



Intelligent Learning System to Help People with Color Impairment Using Image Processing Algorithms

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Abstract

This study presents a novel framework to help people with color impairment in identifying colors. The proposed framework consists of three stages. These stages are electronically performing the Ishihara test, performing the color blindness type recognition test, and guiding the person to color by voice. The first stage, the person is subjected to an electronic color blindness test, by displaying different plates containing several points of different sizes and colors. The person is required to correctly identify the number or shape in the plate and at the end, the system determines the extent to which a person is color blind. The second stage is a color recognition test to determine the type of color blindness. If there is difficulty in determining red, this is called protanopia. But the difficulty in identifying the green color is called deuteranopia. While the inability to recognize the blue color is called tritanopia. And finally, the difficulty in identifying the colored style is called achromatopsia. The third stage is assistance phase and is divided into three subsectors are: smart educational system, identifying colors and extracting the content. The proposed system differs from other systems in that it is an integrated system. It includes identifying color blindness, determining its type, and finally aiding color blindness person. Also, it is the first system that deals with the rare type of color blindness called achromatopsia in addition to its other three types. The results obtained confirmed that the proposed system as well as the smart educational system are characterized by high accuracy and effectiveness.

Keywords: Intelligent Learning System; Color Impairment; Image Processing

1. Introduction

Colour-blindness has a significant impact on the life of the affected person because it impairs their ability to distinguish between primary colors (red, green, and blue) and prevents them from working in many jobs and professions that require accurate color knowledge, such as painters, fashion designers, driving, or enrollment in military colleges. Color blindness and its types must be identified for a variety of reasons: colour blindness testing can reveal whether a person has trouble identifying colours, assisting researchers in identifying color blindness and its impact on the life of a person with CVD, assisting People with Colour Impairment in understanding the issue of CVD and knowing the type of color blindness can reduce a person's reliance on others.

The impact of colour blindness on job performance is mostly determined by the employer's color requirements and the severity of the person's color vision loss. As a result, anyone contemplating a job that requires accurate color discrimination should take a colour blindness test. Most people with colour blindness are ignorant of their condition and do not believe it has a substantial impact on their daily life. Color blindness is not treatable with medication. The research challenge can be phrased as follows: The development of an instructional method to aid color-impaired people based on the acoustic element and image processing is required.

Color Vision Deficiency (CVD) is a common disorder that affects color perception to the point where many people have major problems in their daily lives [1]. Only about 8% of men and 0.1% of women in the world cannot see color properly. This condition is referred to as (CVD) or color blindness [2]. Anomalous trichromacy is a common form of congenital color deficiency resulting from a genetic alteration in the photopigments of the eye's light receptors. The changes reduce sensitivity to red and green shapes [3]. Color serves as a nonlinguistic code that gives instant information about the world around depending on color vision and visual perception theories [4].

As a result, the goal was to assist this group by developing a smart system based on the Ishihara test to identify and know people with color blindness, as well as to determine the level of injury and any type of color blindness infected with it, so that the system can assist him in identifying the color of through received through the camera and converting the color to sound through a speaker to hear the color. As a result, the patient no longer required the presence of another person to tell him about the colors.

The aim of this paper is creating a color identification system based on sound and visual processing for color-impaired persons?

2. Research Hypotheses

The main hypothesis of this thesis can be stated as follows:

There is an effectiveness of the proposed educational system in the current study in helping colour-impaired people to identify the colour of the subject of study among the sample members.

Several sub-hypotheses are derived from this hypothesis:

- There are statistically significant differences at level 0.05 between the mean of students' degrees on the pre-test and post-test for the experimental group that was subjected to the educational system in favour of the post-test.
- There are statistically significant differences at level 0.05 between the mean of students' degrees in the post-test for each of the experimental group that were subjected to the educational system and the control group that were not subjected to the educational system in favour of the experimental group that was subjected to the educational system.

3. Related Work

Meenakshi S and Anshu Singla (2022) [5] had presented a fuzzy-based system for simulating and compensating confusion hues in images to different levels of colour blindness. Colour compensation was examined in normal vision and colourblind people with red, and green colour blindness. The result of colour compensation was an accuracy reached 91%. The effectiveness of the simulation was assessed using cutting-edge internet tools and its accuracy reached 95.8%. The collected findings support the efficacy of the proposed fuzzy technique.

Sheikh Muhammad Saleem (2017) [6] had presented the differences in colour vision among 3,110 Kashmiris individuals. The results concluded that Deuteranomaly is the most frequent kind among Kashmiris with a rate of (52.74 %), followed by Protanopia (21 %). Also, Protanomaly was (11.64 %), with (8.5 %) for males and (1.3 %) for females.

Amir Rosenblatt, Eyal Cohen and Chaim Stolovitch (2016) [7] had compared the Ishihara booklet with smartphone apps for colour vision testing. The results showed that testing using smartphone applications has an advantage as it was available easily. But users of these applications should be aware that some may have a different sensitivity to detecting colour vision deficiency compared to the Ishihara booklet. It is also not useful in clinical use. Therefore, further validation of these applications is required.

Keun Young Ahn and Youn Jin Lee (2022) [8] had proposed an intelligent learning system to colour analysis and improvement plan of digital textbooks user interface design elements. it was found that the use of appropriate colours affects the learning, it is considered that the inappropriate use of colour is an important factor affecting learning and needs improvement. Considering that it is the transition period for the utilization and dissemination of digital textbooks, it is expected that several of colours will become more active in user interface design elements of digital textbooks.

Rong Ye and Ce Li (2022) [9] had proposed a smart learning system based on a colourblind image correction algorithm to accommodate digital images for colour vision deficiency users. The algorithm has two parts: image segmentation by K-means and system-clustering algorithms, and image correction based on similarity judgement and multi-factor selection of a colour replacement. then test the efficacy of algorithm through simulations.

Kashif Naseer Qureshi, et al. (2021) [10] had proposed a Secure system for the Internet of Schools Things (S-IoST) for smart schools. It depends on a new sophisticated communication system combined with 5 G cellular systems, sensing technologies, intelligent transportation systems, and IoT networks. It is done by providing a more secure alert mechanism that makes users get to and from school and home easily. The system was evaluated in terms of data delivery, timing, and response alert factors and the results proved the effectiveness of it.

Satrugan Kumar Singh and Jainath Yadav. (2021) [11] had created a soft computing system to recognize patterns. The system had built using the MATLAB program. This is done through computerized estimation of handwritten numbers and alphabets in a document image. The results showed that the proposed system achieved an accuracy of up to 96.24%.

Yinan Miao, Jun Young Jeon and Gyuhae Park (2020) [12] had proposed a fast and non-invasive fracture detecting method. It used a light control and a set of image pre-processing methods. This method requires a low-cost web camera. The results reveal that the suggested technique can identify surface cracks on pressed panels with high accuracy and efficiency while maintaining a consistent performance.

R.Udendhran, et al. (2020) [13] had developed and analyzed a deep learning approach to enhance image processing architecture for embedded vision systems. Deep learning algorithms were implemented and tested on embedded vision, and the results were positive and proved the efficiency of this approach.

4. The Proposed System

The proposed system aims to help people with colour discrimination. This is done by conducting a test to identify colour-blindness, determine the type of colour blindness, as well as to help them identify the different gradations of basic colours in a written and audible method, and finally the number of objects that make up the image.

The proposed system consists of three main parts. These parts are colour-blindness identification (Ishihara Test), colour blindness type identification and colour-blindness aiding. The following figure shows a block diagram of these components.

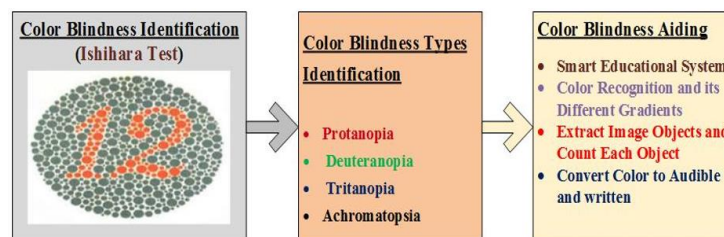


Figure 1: The Proposed System Block Diagram

4.1. Feature Extraction

The Colour image feature extraction technique that is used in the proposed system is CCV. It is a more efficient technique than a color histogram. Conceptually, the coherence of color can be described as the degree to which pixels of that color are part of large regions of a similar color [14, 15].

The coherence measure categorizes pixels as either incoherent or coherent. Coherent pixels are a part of some substantial connecting region, whereas incoherent pixels are not. The color coherence pair's vector for the image was represented as follows [16, 17]:

$$\langle (\alpha_1 + \beta_1) \rangle, \dots, \langle (\alpha_n + \beta_n) \rangle$$

Where:

α_n : the number of coherent pixels.

β_n : the number of incoherent pixels.

The similarity between these vectors will be obtained as follows [104].

$$D(\mathbf{a}, \mathbf{b}) = \sum_{i=0}^n (|a_{c_i} - b_{c_i}|) + (|a_{N_i} - b_{N_i}|)$$

Where:

c_i : the of coherent pixels colored with i.

N_i : the number of incoherent pixels colored with i.

In CCV each histogram bin was partitioned into two types: coherent and incoherent pixel value belongs to a large informally colored region that falls into coherent type. Otherwise, it falls into the incoherent type. A color coherent vector represents this classification for each color in the image [18]. This technique extracts (16) color features for both training images and the query images. These features are: (Rc,Ri, Gc,Gi, Bc,Bi, RGc, RGi, RBC, RBi, GBc, GBi, Whitec, Whitei, Blackc and Blacki). The extracted features from training images will be saved in the database.

4.2. Matching Processing

There are many methods used for pattern matching. The Weighted Euclidean Distance (WED) measure is the technique used in the proposed system. It is one of the fundamental and widely used techniques in matching [19]. ED scale technique was used to match between the features of the query image and the features of the images stored within the database. This was done to extract the most similar images (color gradients) of the query color images. The formula for WED measure can be written as follows [20]:

$$d(\mathbf{v}, \mathbf{v}^k) = \sqrt{\sum_{i=1}^n p_i (\mathbf{v}_i - \mathbf{v}_i^k)^2}$$

$$\bar{\mathbf{v}}_i = \frac{\sum_{k=1}^N \mathbf{v}_i^k}{N}$$

$$P_i = \frac{N}{\sum_{k=1}^N (\mathbf{v}_i^k - \bar{\mathbf{v}}_i)^2}$$

Where:

- v_i : is to balance the differences in the dynamic scope.
- P_i : is weight added.
- K : is the similar image index.
- N : is the number of images in databases.

After matching, the similarity between the query image and each image in the database is displayed. The values of similarity are then sorted in descending so that the high (similarity ratio) is the most similar. The color gradients derived from any color are known to be similar to this color. So, the color gradients that are like each color are displayed. Then displayed color written and audible. Figure 2 shows a block diagram for aiding weak distinguish color person to color identification. Figures 3 show the training and testing phase of aiding CVD person in color identification.

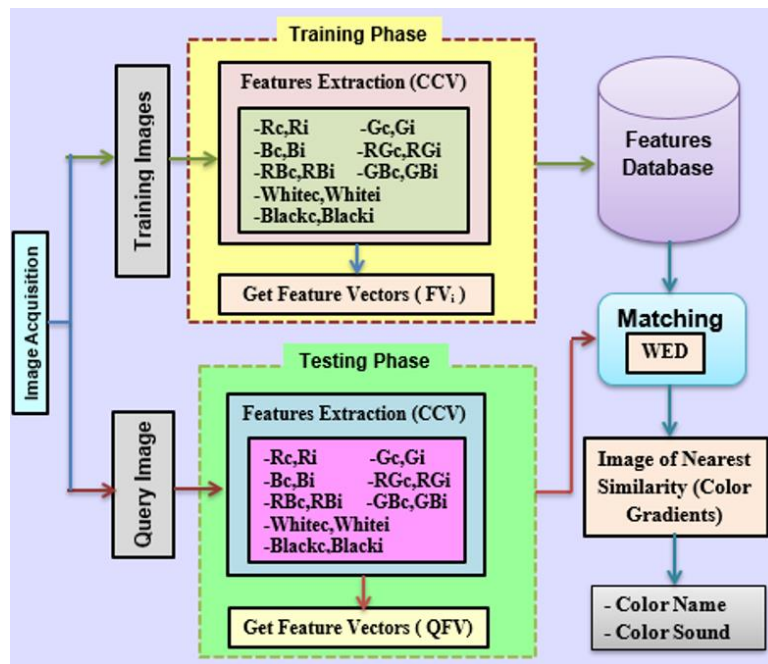


Figure 2: Aiding CVD to Color Identification Block Diagram

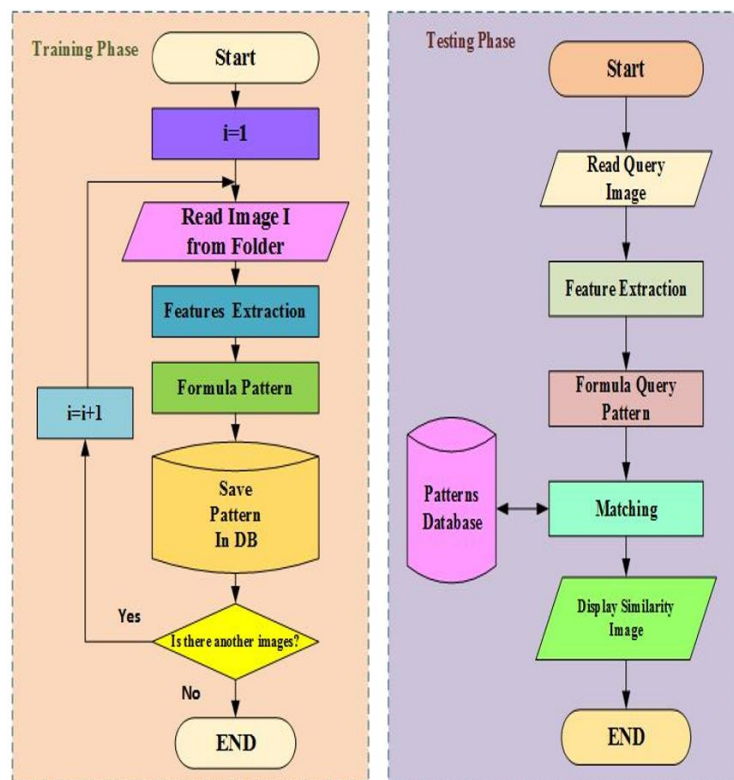


Figure 3: Training and Testing Phase Flowchart

4.3. Learning System to Help Students with Colors Discrimination

The block diagram of educational system is shown in figure 4. The system consists of a set of tools that are covered in the next part:

- A pre-test for colours discrimination.
- Educational content to help students with colors discrimination.
- Post-test for colours discrimination.

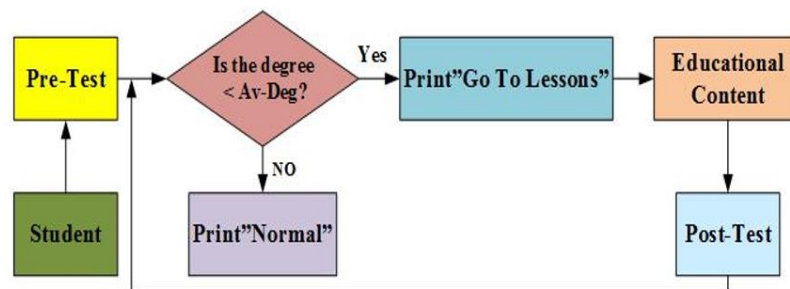


Figure 4: The Educational System Block Diagram

5. Experimental Results

Each part of the proposed system has its own results. These results are displayed as follows:

5.1. Ishihara Test Results

The test was conducted on a random sample of (300) students from Third-year middle school students. For the academic year 2020/2021 at Mustafa Hakam Preparatory School. Their ages range from (14-15) years. The test found 20 students with CVD. As a result, they were directed to make the color blindness type test. Results of this test are displayed in the following chart.

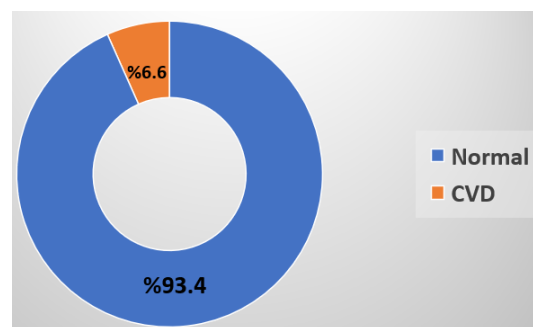


Figure 5: Ishihara Test Results

5.2. Colour Blindness Type Test Results

Colour blindness type test was applied to the 20 CVD students who resulted from the previous test. This is done to determine which colors they have difficulty to recognize. Results of this test are displayed in the following chart.

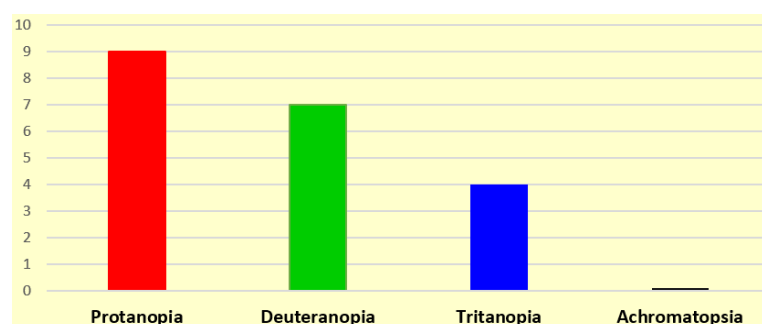


Figure 6: Colour Blindness Results

5.3. Performance of the Smart learning System

The study sample includes 20 color-blind students between the ages of (14-15) years old. The sample was divided into two groups, each group of 10 students, where the first group was subject to the learning system. While the second group had a size of 10, which is the group that was not subject to the learning system, that is, the test was conducted on it in paper form.

Table 1: Students who Suffer from Poor Color Discrimination and the Numbers of Examined either Male or Female

Color Blindness Type	Number
Protanopia	9
Deuteranopia	7
Tritanopia	4
Achromatopsia	0
Sample Total	20

I. First Hypothesis

There are statistically significant differences at level 0.05 between the mean of students' degrees in the pre-test and post-test for the experimental group that was subjected to the smart learning system for colors discrimination in favor of the post-test.

To test the validity of this hypothesis, the researcher calculated the mean of students' degrees, the standard deviation and significance value in the pre and post-tests for the experimental group. The researcher used the Wilcoxon test as shown in table 2.

Table 2: The Wilcoxon value by significance of Z for the mean degrees of the experimental group for the pre and post tests

Group	Mean Degrees	N	Standard Deviation	Z	Sig
Pre-test	13.60	10	3.89	2.816	0.000
Post-test	32		5.24		

The previous table shows that there are statistically significant differences between the mean of students' degrees at the 0.05 level in favor of the post-test, where the calculated significance value was 0.000, which is a statistically significant value at the significance level of 0.05, indicating the effectiveness of the smart learning system for colors discrimination.

II. Second Hypothesis

There are statistically significant differences between the mean of students' degrees in the post-test for each of the two groups (the experimental group subjected to the smart learning system and the control group not subjected to the smart learning system) in favor of the experimental group that was subjected to the smart learning system.

To test the validity of this hypothesis, the researcher calculated the mean of students' degrees, the standard deviation and significance value in the post-tests for the two groups (experimental and control). The researcher used the Wilcoxon test as shown in table 3.

Table 3: The Wilcoxon value by significance of Z for the mean degrees of the experimental and control group for post-test

Group	Mean Degrees	N	Standard Deviation	Z	Sig.
Experimental Group	32	10	5.24	2.805	0.000
Control Group	14		2.44		

The previous table shows that there are statistically significant differences between the mean of students' degrees in the post-test for each of the two groups (the experimental group subjected to the smart learning system and the control group not subjected to the smart learning system) in favor of the experimental group that was subjected to the smart learning system, where the calculated significance value was 0.000, which is a statistically significant value at the significance level of 0.05 which indicates the effectiveness of the smart learning system for colors discrimination.

5.4. - Discussion and Interpretation of the Results:

- By testing the first hypothesis, the results indicate that there were statistically significant differences at level 0.05 between the mean of student's degrees for the experimental group that were subjected to the learning system in the pre and post measurements of the test in favor of the post measurement.
- By testing the second hypothesis, the results indicate that there were no statistically significant differences at level 0.05 between the mean of students' degrees in pre and post measurements of the test of the control group that was handled in the traditional method.
- By testing the third hypothesis, the results indicate that there were statistically significant differences at level 0.05 between the mean of students' degrees in the post-measurement of the test for each of the two groups (experimental and control) in favor of the experimental group that was subjected to the smart educational system.

5.5. Colour and its Gradients Recognition Test Results

Evaluation of retrieval performance is a crucial problem in content-based image retrieval. Many different methods for measuring the performance of a system have been created and used by researchers. The most common evaluation measures used in CBIR are precision, recall and F – measure which are defined as [21]:

$$\text{Precision} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images retrieved}}$$

$$\text{Recall} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images in database}}$$

$$\text{F_measure} = \frac{\text{Precision} * \text{Recall}}{\text{TPrecision} + \text{Recall}}$$

Previous metrics were used in the proposed system in the identification test of color and its gradients. The test was conducted on 50 color images. Figures (7:9) are shown recall, precision, and F – measure curves for content-based colour image retrieval.

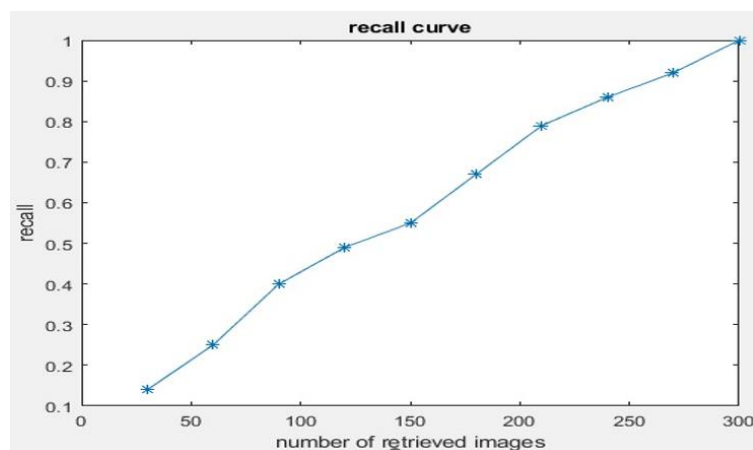


Figure 7: Recall Curve for Color Image Retrieval

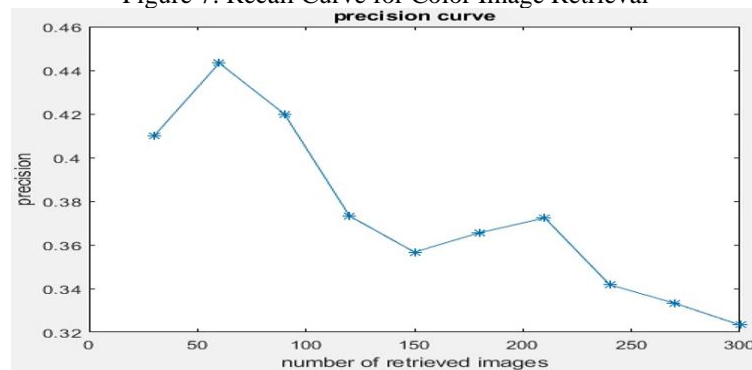


Figure 8: Precision Curve for Color Image Retrieval

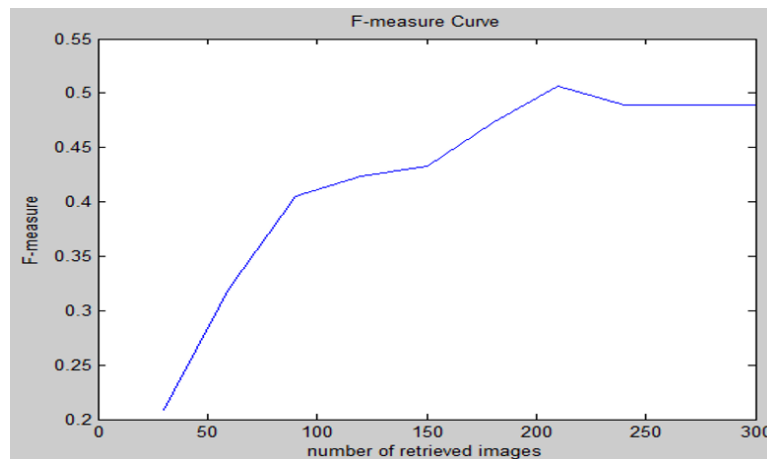


Figure 9: F-measure Curve for Color Image Retrieval

It is therefore clear that the proposed system achieves a high efficiency in identifying colors.

5.6. Diagnosing Anaemia Type Results

For the testing stage (105) analysis samples of patients with the types of anaemia mentioned earlier were provided. The measures that are used in the diagnosis of anaemia are Precision, Sensitivity, Specificity, and F-measure. These measures are defined as [22].

$$\text{Precision (P)} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Positives (FP)}}, 0 \leq P \leq 1$$

$$\text{Sensitivity (S)} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}}, 0 \leq S \leq 1$$

$$\text{Specificity} = \frac{\text{True Negatives (TN)}}{\text{True Negatives (TN)} + \text{False Positives (FP)}}$$

Where:

- TP: test result that correctly indicates the presence of a condition or characteristic.
- FP: test result that wrongly indicates that a particular condition or attribute is present.
- FN: test result that wrongly indicates that a particular condition or attribute is absent.
- TN: test result that correctly indicates the absence of a condition or characteristic.

$$\text{Accuracy} = \frac{\text{um of correct classifications}}{\text{Total number of classifications}} = 0.95$$

$$\text{Error Rate} = 1 - \text{Accuracy} = 0.05$$

Table 4: Display Confusion Matrix for some Types of Anemia

Type	Num	Aplastic	Sickle Cell	Hemolysis	Bone Marrow	Iron Deficiency	Vitamin Deficiency	Normal
Aplastic	15	4	0	1	0	0	0	0
Sickle Cell	15	0	3	0	0	0	0	0
Hemolysis	15	0	0	1	0	0	0	0
Bone Marrow	15	0	1	0	3	0	0	1
Iron Deficiency	15	1	0	0	0	4	0	0

Table 4: Display Confusion Matrix for some Types of Anemia

Type	Num	Aplastic	Sickle Cell	Hemolysis	Bone Marrow	Iron Deficiency	Vitamin Deficiency	Normal
Vitamin Deficiency	15	0	0	0	1	0	3	0
Normal	15	0	0	0	0	0	0	4

Table 5: Testing Result

Disease Type	TP	TN	FP	FN	Precision	Sensitivity	Specificity	F-measure
Aplastic	4	10	1	0	0.8	1	0.91	0.81
Sickle Cell	3	12	0	0	1	1	1	1
Hemolysis	1	14	0	0	1	1	1	1
Bone Marrow disease	3	12	0	2	1	0.6	1	0.69
Iron Deficiency	4	10	1	0	0.8	1	0.91	0.81
Vitamin deficiency	3	12	0	1	1	0.75	1	0.82
Normal	4	11	0	0	1	1	1	1
Aver					0.94	0.91	0.97	0.88

This means that the proposed system can diagnose anemia diseases with satisfactory results. With an accuracy of up to 95%.

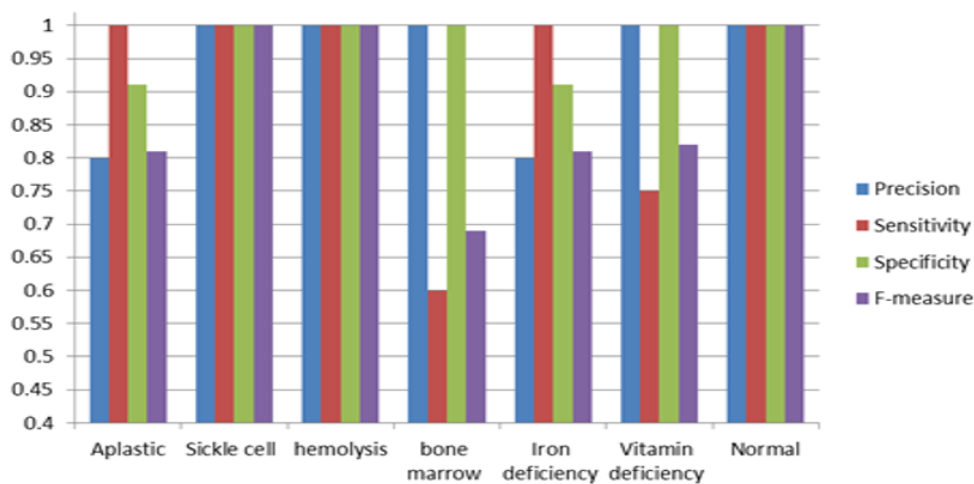


Figure 10: Precision, Sensitivity, Specificity and F-measure for Classification Diagnosing some Anemia Diseases.

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