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Systematic Literature Review: Predicted Color Output in UI/UX Design Using Machine Learning

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ABSTRACT

An attractive user interface (UI) design is greatly influenced by the selection of appropriate colors, but the selection process tends to be subjective. To address this challenge, this study was conducted to identify commonly used machine learning techniques and evaluate their effectiveness in recommending colors based on RGB and HSL features. The method used was a Systematic Literature Review (SLR) of 39 articles published between 2020 and 2025. The study was conducted through three main stages, namely planning, implementation, and reporting. The review results show that approaches such as K-Means are widely used in the dominant color extraction stage, while classification algorithms such as Support Vector Machine (SVM), Artificial Neural Network (ANN), and Random Forest are applied for color prediction and recommendation. Random Forest is one of the models that shows superior performance, especially in terms of prediction stability and the ability to handle large numbers of variables. The model development process usually begins with color quantization, followed by data labeling and model training. Based on these findings, it can be concluded that Random Forest is a reliable model in color recommendation systems, especially when supported by good data preprocessing stages and proper parameter tuning.

Keywords: System Literature Review, Machine Learning. Random Forest, UI/UX Design

INTRODUCTION

As digital technology continues to evolve and touch nearly every aspect of life, the demand for high-quality digital interfaces has grown significantly. Users no longer expect merely functional systems; they also seek intuitive, visually appealing interfaces that deliver an enjoyable experience. In this context, User Interface (UI) and User Experience (UX) design play a crucial role in ensuring that a digital product is well-received by users. UI/UX is not merely about visual aesthetics but is closely tied to perceptions of comfort, trust, and ease of use. One of the most fundamental and influential visual aspects in UI is color, which possesses a unique ability to convey messages without words. Color can direct users' attention, establish information hierarchies, and even evoke specific emotions that influence perceptions of the entire application. Various studies have shown that the right choice of colors can improve readability, strengthen brand identity, and create an emotional atmosphere that aligns with the context of use (Bonacin et al., 2022; Karim et al., 2024a). Other studies have also proven that harmonious colors can enhance the user experience and increase satisfaction when interacting with a system(Y. Zhang et al., 2023). However, in practice, the color selection process is often subjective, based on the designer's intuition or personal preferences. This can lead to inconsistencies and a lack of objectivity, especially when the design must accommodate diverse user preferences (D. Y. Zhang et al., 2020).

To address this challenge, data-driven approaches have begun to be introduced through the use of Machine Learning (ML). ML enables systems to learn from existing data, such as images, interface elements, or user preferences, to generate color recommendations that are not only aesthetically pleasing but also contextually relevant. ML-based color recommendation systems typically work by analyzing color features such as RGB (Red, Green, Blue) or HSL (Hue, Saturation, Lightness), then proposing color combinations deemed harmonious and effective (Hou et al., 2021). Applications of such systems can be found in various fields, such as mobile app design, user-preference-based room lighting systems, and even color trend prediction in the fashion industry (Cuenca-Jiménez et al., 2022; Yoo et al., 2022).

The technical approaches used in developing color recommendation systems are quite diverse. Some studies employ classification and regression methods such as Support Vector Machine (SVM), Decision Tree, and K-Nearest Neighbor to map color data into specific labels, such as user preferences or emotional categories. On the other hand, clustering methods like K-Means are widely used in the initial stages to group dominant colors from

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an image. Meanwhile, deep learning approaches such as Convolutional Neural Network (CNN), Autoencoder, and

Generative Adversarial Network (GAN) are beginning to be explored to capture complex patterns that cannot be identified by traditional techniques (Y. Liu et al., 2023; Ma et al., 2024).

However, there is no consensus among researchers on which techniques are most effective and widely used in color recommendation systems, particularly those based on RGB and HSL features. Some studies focus on improving color prediction accuracy from a technical performance perspective, while others emphasize how the recommendation results are aesthetically accepted by users(Dabas et al., 2020; Zhao et al., 2024). Additionally, different usage contexts such as banking app design versus entertainment app design also influence the selection of algorithms and color features used. This is why it is important to systematically map out various ML approaches and techniques in color recommendation.

To address this need, this study employs a Systematic Literature Review (SLR) approach, analyzing 39 International journals (36 from Scopus and 3 from other sources) published between 2020 and 2025. This review is conducted methodologically to identify and evaluate the machine learning approaches used in color recommendation systems for UI/UX design. The primary objective of this study is to answer two research questions: (1) What machine learning techniques are used to recommend colors based on color features (RGB and HSL), and (2) Which algorithms are most effective in color recommendation systems based on classification or regression. This study is expected to contribute by mapping trends and the effectiveness of ML approaches in UI/UX color design, as well as providing a strong foundation for the development of adaptive color recommendation systems in the future. With this approach,

Unlike previous studies that focus on individual models, this paper contributes by synthesizing multiple ML methods in color recommendation systems and comparing their relative effectiveness based on data types (RGB, HSL, image-based).

METHOD

The topics in this study were conducted to answer the main research questions, namely:

1. (RQ1) What machine learning techniques are used to recommend colors based on color features (RGB, HSL)?
2. (RQ2) What algorithm is most effective in a color recommendation system based on classification or regression?

To answer these questions, the method used in this study was a Systematic Literature Review (SLR). SLR was chosen because it can systematically, structurally, and transparently identify, evaluate, and synthesize the results of previous research in a particular field. The main purpose of using SLR is to provide a comprehensive and objective overview of the approaches that have been used in a particular topic, in this case, ML-based color recommendation systems for UI/UX design.

In its implementation, this SLR refers to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards. PRISMA is an evidence-based guideline used to compile systematic reports and meta-analyses in a complete and transparent manner. The PRISMA approach in this study is divided into four main stages: identification, screening, eligibility, and inclusion.

The first stage is identification, which is the process of identifying literature relevant to the research topic. At this stage, the researchers searched for scientific articles from the Scopus database using the keywords: machine learning color recommendation, color scheme recommendation system, RGB color prediction neural network, color design for UI, and color preferences by application type. The search was conducted with publication year restrictions between 2020 and 2025. A total of 478 articles were identified in the initial stage. After the identification process, the screening stage was conducted, which involved filtering articles based on inclusion and exclusion criteria. The inclusion criteria used in this study included: (1) articles published between 2020 and 2025, (2) articles in Scopus-indexed journals with Q1–Q4 classification, (3) articles relevant to the topic of color recommendation systems and mentioning the machine learning techniques used. The exclusion criteria included: (1) duplicate articles, (2) articles that do not meet the publication year limit, and (3) articles that do not include an abstract or do not have relevant methods.

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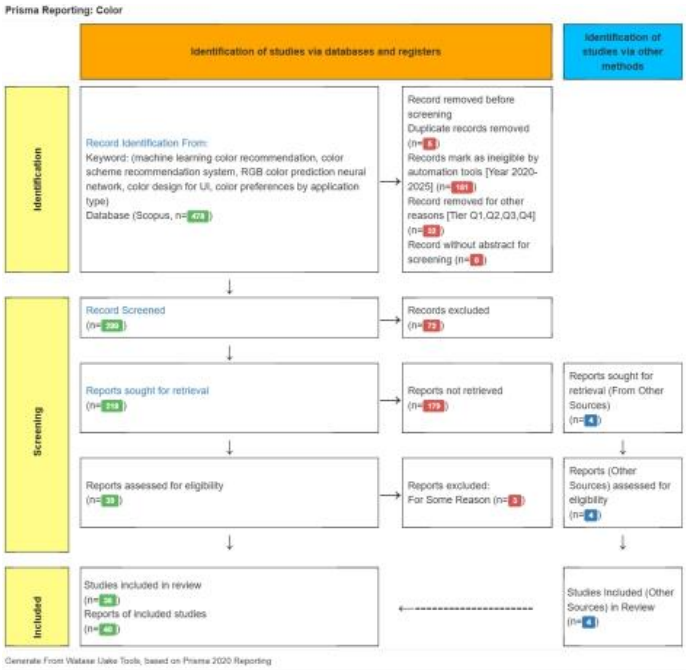

Fig. 1 Prisma
Source: Research data

To support documentation and visualization of the PRISMA process, a web-based tool was utilized to systematically record the selection and validation stages of all 39 reviewed articles.

The extracted data were then categorized to address RQ1 and RQ2. Based on the analysis results, it was found that the most commonly used techniques in color recommendation systems are K-Means clustering for dominant color extraction, and Support Vector Machine (SVM) and Artificial Neural Network (ANN) for color prediction or classification(Hou et al., 2021; Y. Liu et al., 2023). Additionally, deep learning-based models such as CNN and Autoencoder are increasingly being used due to their ability to understand complex representations of color features (Cuenca-Jiménez et al., 2022; Y. Zhang et al., 2023). Through this PRISMA process, this study successfully compiled and synthesized the literature systematically, thereby contributing meaningfully to the development of more adaptive, effective, and relevant machine learning-based color recommendation systems tailored to the needs of contemporary UI/UX design.

RESULT

This section presents findings from articles that have been synthesized and analyzed to answer research questions. This study aims to map the development of machine learning (ML) techniques in RGB and HSL feature-based color recommendation systems through a Systematic Literature Review (SLR) approach. A total of 39 scientific articles published between 2020 and 2025 were analyzed using the PRISMA method, consisting of 36 Scopus-indexed articles and 3 additional relevant articles from other sources. The results of this study are presented based on research question categories and accompanied by visual data interpretation.

The reviewed articles were from the period 2020 to 2025 with a relatively even distribution. The years 2020 and 2022 had the highest number of publications, with 7 articles each, followed by 2021, 2024, and 2025 with 6 articles each, and 2023 with 5 articles. This indicates that research on color recommendation systems using machine learning approaches is still relatively new but has been developing consistently each year.

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Fig. 2 Number of articles by year
Source: Research data

Geographically, the majority of researchers are from China (39.4%), followed by India (15.2%), the United States (9.1%), and South Korea (9.1%). The rest are from countries such as Hungary, Japan, Brazil, Germany, Jordan, and others, each accounting for 3%. This data indicates that the issue of color recommendations in digital interface design has attracted the attention of the global scientific community, particularly in countries with active technology research ecosystems.

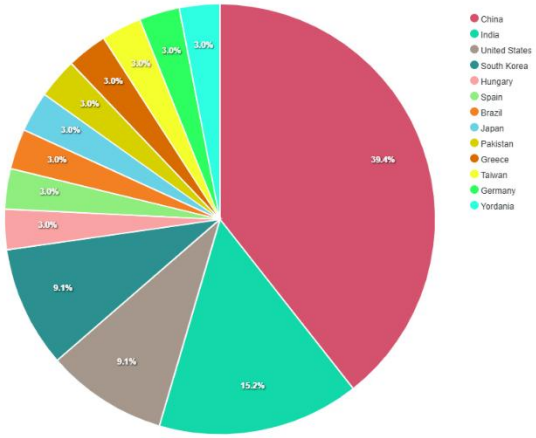

Fig. 3 Number of articles by country
Source: Research data

Based on the classification of 39 articles, it was found that the term Machine Learning was explicitly mentioned in 27 articles, followed by Artificial Intelligence in 22 articles, as well as specific approaches such as Deep Neural Network (6 articles) and Artificial Neural Network (3 articles). Several articles also explored hybrid modeling such as the combination of CNN + SVR/RVM to improve system performance.

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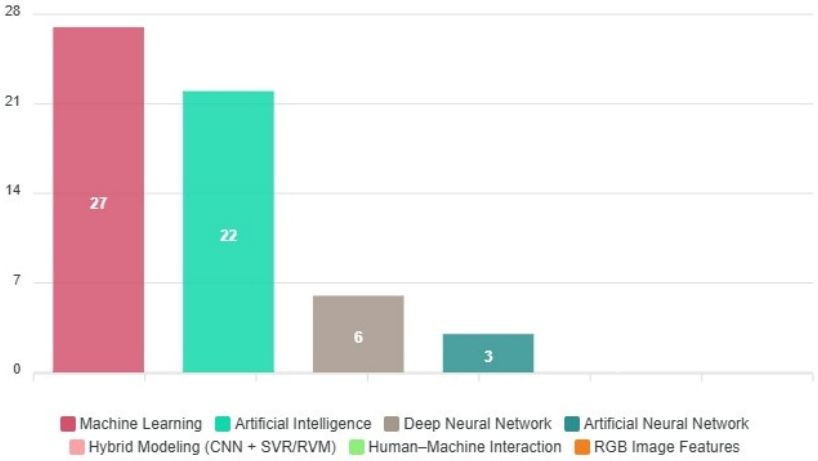

Fig. 4 Number of commonly used methods
Source: Research data

RQ1: What machine learning techniques are used to recommend colors?
In this study, the identification of 25 journals shows that RGB features are the most widely used variables as inputs in color recommendation systems. This is not surprising because RGB is widely available in digital image data and is easy to process by machine learning algorithms. Some studies also involve features such as HSL, Histogram-based Image Features, and SRI, but their frequency is much lower than RGB(El-baki et al., 2025). To answer RQ1 regarding the machine learning techniques used, it was found that the most commonly used models are Random Forest and Convolutional Neural Network (CNN). Random Forest is widely used because it is effective in processing numerical data such as RGB and relatively stable without requiring extensive parameter tuning. Meanwhile, CNN frequently appears in studies utilizing full visual data or color patterns from images, especially when the system is designed to understand the overall UI context. Some journals also apply SVM, ANN, and hybrid approaches like CNN-RF, depending on data complexity and prediction objectives. This pattern shows that the choice of technique is highly dependent on the form of input and the context of use. However, Random Forest and CNN remain the top choices due to their balance between accuracy, efficiency, and flexibility.

Table 1
Summary of Color Feature Variables and Machine Learning Models

Artikel	RGB	*Predicted Color Output*	*Predicted Plant Parameters Output*	*Histogram-base Imaged Features*	SRI	Model
(Y. Zhang et al., 2023)	✓	✓		✓		*Random Forest*
(Hou et al., 2021)	✓	✓		✓		CNN
(Cuenca-Jiménez et al., 2022)	✓	✓				CNN
(Y. Liu et al., 2023)	✓	✓	✓			*Random Forest*
(Ma et al., 2024)			✓	✓	✓	CNN

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(Zhao et al., 2024)	✓	✓				SVM
(Yuan, 2024)	✓	✓		✓		*Descision Tree*
(Seo et al., 2021)	✓	✓	✓			*Random Forest*
(Y. Wang & Qin, 2022)	✓		✓			CNN
(Ficzere et al., 2024)	✓	✓		✓	✓	ANN
(C. Liu & Zhuang, 2025)	✓	✓		✓		GAN
(M. Wang & Zhao, 2022)	✓	✓			✓	CNN
(Museros et al., 2020)	✓	✓				SVM
(Q. Wang et al., 2025)	✓	✓		✓		*Hybrid* CNN- RF
(X. Li et al., 2021)	✓	✓		✓		CNN
(H. Li et al., 2024)	✓	✓				*Gradient Boosting*
(Lu et al., 2024)	✓					*Decision Tree*
(Karim et al., 2024b)	✓	✓		✓	✓	*Rule-based*
(Manzoor et al., 2020)	✓	✓		✓		GAN

RQ2: Which algorithm is most effective in classification- or regression-based color recommendation systems?

To answer RQ2 regarding which algorithm is most effective in classification- or regression-based color recommendation systems, a review of 25 journals shows that several algorithms are more frequently used and have been proven to provide satisfactory results. One of the most prominent algorithms is Random Forest. This algorithm is widely used because it is suitable for numerical data such as RGB and HSL. Random Forest is considered sufficiently accurate, stable, and not overly complex when implemented. Some journals, such as (Q. Wang et al., 2025), also mention that Random Forest can provide consistent results for color classification. Additionally, Convolutional Neural Networks (CNNs) are also widely used, particularly in research based on images or visual design. CNN is very helpful when a color recommendation system needs to understand the overall UI appearance, not just color numbers. Examples can be seen in the studies (Cuenca-Jiménez et al., 2022) and (Ma et al., 2024), where CNN is used to recognize color patterns in images. Other algorithms such as SVM, ANN, and Decision Tree also appear in some journals, but their usage is not as widespread as Random Forest or CNN. Typically, these algorithms are used in more specialized research or on smaller datasets.

Overall, it can be concluded that Random Forest and CNN are the two most widely used and most effective algorithms in color recommendation systems, depending on the data format and application objectives. Random Forest excels with numerical data, while CNN is more suitable for visual data.

CONCLUSION

This study was conducted to identify the Machine Learning techniques commonly used in RGB and HSL-based color recommendation systems, as well as to determine which algorithms are most effective for

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color classification or prediction tasks. From a review of 39 relevant journals, it was found that the majority of studies use RGB features due to their ease of processing and widespread use in digital image data. In terms of algorithms, the two most commonly used and effective approaches are Random Forest and Convolutional Neural Network (CNN). Random Forest is often chosen in studies using numerical data such as RGB because its results tend to be stable and not too complex to implement. Meanwhile, CNN is typically used in image- or visual-based research due to its ability to capture color patterns comprehensively. After considering the results of the literature review and adjusting them to the needs of this final project, the researcher chose to use the Random Forest model as the main algorithm in the development of a Machine Learning-based color recommendation system. This selection was based on its ability to handle RGB numerical data efficiently, the stability of the classification results, and its suitability for the purpose of the system to be built, which is to recommend colors that are accurate and relevant for digital UI/UX design.The novelty of this study lies in its structured comparison of various machine learning algorithms,particularly Random Forest and CNN based on RGB and HSL features, which has not been comprehensively reviewed in previous literature. This synthesis provides a practical reference for future research and development of intelligent, data-driven color recommendation systems in the field of UI/UX design.

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