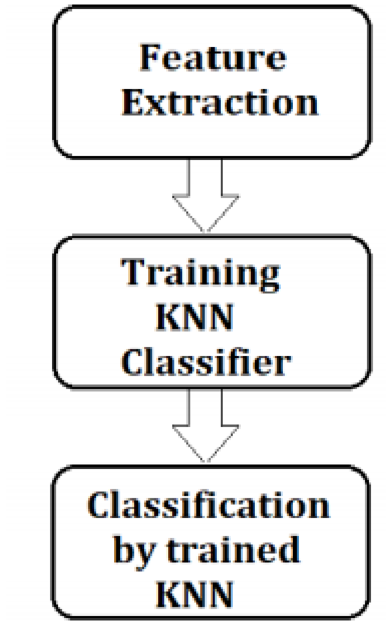


Fig. 3. Colour Classification using KNN

Feature Extraction.

The colour distribution of a picture is represented by the colour histogram. In the digital realm, the term "colour histogram" refers to the number of pixels in a picture that are made up of colours from a set of colour ranges divided by the image's colour space which is a collection of all conceivable colour values. An input image's RGB colour histogram can be obtained. The highest value of pixel count for RGB as an attribute is combined with the bin number of histogram to produce the dominant RGB values for constructing feature vectors for training. Because the KNN classifier is a supervised learning system, the RGB values for each training image are acquired using colour histogram and labelled.

Training KNN Classifier.

RGB colour Histogram measurements are used to train the KNN classification algorithm.

Classification by Trained KNN

A classifier is an algorithm that performs classification in a concrete execution. The term "classifier" refers to a mathematical function that plots supplied data into a group using a classification technique. The KNN method saves all of the cases it encountered, and fresh cases are classified using the similarity measure. The classification processes are shown in figure 4.

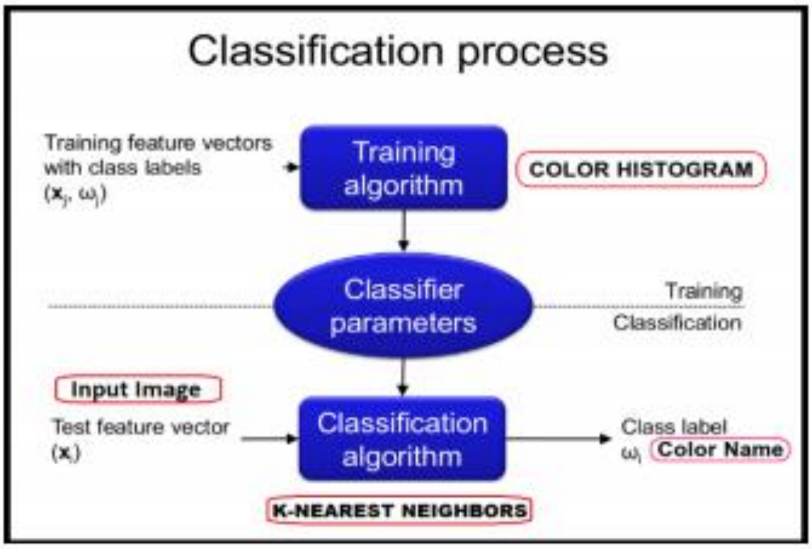


Fig. 4. Classification Process

Pseudocode to Implement The KNN Classification

Given a new item:

1. Determine the distances between the new item and the rest of the objects.
2. Select a set of k lesser distances.
3. In these k distances, choose the most prevalent class.
4. That is the class in which the new item will be classified.

4 IMPLEMENTATION AND RESULTS

This paper focuses on colour detection using a KNN that has been trained using RGB colour histograms. Black, blue, green, orange, red, violet, white, and yellow are among the eight (8) colors it can identify. Colours are introduced in photographs on unsplash.com, and each colour includes numerous training data, which are utilized to construct datasets for all the colours. The data set may be enlarged to accommodate more operations. The application employs the KNN algorithm, which was developed using digital image processing technologies.

4.1 Feature Extraction

Here, we got the colour histogram of our test image by finding the peak pixel values for RGB in figure 5.

Fig. 5. Test Image

The dominant R, G, and B values were produced by utilizing the bin number of a histogram with the peak value of pixel count for R, G, and B as a feature to create feature vectors for training. The prominent R, G, and B values of the orange picture seen above, for example, are [255, 132, 0], that is, [R,G,B]. The KNN classifier is a supervised learner using feature vectors stored in a csv file, the dominating R, G, and B values for each training image were obtained using Color Histogram and then labelled. Thus, the creation of the training feature vector dataset which is given in table 2 below:

Table 1. Table listing the training feature vector dataset/ RGB Histogram values(bins)

RED	YELLOW	GREEN	ORANGE	WHITE	BLACK	BLUE	VIOLET
139,0,0	255,255,0	159,217,140	252,79,19	249,255,241	9,0,0	3,91,188	127,0,255
204,22,0	255,242,39	125,194,75	255,102,0	253,251,251	28,29,33	0,0,254	111,0,255
206,0,25	249,217,94	37,202,38	255,127,0	242,233,228	27,32,35	0,0,255	82,24,250
220,0,3	252,234,4	0,166,82	255,128,0	242,233,228	36,29,33	1,119,193	63,0,255
254,0,0	255,183,9	64,189,85	255,103,0	250,240,230	0,0,0	0,48,143	138,43,226
61,13,3	247,224,23	0,128,1	255,122,1	243,239,227	49,54,57	0,0,154	160,32,240
128,24,24	254,242,0	35,67,17	254,101,33	255,237,231	47,47,47		
174,32,26	246,191,39	123,252,1	255,153,0	229,224,221	40,39,45		
254,0,2	255,215,12	0,255,0	255,103,0	248,249,254	37,37,37		
209,23,23	255,166,0	33,83,54		238,228,220	10,18,13		
		125,232,88			28,28,28		

Training the KNN Classifier

The Classifier is trained using the RGB Colour Histogram measurements in the table above. It stores the training data in memory for future classification. To get k, we counted our classes which is the eight colours and to avoid getting a tie in the voting stage we make k odd, therefore k = 3.

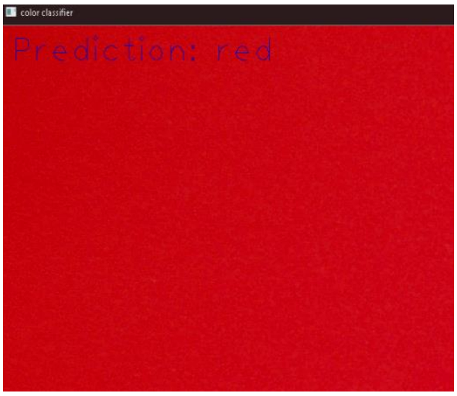
Classification by Trained KNN

1. Obtaining training data is the first step.
2. Obtaining test image characteristics
3. Euclidean distance calculation
4. Obtaining the k closest neighbors.
5. Voting of neighbors.
6. Prediction of colour.

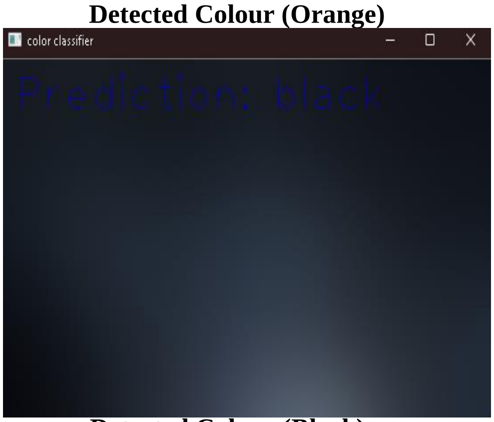
When the picture is loaded, the model reads it and then looks for training data. If the data for training is ready, it loads the classifier and if the training data is not ready, it creates a training data for the image. It then gets the detected colour and displays it.

The results of the model reveal that when the KNN algorithm is paired with digital image processing technology, it is possible to detect colours in pictures as shown in figure 6 and 7.

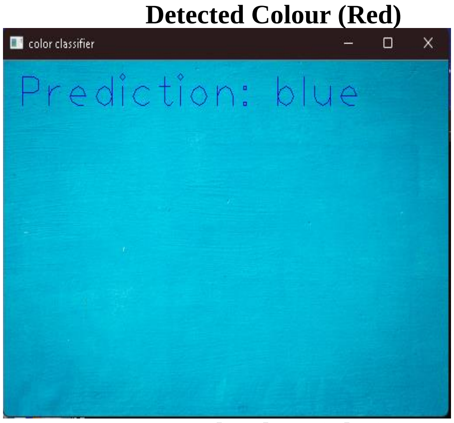
Detected Colour (Orange)



Detected Colour (Red)



Detected Colour (Black)



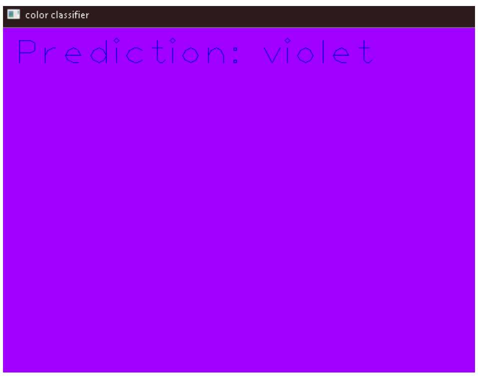
Detected Colour (Blue)

Fig. 6. Detected colours

Detected Colour (Green)

Detected Colour (Orange)

Detected Colour (Yellow)



Detected Colour (Violet)

Fig. 7. Detected colours

4.2 Comparison

In previous works, they were able to detect more colours but their accuracy was low especially for red, yellow and violet. Some also converted RGB images to HSV colour model to detect colours. In this work, RGB the default colour model of images was used and the accuracy of the above mentioned colours were improved.

5 Conclusion

The findings imply that training data and K value are both important factors in determining accuracy, and that using more relevant training data might improve accuracy. Lighting and shadows are another crucial component; the photographs should be taken in appropriate lighting conditions. All eight colours were detected, so the aim of goals of this project was achieved. White has the highest possibility of being detected while violet has the lowest. Based on the findings of this study, Colour Detection in RGB Images can be enhanced by: (i) accounting for light intensity in the surroundings; (ii) the performance of this proposed methodology being compared to other techniques; (iii) conducting other studies using other Machine Learning algorithms or using Neural Networks; (iv) using a computer system with higher systems configurations in order to handle much larger datasets because training the model on a system with lower configurations takes longer time to accomplish, and (v) developing softwares that detects colour in images automatically.

References

1. Gonzalez, R. C., Woods, R. E., & Eddins, S. L. (2010). Morphological reconstruction. *Digital image processing using MATLAB, MathWorks*.
2. Praveen, P. (2020, July 17). Color detection using opencv python. Medium. Retrieved November 23, 2021, from https://medium.com/programming-fever/color-detection-using-opencv-python-6eec8dcde8c7.
3. Folorunso, S. O., Awotunde, J. B., Adeniyi, E. A., Abiodun, K. M., & Ayo, F. E. (2021, November). Heart Disease Classification Using Machine Learning Models. Communications in Computer and Information Science, 2022, 1547 CCIS, pp. 35–49.
4. Awotunde, J. B., Abiodun, K. M., Adeniyi, E. A., Folorunso, S. O., & Jimoh, R. G. (2021, November). A Deep Learning-Based Intrusion Detection Technique for a Secured IoMT System. Communications in Computer and Information Science, 2022, 1547 CCIS, pp. 50–62
5. Oladipo, I. D., AbdulRaheem, M., Awotunde, J. B., Bhoi, A. K., Adeniyi, E. A., & Abiodun, M. K. (2022). Machine Learning and Deep Learning Algorithms for Smart Cities: A Start-of-the-Art Review. EAI/Springer Innovations in Communication and Computing, 2022, pp. 143–162.

6. Awotunde, J. B., & Misra, S. (2022). Feature Extraction and Artificial Intelligence-Based Intrusion Detection Model for a Secure Internet of Things Networks. Lecture Notes on Data Engineering and Communications Technologies, 2022, 109, pp. 21–44.
7. Kar, S. K., & Mohanty, M. N. (2013, January). Statistical approach for color image detection. In *2013 International Conference on Computer Communication and Informatics* (pp. 1-4). IEEE.
8. Swain, M. J., & Ballard, D. H. (1991). Color indexing. *International journal of computer vision*, *7*(1), 11-32.
9. Sarraf, S. (2016). Hair color classification in face recognition using machine learning algorithms. *American Academic Scientific Research Journal for Engineering, Technology, and Sciences*, *26*(3), 317-334.
10. Yousif, M. A., & Awouda, A. A. (2019). Design And Implementation Of Colour Detection Technique Using Fuzzy Logic, International Journal of Social Science and Technology (IJSSTR), ISSN : 2415-6566, Volume 4 No.5, pp. 46–58. http://www.ijsstr.com/data/frontImages/5._October_2019.pdf.
11. Awotunde, J. B., Ajagbe, S. A., Oladipupo, M. A., Awokola, J. A., Afolabi, O. S., Mathew, T. O., & Oguns, Y. J. (2021, October). An Improved Machine Learnings Diagnosis Technique for COVID-19 Pandemic Using Chest X-ray Images. In *International Conference on Applied Informatics* (pp. 319-330). Springer, Cham.
12. Koehrsen, W. (2021). Overfitting vs. Underfitting: A Complete Example. Medium. Retrieved 23 November 2021, from https://towardsdatascience.com/overfitting-vs-underfitting-a-complete-example-d05dd7e19765.
13. Kayhan, Nasim, and Shervan Fekri-Ershad. "Content based image retrieval based on weighted fusion of texture and color features derived from modified local binary patterns and local neighborhood difference patterns." *Multimedia Tools and Applications* 80.21 (2021): 32763-32790.
14. Pooja K S, R N Shreya, Sree Lakshmi M, Yashika B C, & Mrs. Rekha B N. (2017). Color Recognition using K-Nearest Neighbors Machine Learning classification algorithm trained with Color Histogram Features. International Research Journal Of Engineering And Technology (IRJET), 8(1), 1935-1937.
15. Raguraman, P., Meghana, A., Navya, Y., Karishma, S., & Iswarya, S. (2021). Color Detection of RGB Images Using Python and OpenCv. International Journal Of Scientific Research In Computer Science, Engineering And Information Technology, 109-112. https://doi.org/10.32628/cseit217119
16. Yen, C.-H., Huang, P.-Y., & Yang, P.-K. (2020). An Intelligent Model for Facial Skin Colour Detection. International Journal of Optics, 2020, 1-8.
17. Bayraktar, R., Akgul, B. A., & Bayram, K. S. (2020). Colour recognition using colour histogram feature extraction and K-nearest neighbour classifier. New Trends and Issues Proceedings on Advances in Pure and Applied Sciences, (12), 08–14. https://doi.org/10.18844/gjpaas.v0i12.4981
18. Shu, J., Lei, J., Gao, Q., & Zhang, Q. (2019). Combing colour detection and neural networks for gland detection. Proceedings Of The 2Nd International Conference On Artificial Intelligence And Pattern Recognition - AIPR '19. https://doi.org/10.1145/3357254.3357280
19. Maniyath, S., Hebbar, R., Akshatha K.N., Architha L.S., & Subramoniam, S. (2018). Soil Color Detection Using Knn Classifier. 2018 International Conference On Design Innovations For 3Cs Compute Communicate Control (ICDI3C). https://doi.org/10.1109/icdi3c.2018.00019

20. Sudharshan Duth, P., & Mary Deepa, M. (2018). Color detection in RGB-modeled images using MAT LAB. International Journal Of Engineering & Technology, 7(2.31), 29. https://doi.org/10.14419/ijet.v7i2.31.13391
21. Liu, C., & Wang, L. (2016). Multi-scale fuzzy color recognition and segmentation of color image. 2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD). doi:10.1109/fskd.2016.7603312
22. Eyupoglu, C. (2016). Implementation of color face recognition using PCA and k-NN classifier. 2016 IEEE NW Russia Young Researchers In Electrical And Electronic Engineering Conference (Eiconrusnw). https://doi.org/10.1109/eiconrusnw.2016.7448153
23. Arumugadevi, S., & Seenivasagam, V. (2016). Color image segmentation using feedforward neural networks with FCM. International Journal of Automation and Computing, 13(5), 491–500. doi:10.1007/s11633-016-0975-5.
24. Dhanachandra, N., Manglem, K., & Chanu, Y. J. (2015). Image Segmentation using K-means Clustering Algorithm and Subtractive Clustering Algorithm. Procedia Computer Science, 54, 764-771.
25. Rachmawati, E., Khodra, M. L., & Supriana, I. (2015, August). Histogram based color pattern identification of multiclass fruit using feature selection. In 2015 International Conference on Electrical Engineering and Informatics (ICEEI) (pp. 43-48). IEEE.
26. Siddesha, S., Niranjan, S., & Manjunath Aradhya, V. (2018). Color Features and KNN in Classification of Raw Arecanut images. 2018 Second International Conference On Green Computing And Internet Of Things (Icgciot). https://doi.org/10.1109/icgciot.2018.8753075
27. Bhagya R Navada, Santhosh K V, Prajwal S, & Harikishan B Shetty. (2014). An Image Processing Technique for Color Detection and Distinguish Patterns with Similar Color: An aid for Color Blind People. In International Conference on Circuits, Communication, Control and Computing (pp. 333-336). MSRIT, BANGALORE, India.
28. Senthamaraikannan, S.Shriram, & Dr.J.William. (2014). Real time color recognition. International journal of innovative research in electrical, electronics, instrumentation and control engineering, 2(3), 1251-1253.