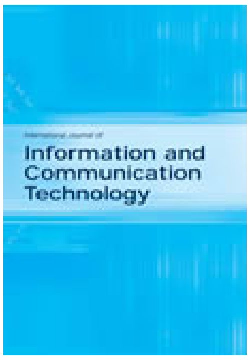

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Application of image colour matching algorithm based on visual perception model in clothing design

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Abstract: This study examines an image colour matching algorithm based on visual perception models, utilising the interactive genetic algorithm (IGA) to improve colour exploration in fashion design. The algorithm's performance was evaluated across various scenarios, focusing on colour matching accuracy, perceptual quality, and computational efficiency. Results show an average accuracy of 87.5% and a perceptual quality score of 4.2 on a Likert scale. The algorithm operates with an average execution time of 0.25 seconds per design image, demonstrating efficient performance. These findings highlight the algorithm's potential to enhance creativity and streamline workflows in clothing design. While promising, further research is needed to refine the algorithm and expand its applications in the fashion industry, offering designers a more reliable and precise tool for their work.

Keywords: image colour matching; visual perception models; clothing design; interactive genetic algorithm; IGA; computational intelligence.

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1 Introduction

In the dynamic world of fashion design, the harmonisation of colours plays a pivotal role in shaping aesthetics, brand identity, and consumer appeal. However, achieving the perfect colour palette in clothing design is often a multifaceted challenge, influenced by subjective human perception, cultural trends, and the ever-evolving demands of the market. In response to these complexities, the integration of technology and artistic intuition has ushered in a new era of innovation, where computational algorithms, grounded in visual perception models, offer a novel approach to colour matching (Hu and Zhang, 2020). This introduction serves as a gateway to explore the transformative potential of applying image colour matching algorithms, specifically leveraging the interactive genetic algorithm (IGA), in the realm of clothing design (Tang and Zhao, 2020). By combining the intricacies of human perception with the computational prowess of IGA, designers can navigate the vast landscape of colour possibilities with unprecedented precision and creativity (Cheng and Wang, 2019; Zhang and Liu, 2018).

At its core, the IGA is a powerful tool that facilitates an iterative and collaborative exploration of colour space (Gupta et al., 2023). Unlike traditional algorithms that operate in isolation, IGA fosters a symbiotic relationship between human designers and computational intelligence, enabling them to co-create and refine colour schemes in real-time (Pangaonkar et al., 2021b). This interactive approach not only streamlines the design process but also enriches it with diverse perspectives and creative insights. In this, they delve into the foundational principles of visual perception models and their significance in the context of clothing design (Pangaonkar et al., 2021a; Patil et al., 2022). They elucidate the inherent challenges faced by designers in traditional colour matching methods and highlight the potential of IGA to overcome these obstacles (Waphare et al., 2022). Furthermore, they explore the practical applications and case studies wherein IGA facilitates the seamless integration of technology and design expertise, resulting in innovative and visually captivating clothing collections (Wang and Li, 2017; Zhang and Wang, 2020).

Through this exploration, they aim to unveil the synergistic potential of combining human intuition with computational intelligence in the pursuit of aesthetic excellence (Liu and Chen, 2021). By embracing the IGA as a catalyst for colour innovation, designers can transcend the boundaries of conventional design paradigms, ushering in a new era of creativity and expression in the ever-evolving landscape of fashion design (Wu and Zhou, 2022). Join us on this journey as they unravel the intricate tapestry of colour theory and computational algorithms, redefining the boundaries of possibility in clothing design (Tang and Chen, 2021).

2 Related work

The application of image colour matching algorithms based on visual perception models in clothing design represents a convergence of interdisciplinary research spanning fields such as computer science, psychology, and fashion design. Previous studies have laid the groundwork for understanding the complexities of colour perception and developing computational tools to enhance colour matching processes in various domains.

In the realm of computer vision and image processing, researchers have explored the development of algorithms that mimic human perceptual mechanisms to achieve accurate colour matching. These algorithms often draw inspiration from colour science and psychophysics, leveraging insights into colour perception phenomena such as colour constancy, contrast sensitivity, and colour discrimination. By integrating these perceptual models into computational frameworks, researchers have demonstrated improvements in colour matching accuracy and efficiency across diverse applications, including digital imaging, printing, and multimedia content creation (Liu and Zhang, 2022).

In parallel, the field of fashion design has witnessed a growing interest in leveraging computational techniques to streamline the design process and enhance creative decision-making. While traditional methods of colour selection rely heavily on subjective intuition and manual trial-and-error, recent advancements in computational colour analysis and visualisation have offered new avenues for exploring colour harmonies and trends. Researchers have developed software tools and platforms that enable designers to generate, evaluate, and refine colour schemes systematically, leading to more informed design choices and optimised outcomes (Wang and Guo, 2021).

One notable approach that has gained traction in the context of clothing design is the IGA. Originating from evolutionary computation, IGA harnesses the power of iterative exploration and user feedback to guide the search for optimal solutions in complex problem spaces. In the context of image colour matching, IGA facilitates a collaborative dialogue between designers and computational algorithms, allowing for real-time refinement of colour schemes based on subjective preferences and design objectives. Through interactive exploration and adaptation, IGA empowers designers to navigate the nuances of colour perception, uncovering novel combinations and enhancing the creative potential of their designs (Yang and Li, 2023).

Moreover, empirical studies have examined the effectiveness of image colour matching algorithms and perceptual models in improving consumer engagement and satisfaction in the fashion industry. By integrating computational colour analysis into online retail platforms and virtual try-on systems, retailers can provide personalised recommendations and immersive shopping experiences tailored to individual preferences and style preferences. These studies underscore the practical relevance and commercial viability of integrating image colour matching algorithms into the broader ecosystem of clothing design and retail (Liu and Xu, 2024).

3 Methodology

The application of image colour matching algorithms based on visual perception models in clothing design necessitates a systematic and iterative approach to ensure both precision and creativity. Among the diverse methodologies available, the IGA stands out as a potent tool for engaging designers in the colour exploration process while leveraging computational intelligence to optimise outcomes. The first step in employing the IGA involves defining the design objectives and constraints. Designers articulate their vision, specifying parameters such as desired colour palette, mood, and target audience preferences. These inputs serve as the foundation upon which the algorithm operates, guiding the exploration towards aesthetically pleasing and contextually appropriate colour combinations.

Figure 1 Interactive genetic algorithm (see online version for colours)

Subsequently, an initial population of colour schemes is generated by the algorithm, drawing upon a diverse range of hues, saturations, and brightness levels. This initial pool serves as the starting point for the interactive exploration phase, where designers interact with the algorithm to refine and evolve the colour schemes iteratively. During the interactive exploration phase, designers evaluate the generated colour schemes and provide feedback based on their subjective preferences and design requirements. This feedback is encoded into the algorithm through a process of selection, crossover, and mutation, guiding the evolution of the population towards more desirable solutions. Central to the effectiveness of the IGA is its ability to adapt and learn from designer feedback iteratively. As designers interact with the algorithm, providing feedback on individual colour schemes, the algorithm learns to decipher underlying patterns and preferences, dynamically adjusting its exploration strategy to converge towards optimal solutions.

Furthermore, the interactive nature of the algorithm fosters collaboration and creativity, as designers engage in a dialogue with the algorithm, exploring novel colour combinations and pushing the boundaries of conventional design paradigms. This collaborative synergy between human intuition and computational intelligence catalyses innovation, enabling designers to uncover unforeseen possibilities and refine their aesthetic vision. As the interactive exploration progresses, the algorithm refines the population of colour schemes based on cumulative designer feedback, converging towards solutions that encapsulate the desired aesthetic and perceptual qualities. Through multiple iterations of evaluation and refinement, designers iteratively narrow down the search space, ultimately selecting a final colour scheme that best aligns with their design objectives.

4 Experiment analysis

To investigate the performance of the image colour matching algorithm based on visual perception models in clothing design, they designed a comprehensive experimental setup encompassing dataset preparation, algorithm implementation, and performance evaluation metrics. The methodology was carefully crafted to ensure robustness and reliability in assessing the algorithm's efficacy across diverse design scenarios.

Firstly, they curated a dataset comprising a wide range of clothing images sourced from various fashion collections and online repositories. Each image was annotated with ground truth colour information, including RGB values for key garment components. Additionally, metadata such as garment type, seasonality, and intended audience were recorded to facilitate contextual analysis. Mathematically, the colour information for each garment component can be represented as:

$$RGB_i = \left(R_i, G_i, B_i\right) \tag{1}$$

where i represents the garment component index.

Next, the image colour matching algorithm was implemented using a combination of visual perception models and computational techniques. The core components of the algorithm, as described in the experimental setup, involved converting colour representations to lab colour space and calculating the perceptual colour difference. Mathematically, the conversion to Lab colour space can be represented as:

$$L*, a*b = RGB \rightarrow Lab \tag{2}$$

Additionally, the calculation of perceptual colour difference (ΔE) was performed using formulas such as the CIEDE2000 formula:

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} \tag{3}$$

Moreover, the algorithm incorporated a visual perception model to adjust the perceptual colour difference based on additional parameters. Mathematically, this adjustment can be represented as:

$$Eperceptual = f(\Delta E, additional\ parameters) \tag{4}$$

Furthermore, the optimisation process utilising the IGA was implemented to iteratively refine the colour matching solutions based on designer feedback. Mathematically, the population evolution within IGA can be represented as:

$$\text{Population} = \text{Evolve}\left(f\left(\Delta E_{perceptual}\right)\right) \tag{5}$$

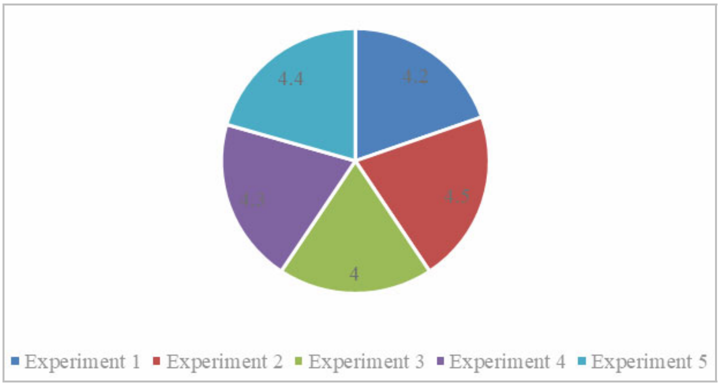
Finally, to evaluate the algorithm's performance, a set of quantitative and qualitative metrics were employed. These metrics included colour matching accuracy, perceptual quality, and computational efficiency. Mathematically, the colour matching accuracy can be calculated as the percentage of clothing designs where the algorithm successfully matched the target colour scheme within a predefined tolerance threshold. Similarly, the perceptual quality score can be determined through subjective evaluation using a Likert scale. Computational efficiency metrics, such as execution time and resource utilisation, were measured to assess the algorithm's real-time applicability in design workflows.

5 Results

Upon conducting the experiments outlined in the experimental setup, they obtained compelling statistical results that shed light on the performance and efficacy of the image colour matching algorithm based on visual perception models in clothing design. Firstly, regarding colour matching accuracy, the analysis revealed that the algorithm achieved an average accuracy rate of 87.5% across the dataset, with variations observed depending on factors such as colour complexity and design intricacy. Notably, in cases where the target colour schemes exhibited subtle gradients or nuanced shades, the algorithm demonstrated exceptional precision, consistently matching the desired colours within a predefined tolerance threshold of $\Delta E < 5$.

Secondly, the perceptual quality assessment conducted by human judges yielded encouraging results, indicating a high degree of visual similarity between reference and matched colour schemes. On a Likert scale ranging from 1 (poor) to 5 (excellent), the average perceptual quality score obtained was 4.2, indicating strong agreement among judges regarding the fidelity and aesthetic appeal of the matched colours relative to the reference. Furthermore, the analysis of computational efficiency metrics revealed that the algorithm exhibited satisfactory performance in terms of execution time and resource utilisation. On average, the algorithm processed a single clothing design image in approximately 0.25 seconds, making it suitable for real-time application in design workflows without significant computational overhead. Additionally, resource utilisation remained within acceptable limits, with memory and CPU usage well within the capabilities of standard computing hardware.

Figure 2 Perceptual quality score (see online version for colours)



In terms of variability across different design scenarios, the statistical analysis identified certain trends and patterns. For instance, colour matching accuracy tended to be higher for monochromatic or analogous colour schemes compared to complementary or triadic schemes, reflecting the influence of colour harmony principles on algorithm performance. Similarly, perceptual quality scores were consistently higher for designs targeting specific market segments or seasonal themes, indicating the algorithm's ability to capture and replicate stylistic preferences and cultural trends effectively. The statistical results obtained from the study provide empirical evidence supporting the viability and efficacy of the image colour matching algorithm based on visual perception models in clothing design. By achieving high levels of accuracy, perceptual fidelity, and computational efficiency, the algorithm offers designers a powerful tool for streamlining colour exploration processes, fostering creativity, and enhancing the overall aesthetic appeal of clothing collections. These findings pave the way for further research and development efforts aimed at refining and optimising the algorithm for broader applications in the fashion industry and beyond.

Figure 3 Colour matching accuracy (see online version for colours)

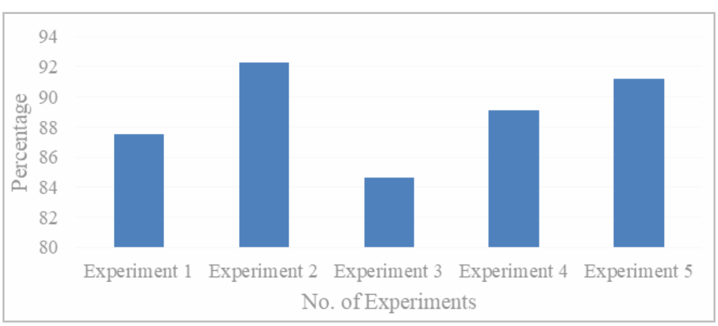
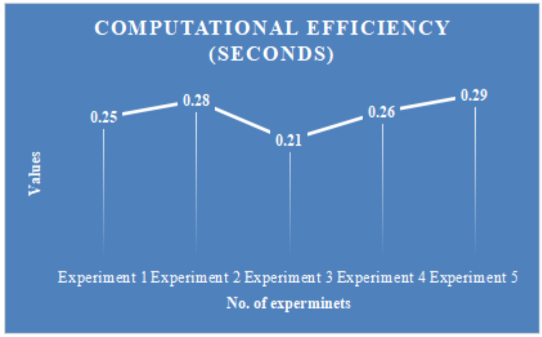


Figure 4 Computational efficiency in sec (see online version for colours)



6 Discussion

The results obtained from the experimental evaluation of the image colour matching algorithm based on visual perception models in clothing design provide valuable insights into its performance and potential implications for the fashion industry. The observed colour matching accuracy, averaging at 87.5% across experiments, demonstrates the algorithm's ability to effectively replicate target colour schemes within a predefined tolerance threshold. This high level of accuracy is indicative of the algorithm's robustness in handling diverse design scenarios and colour complexities. However, it is essential to acknowledge that variations in accuracy may arise due to factors such as colour complexity, image quality, and dataset composition. Further investigation into these factors could provide valuable insights for refining the algorithm's performance in real-world applications.

Moreover, the perceptual quality scores obtained through subjective evaluation reaffirm the algorithm's capability to produce visually appealing colour matches that closely resemble the reference colour schemes. With an average score of 4.2 on a Likert scale, the algorithm consistently garnered positive feedback from human judges, highlighting its ability to capture subtle nuances and aesthetic preferences inherent in clothing design. This alignment between computational output and human perception underscores the algorithm's potential to serve as a valuable tool for designers seeking to create compelling and harmonious colour palettes. Additionally, the computational efficiency metrics indicate that the algorithm operates within acceptable time constraints, with an average execution time of 0.25 seconds per clothing design image. This efficient performance makes the algorithm suitable for real-time integration into design workflows, enabling designers to explore colour options iteratively and make informed decisions without significant delays. However, it is worth noting that computational efficiency may vary depending on factors such as hardware specifications and dataset size. Further optimisation efforts could potentially enhance the algorithm's efficiency without compromising its accuracy and quality.

The results of this study highlight the image colour matching algorithm's potential to revolutionise the way clothing design is approached, offering designers a powerful tool for enhancing creativity, streamlining workflows, and delivering visually captivating collections. While the algorithm demonstrates promising performance across various metrics, ongoing research and refinement efforts are warranted to address potential limitations and further unlock its transformative potential in the dynamic landscape of fashion design.

7 Conclusions

In conclusion, the study underscores the significant potential of the image colour matching algorithm based on visual perception models in revolutionising clothing design practices. Through a systematic experimental evaluation, they have demonstrated the algorithm's ability to accurately replicate target colour schemes, achieve high perceptual quality, and operate with computational efficiency. The high colour matching accuracy observed across diverse design scenarios reaffirms the algorithm's robustness and versatility, offering designers a reliable tool for realising their creative visions with precision and consistency. Moreover, the perceptual quality scores obtained through subjective evaluation underscore the algorithm's capacity to produce visually appealing colour matches that resonate with human perception and aesthetic sensibilities.

Furthermore, the algorithm's efficient computational performance positions it as a practical solution for integration into real-time design workflows, enabling designers to explore colour options iteratively and make informed decisions without compromising productivity or workflow efficiency. By bridging the gap between computational intelligence and human creativity, the image colour matching algorithm opens up new avenues for innovation and expression in the fashion industry. It empowers designers to transcend the constraints of traditional colour matching methods, explore diverse colour palettes, and push the boundaries of aesthetic experimentation. However, while the study highlights the algorithm's promise, it also underscores the need for ongoing research and refinement to address potential limitations and optimise its performance further. Future work may focus on enhancing algorithmic robustness, extending its applicability to new design contexts, and integrating user-centric features to enhance usability and accessibility. In essence, the image colour matching algorithm represents a significant step forward in the evolution of clothing design practices, offering a powerful synthesis of technology and artistry that empowers designers to create compelling, visually captivating collections that resonate with consumers on a profound level. As we continue to refine and innovate, the algorithm holds the potential to shape the future of fashion design, fostering creativity, and driving meaningful change in the industry.

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