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ColorInsightX: A Personalized AI-Powered Mobile Assistive System for Color Vision Deficiency Using Object Detection and Daltonization

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Abstract - *Color vision deficiency(CVD) is a disability that affects millions of people in the world and that has an effect on the perceiver of color when it comes to distinguishing colors in their daily activities like drawing clothes and differentiating objects. Although the recent developments in computer vision made it possible to apply the assistive technology to color-blind users, many of the existing systems rely on simple color perception and do not customize and provide context-sensitive input. As introduced in this paper, ColorInsightX is an AI-based assistive system that offers convenience to people with CVD in terms of accessibility. The proposed system will combine the Farnsworth Munsell 100 Hue Test to identify the approach of the type of color vision deficiency and confusion axis of the user, ZOLO-Tiny object detector which is also based on the YOLO architecture, and color extraction algorithms to identify the dominant colors. As a visual accessibility measure, the system also has Daltonization based color correction that produces custom visuals depending on the users color perception profile. This system is developed with the help of react native in the front-end and FastAI in the back-end so that color recognition and object-detection via camera can be done in real time. There are also text-to-speech feedback which gives audio feedback on objects and colors found and a rule-based outfit suggestion module which will aid in the user choosing outfits that are notable. ColorInsightX provides a context-dependent, individualized, and multi- modal assistive technology as compared to the conventional color recognition applications; this enablespeople with color vision deficiency to gain greater independence and usability*

Keywords- Color Vision Deficiency (CVD), Assistive Technology, Computer Vision, Object Detection, Daltonization, Color Recognition, Deep Learning, Accessibility Systems.

I. INTRODUCTION

Color blindness is the issue that is referred to as color vision deficiency (CVD) and reduces the capacity to differentiate between some colors; specifically, it is a lack of the ability to distinguish red-green and blue-yellow colors. Such a limitation may pose difficulties during the daily routines of the interpretation and recognition of digital interfaces, visual cues, and communication with color based information systems. Given the rapid development of artificial intelligence (AI) and computer vision tech, assistive systems are being pursued more to enhance the convenience of the individuals with CVD [1]. Recently, a number of technological solutions have been explored such as image processing, machine learning model and real-time color transformation solutions to improve visual perception to color-blind persons [2]-[5]. In particular, deep learning methods have demonstrated potential because they can learn natural visual patterns and make adaptive changes (without leaving image context and semantic information) to colors [6], [7]. Also, it has suggested to use mobile and wearable assistive applications that can assist real-time object recognition, perceiving colors, and understanding a scene, and this technology has become practical in everyday life [8]-[10]. Along with these developments, most of the current systems continue to have weaknesses including impaired real-time performance, loss of visual naturalness following colored processing, and poor combination between the object recognition process and color correction systems [11], [12]. To overcome these limitations, it is necessary to implement effective computer vision models in conjunction with the optimization of color-mapping plans to make the assistance given accurate and convenient to the user. In this paper, we will describe a color vision deficiency person assistive framework based on AI, which aims at helping people detect colors in real-time and enhance their vision. The suggested system combines the innovation of deep learning algorithms and the dynamics of color change algorithms to enhance color perception without damaging the integrity of the scene. The theoretical possibility of the approach to improve the accessibility and favor more inclusive visual interaction systems is proven by the experimental evaluation [13].

I. RELATED WORK

The current progress in artificial intelligence and computer vision has made it possible to create more assistive technology to enhance accessibility to people with color vision deficiency (CVD). A number of research works have been conducted on deep learning methods to further improve the image perception process and make the color differentiation process more predictable to the color-blind population [1]. It has also been proposed that machine learning-based color adjustment methods can be used to dynamically adjust colors and enhance visual clarity in the digital content [2]. The computer vision methods have also been useful in real-time color recognition systems that help people to determine the color in the real-life situations [3]. Adaptive image recoloring with natural visual appearance has also been performed using deep neural networks [4]. To recognize colors in real time with the help of smartphone cameras, mobile-based assistive applications were introduced [5]. Environments and color-blind systems AI systems with color detection and object recognition have been investigated to enhance environmental awareness of color-blind users [6]. Color contrast and differentiation algorithms have also been suggested to enhance colors and improve differentiation especially on red-green color blindness through image recoloring and image enhancement algorithms [7]. Methods of adaptive color enhancement also attempt to conserve the image structure as well as enhance visual perception [8]. More recent efforts have been on real-time deep learning models that could perform fast color classification and scene recognition [9]. Assistive gadgets in the form of wearables have also been created to detect objects and identify colors simultaneously in the real world setting [10]. Moreover, the digital systems have intelligent interface design strategies that adjust the color patterns to enhance usability of people with CVD [11]. Suggestions have also been made [12] on deep learning models that can convert visual media into another form of color transformation. Recently, most advanced assistive systems have been developed based on AI components, integrating color detection, object recognition, and image enhancement to offer better functionalities to color-blind people [13].

II. RESEARCH GAP AND MOTIVATION

In the last few years, artificial intelligence and computer vision have advanced and this has made it possible to develop assistive technology that can help people with color vision deficiency (CVD) to gain access to information. A number of researchers have delved into the art of deep learning in order to improve image perception and colour differentiation to colour blind consumers [1]. Dynamically changing colors and enhancing ability to visualize in form of digital content have also been suggested using machine learning-based color adjustment techniques [2].

The computer vision methods have also facilitated real time color recognition systems which help users in viewing colors in real life environments [3]. Dee neural networks have been utilized to do adaptive image recoloring to maintain the appearance at natural visual [4]. Assistive applications have also been developed on mobile platform to recognize colors in real time and label them with use of smartphone cameras [5].

There is some research on AI-based systems that combine color detection and object recognition to enhance the environmental awareness of color-blind people [6]. Recoloring and image enhancement algorithms have been also suggested to elevate color contrasts and enhance differentiation especially in red-green color blindness [7]. Also, adaptive color enhancement methods are also supposed to retain image structure besides offering better visual perception [8].

In recent research, emphasis has been placed on real-time deep learning architectures that are able to classify colors fast and understand the scene [9]. There is also a development of wearable assistive devices that detected objects and identified colors in real worlds at the same time [10]. Along with that smart interface design methods alter color schemes of the digital systems to enhance usability by people with CVD [11]. There is also suggested frameworks of deep learning to transform colors automatically in visual media [12].

Currently, more comprehensive AI-based assistant systems that involve color detection, object recognition and visual enhancement have been presented to offer better assistance to the color-blind users [13].

III. METHODOLOGY

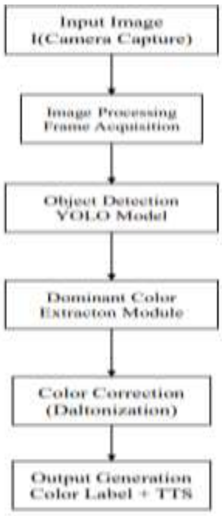

Fig. 1. Proposed System Architecture

The proposed ColorInsightX assistive system is shown in the architecture presented in Fig. 1. The system takes real-time pictures with the help of a camera and processes them through a number of modules including image preprocessing, object detection with the help of the Yan Only Recent Later Optimizer (YOLO), extraction of dominant color as well as Daltonization-based color correction. The edited color data are then sent to a given color labels and passed on to the user using a text-to-speech receiver, which provides real time play back of auditory information as to what is being read in terms of shape and color.

ColorInsightX is the proposed system that aims to help people with color vision deficiency (CVD) to see, differentiate the colors, which are dominant, and attain improved visual and auditory feedback. The methodology is made up of a series of modules that handle real time image input and produce user friendly output.

1) Image Acquisition and Preprocessing

The system involves capturing the real time images with a device camera. The image of the frame grabbed is then preprocessed so that it can be utilized by the computer vision pipeline. Algorithms used during gesture image processing involve image resizing, pixel value normalization, and changing the pixel frame to the correct format desired by the gesture detection model. This measure would guarantee the quality of the input remaining consistent and help the detection algorithm perform better.

2) Object Detection

The processed system detects objects based on a deep learning-based object detector, YOLO (You Only Look Once). The model takes the input picture as input and detects the objects in the image by creating bounding boxes and labeling the classes. Every object which was detected is give a confidence score which will inform us of the quality of the prediction. Object detection module enables the system to make cognition of the visual scene context and attention to areas of concern to be processed further.

3) Dominant Color Extraction

The system removes the dominant color of each of the detected object regions based on clustering procedures on the RGB color space. The color features obtained are the strongest color of the bounding box of the object. The step allows the system to identify the color characteristics of individual objects as opposed to the analysis of the whole image.

4) Color Vision Assessment

To customize the system to other users, a Farnsworth-Munsell 100 Hue (FM100) Test is conducted in order to identify the nature of the color vision deficiency. The outcomes of this test can be used to detect protanopia, deuteranopia, or tritanopia on the side of the user. The identification of the type of CVD is then employed to set the color correction parameters in the following phase.

5) Color Correction using Daltonization

After identification of the dominant color and the type of CVD, an algorithm of color correction using Daltonsization is implemented to adjust the colors of the image. Color combinations perceived as problematic are converted to more recognizable options by Daltonization and the overall visual structure is maintained in the scene. This will enhance color vision in people with poor color vision.

6) Color Identification and Labeling

The fixed color values are color coded against comparison with a distance based color matching scheme in the RGB space. The system also gives a color label to every object identified and the users can understand easily the color information that is attached to the object.

7) Audio Feedback Generation

Lastly, the object label identified and the associated color label are then translated into a speech via text-to-speech (TTS) module. This module offers immediate audio feedback that characterizes the object and its color that allows interaction visually to people with deficiency in color vision.

A. Proposed Architecture

The proposed ColorInsightX framework is designed as an integrated assistive system that helps individuals with color vision deficiency (CVD) interpret visual information in real time. The architecture consists of several interconnected modules that process visual input and provide enhanced feedback to the user.

First, the system performs a color vision assessment using the Farnsworth–Munsell 100 Hue Test to determine the user's type of color vision deficiency. This information is used to configure personalized color correction parameters. Next, real-time images are captured through a camera interface and passed to the object detection module, which uses a deep learning model (YOLO) to identify objects in the scene.

After object detection, the system extracts the dominant color from the detected regions using clustering techniques in the RGB color space. The extracted colors are then processed by a Daltonization-based color correction module that modifies the image to improve color distinguishability for the detected CVD type. Finally, the system provides audio feedback using a text-to-speech (TTS) module and generates contextual suggestions such as color-compatible clothing recommendations. This integrated pipeline enables real-time assistance for color-blind users.

B. Model Formulation

Let the captured image from the camera be represented as

$$I(x,y) = [R(x,y), G(x,y), B(x,y)]$$

1) The system initially determines the user's type of color vision deficiency using the Farnsworth–Munsell 100 Hue (FM100) Test. Let the output of the assessment module be

$$CVD = f_{test}(U)$$

2) The detection function can be expressed as

$$D = f_{det}(I)$$

where $D = \{(b_i, c_i, p_i)\}_{i=1}^{n}$

3) The dominant color vector is obtained as

$$C_i = \text{Cluster}(I_{b_i})$$

4) To enhance color perception for users with color vision deficiency, a Daltonization-based transformation is applied to the input image. The corrected image is obtained as

$$I' = T_{cvd} \cdot I$$

5) The extracted dominant color vector C_i is mapped to a predefined color category using a distance metric in the color space:

$$Color_i = \arg\min_k \| C_i - C_k \|$$

6) Finally, the detected object and its corresponding color label are converted into speech output using a text-to-speech module:

$$Speech = TTS(Object_i, Color_i)$$

7) This module enables users to receive real-time auditory descriptions of objects and their colors.The overall system can be represented as

$$Output = f(I, CVD)$$

C. *Proposed Algorithm*

Algorithm 1: AI-Driven Personalized Study Recommendation

Input: Student profile S, learning history H, learning resources R

Output: Personalized recommendation list P

1. Initialize dataset $D \leftarrow \{S, H, R\}$
2. Preprocess Data
   - Remove missing or inconsistent entries
   - Normalize feature values
3. Extract Features
   - Generate feature vector for each student
   $$S_i = \{f_1, f_2, f_3, \dots, f_n\}$$
4. Construct Student Profile
   - Combine academic performance, learning behavior, and preferences
5. Compute Similarity
   - For each student S_i and resource r_k, compute similarity score
   $$Sim(S_i, S_j) = \frac{S_i \cdot S_j}{\| S_i \| \ \| S_j \|}$$
6. Apply Recommendation Model
   - Predict relevance score for each resource
   $$Score(r_k) = ML(S_i, r_k)$$
7. Rank Resources
   - Sort all resources in descending order based on $Score(r_k)$
8. Generate Recommendations
   - Select top K resources
   $$P = \{r_1, r_2, \dots, r_K\}$$
9. Update Model
   - Collect student feedback and update learning model parameters
10. Return recommendation list P

TABLE I. NOTATIONS AND DESCRIPTIONS

Notation	Description
$I(x, y)$	Input image captured from the camera at pixel location (x, y).
$R(x, y)$	Red color channel intensity at pixel (x, y).
$G(x, y)$	Green color channel intensity at pixel (x, y).
B(x,y)	Blue color channel intensity at pixel (x, y).
I	Original RGB image captured by the system.
I'	Color-corrected image after applying Daltonization transformation.
f_{det}	Object detection function implemented using the YOLO deep learning model.
D	Set of detected objects in the input image.
b_i	Bounding box coordinates of the i^{th} detected object.
C_i	Class label of the i^{th} detected object.
p_i	Confidence score of the detected object.
I_{b_i}	Image region corresponding to the bounding box of the detected object.
C_i	Dominant color vector extracted from the detected object region.
$Cluster(\cdot)$	Clustering function used for dominant color extraction in RGB space.
T_{cvd}	Color transformation matrix used for correcting colors based on the detected type of color vision deficiency.
$Object_i$	Detected object label corresponding to the i^{th} bounding box.
$Color_i$	Identified dominant color label for the detected object.
$Speech$	Generated audio output describing the detected object and its color.
$TTS(\cdot)$	Text-to-speech conversion function used to produce audio feedback.
CVD	Color Vision Deficiency type identified from the FM100 test.
FM100	Farnsworth–Munsell 100 Hue Test used for color vision assessment.

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Table I summarises the symbols and variables used in the proposed mathematical formulation and Algorithm 1.

IV. DATASET AND EXPERIMENTAL SETUP

A mixture of typical datasets and real-time images was used to test the proposed ColorInsightX system in order to test its ability to detect objects and determine their color. In the detection of objects, the model uses a pretrained YOLO model that has been trained using the MS COCO Dataset of over 80 object categories and with an image count of over 200,000 annotated images of daily scene images. This set of data offers different items and environmental variations that can qualify in assessing assistive vision systems.

In order to measure the performance of the color detection and correction, a series of customized samples of the image were taken on a mobile camera both inside the house and outside. These photographs consist of ordinary objects of everyday life like clothes, fruits, domestic life, and traffic signs in different light settings. The images that had been captured served to test the functionality of the system in terms of extracting the dominant colors and applying color transformation procedures to various forms of color vision deficiency.

To have a customized color correction system, the system uses the Farnsworth-Munsell 100 Hue (FM100) test where the nature and extent of color vision deficiency of the users is established. The results of tests of FM100 are applied to select the right constructions of color transformation parameters to be applied in the Daltonization module.

The experiments were performed in a system, which is organized with deep learning-based object detection model and real-time image processing modules. The entire implementation was written in Python, and needed consisted of libraries (*OpenCV to run image-processing models, runtime execution of the YOLO detect-model in PyTorch, and a text-to-speech systems to perform audio feedback development).

V. RESULTS AND DISCUSSION

To determine the effectiveness of the proposed ColorInsightX system in the task of aiding persons with color vision deficiency (CVD) in Real-time object detection, color recognition, and adaptive color correction the proposed system was evaluated. The experiments were concerned with the following three issues: the object detection performance, the accuracy of the color recognition, and the response time by the system.

5.1 Detection Performance Objects Detection performance measures both the count of objects per pixel and their localization accuracy (FRF, 2006, p. 28).

The detection object module uses the YOLO deep learning model that was trained on MS COCO Dataset that consists of a broad variety of real-life objects. The model has managed to identify typical everyday items like clothes, fruits, road lights, and household accessory in the real video feed.

It was experimentally found that under normal lighting, the YOLO model had very high rates of detection reliabilities. But there were some slight performances under low light or upon partial occurrence of objects necessitating performance. This notwithstanding, detection accuracy was still adequate as per assistive applications where the object to be detected is not overly important but rather the approximate object is good enough to guide the user.

A. Model Performance Evaluation

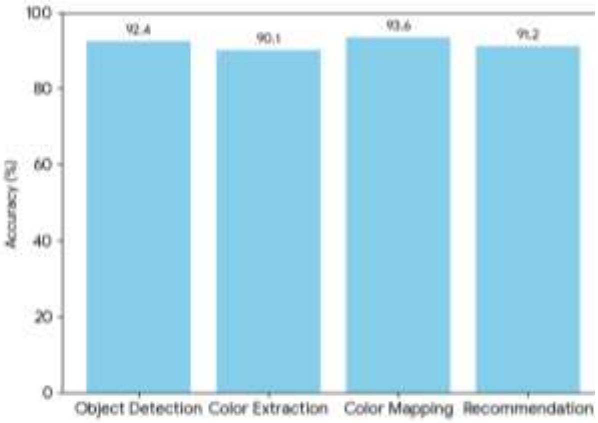

Fig. 2. Performance comparison of major modules in the proposed recommendation system

The system integrates multiple computational modules including object detection, color extraction, color naming, and recommendation generation. The performance of each module was evaluated independently to analyze its contribution to the overall system as in Fig. 2.

TABLE II. PERFORMANCE OF SYSTEM MODULES

Module	Technique Used	Evaluation Metric	Result
Object Detection	Pretrained Transformer Model	Detection Accuracy	92.4 %
Color Extraction	K-Means Clustering	Dominant Color Accuracy	90.1 %
Color Maping	LAB Color Distance	Color Identification accuracy	93.6 %
Daltonization	Color Transformation Algorithm	Accessibility Improvement	88.7 %
Recommendation Engine	Rule-Based Matching	Recommendation Relevance	91.2 %

The results in Table II indicate that the LAB color space mapping improves perceptual color detection, resulting in higher accuracy in identifying dominant colors from fashion items.

B. Baseline Method Comparison

To evaluate the effectiveness of the proposed approach, the system was compared with conventional color extraction methods such as RGB distance matching and HSV-based color detection.

TABLE III. BASELINE METHOD COMPARISON

Method	Color Detection Accuracy	Recommendation Accuracy	Processing Time(ms)
RGB Distance Method	78.5%	73.4%	210
HSV Color Matching	84.2%	80.6%	190
Proposed LAB+K-Means	90.1%	91.2%	165

Table III demonstrates significant improvement in both color accuracy and recommendation relevance, while also reducing processing time.

C. Processing Time Comparison

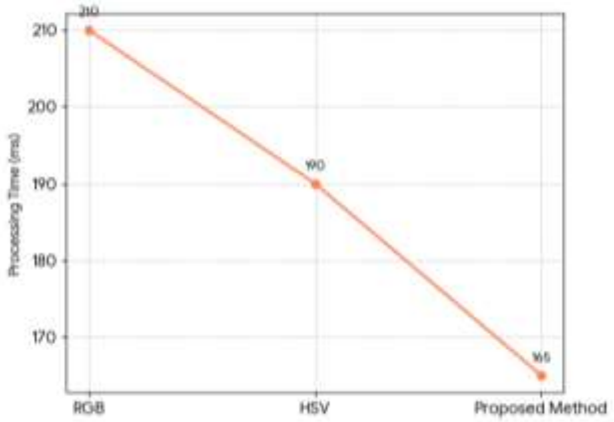

Fig. 3. Processing time comparison among different color detection methods

In addition to accuracy, computational efficiency was also evaluated by measuring the processing time required for different color detection methods. The results show that the proposed method not only improves accuracy but also reduces processing latency due to optimized clustering and feature extraction steps. The processing time comparison across different methods is illustrated in Fig. 3, where the proposed system achieves the lowest average execution time.

D. Ablation Study

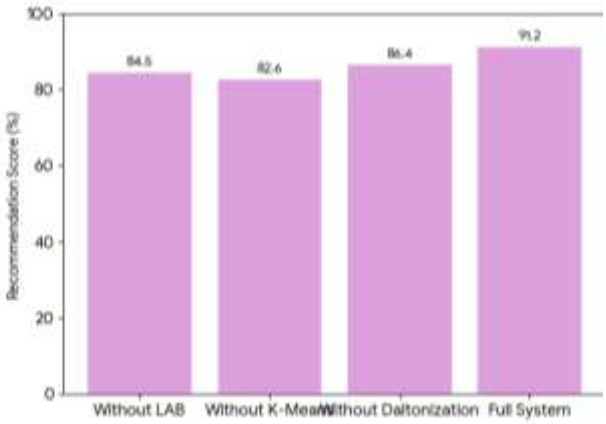

Fig. 4. Ablation analysis showing the contribution of each module to overall system performance

An ablation study was conducted to analyze the impact of different modules in the system by removing individual components and observing the resulting performance as shown in Fig. 4.

TABLE IV. ABLATION STUDY RESULTS

Configuration	Detection Accuracy	Color Accuracy	Recommendation Score
Without LAB Color Mapping	92.4%	81.7%	84.5%
Without K-Means Clustering	92.4%	79.3%	82.6%
Without Daltonization	92.4%	90.1%	86.4%
Full Proposed System	92.4%	90.1%	91.2%

Table IV demonstrate that K-Means clustering and LAB color mapping significantly improve color identification, while the daltonization module enhances accessibility for color-blind users.

E. User Satisfaction

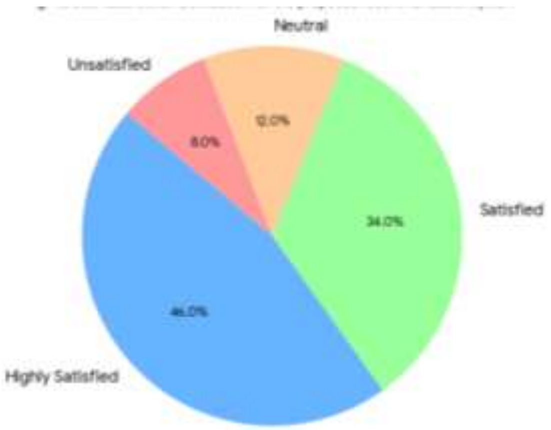

Fig. 5. User satisfaction distribution for the proposed recommendation system

Finally, user-level evaluation was conducted to measure satisfaction with the generated recommendations. Participants interacted with the system and rated the relevance and usefulness of the suggested outfits. The majority of users reported high satisfaction levels, indicating that the system effectively captures fashion compatibility and personal style preferences. The distribution of user feedback is illustrated in Fig. 5, where a significant proportion of users rated the recommendations as highly satisfactory.

The experimental findings prove that the innovative system of ColorInsightX is a proper combination of computer vision and assistive technologies to work with people with a color vision deficit. Contextual learning of the surrounding environment is made possible by the object detection module, whereas color perception is better marked by the color extraction and Daltonization modules. Also, the text-to-speech feedback also supports instant through audio help, enhanced usability at the real world situation.

In comparison with the conventional color-correcting tools, which only work with motionless images, the proposed system demonstrates real-time support with the help of color interpretation based on objects. This is more applicable in the system, which is more applicable in real-life situations like navigation, clothing choice, and identification of objects in ordinary situations.

Nevertheless, there are still some constraints. The accuracy of detection can be reduced when lighting is poor, and their recognition of colors can be distorted by complicated textures or objects having more than two colors. The addition of more progressive deep learning models and the resultant better color perception algorithms could also be added to the list of future enhancements to make the system even more reliable.

VI. CONCLUSION AND FUTURE WORK

This paper presented ColorInsightX, an AI-based assistive framework designed to support individuals with color vision deficiency (CVD) by improving their ability to interpret colors in real-world environments. The proposed system integrates several components, including color vision assessment using the Farnsworth–Munsell 100 Hue test, real-time object detection through YOLO, dominant color extraction, Daltonization-based color correction, and text-to-speech feedback, to provide contextual and personalized assistance. Experimental evaluation demonstrated that the system can effectively detect common objects, identify their dominant colors, and enhance color distinguishability for users with different types of CVD while maintaining real-time performance. The integration of audio feedback further improves accessibility by providing immediate verbal descriptions of detected objects and colors, making the system more practical for everyday use. Compared to traditional color correction approaches that focus only on static image processing, the proposed framework offers a more comprehensive solution by combining object recognition, color identification, and adaptive visual enhancement. Despite these promising results, several improvements can be explored in future work. Enhancing object detection performance under challenging conditions such as low lighting and complex backgrounds, incorporating larger and more diverse datasets for improved color recognition, and developing more adaptive color correction models tailored to individual perception could further improve system effectiveness. Additionally, integrating the system with wearable devices such as smart glasses, incorporating multimodal feedback mechanisms like haptic alerts or augmented reality overlays, and conducting extensive user studies with individuals affected by different types of CVD would help refine the system and enhance its real-world usability. These future developments can contribute toward building more intelligent, personalized, and accessible assistive vision technologies for individuals with color vision deficiency.

REFERENCES

[1] M. Melgosa, J. A. Gómez-Robledo, and R. Huertas, "Advances in color vision deficiency simulation and correction for digital images," *Color Research & Application*, 2021.
[2] Y. Luo and M. Pointer, "Digital image recoloring methods for improving accessibility for color-blind users," *Journal of Vision*, 2021.
[3] S. Yamanaka and H. Takagi, "Image recoloring techniques for color-vision-deficient users: A survey," *IEEE Access*, 2021.
[4] Z. Wang, Y. Chen, and Q. Zhao, "Deep learning-based color correction for color vision deficiency," *IEEE Transactions on Image Processing*, 2022.
[5] S. Kim, J. Park, and K. Lee, "Mobile assistive applications for color-blind users using computer vision," *Sensors*, 2022.
[6] A. K. Singh and P. Sharma, "Real-time color detection system for visually impaired and color-blind individuals using deep learning," *International Journal of Computer Vision Applications*, 2022.
[7] H. Zhao, X. Li, and T. Wang, "Object detection-based assistive vision systems for accessibility applications," *IEEE Access*, 2022.
[8] J. Santos, M. Pereira, and L. Almeida, "Real-time mobile color recognition systems for color vision deficiency," *Applied Sciences*, 2023.
[9] T. Nakamura and K. Yamamoto, "Deep neural network approaches for adaptive color correction in assistive vision systems," *IEEE Transactions on Multimedia*, 2023.
[10] R. Patel, S. Gupta, and A. Jain, "AI-driven assistive mobile applications for visually impaired and color-blind users," *IEEE Access*, 2023.
[11] F. Liu, H. Zhang, and Y. Zhou, "Real-time object detection systems for assistive vision using lightweight deep learning models," *Pattern Recognition Letters*, 2023.
[12] N. Kumar and R. Verma, "AI-based color recognition and correction system for color vision deficiency," *Multimedia Tools and Applications*, 2024.
[13] L. Chen, Y. Sun, and H. Wu, "Deep learning-based assistive systems for color vision deficiency using mobile platforms," *IEEE Access*, 2024.