IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Assistive Technologies for Color Deficient Individuals: A Review

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Abstract— Color blindness is a type of disease in which a person cannot differentiate between some colors like red-green blue-yellow. A color blindness test helps to detect the correct type of color blindness. If you cannot pass the test you suffer from color vision deficiency. It is also called color blindness. Most color blindness tests can specify that children who have problems identifying colors such as red-green and blue-yellow can be treated easily if they are below 5 years. This could be A characteristic in specific activities in school and at home. Color blindness is a very common condition: out of 10 people one color blindness patient has some level of color blindness of visual impact, however there are many tasks in daily life that require the ability of color recognition and visual discriminate. Color blindness cannot be cured. Today, technology gets up with solutions to help individuals with color blindness to see the image and distinguish between the different yet the most basic colors using some algorithms.

Keywords—Color Vision Deficiency, Color Correction, Recoloring, Accessibility.

Introduction

Color vision deficiency (CVD), commonly known as color blindness, is a visual impairment affecting a significant portion of the population, with approximately 1 in 12 men and 1 in 200 women worldwide being affected. Individuals with CVD experience difficulty in distinguishing between certain colors, particularly red, green, or blue lights. While most people with color blindness can see objects as clearly as others, they struggle with accurate color perception due to a deficiency in one or more types of cones, the photoreceptor cells responsible for color vision.

The causes of color blindness vary, with the condition often being genetic and inherited from one's mother. Additionally, certain diseases such as diabetes and multiple sclerosis, as well as factors like aging and medication, can lead to acquired color vision deficiency. There are three main types of color blindness based on the cones affected: monochromacy, dichromacy, and anomalous trichromacy. Dichromacy, the focus of this paper, encompasses three subtypes: protanopia (missing L-cones), deuteranopia (missing M-cones), and tritanopia (missing S-cones).

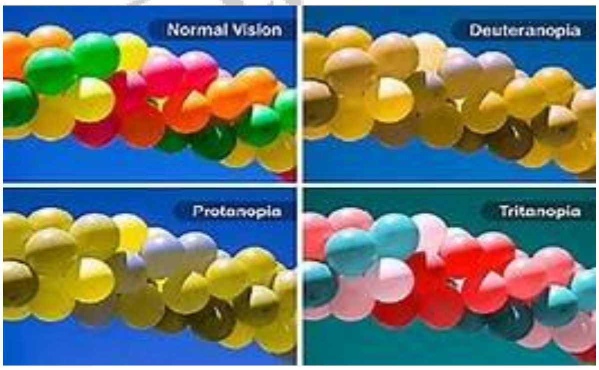


FIGURE 1: Types of color vision deficiency

Despite the lack of a cure for color blindness, advancements in technology have enabled the development of vision aid kits to assist color deficient individuals in recognizing and differentiating colors. Mobile applications utilizing various algorithms have emerged as practical solutions to help individuals with color blindness perceive colors more accurately.

TABLE I

SUMMARIZES THE DIFFERENT COLOR-BLIND TYPES, THEIR CAUSES AND EFFECTS.

Color Blind Type	Cause	Effect
Monochromacy	No cones or only one cone type exists	Inability to see any color.
Dichromacy	One cone type is missing, three types: 1)Protonopia: Lcones are missing. 2)Deuteranopia: M-cones are missing. 3)Tritanopia:S cones are missing	Inability to see the color corresponding to the missed cone type. Inability to see red color(red blind) Inability to see green color(green blind). Inability to see blue color(blue blind).
Anomalous Trichromacy	All cone types exists but they are not aligned, three types: 1)Protanomaly: Lcones are not aligned. 2)Deuteranomaly: M-cones are not aligned. 3)Tritanomaly: Scones are not aligned.	Reduction in sensitivity to a particular color. Less sensitivity to red color(red weak). Less sensitivity to green color(green weak). Less sensitivity to blue color(blue weak).

Related Work

Recent advancements in palette-based image recoloring methods have been shaped by user expectations. [1] introduced a method incorporating observed color separation priors derived from a user study. Distilling key expectations (R1-R5) from 30 participants, including the need for distinct palette colors and faithful adjustments, the authors identified three foundational color separation priors: sparsity, smoothness, and unity. These ensure minimal reliance on palette colors, coherence in color separation, and balanced representation of pixel colors, respectively. While promising, challenges in complexity and parameter optimization remain. Nonetheless, this approach holds potential for enhancing both fidelity and user experience in digital image manipulation.

The color reproduction method presented in this study [2] offers advantages in optimizing images using detail and naturalness criteria. By prioritizing these criteria, the method enhances image quality and ensures a visually appealing outcome. Additionally, the approach caters to individuals with color deficiencies, addressing their specific needs while maintaining natural color perception for standard viewers. However, limitations may arise in the method's adaptability to diverse image types and viewer preferences, as well as potential challenges in subjective evaluation and generalization across different contexts. Despite these considerations, the method represents a significant step toward improving image optimization techniques with targeted criteria.

The Android-based mobile application [3] assists color-blind individuals by recognizing colors through color segmentation and a thresholding algorithm. Users input their Ishihara Test answers and receive real-time filters and test results, along with informational features on color blindness. The app calculates test results, recommends filters based on color-blindness type, and applies real-time camera segmentation with selected filters for immediate feedback. This approach offers personalized color recognition assistance, but its effectiveness relies on algorithm precision and user input accuracy, with a limited focus on broader aspects of color-blindness management.

This work [4] presents two algorithms for designing transmittance filters to enhance camera colorimetry. It aims to satisfy the Luther condition by finding filters that best align with camera sensitivities. Data-driven filter optimization, corrects color based on measured lights and surfaces. While the default optimization formulation yields non-smooth filters with low light transmission, constraints are introduced to ensure filter smoothness and minimum light transmission. The optimization problem is formulated to find the filter coefficients that minimize the difference between stacked matrices of measured and target color responses, subject to linear basis constraints and bounds on transmittance. Quadratic programming is employed to solve this optimization problem efficiently.

The article [5] suggests a novel degree-adaptable recoloring algorithm proposed to address color vision deficiency (CVD) by simultaneously considering naturalness preservation and contrast enhancement. This method introduces an innovative approach to automatically balance the trade-off between contrast enhancement and naturalness preservation for individual colors, resulting in optimal compensation effects tailored to the degree of CVD. To evaluate its effectiveness, a subjective evaluation experiment involving 14 volunteers with varying degrees of CVD is conducted. This experiment compares the compensation effects of existing recoloring algorithms with the proposed personalized recoloring algorithm. Additionally, it includes a comparison between CVD degrees measured by the computational model and traditional clinical CVD tests. To facilitate practical use, an application for CVD users is provided, enabling them to select the appropriate CVD degree for achieving the best recoloring result tailored to their individual visual impairments.

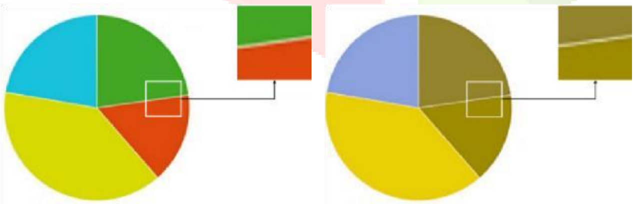
The Colorblind Pal app [6] offers real-time color correction for individuals with color vision deficiencies, providing personalized adjustments based on the user's specific type and degree of color blindness. Its intuitive interface and compatibility with various devices enhance accessibility, while features such as color identification and customization options enhance usability. However, reliance on technology may introduce challenges related to device compatibility and technical issues, and the app's effectiveness may vary in scenarios where accurate color identification is critical. Additionally, users with severe forms of CVD may encounter limitations in accurately representing colors, highlighting the importance of ongoing development and user awareness.

The Colorblind Assistant app [7] offers several advantages in aiding individuals with color vision deficiencies (CVD). Its real-time color correction and identification features provide practical assistance in various tasks, enhancing accessibility and usability for users with CVD. The app's customizable settings and compatibility with different devices cater to individual preferences and needs, while its intuitive interface ensures ease of use for a wide range of users. However, the app's effectiveness may be influenced by factors such as lighting conditions and screen quality, potentially affecting accuracy in color identification. Additionally, reliance on technology may introduce challenges related to device compatibility and potential technical issues. While the app aims to address the needs of individuals with CVD, its effectiveness in accurately representing colors for users with severe forms of color blindness may vary, requiring ongoing development and user awareness to address potential limitations. Last updated in 2014.

This work [8] presents a Google Glass application for individuals with color blindness or color vision deficiency (CVD) offers significant advantages in addressing everyday challenges related to color perception. By leveraging new technical devices and state-of-the-art application development, it enhances the color perception of users, improving their ability to distinguish colors in various contexts. The app proves particularly useful for non-time-critical tasks such as identifying colors of objects, selecting appropriate clothing, or interpreting color-coded information like map legends. However, potential disadvantages may include limitations in accuracy or reliability of color recognition, dependency on device compatibility and functionality, and challenges in adapting to different environments or lighting conditions.

EnChroma glasses [9] offer several advantages for individuals with color vision deficiencies (CVD). Firstly, they provide a transformative experience by enhancing color perception and enabling users to see a broader spectrum of colors. This can greatly improve quality of life, allowing users to appreciate art, nature, and everyday surroundings in a new way. Additionally, EnChroma glasses are available in various styles and prescriptions, catering to different preferences and needs. They are also durable and lightweight, ensuring comfort and long-term usability. However, EnChroma glasses have some limitations, including their high cost, which may be prohibitive for some users. Additionally, while they can enhance color perception, the extent of improvement varies depending on the individual's type and severity of color blindness. EnChroma glasses may not completely correct color vision deficiencies, and users may still experience some limitations in certain situations or with specific colors.

This work [10] introduces a rapid color modification method tailored for individuals with color vision deficiencies, addressing difficulties in discriminating certain color differences. By employing both spatial and temporal re-coloring algorithms, the proposed approach enhances color contrast between colors perceived differently by color-blind users and maintains temporal color consistency in video sequences. This innovative method significantly reduces computational complexity, ensuring efficient video re-coloring. Experimental results demonstrate that the proposed method effectively improves the comprehensibility of video sequences for color-blind individuals, all while minimizing computational burden. Limitations may include potential variations in effectiveness depending on the severity and type of color vision deficiency, as well as the need for further validation across a broader range of video content and user demographics.



(a) (b)

FIGURE 2. Image for which color vision deficient people experience altered perception: (a) pie chart as perceived by people with normal vision, (b) pie chart as perceived by people with color vision deficiency.[10]

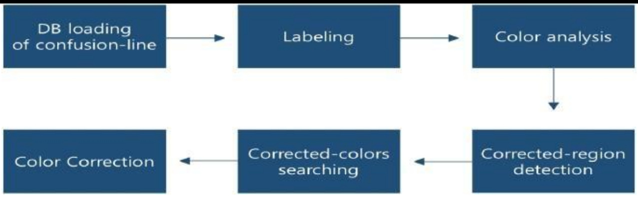


FIGURE 3. Block diagram of the optimal color–correction method.[10]

III.METHODOLOGY

The methodology employed for this survey paper involved a systematic review of existing literature, research papers, and technological solutions pertaining to color vision deficiency (CVD) and assistive technologies for individuals with color blindness. Initially, extensive searches were conducted across academic databases such as IEEE Xplore, PubMed, and Google Scholar utilizing keywords including "color blindness," "color vision deficiency," and "assistive technologies," without any constraints on publication date. Subsequently, studies and papers focusing on various aspects of CVD, encompassing its causes, types, effects, and assistive technologies, were meticulously selected based on inclusion criteria. Only peer-reviewed articles, conference papers, and reputable sources were included to ensure the reliability and quality of the gathered information.

Upon gathering relevant studies, data extraction and synthesis were conducted to distill pertinent information from the selected literature. This included details on the causes and effects of different types of color blindness, as well as descriptions of assistive technologies and methodologies for color correction and enhancement. The extracted data were then synthesized and organized thematically to facilitate a comprehensive understanding of the current landscape of research and technological advancements in the field.

Subsequently, a critical analysis was undertaken to identify common trends, challenges, and gaps in the existing literature and technological solutions. Special emphasis was placed on evaluating the effectiveness, usability, and limitations of various assistive technologies and methodologies for individuals with color vision deficiencies. The findings of the literature review and analysis were systematically presented in the related work section, categorizing the reviewed studies and technologies based on their approaches and outcomes. Each study and technological solution was summarized, highlighting its key contributions, methodologies, and implications for individuals with color blindness.

Finally, based on the synthesized findings and critical analysis, conclusions were drawn regarding the current state of research and technological advancements in the field of assistive technologies for color-deficient individuals. Recommendations for future research directions and the development of more effective and user-friendly assistive technologies were provided, aiming to address the identified gaps and challenges and further enhance the quality of life for individuals with color vision deficiencies.

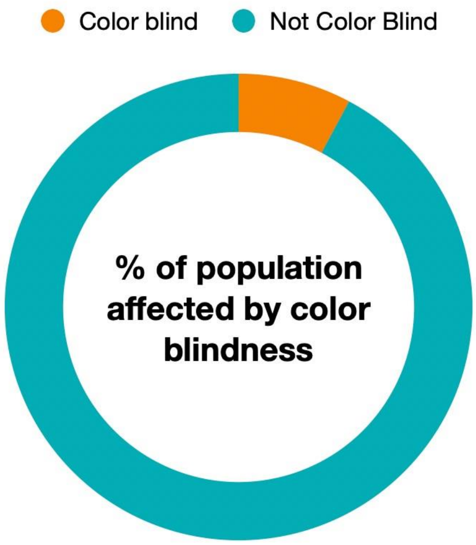


FIGURE 4. Percentage of people affected by color blindness.

IV.CONCLUSION

This paper provides a comprehensive overview of various assistive technologies and methods designed to address the challenges faced by individuals with color vision deficiencies. Through an analysis of methodologies, the review highlights the diverse range of approaches used to assist color-deficient individuals, including digital applications, wearable devices, and image processing algorithms. The conclusion drawn from this extensive examination underscores the importance of continued research and development in the field of assistive technologies for color-deficient individuals. While existing methods show promising results in enhancing color perception and improving accessibility, further advancements are needed to address the varying needs and preferences of individuals with different types, degrees and tests of color vision deficiencies. It is crucial for the development of effective and user-friendly assistive technologies that positively impact the lives of those affected by color blindness.

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