Dominant Color Extraction from Images: A Comparative Study and a Human-Perception–Driven Approach

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I. Introduction

Visual communication depends on color as one of its fundamental components. The system enables human beings to detect visual elements which help them understand both the meaning of images and their essential details. The growing use of digital images in computer vision and multimedia retrieval and design and aesthetics applications requires better methods to extract dominant colors accurately. Dominant colors serve as an efficient method to show images which people use for image search and segmentation and compression and palette development according to [1].

The process of obtaining correct dominant color information proves difficult to achieve. The main method used in traditional approaches involves clustering [1] RGB pixel values based on their color space positions. The RGB color model provides simple computational operations but its perception remains uneven because tiny numerical changes produce major visual effects and vice versa. The RGB clustering methods together with histogram methods select colors based on image area size but they fail to detect small distinct regions which results in color palettes that differ from human visual perception. The image in Fig.1 displays different blue tones which dominate the picture yet the small yellow moon stands out as the most noticeable color despite its small size in the image. The analysis of this image through histogram- or clustering-based methods produces only the most prominent blue tones which they identify as representative colors. The human eye requires the deep blue background to contrast with the small bright yellow moon which makes up only a small part of the scene.

Researches have studied new color spaces and extraction methods to solve the current limitations of the system. The CIELAB color space functions to match human color perception because it allows data clustering through perceived color differences instead of using actual numerical data. The perceptual uniformity between colors enables human-perceived similar colors to maintain consistent representations in the feature space.

Research from the past few years has developed perceptual feature-based dominant color extraction techniques which unite large-K clustering with color feature scoring methods [1]. The evaluation methods for candidate colors depend on perceptual elements which include contrast and saturation and prominence and spatial extent to create color representations that are both stable and perceptually significant.

Fig. 1. Example of an image in which a visually prominent but spatially small region, the yellow moon, poses a challenge for dominant color extraction algorithms.

The conventional clustering-based methods focus on colors which cover extensive image areas yet saliency-driven models successfully detect important visual areas regardless of their dimensions [2]. The observation led to the development of feature-based methods which use visual importance signals including contrast and prominence to predict human attention without performing saliency map calculations [1].

This research conducts a comparative analysis of four dominant color extraction techniques:

(1) **K-means clustering in the RGB color space**, representing a traditional pixel-based approach;
(2) **K-means clustering in the CIELAB color space**, which incorporates perceptual color differences through a more uniform representation;

(3) **A perceptual feature-based method combining large-K clustering and color feature scoring**, as proposed by Chang and Mukai (2022) [1].

(4) **a proposed human-perception–driven dominant color extraction method**, which extends feature-based approaches by integrating perceptual color representation, saliency-inspired cues, region-level analysis, and perceptual diversity constraints;

The evaluation of these methods assesses their performance through three main criteria which include perceptual accuracy and color differentiation and their capacity to detect important visual areas. The research results aim to explain current dominant color extraction methods better while evaluating the new method's ability to match extracted colors with human eye perception.

II. Literature Review

A. RGB-Based Dominant Color Extraction Methods

The first dominant color extraction techniques worked directly with RGB color space because it represents digital images natively and provides easy computational access. The methods use image data as a big collection of RGB pixel vectors to create a compact color summary through a limited set of representative colors.

The histogram-driven extraction method which uses RGB-based techniques represents a typical family of techniques that extract dominant colors by dividing the image into discrete bins and choosing the most common bins. These methods provide fast and easy results but they use frequency data to determine importance instead of visual significance. The resulting design allows viewers to disregard any visually appealing colors which appear in limited areas. The research on dominant colors shows that standard histogram- and clustering-based methods select big areas first even though small areas produce essential visual differences [1].

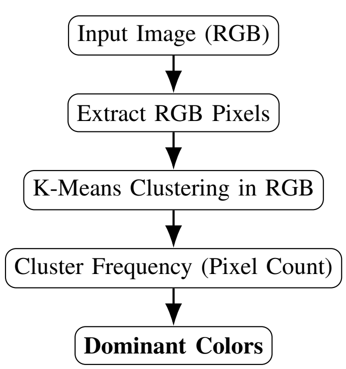

Fig. 2. Pipeline of RGB-based dominant color extraction. Pixels are clustered directly in the RGB color space using K-means, and dominant colors are selected based on cluster frequency, favoring colors that occupy larger image regions.

The K-means clustering method in RGB serves as a common baseline which groups pixels through Euclidean distance in the RGB cube to generate palette colors from cluster centroids. The method remains widely used in practice because it generates simple yet effective color palettes at a fast pace; researchers consider it one of the simplest methods to generate RGB palette colors [1].

RGB K-means serves as a baseline method but it contains two significant flaws which affect its performance. The first issue arises because Euclidean distances measured in RGB space fail to accurately represent how people perceive color differences which results in clusters that do not match human color categorization. The K-means algorithm depends heavily on the size of the areas which each color occupies because small but visible clusters tend to disappear from the final color palette.(Fig. 3).

Fig. 3. Example of RGB-based dominant color extraction using K-means. Palette bar widths are proportional to cluster size (pixel frequency), causing large background regions to dominate the palette while small but visually salient colors are under-represented or omitted.

The observed behavior demonstrates the same pattern which researchers have identified in their studies about how small noticeable areas which include bright objects against dark backgrounds become important for perception yet occur infrequently in data thus frequency-based approaches fail to detect them [1].

Research findings from practical studies indicate that RGB produces inferior clustering results than other color spaces which are more suitable for human perception. Research studies about K-means clustering performance in various color systems show that HSV color space produces better results than RGB because its hue and saturation components help better distinguish objects than RGB values do [3]. Research studies demonstrate that K-means clustering produces superior results when analyzing HSV and CIE L*a*b* data compared to RGB data according to comparative segmentation experiments [4]. Research indicates that K-means and fuzzy C-means clustering methods fail to produce accurate color segmentation when the number of colors is automatically determined in RGB images but Mean Shift applied to perceptual color spaces delivers results that align with human visual perception [5].

The RGB-based dominant color extraction methods which use histogram-based and RGB K-means approaches should be considered as starting points for further development. These methods work well for their purpose but they do not succeed in retrieving human-perceived dominant colors when these colors appear as small elements which have high contrast with their surroundings. The existing restrictions drive researchers to adopt perceptual color spaces together with perception-based scoring methods which they will present in following sections.

B. CIELAB-Based Dominant Color Extraction Methods

The diagram in Fig. 4 shows how researchers moved from using RGB for dominant color extraction because RGB-based methods fail to match human color perception. The CIELAB (Lab) color space stands as a popular alternative which scientists use for dominant color extraction and color-based image analysis. The CIELAB color space functions to create a system where Euclidean distances between color vectors match the way people perceive color differences which makes it perfect for K-means clustering algorithms that use distance calculations.

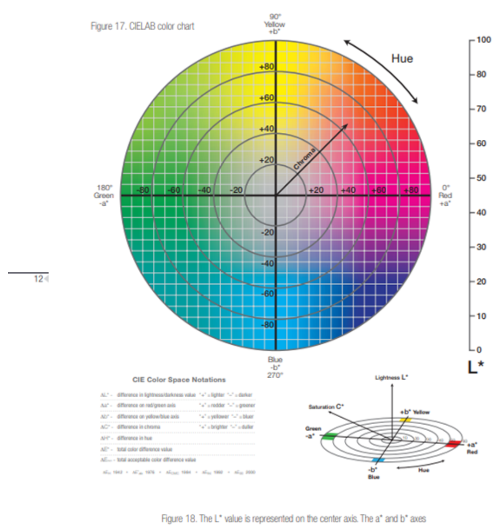

Fig. 4. Visualization of the CIELAB color space. The L axis shows lightness values which range from black at 0 to white at 100. The a and b axes in this system show opponent color dimensions which extend from green to red and blue to yellow respectively. The CIELAB system uses a perceptually uniform design which enables Euclidean distance measurements to represent the actual color differences that people experience.

The CIELAB color space which the International Commission on Illumination (CIE) created functions to create perceptual uniformity because it makes Euclidean color vector distances match the way people perceive color differences.

The CIELAB system differs from RGB because it separates luminance (L) from chromatic components (a and b) which allows for better distance-based comparisons of perceptual changes. The specific characteristics of CIELAB make it an ideal choice for K-means clustering because this algorithm depends on Euclidean distance calculations to perform color grouping.

Research studies have shown that CIELAB clustering methods generate more organized and visually appealing results than RGB clustering methods. The authors Chebbout and Merouani [4] tested different clustering methods for color image segmentation and found that CIELAB produced better results than RGB for both segmentation accuracy and boundary definition. Their research shows that the uniformity of perception leads to better stability in cluster formation.

The research of Anilkumar *et al.* provides empirical evidence which supports the application of CIELAB. The authors in [6] evaluated CIELAB and CMYK color spaces for K-means image segmentation in automated leukaemia detection applications. The research findings demonstrate that CIELAB produces better results than CMYK when it comes to creating meaningful color segments which work well for tasks needing exact color identification. The research by the authors examines medical image segmentation instead of dominant color extraction yet their results confirm CIELAB works well for Euclidean-distance-based clustering operations which need perceptual accuracy.

Research conducted in different fields demonstrates that perceptual color spaces provide better results than RGB color spaces. The research by Kumar *et al.* [3] showed that K-means clustering with RGB data produces inferior results than HSV perceptual representations when analyzing satellite images to distinguish between different visual areas. The reported restrictions of RGB clustering methods validate the overall pattern which favors using perceptual color spaces instead of HSV. The analysis of textiles and cultural heritage materials demonstrates that clustering in perceptual color spaces produces better results than RGB-based extraction because it enhances both extraction robustness and interpretation quality [5].

Standard CIELAB-based dominant color extraction methods maintain their frequency-based operation despite their various benefits. The selection of dominant colors depends on cluster size because colors which appear in big image areas will determine the color palette. The visual importance of small areas including highlights and accents and high-contrast objects does not guarantee their proper representation in the output. The study reveals that human color dominance perception requires more than what perceptual uniformity can explain.

The research by Chang and Mukai [1] solves this problem through their development of CIELAB-based clustering which includes perceptual feature scoring. The method uses perceptually important factors which include contrast and saturation and prominence to evaluate candidate colors instead of depending only on cluster frequency. Their research shows that adding perceptual elements to the system enables better detection of dominant colors which match how people see things.

The CIELAB-based dominant color extraction methods outperform RGB-based methods because they use distance measures which match human perception and they produce more reliable clustering results. The system depends on spatial frequency to detect colors but it fails to identify important colors which exist in limited areas. The existing problems drive researchers to create new methods which combine feature detection with perception systems for solution development.

C. Feature-Based and Perception-Aware Dominant Color Extraction Methods

The use of CIELAB color space for distance-based clustering enhances reliability but dominant color extraction through clustering methods continues to operate based on frequency patterns. The methods for dominant color detection base their results on color cluster size in space but this approach might ignore important visual elements which occupy minimal space. The current method faces a major restriction which recent studies attempt to solve through their development of feature-based and perception-aware dominant color extraction methods.

The color feature–based dominant color extraction method which Chang and Mukai [1] developed serves as a representative and influential example of this paradigm. Their research directly opposes the belief that spatial frequency patterns by themselves determine which image people will perceive. The authors propose that dominant color selection should combine multiple perceptually important elements which better represent how humans process visual information.

The method developed by Chang and Mukai uses a two-stage approach to extract dominant colors from images. The first step involves creating numerous candidate colors through clustering with a high cluster number (large-K) which operates in a color space that matches human perception. The first clustering process achieves two goals by covering all colors in the image and making the results less dependent on the starting points. The process of this step differs from conventional methods because it chooses to segment the color space excessively to maintain all essential color options.

The second stage requires evaluation of candidate colors through perceptual features which measure visual importance instead of using spatial frequency as the only factor. The system includes three sets of features which measure color contrast and chromatic strength and perceptual prominence to determine how much human eyes focus on specific colors in images. The system uses a feature-based scoring function to rank candidate colors before it chooses the dominant colors from the top-scoring options. The selection process based on features enables the system to keep colors which have limited space in the design but create strong visual effects through their contrast and attention-grabbing qualities.

The method uses a different approach than frequency-based dominance which standard CIELAB K-means methods and RGB use. The clustering-based methods use pixel count as their default method to determine dominance but feature-based methods separate the importance of features from their physical size. The visual impact of colors in an image allows dominant elements to be recognized even when they take up only a small portion of the picture. The approach solves the problems which traditional clustering methods fail to detect because they miss important small areas that people can detect.

Research on visual attention and saliency shows that human eyes focus on objects which stand out through their contrast and distinct appearance rather than their size. The authors Chang and Mukai use their feature design to implement saliency-inspired principles through their emphasis on perceptual contrast and visual distinctiveness even though they do not perform explicit saliency map calculations. Research studies about saliency-driven image analysis have shown that important visual areas draw human attention without regard to their actual dimensions [2]. The research findings validate the application of perceptual characteristics which represent visual focus for dominant color detection methods.

The extraction methods based on feature detection of dominant colors provide various benefits yet they contain specific drawbacks. The design of perceptual features together with their relative weighting introduces new parameters which affect how well the system performs on various image types. The scoring method based on features requires evaluation at either pixel or cluster levels but it remains vulnerable to noise and local scene changes in complicated imaging environments. The current system requires additional improvements through superpixel segmentation at the region level to generate stable semantic features for computation.

The extraction methods of dominant color through feature-based and perception-aware approaches have moved beyond the previous frequency-driven clustering methods. The methods achieve better alignment between extracted color palettes and human visual perception through their integration of perceptual cues which include contrast and prominence. The authors depend on local features which leads them to develop new methods that use region-based and structure-aware frameworks which they will discuss in following sections.

D. Saliency-Related Work and a Human-Perception–Driven Dominant Color Extraction Method

The previous sections demonstrate how research about dominant color extraction has evolved from using RGB methods to CIELAB methods and then to feature-based scoring which better matches human perception. The detection of dominant colors through feature-based methods remains insufficient because visual importance in attention-based systems differs from area-based systems. The need to include saliency emerges because this concept has received extensive research in visual attention modeling to identify which areas people tend to detect first.

The classical saliency models propose that human attention follows multiple scales of contrast and feature visibility instead of using pixel frequency as the sole factor. The Itti–Koch model serves as a basic method which creates center–surround feature maps across intensity and color opponency channels before uniting them into a saliency map that shows the most noticeable visual areas [2]. The spectral residual method along with other subsequent developments show that saliency estimation becomes possible through frequency domain analysis by identifying frequency domain irregularities which differ from global statistical patterns [7]. The activation and normalization process in graph-based formulations produces stable saliency maps for different images through their graph structure which enhances saliency estimation accuracy. The Graph-Based Visual Saliency (GBVS) framework serves as a standard attention estimation method because it provides robust results according to [8].

The process of dominant color extraction benefits from saliency because it enables the system to select important colors which appear in significant visual areas regardless of their size. The approach solves the main problem which clustering- and histogram-based methods experience because they fail to detect rare colors which produce significant visual differences [1]. The authors Chang and Mukai [1] demonstrate this restriction through their proposed feature-based scoring method which uses perceptual elements including contrast and saturation to achieve saliency-like results without needing a separate saliency map. The addition of a saliency signal as an explicit component would enhance the connection between human attention and the model because it uses predicted visual importance to determine region weights instead of depending on cluster statistics alone.

The proposed Human-Perception–Driven Dominant Color Extraction (HPD-DCE) method (Fig. 5) combines saliency-related information with perceptual models and region-based evaluation to create the system. The first step involves converting the input image to CIELAB because this conversion method enables distance calculations which produce results that match human perception according to Section 2.2. The system generates a GBVS-style saliency map to determine which areas need most attention through its attention mechanism system [2], [8]. The image undergoes superpixel segmentation to achieve two goals which include noise reduction at pixel level and maintenance of spatial relationships between different image elements. The system extracts region-level features which combine perceptual statistics including Lab mean values and chroma information with saliency data and region size to create a fixed descriptor. The region-based approach becomes essential for dominant color extraction because it stops small pixels and thin boundaries from controlling the palette selection process.

The HPD-DCE system performs feature computation before it uses a perception-based scoring function which unites saliency with chroma/contrast and diversity and area to generate candidate region color rankings. The approach extends the feature-based philosophy of Chang and Mukai [1] through its saliency-based importance calculation which maintains the perceptual elements that enable color distinction. The system uses ΔE based perceptual diversity filtering to pick colors which stay distant from each other in perceptual space while preventing the selection of similar colors that only differ in hue or lightness. The final step of category enforcement (e.g., dark/background tones and warm/highlight tones and mid-tone structure colors) helps developers create color schemes which match human interpretations of scenes instead of using only statistical methods.

The system provides multiple benefits through its operation

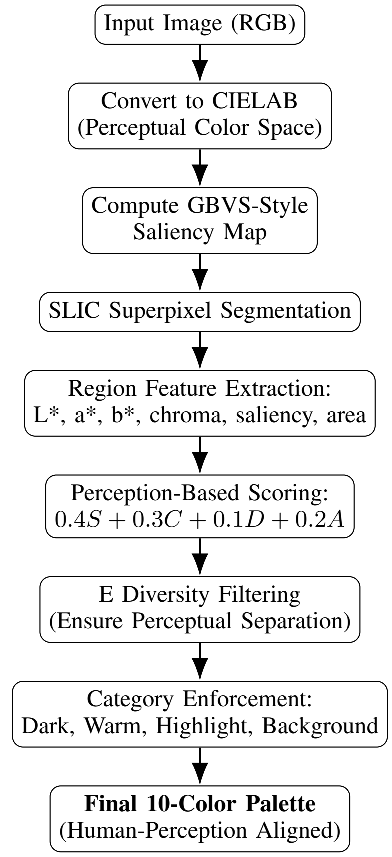

Fig. 5. Overview of the proposed human-perception–driven dominant color extraction (HPD-DCE) method. The proposed approach extends feature-based dominant color extraction strategies by integrating perceptual color representation (CIELAB), saliency-inspired cues, region-level analysis, multi-feature scoring, and perceptual diversity constraints to generate a compact 10-color palette that better reflects human visual perception.

but users need to consider several operational challenges. The sensitivity of saliency maps depends on three factors which include image content and texture density and lighting conditions that cause them to focus on high-frequency edges and specular highlights. The selection of color representativeness through saliency does not guarantee success because it needs to be combined with both chromatic distinctiveness and palette diversity to prevent choosing multiple highlight colors that are similar to each other. The current study requires a new design approach which combines different elements because its current design restrictions need to be addressed. The system in Fig. 5 uses saliency as one of multiple indicators to determine dominance instead of depending on it as the only factor. The research on saliency provides essential concepts and computational methods which enable the identification of important visual areas and these methods should be incorporated into a region-based perceptually uniform system which extends beyond CIELAB clustering and feature scoring [1].

III. Methods

The following section explains the experimental approach which enables researchers to evaluate four leading color extraction methods including RGB K-means and CIELAB K-means and Chang and Mukai's feature-based approach and HPD-DCE. The evaluation of methods takes place through identical data preparation and standardized experimental conditions which prevent extraction strategy performance variations from resulting from different input data.

A. Data

The research team conducted their experiments using natural images which presented different visual elements including object-based scenes and textured backgrounds and continuous color transitions and small yet noticeable image areas. The system requires multiple approaches because different methods for dominant color extraction produce different results when dominance stems from spatial extent or perceptual contrast or attention-related cues. The research team conducted experiments using images but they also obtained perceptual data through tests with actual human subjects. Users chose five dominant colors for each image through their manual selection process. The human-selected color palettes functioned as perceptual ground truth which researchers used to evaluate both quantitative and qualitative aspects of dominant colors that algorithms produced.

1) Image Preprocessing: The preprocessing of all images occurs through an identical method which leads to dominant color extraction results. The system processes each image by converting it into a three-channel RGB format which represents the image. The system duplicates grayscale input data into three channels while it discards any alpha channel information to keep only the RGB channels. The pixel values get converted into floating-point numbers which range from 0 to 1.

The system maintains a balance between fast processing and realistic image appearance through automatic aspect ratio preservation when it reduces images that exceed a specific maximum dimension. The process decreases both processing time and memory requirements while maintaining the scene's visual appearance. The preprocessing pipeline runs with identical parameters for all methods to achieve equal performance evaluation.

B. Compared Algorithms

The research evaluates four main color extraction techniques which researchers use to compare their performance.

(1) RGB K-means (baseline). The system uses RGB pixel vectors to represent the input image. The K-means clustering model operates on a random selection of pixels for performance reasons before it distributes all pixels across different clusters. The system selects dominant colors to function as cluster centroids while it ranks colors based on their frequency of appearance in pixels to generate a palette which shows where each color appears most often.

(2) CIELAB K-means (perceptual baseline). The process of this method duplicates the RGB K-means workflow but it uses CIELAB space for clustering operations. The CIELAB system enhances the perception of Euclidean distances but cluster size remains the primary factor which makes small important regions less visible.

(3) Chang and Mukai feature-based method (perception-aware baseline). The authors of Chang and Mukai [1] describe a method to produce an extensive collection of candidate colors through large-K clustering. The system uses a feature-based scoring method to rank candidate colors which evaluates their perceptual importance through chromatic strength and contrast/prominence instead of depending on spatial frequency alone. The top candidates who achieved the highest ranking make up the dominant color scheme of the final selection. The research uses this method as its most powerful perception-aware baseline.

(4) Proposed HPD-DCE method (human-perception–driven). HPD-DCE extends feature-based dominance through its implementation of saliency-inspired importance cues and region-level stability. The system unites CIELAB color representation with saliency detection and superpixel segmentation and region feature combination and weighted evaluation and perceptual diversity filtering and category enforcement to produce a palette which better matches human visual perception. The system architecture appears in Fig. 5.

C. HPD-DCE: Proposed Human-Perception–Driven Method

HPD-DCE solves two main problems which researchers have found in their studies: (i) The system currently uses frequency-based methods which select large background areas instead of smaller details and (ii) The system shows poor performance when dealing with noisy data and local texture variations at the pixel level. The system functions through the following process. The first step involves converting the image into CIELAB format because this color space enables distance measurements that align with human perception. Second the GBVS-style saliency map system determines which areas in the image need the most attention based on their importance. The third step involves using SLIC superpixels to divide the image into spatially connected areas. The system calculates perceptual features for each region through which it computes CIELAB color values and chroma measurements and saliency values and region dimensions. The system uses a weighted scoring function to determine the order of candidate region colors (as shown in Fig. 5). The final step involves ΔE diversity filtering to remove duplicate palette entries and category enforcement which promotes balanced color palettes that must contain dark/background tones and highlights and chromatically prominent colors.

[h] Human-Perception–Driven Dominant Color Extraction (HPD-DCE) [1] Input image I, palette size K Dominant color palette $\mathcal{P}$

Preprocess I (RGB conversion, normalization to $[0, 1]$, aspect-ratio-preserving resize) Convert I from RGB to CIELAB Compute saliency map S (GBVS-style) Segment image into superpixels $\{R_i\}$ using SLIC

each region R_i Compute mean CIELAB color μ_i Compute chroma C_i, mean saliency S_i, and area A_i Compute distinctiveness/diversity cue D_i (e.g., distance to global mean) Compute region score $Score_i = 0.4S_i + 0.3C_i + 0.1D_i + 0.2A_i$

Rank regions by $Score_i$ Select candidates with ΔE diversity filtering Apply category enforcement (dark/background, highlight, warm/strong chroma) Output top K colors as palette $\mathcal{P}$

IV. Results

The following section contains both qualitative and parametric assessments of the main color extraction techniques which were described earlier. The analysis bases its evaluation on three factors which include how well the results match human vision and how easily people can understand the results and their relationship to human color perception. The evaluation examines which methods perform best when dealing with background dominance and object-specific colors and attention-driven visual cues. The quantitative assessment involves matching the dominant colors which each method produces to the palettes which users selected during the study. The evaluation examines five aspects between the two methods which include color distance measurement through ΔE and matching speed and chromatic emphasis and perceptual diversity and visual saliency alignment.

A. Qualitative Comparison of Dominant Color Palettes

The figure 6 shows a qualitative assessment of the dominant color schemes which were obtained from an image showing a flying duck in front of a textured water background. The image presents a difficult challenge because the important colors of objects take up minimal space in the image compared to the surrounding background area.

The RGB K-means baseline generates a color palette which shows mainly green and gray colors that represent water surfaces but it fails to show the blue wing and yellow beak colors of the objects. The outcome demonstrates how RGB-based clustering contains a powerful frequency bias. The CIELAB K-means method enhances the ability to distinguish colors perceptually yet it operates based on frequency which produces results where background colors remain the most prominent.

The feature-based method which Chang and Mukai developed maintains the essential color meanings of objects through their method. The duck's blue yellow and red colors which hold semantic value remain intact according to this method. The results show that perceptual feature scoring works well to separate dominance from space size while keeping important visual elements.

The HPD-DCE method proposed in this study detects multiple chromatically significant areas which include both deep blue and medium-colored sections. The illustration fails to show the yellow beak and red chest area in this particular example. The observed behavior demonstrates a well-documented property of saliency-based dominance which causes attention predictions to prefer background patterns instead of object meaning when low-level saliency results from texture and contrast differences.

B. Failure Cases and Complementary Behavior

The example in Fig. 6 demonstrates a critical restriction which occurs when using saliency to extract dominant colors. The estimation process for saliency detection will focus on background areas with texture when the foreground object lacks prominent low-level saliency indicators including isolated highlights and sharp contrast. The methods which use feature-based techniques that detect color-level chromatic contrast and perceptual prominence perform better than saliency-based methods in these situations.

The behavior shows that HPD-DCE and feature-based dominance work together to enhance different parts of human perception. The object-specific color preservation of feature-based methods works best for this task while saliency-driven methods perform best in scenes that draw attention through contrast and highlights and localized prominent features. The research indicates that dominant color extraction requires multiple dimensions to function properly because a single perceptual cue cannot represent its complete nature.

C. Parameter Ablation Study

The proposed HPD-DCE method required a parameter ablation study to evaluate its stability and sensitivity which examined three essential elements: perceptual scoring weights and perceptual diversity threshold (ΔE) and superpixel granularity. The evaluation of all ablation results focuses on qualitative assessment because dominant color extraction mainly deals with how people understand visual information.

1) Effect of Scoring Weights: HPD-DCE determines candidate region color rankings through a system which combines saliency (S) with chroma (C) and perceptual distinctiveness (D) and region area (A) values. The system operates with default settings which distribute equal weight to all components.

$$0.4S + 0.3C + 0.1D + 0.2A.$$

The research team evaluated three different configuration sets which used saliency-dominant and chroma-dominant and area-dominant weightings. The saliency weight increase made the model focus on areas with high visual importance such as highlights and textures but it sometimes made background elements more prominent than they should be. The weighting system based on chroma dominance produced better results for colors with high saturation but it also made neutral structural elements less visible. The implementation of area-dominant weighting brought back frequency bias which produced palettes that were mostly background content. The balanced configuration produced the most realistic color combinations which worked well for all different types of scenes.

2) Effect of Perceptual Diversity Threshold: The perceptual diversity threshold ΔE determines the smallest color distance which must exist between entries in a palette. The system produced unnecessary color duplication because of its low threshold settings which made it difficult to distinguish between colors. The system generated insufficient color options when it used high threshold values because it failed to include important shades of color. The threshold of $\Delta E \approx 12$

Fig. 6. Qualitative comparison of dominant color extraction methods on a natural image. From left to right: original image, RGB K-means, CIELAB K-means, feature-based method of Chang and Mukai, and the proposed HPD-DCE method. RGB and CIELAB clustering are dominated by background colors, while the feature-based method preserves object-specific colors. HPD-DCE captures salient chromatic regions but may emphasize background structure when low-level saliency is dominated by texture.

TABLE I
QUALITATIVE COMPARISON OF DOMINANT COLOR EXTRACTION METHODS ACROSS PERCEPTUAL CRITERIA.

Method	Small Salient Colors	Background Suppression	Perceptual Diversity
RGB K-means	Poor	Poor	Low
CIELAB K-means	Poor	Poor	Medium
Chang & Mukai	Strong	Strong	High
HPD-DCE	Strong (attention-driven)	Medium	High

produced the most optimal results by achieving the right mix between different objects and complete object representation.

3) Effect of Superpixel Granularity: The number of superpixels determines the spatial resolution of region-level analysis. The algorithm produced incorrect results because it used either too few superpixels which led to region mixing or it performed segmentation at too high a level which produced noisy unstable color candidates. The palettes produced their most stable and understandable results when using intermediate value settings.

TABLE II
DEFAULT PARAMETER SETTINGS USED IN HPD-DCE EXPERIMENTS.

Parameter	Value
Number of superpixels	250
ΔE diversity threshold	12
Scoring weights (S, C, D, A)	$(0.4, 0.3, 0.1, 0.2)$

D. Summary of Findings

The experimental results show that no single dominant color extraction strategy exists which can perfectly replicate all human visual perception elements. The clustering results from RGB- and CIELAB-based methods depend on spatial frequency which results in background color influence but feature-based methods maintain object colors better. The proposed HPD-DCE approach builds upon these feature-based methods by uniting attention-driven cues with region-level analysis to generate color palettes which better represent visual prominence through perceptual diversity. The success of HPD-DCE depends on the accuracy of saliency estimation because these two methods work together to extract dominant colors through feature-based and saliency-driven approaches.

The human subject study from this work supports the qualitative criteria listed in Table I through direct perceptual assessment of the evaluated methods. The evaluation shows that palettes which achieve high scores in perceptual diversity and salient color preservation will produce better chroma and diversity results than human-generated color schemes. The research collects dominant color choices from actual users to create a human perception-based assessment system which serves as a foundation for qualitative evaluation.

V. CONCLUSION

The research compared different methods for dominant color extraction through the development of a human-perception–driven dominant color extraction (HPD-DCE) system which combines perceptual color representation with region-level analysis and saliency-inspired cues. The research used qualitative evaluation together with controlled parameter analysis to show that RGB and CIELAB clustering methods based on traditional methods depend heavily on spatial frequency which leads to missing important small color elements that humans can perceive.

The method of Chang and Mukai demonstrates how feature-based dominant color extraction works through its ability to separate color dominance from area by using perceptual elements which include contrast and chromatic strength. The HPD-DCE method builds upon this approach through its implementation of attention-based data processing and its ability to combine information at different regional levels which results in the detection of various visual elements that go beyond simple frequency analysis.

The experimental data shows that HPD-DCE fails to demonstrate superior performance than feature-based methods when objects become more visible because of color differences instead of basic visual attention cues. The results show that feature-based and saliency-driven methods work together in a way that demonstrates how perception of color dominance exists across multiple dimensions. The research indicates that dominant color extraction requires more than one perceptual criterion to achieve complete measurement.

Research should investigate new methods which unite feature-based dominance with higher-level semantic or object-aware saliency and improved attention models that duplicate human visual processing. The evaluation of dominant color extraction methods would become more perceptually grounded through the implementation of user studies and task-specific assessments. The research findings from this study help scientists understand color extraction better through perceptual dominance while showing that using multiple perceptual cues leads to better human-computer visual alignment.

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