International Cartographic Association
Association Cartographique Internationale

Map Color Transformation and Recommendation System for Color Vision Deficiency

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Keywords: Color Vision Deficiency, Daltonization, Neural Collaborative Filtering, Colorblind Map

Abstract

Color vision deficiency (CVD) is a visual condition caused by abnormalities in the retina's cone cells, impacting the ability to distinguish certain colors. This condition affects approximately 8% of males and 0.5% of females globally, with significant implications for interpreting visual information. Maps, as vital tools for spatial exploration, rely heavily on color differentiation to convey information such as land use, elevation, and geographic features. However, CVD users often struggle to discern these distinctions, reducing the usability of maps and increasing the risk of misinterpretation. This study addresses this gap by developing a novel map color transformation system tailored to CVD users. Using Daltonization techniques within the CIE Luv color space, the study enhances color differentiation for individuals with different types and degrees of CVD. The CIE Luv space, known for its perceptual accuracy, allows for precise manipulation of color distances, enabling transformations that maximize distinguishability while preserving naturalness. The method begins by clustering map colors using K-means clustering and calculating cluster centroids. These centroids are then adjusted based on Confusion Points and Lines unique to each type of CVD (protanopia, deuteranopia, and tritanopia). By optimizing the angular separation (θ) between clusters in polar coordinates, the system ensures improved color differentiation for CVD users.

To evaluate the system, a survey involving 25 red-green CVD participants was conducted (Figure 1). Participants first completed the Ishihara test to determine their CVD type and severity. They were then presented with 120 maps, transformed using different cluster configurations (4, 6, 8, 10, 12 clusters), and asked to rate the distinguishability of key features. In response, a neural collaborative filtering (NCF) recommendation system was developed to predict and recommend map configurations tailored to individual users. The NCF model utilized user embeddings derived from Ishihara test results and item embeddings based on map color properties, including hue distributions and clustering configurations. Unlike traditional binary recommendation models, this system predicted preferences on a 0–5 scale using Softmax. The integration of advanced machine learning techniques and perceptual color spaces allowed the system to adapt to diverse user needs and map types, demonstrating its scalability and effectiveness.

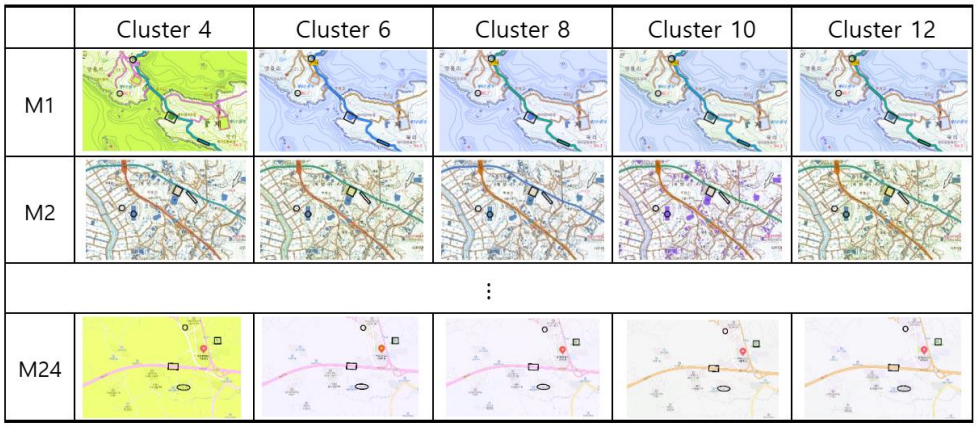

Figure 1. Map Color Daltonization

Abstracts of the International Cartographic Association, 10, 138, 2025
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada.
https://doi.org/10.5194/ica-abs-10-138-2025

Results indicate that the Daltonization process significantly enhances map usability for CVD users, and the recommendation system shows promising potential, despite being constrained by a limited dataset. By transforming the colors of existing maps rather than creating new color schemes, the approach ensures efficiency and adaptability. This research contributes to the field of accessible cartography, addressing the unique challenges faced by CVD users and promoting inclusivity in spatial tools. Future work will focus on expanding the dataset, incorporating additional types of CVD, and refining the recommendation system to improve its accuracy and reliability.

Acknowledgements

This study was supported by the National Information Institute in the Republic of Korea.