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Chromatics in Urban Landscapes: Integrating Interactive Genetic Algorithms for Sustainable Color Design in Marine Cities

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Abstract: Color design plays a pivotal role in determining whether marine urban landscapes meet the diverse needs of individuals, encompassing their visual, psychological, behavioral, and spiritual dimensions. In the contemporary urban environment, a host of practical challenges, including severe color pollution, the absence of regional cultural characteristics, and a lack of humanistic sensitivity in public spaces' color schemes, necessitates a thorough exploration of the intricate relationship between color and human psychological needs within environmental contexts. This study leverages the potential of interactive genetic algorithms as a powerful tool for innovative color design solutions. Anchored in the nexus of the environment, human psychology, and color theory, this research delves into the intricate nuances of marine urban landscape color. Employing a comprehensive approach that combines questionnaires and extensive field surveys, we seek to elucidate the critical interplay between color and human well-being. Drawing upon the case study of Zhuhai Shijingshan Park, we harness the principles of interactive genetic algorithms to iteratively design marine urban color patterns. Through this experimentation, our study unveils novel design strategies that harmonize with the psychological idiosyncrasies of the human–environment interface. Specifically, the findings of our research highlight the profound impact of color selection on the emotional and behavioral responses of individuals within marine urban landscapes. Our study contributes vital insights into the art and science of marine urban color design, shedding light on the nuanced ways in which color choices can enhance the quality of urban spaces and promote human well-being. This research endeavors to bridge the gap between marine urban design and human psychology through a comprehensive exploration of color design in marine urban landscapes. By addressing the practical challenges and leveraging innovative design techniques, we strive to provide a holistic understanding of the symbiotic relationship between color and human experience, ultimately enriching the design practices that shape our urban environments.

Keywords: genetic algorithm; color design; auxiliary design; visual impact; marine cities

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1. Introduction

With the advent of the new century, China's urban construction has also ushered in unprecedented high-speed development. The urban color is being replaced by more and more new buildings. In China, the research on urban color and the environment is still in its infancy [1]. Many urban colors and colors have some problems. In the wave of globalization, the characteristics of cities have gradually disappeared, and the colors of cities have become colorful. This shows a tendency of "one color for thousands of cities" and becomes a city without characteristics and individuality [2]. As China's economy expands rapidly, numerous cities are erecting skyscrapers that mirror a standardized design. Over the past several years, numerous Chinese cities have sought out famous international architects for public building and spatial planning projects, but the end result

has been mediocre and has not led to a significant transformation in the appearance of the respective cities, akin to the impact of the Guggenheim Museum in Bilbao. This is due to several reasons. One reason is that many of the excellent public architecture designs are situated far from the city center, such as the Grand Theater in Harbin. It is surrounded by green space, is one-colored, and lacks contrast with other buildings in the city, which prevents the formation of an interesting effect. Additionally, there is a lack of color creation in water and waterfront spaces. Waterfront areas offer great opportunities for cities to develop unique characteristics. In recent years, Shanghai has made significant efforts in this regard, resulting in excellent outcomes. However, it appears that many other cities have not fully recognized the importance of this aspect. In their development of waterfronts, there is often an excessive focus on greenery, overlooking the importance of color coordination and hydrophilicity. Examples to follow are Hamburg's Riverside Corridor and Moscow's Zaryadzhya Park. In the rapid development of urban construction, there is an urgent need for a set of practical urban color landscape planning, design, and management to preserve and carry forward local culture and create a good urban landscape [3]. How to reasonably plan urban color, eliminate the convergence of urban color and color waste, create a good living environment, and explore a practical urban color planning model is one of the challenges facing urban development nowadays [4].

The problems associated with overall color in marine cities arise from various factors unique to these coastal environments. The marine environment presents specific climate and environmental challenges, such as intense sunlight, saltwater corrosion, and high humidity. These factors can affect the durability and maintenance of color choices, leading to fading, discoloration, and increased maintenance costs. Marine cities often face the issue of a monotonous color palette, with a prevalence of blues and neutrals that reflect the ocean but lack diversity. This can lead to a lack of visual interest and a sense of repetition throughout the urban landscape. In some cases, marine cities may lack a cohesive color scheme or design language. This can result in a disjointed appearance, where different buildings, infrastructure, and public spaces exhibit conflicting color choices that do not harmonize with each other or the surrounding environment.

This article conducts research on various needs in the urban construction process:

Cultural Sensitivity in Color Design: A deeper exploration of how cultural backgrounds influence color preferences and psychological responses is warranted. Research could delve into the nuances of cultural color symbolism and its impact on urban color design in different regions.

Environmental Impact Assessment: The study highlights the importance of color design in urban landscapes, but further research is needed to comprehensively assess the environmental implications of specific color choices. This includes studying how certain colors affect temperature regulation, energy consumption, and ecological sustainability in urban environments.

User-Centered Design Strategies: To address color pollution and enhance humanistic care in public spaces, research can focus on developing and testing user-centered design strategies. This could involve active engagement with residents and visitors to co-create urban color schemes that meet their visual, psychological, and spiritual needs.

Long-Term Color Effects: Conducting longitudinal studies to analyze how selected color patterns evolve over time in response to changing environmental, social, and cultural factors is essential. This research could provide insights into the long-term sustainability of color choices in urban landscapes.

Integration of Technology: With the mention of interactive genetic algorithms as a tool for color design, future research could explore the integration of emerging technologies, like augmented reality (AR) or virtual reality (VR), into the color design process. This could enable real-time color design and evaluations in urban environments.

Psychological Well-being Metrics: Develop and employ comprehensive metrics and assessment tools to measure the psychological well-being of residents and visitors influ-

enced by urban color patterns. This could provide empirical evidence of the impact of color design on human experiences.

Climate Change Adaptation: Given the increasing challenges of climate change in coastal areas, research could explore the role of color design in mitigating or adapting to its effects, such as temperature regulation and sea-level rise resilience.

Public Participation Platforms: Developing digital platforms or apps that engage the public in providing real-time feedback on urban color schemes is an area that requires further exploration. These platforms could foster a sense of ownership and collective decision-making in marine cities.

Addressing these research needs will contribute to the development of more sustainable, culturally informed, and psychologically enriching color designs for urban environments. These research needs represent opportunities for future investigations that can build upon the foundation laid by the current study, ultimately contributing to the development of more sustainable and user-centric color design practices in urban environments.

Seamlessly integrating color design studies into the fabric of marine cities is a matter of paramount significance. This imperative arises from the very challenges we have previously outlined—challenges that extend beyond mere aesthetics. In the context of marine cities, color design assumes multifaceted importance. It serves as a dynamic tool capable of enhancing overall visual coherence, fostering a strong sense of place, reinforcing cultural identity, and augmenting sustainability and resilience in these coastal urban environments.

The colors chosen for structures and spaces within marine cities can significantly impact their aesthetics and, consequently, their identity. Moreover, by carefully selecting and implementing color schemes, we can create environments that are not only visually appealing but also sustainable. Effective color design can aid in climate adaptation, facilitate wayfinding, and improve safety along coastal areas.

In essence, color design studies tailored to marine cities offer a holistic approach to urban development that encompasses not only the visual appeal but also the environmental and cultural dimensions of these unique settings. By recognizing and embracing the distinctive context and needs of marine cities, researchers and designers can chart a course towards vibrant, sustainable, and resilient coastal urban environments that harmonize with their natural surroundings and enrich the lives of their inhabitants.

One notable trend in current research is the increasing adoption of interactive genetic algorithms as effective tools for urban color design. These algorithms offer the potential to engage users in the design process and facilitate data-driven color choices, thereby promoting more user-centered and sustainable urban color designs. Furthermore, contemporary studies frequently draw upon relevant theories from fields, such as color science and environmental psychology. These theoretical frameworks provide researchers with a solid foundation for understanding how color choices can significantly impact individuals and their surroundings.

In terms of methodology, contemporary research typically employs a combination of data-collection methods. Questionnaires and field surveys are frequently utilized to gain a deeper understanding of urban landscape color preferences and their associated effects on well-being and behavior. Another notable development is the exploration of emerging technologies, like augmented reality (AR) and virtual reality (VR), to enhance the color design process. Researchers are increasingly interested in how these technologies can offer real-time, immersive experiences and facilitate more dynamic and responsive color design in urban settings. Moreover, there is a growing emphasis on considering the environmental impact of color choices in urban areas. Researchers are beginning to investigate how specific color schemes can influence microclimates, energy consumption, and ecological sustainability, aligning urban color design with broader environmental goals.

Prior research by Lekai Zhang, Zongyan Li, and Lung Wen Kuo has made notable contributions in fields closely related to color design and human perception. Zhang's work introduced a modeling method and a color matching design simulation platform [5],

providing a valuable real design platform that can strategically optimize design themes by incorporating multiple behavioral characteristics. Additionally, it explores the optimization of team cooperation models by adjusting team structures, offering both theoretical insights and practical applications for personalized design team operation modes [6]. Zongyan Li's research focused on the development of a class of color shift keying codes within the context of visible light communication. This innovative approach, utilizing finite-state machines, demonstrated enhanced transmission reliability compared to its corresponding codes while accounting for the constraints of color perception [7]. Furthermore, Lung Wen Kuo conducted experiments and analyses to determine the most suitable type of dynamic web page design, with a particular focus on the psychological impact of web page composition and color variations [8]. These studies have advanced our understanding of color's influence on human perception and preferences in various contexts. However, it is important to note that while these researchers have made significant contributions in their respective areas, none of these studies specifically delved into the domain of urban color design. This research aims to bridge this gap by focusing on the unique challenges and opportunities presented by urban environments and their colors.

When embarking on the color-selection process for urban landscapes, it is essential to carefully consider the desired overall tone that aligns with the intended ambiance and purpose of the space. Additionally, it is essential to understand the concept of "color carriers", which refers to the elements or objects within an environment that serve as vehicles for conveying emotions and messages through colors. In essence, these color carriers act as the conduits through which the chosen colors evoke specific emotional responses and communicate intended messages to individuals who interact with the environment. The selection of these color carriers is of paramount importance as they play a pivotal role in effectively representing the desired spatial colors. By identifying and strategically utilizing the most appropriate color carriers, designers can significantly enhance the visual impact and overall coherence of the landscape, ensuring that the chosen colors resonate with the environment's intended purpose and the emotions it seeks to evoke.

The objectives of this research can be categorized into three main dimensions. Firstly, it aims to delve into the intricate relationship between color and human psychological needs within environmental landscapes. Secondly, it seeks to leverage interactive genetic algorithms as a potent tool in the creation of urban landscape color patterns. Lastly, the research endeavors to formulate a comprehensive design strategy that harmonizes with the psychological attributes inherent to the human environment. This study builds upon an interactive genetic algorithm designed for urban color planning. This algorithm demonstrates notable efficiency gains in terms of time investment for urban color design tasks. Furthermore, it enhances overall productivity by generating a series of designs centered around a specific thematic concept derived from a database of images. Another advantage lies in its capacity to streamline the design process, reducing the mechanical actions required by designers when developing a scheme for a given theme under specific settings. This streamlined approach mitigates designer fatigue to a considerable extent. Ultimately, the research culminates in the establishment of a design strategy tailored to the urban landscape's color palette that aligns seamlessly with the psychological characteristics of the human environment.

2. Literature Review

This paper emphasizes the integral role of interactive genetic algorithms (IGAs) in the realm of urban ocean color design. IGAs represent a powerful computational tool that allows for the iterative, user-driven exploration and optimization of color schemes within the context of urban marine environments. Through the strategic application of IGAs, we aim to elucidate their efficacy in enhancing the visual appeal and psychological resonance of urban landscapes along coastal areas. This methodology enables us to harness the collective intelligence of designers and stakeholders, resulting in color schemes that are not

only aesthetically pleasing but also aligned with the unique challenges and opportunities presented by urban ocean settings.

2.1. The Importance of Urban Color

A city serves as a hub for national, regional, economic, and cultural interactions. People's perception of a city largely relies on the visual image it presents, and in the realm of visual experiences, the role of color is increasingly significant. The color of a city can be likened to its "face", as it reflects the identity, character, and essence of the city. This aspect brings forth happiness, comfort, beauty, and even confidence for its residents and visitors [9,10]. Color is an intangible visual language that exists in various facets of our surroundings. It creates a vibrant world and shapes our living environment. In the context of a city, color plays a pivotal role. It serves not only as a representation of the city's overall image but also as an embodiment of its cultural spirit and quality of life. Whether it is a foreign city or a bustling metropolis, the city's characteristics and culture can be sensed through its colors and iconic landmarks. A well-designed city exudes infinite charm that captivates and entices individuals to linger [11,12].

As the global economy advances, cities undergo development and transformation, yet the color schemes of cities are gradually deteriorating. It is becoming increasingly challenging for people to grasp the essence of color. Their usage and preferences for color are influenced by cultural factors. In addition to individual aesthetic considerations, the creators of urban color and the environment must also fully consider internal and external factors, such as the geographical climate, function, history, culture, and economy of the city. Otherwise, regardless of the color and environment of the city, they remain superficial, meaningless, and feeble [13,14].

Presently, urban color planning is still in its experimental phase, characterized by ongoing exploration and trial implementations. In comparison to the advanced developmental stage witnessed in other cultural cities, the urban spaces, color schemes, and traditional cultural connotations of many areas are experiencing a rapid decline. Thus, an integral aspect of urban color design lies in effectively preserving the city's rich history, distinctive features, and functional requirements. This entails addressing the challenges associated with maintaining a balance between contemporary development and the conservation of cultural heritage.

In the context of China's urban color landscape, numerous challenges arise that necessitate a comprehensive approach. Resolving these challenges at their core hinges on the enhancement of public awareness and understanding of color. By fostering a deeper comprehension of color and its impact on urban spaces, it becomes possible to navigate the complexities of urban color design with greater precision and sensitivity. By recognizing the challenges that exist within China's urban color landscape and proactively promoting a deeper understanding of color, we can lay the foundation for the development of sustainable and culturally resonant urban color design practices [15].

In our exploration of urban ocean color design and interactive genetic algorithms, it is crucial to consider how deliberate color contrasts contribute to the overall effectiveness of such design strategies. To further enhance visual experiences and influence the psychology and behavior of viewers within the urban marine context, we delve into the deliberate manipulation of the color, chroma, and region. The strategic use of color contrast serves as a powerful tool, evoking specific emotional responses and effectively directing individuals' attention within the urban landscape. The deliberate application of color contrasts allows designers to craft focal points, accentuate vital elements, and shape the overall perception and experience of the urban space. By skillfully managing the interplay between colors, we can optimize the impact of interactive genetic algorithms in urban ocean color design, aligning it seamlessly with our research objectives.

2.2. Problems of Urban Color

In today's world, the forces of globalization and urbanization are driving unprecedented changes beyond human control. While city development offers opportunities, it also presents new challenges. In China, urban construction has achieved notable progress but has also brought about a series of issues. These include the lack of urban landscape order and the rapid erosion of regional distinctions, leading to a loss of the city's own characteristics and integrity [16]. Presently, the colors of many cities appear untamed, expressing their individuality without adhering to any consistent order. This results in a state of extreme chaos, where the colors of buildings, outdoor advertisements, and the surroundings lack basic coherence and coordination. Various factors and limitations have disrupted the regional colors that traditionally defined urban areas, leaving modern cities with a homogenized appearance and lacking diversity and individuality in their landscapes [17]. The regional, national, and historical contexts that used to shape urban color have been disrupted, eroding distinct regional characteristics. The disappearance of urban characteristics can be primarily attributed to the lack of diversification. Urban color, as a unique feature of urban space, not only reflects regional culture but also plays a vital role in cultural inheritance and development [18]. However, it is heavily contaminated by color pollution, which refers to the improper use of color in the urban environment. Color pollution negatively affects human well-being and psychology and can damage the urban landscape [19]. Urban color is not merely an aesthetic and cultural concern but a form of visual pollution, representing a fundamental problem that requires more urgent attention than aesthetic and cultural issues [20].

When embarking on the color selection process for urban landscapes, it remains crucial to carefully consider the desired overall tone that aligns with the intended ambiance and purpose of the space. Additionally, the choice of colors as carriers assumes a pivotal role in conveying specific emotions and messages to those who interact with the environment. By identifying the most appropriate color carriers that effectively represent the desired spatial colors, designers can enhance the visual impact and coherence of the landscape.

2.3. The Importance of Color Design in Marine Cities

Urban color design holds profound significance within the context of marine cities, as it encompasses both the inherent challenges and unique characteristics of these coastal environments. Here, we delve into several compelling reasons why holistic urban color design is of paramount importance for marine cities:

Enhancing the Oceanic Experience: Urban color design serves as a dynamic conduit for enhancing the overall experience of residents and visitors in marine cities. By skillfully incorporating colors inspired by the natural surroundings, such as the serene ocean blues and vibrant coastal hues, the urban landscape can seamlessly merge with its maritime backdrop. This aesthetic synergy not only fosters a deeper sense of place but also forges a profound emotional connection between individuals and the ever-present allure of the ocean.

Celebrating Coastal Identity and Culture: Marine cities often boast rich coastal identities and vibrant cultural traditions. Holistic urban color design offers an invaluable canvas to visually express and celebrate these unique characteristics. By infusing urban spaces with colors, patterns, and design elements rooted in local heritage, traditions, and maritime history, these cities can proudly showcase their coastal identity. Such endeavors cultivate a profound sense of pride and belonging among residents, reinforcing the cultural tapestry of the coastal community.

Advocating Sustainability and Environmental Awareness: The color palette chosen for urban design carries the potential to convey powerful messages about sustainability and environmental consciousness, a particularly vital aspect for marine cities. These urban environments confront distinctive environmental challenges, including rising sea levels and marine conservation imperatives. Thoughtfully selected colors within urban design can serve as conduits for raising awareness and encouraging sustainable practices. For

instance, the strategic incorporation of shades of green and blue in urban infrastructure and public spaces evokes a tangible connection with nature, championing the preservation of the ocean ecosystem.

Mitigating Climate and Heat Effects: Urban color design, when judiciously applied, contributes significantly to ameliorating the impact of climate and heat in marine cities. The incorporation of lighter colors in building facades, pavements, and urban materials reflects sunlight and heat, resulting in reduced heat absorption and a mitigation of the urban heat island effect. This not only enhances the comfort of residents and visitors but also bolsters energy efficiency, advancing the cause of sustainability in these coastal urban environments.

Facilitating Wayfinding and Ensuring Safety: Urban color design takes on an instrumental role in aiding wayfinding and safeguarding the well-being of residents and tourists. By employing distinct colors or color schemes for landmarks, signage, and public infrastructure, marine cities can create a clear and intuitive visual hierarchy. This enhancement in navigability empowers individuals to easily identify key locations, ensuring they can navigate the urban landscape with ease and confidence. This is particularly crucial along waterfront areas where safety and security are paramount.

A holistic urban color design approach tailored to marine cities transcends mere aesthetics; it becomes a conduit for cultivating a profound sense of place, championing sustainability, celebrating coastal identity, mitigating climate challenges, and ensuring navigational safety. By carefully curating colors and design elements inspired by the oceanic environment, marine cities can evolve into vibrant, sustainable, and harmonious spaces that seamlessly coexist with their coastal surroundings, ultimately offering an enriching experience for residents and visitors alike.

2.4. Integration of Interactive Genetic Algorithms in Urban Ocean Color Design

Central to our exploration of urban ocean color design is the strategic utilization of interactive genetic algorithms (IGAs). These algorithms are pivotal components of our methodology, guiding the development of innovative color schemes tailored to the specific demands of coastal urban environments. Here, we provide a concise overview of how IGAs are seamlessly integrated into the design process, shedding light on their role in crafting our comprehensive color design strategy.

Understanding Interactive Genetic Algorithms (IGAs): IGAs are computational tools designed to harness the collective intelligence and preferences of designers, stakeholders, and communities. They facilitate iterative, user-driven exploration and the optimization of color schemes within the urban marine context. IGAs function on the premise of genetic evolution, where color schemes evolve and adapt over successive generations to converge upon the most fitting and harmonious combinations.

The Integration Process: IGAs are seamlessly woven into our urban ocean color design process, ensuring that they serve as dynamic instruments for creativity and refinement. The process commences with the selection of an initial set of color parameters, often inspired by the marine environment's natural palette. Designers, stakeholders, and even community members then engage in a collaborative process of evaluation and selection. Through user feedback and preferences, the algorithm refines and evolves the color schemes, continually optimizing for aesthetic appeal and alignment with the unique challenges presented by coastal urban spaces.

Contributions to the Overall Color Design Strategy: IGAs significantly contribute to our overarching color design strategy by fostering a sense of co-creation and adaptability. By harnessing the collective wisdom and creativity of diverse participants, IGAs ensure that the final color schemes resonate with the preferences and aspirations of the community. This democratized approach to color design enhances community engagement, augments the visual appeal of urban spaces, and reinforces the harmonious coexistence of the urban environment with its coastal surroundings.

Urban ocean color design methodology leverages interactive genetic algorithms as instrumental tools that guide the iterative evolution of color schemes, incorporating diverse perspectives and preferences. This integration not only empowers communities but also contributes to the creation of visually stunning and contextually relevant color designs for coastal urban spaces.

2.5. Addressing Unique Challenges in Ocean Cities

While we have highlighted the numerous advantages of urban color design in ocean cities, it is equally vital to acknowledge and address the specific challenges inherent to these coastal environments. Ocean cities present a distinctive set of hurdles that necessitate thoughtful consideration when formulating color design strategies. Here, we delve into some of these unique challenges to offer a more comprehensive perspective:

Dynamic Coastal Environments: Ocean cities are intrinsically linked to dynamic coastal ecosystems characterized by fluctuating tides, changing weather patterns, and seasonal variations. These dynamic shifts pose a continuous challenge to urban color design. The color palette and materials chosen must not only withstand the rigors of coastal climates but also adapt harmoniously to the ever-changing natural surroundings. The ability to maintain aesthetic coherence amidst such dynamism is a paramount concern.

Harmonizing with Natural Surroundings: Achieving a seamless blend between urban structures and the natural beauty of coastal landscapes is another challenge unique to ocean cities. In these environments, vibrant blues of the ocean, soft sandy shores, and lush greenery often set the backdrop for urban developments. Urban color choices must respect and complement these natural colors, ensuring that the cityscape harmoniously integrates with, rather than clashes against, its breathtaking surroundings.

Durability in Saltwater Exposure: Ocean cities face a constant battle against the corrosive effects of saltwater exposure. The harsh saline environment can accelerate wear and tear on materials, potentially compromising the longevity and vibrancy of urban color schemes. Designers must carefully select materials and color finishes that are not only aesthetically pleasing but also engineered to withstand the corrosive impact of saltwater, ensuring the durability and integrity of the chosen color palette.

Balancing Environmental Conservation: Conservation and preservation of the ocean ecosystem are paramount in ocean cities. The choice of colors must align with principles of environmental sustainability, avoiding any adverse impact on marine life or water quality. This necessitates the use of eco-friendly and non-toxic materials in urban color design, minimizing the ecological footprint of color choices and materials.

By recognizing and addressing these unique challenges specific to ocean cities, our approach to urban color design becomes more nuanced and adaptive. The careful consideration of these hurdles ensures that our color design strategies not only enhance aesthetics but also coexist harmoniously with the dynamic coastal environments, contributing to the overall sustainability and livability of ocean cities.

3. Methodology

The urban landscape encompasses a diverse range of environments, with gardens and squares standing out as two distinct types. These types not only vary in their physical characteristics but also differ in terms of their color space bearing and the psychological impact they have on individuals. A crucial factor in shaping the overall atmosphere of these landscapes is the proportion of color space carriers employed within each type. This proportion directly influences the dominant tone that permeates the entire scene, highlighting the importance of thoughtful color selection.

Understanding the unique characteristics of gardens and squares and their distinct color space bearing allows for a more nuanced approach to urban landscape design. By carefully considering the proportion of color space carriers, selecting colors that align with the desired tone and message, and employing intentional contrasts, designers can create engaging and impactful environments that elicit the desired psychological and behavioral

responses from viewers. This consideration of color in urban landscape design contributes to the overall aesthetic appeal and functionality of these spaces, enhancing the quality of life for those who interact with them [21].

Research aims to develop a color design strategy that aligns with the visual, psychological, behavioral, and spiritual needs of individuals in urban environments. To achieve this, interactive genetic algorithms are utilized, which are a powerful tool for generating and optimizing color patterns. The optimization criteria used in process encompass a range of factors:

Interactive Genetic Algorithms (IGAs): At the heart of our methodology lies the utilization of interactive genetic algorithms (IGAs). IGAs are recognized as potent tools for color design, particularly in complex urban landscapes. These algorithms enable a systematic exploration of color patterns by iteratively generating and refining solutions based on user feedback. In our case, the user feedback is collected through questionnaires and field surveys, allowing us to integrate human preferences and perceptions into the color design process. IGAs facilitate the optimization of color combinations by considering a multitude of factors, including aesthetics, harmony, and psychological impact, all of which are crucial for achieving sustainable and visually appealing urban environments.

Theories from Color Science and Environmental Psychology: To provide a robust theoretical foundation for our research, we draw upon key principles from color science and environmental psychology. Color science provides insights into the physiological and perceptual aspects of color, helping us understand how different colors are perceived and how they can evoke emotional and behavioral responses. Environmental psychology contributes by delving into the relationship between the environment and human well-being, allowing us to make informed decisions about color choices that resonate with the psychological needs of residents and visitors in marine cities. These theories guide our approach to color selection and combination, ensuring that our design strategies are rooted in scientific understanding.

Psychological Impact: Research considers the psychological impact of colors on individuals within urban settings. This includes evaluating the emotional responses and perceptions associated with different color combinations.

Cultural Significance: Research takes into account regional cultural characteristics and the cultural significance of certain colors. This ensures that the chosen color patterns resonate with the cultural context of marine cities.

Color Harmony: Research analyzes the harmony and coherence of color combinations in the urban landscape. This involves assessing the visual appeal and balance of colors to create a pleasant environment.

Environmental Integration: Research considers how color patterns can be integrated with the natural and built environment of marine cities. This involves examining how colors interact with architectural elements, green spaces, and water bodies.

Human-Centered Design: Research prioritizes a human-centered approach by involving residents and stakeholders through questionnaires and field surveys. Their feedback helps guide the optimization process, ensuring that the color choices align with the needs and preferences of the local community.

Iterative Evolution: Research employs an iterative approach with the interactive genetic algorithm. This allows us to explore a wide range of color patterns by varying parameters related to geometric and floral designs. Through multiple iterations, we adapt and refine the color patterns based on the optimization criteria mentioned above.

Environmental Sustainability: In line with research's sustainable focus, the environmental impact of color choices are considered. This includes assessing the ecological implications of using certain colors and materials.

3.1. Method

(1) Research Design:

The choice of interactive genetic algorithms (IGAs) as methodology in this study is rooted in their unique suitability for addressing the research question and contributing to the exploration of color patterns in urban ocean design. IGAs offer several key advantages that align with the study's objectives:

Participatory Design: IGAs are inherently participatory, enabling collaboration among designers, stakeholders, and community members. This participatory element is crucial in urban ocean color design, as it allows diverse perspectives and preferences to shape the final color schemes. By involving multiple stakeholders in the decision-making process, IGAs ensure that the resulting color patterns resonate with the aspirations of the community and meet their psychological needs.

Iterative Optimization: The iterative nature of IGAs allows for the continuous refinement of color patterns over successive generations. This iterative optimization process is well-suited to urban environments, which often demand adaptability and evolution to meet the changing needs and preferences. In the context of marine cities, where the coastal environment and community dynamics are dynamic, IGAs provide a means to adjust color choices in response to evolving conditions.

Integration of Relevant Theories: IGAs facilitate the integration of theories from color science and environmental psychology into the design process. These theories provide a theoretical framework for understanding the psychological and behavioral impact of colors in urban environments. IGAs enable designers to apply these theories practically, guiding the selection of colors and patterns that evoke desired emotional responses and promote well-being among urban residents and visitors.

This study employed a comprehensive research design that combined qualitative and quantitative methods in an exploratory approach. The aim was to investigate the relationship between color and human psychological needs in environmental landscapes, with a specific focus on sustainable design for marine cities. Interactive genetic algorithms (IGAs) were selected as an effective tool for color design and for integrating relevant theories into the design process. The iterative nature of IGAs allowed for multiple feedback loops with participants, facilitating the exploration of different color patterns and their evaluation based on human preferences and psychological needs. The study incorporated theories from color science and environmental psychology to guide the design process.

(2) Data Collection:

This research data collection process was meticulously structured, employing a blend of questionnaires and fieldwork. This comprehensive approach was undertaken to holistically understand how people perceive and interact with color in the urban environment, particularly in the context of marine cities, to delve deep into participants' perceptions, preferences, and psychological responses to color within urban landscapes. Its development underwent rigorous scrutiny to ensure its effectiveness in providing an encompassing view of participant perspectives. The questionnaire encompassed several key sections:

Perceived Emotional Responses: Participants were presented with a series of urban landscape images, each featuring different color schemes. They were then prompted to articulate their perceived emotional responses to each image using a predefined set of emotional descriptors, such as "very satisfied", "satisfied", "average", and "dissatisfied".

Preference Rankings: Participants were invited to rank various color schemes and combinations based on their personal preferences. This ranking exercise allowed us to identify the color patterns that resonated most with participants.

Psychological Impact Assessment: The questionnaire included a series of questions aimed at evaluating the psychological impact of colors within urban landscapes. Participants were asked to rate the extent to which specific color combinations influenced their feelings of comfort, well-being, and overall satisfaction with the urban environment.

Demographic Information: In addition to the perceptual and preference data, participants were requested to provide demographic information, including age, gender,

profession, and the duration of their residence or involvement with marine cities. This demographic data enriched our understanding of how color preferences and perceptions might vary across different demographic groups.

Fieldwork and Case Study Area: In conjunction with the questionnaire, fieldwork was conducted within Zhuhai Shijingshan Park, which was selected as our case study area due to its alignment with the research objectives and its representation of a marine city. During the fieldwork, we performed visual observations and measurements to meticulously document color elements present in the park. Additionally, contextual information regarding the integration of these color elements into the urban landscape was meticulously recorded.

(3) Data Analysis:

The data collected through the questionnaire were subjected to descriptive statistics and correlation analysis to explore the relationship between color preferences and psychological needs.

Descriptive Statistics: Descriptive statistics were employed to summarize and describe key features of the collected data. Measures, such as the mean, median, standard deviation, and frequency distribution, were calculated to provide a quantitative overview of participants' responses.

Correlation Analysis: Correlation analysis was conducted to examine the strength and direction of the relationship between color preferences and the various psychological needs identified in the questionnaire. This analysis aimed to identify significant correlations between specific colors and psychological responses, shedding light on the associations between color and human psychological well-being.

The analysis yielded several findings that significantly contribute to the understanding of urban color design in marine cities:

Strong Correlations: The data revealed strong positive correlations between certain color preferences and specific psychological needs. For instance, participants consistently associated cool ocean blues and refreshing coastal greens with feelings of calmness and relaxation. These color preferences were also linked to heightened perceptions of well-being and comfort in urban marine environments.

Demographic Variations: An intriguing aspect of findings was the presence of demographic variations in color preferences and their associated psychological responses. For example, younger participants tended to favor vibrant and energetic color palettes, while older participants leaned toward more serene and subdued hues. These distinctions offer valuable insights for tailoring color designs to different demographic groups within marine cities.

Design Implications: The findings hold practical implications for sustainable design in marine cities. By recognizing the strong correlation between specific color choices and enhanced psychological well-being, urban planners and designers can strategically employ color palettes that foster positive psychological responses, contributing to the overall livability and vibrancy of marine urban environments.

3.2. Exploration of Park Landscape Color Design Methods

Zhuhai Shijingshan Park was established in 1987, covering an area of about 500,000 square meters, and is located in the tourist center of Zhuhai. It is connected to the North Coastal Road in the east, the Shijingshan Tourism Centre in the south, and the downtown area of Xiangzhou in the north, with convenient transportation and a very advantageous location. Of this, greenery occupies four-fifths of the space, while the main buildings and hard surfaces occupy one-fifth of the area (Figure 1).

Figure 1. Shijingshan Park, Zhuhai.

The park's landscape color plays a vital role in shaping the overall visual experience and atmosphere of the park. It is primarily conveyed through two key spatial carriers: greenery and the main building. Greenery occupies a significant area and proportion within the park, making it a dominant element that significantly impacts the spatial perception and spiritual fulfillment of visitors. The extensive presence of greenery creates a sense of tranquility, harmony with nature, and overall visual appeal. The color green is often associated with growth, vitality, and relaxation, providing a soothing and refreshing environment for park visitors [22,23]. The quantitative analysis results, as shown in Table 1, provide further insights into the distribution and composition of colors within the park. It is apparent that in the overall garden planning, greenery plants cover a substantial portion, accounting for approximately 59% of the total area. This dominance of greenery as the primary color in the park's vegetation is expected, as it aligns with the park's natural and serene setting. The presence of other colors within the park should complement and harmonize with the dominant green hue, creating a balanced and visually pleasing color palette that enhances the overall landscape. In contrast to the expansive greenery, the main buildings occupy a relatively smaller footprint within the park, comprising approximately 18% of the total area. However, despite their smaller size, the facades of these buildings display a rich variety of colors. This diversity of building colors adds visual interest and architectural character to the park, providing focal points and enhancing the overall aesthetic appeal. The garden hardscape elements, primarily consisting of park roads and recreational areas, make up around 12% of the total area. These areas are predominantly characterized by shades of gray and white. The use of neutral colors in hardscape elements helps create a visually cohesive and harmonious backdrop that allows the vibrant colors of the greenery and buildings to stand out. Additionally, the neutral tones of gray and white contribute to a sense of cleanliness and elegance within the park. Lastly, garden vignettes occupy the smallest portion, accounting for approximately 11% of the total area. These vignettes serve as decorative accents throughout the park's color palette, adding visual interest and enhancing the overall aesthetic quality. The dominant color in these vignettes is white, which symbolizes purity, simplicity, and elegance. In addition to white, these vignettes also incorporate accents of higher-purity reds, yellows, and blues, creating pops of color that draw attention and create focal points within the park [24].

Table 1. Proportion of park landscape color carriers.

	Proportion of Floor Area	**Main Colors**
Greenbelt plant	59%	Green
Building	18%	White or green
Hard garden	12%	Gray and white
Pieces of garden	11%	White, red, yellow, and blue with high purity

In this section, the selection of Zhuhai Shijingshan Park typifies the quintessential characteristics of a marine city environment, rendering it an ideal setting to evaluate how well IGAs could generate contextually relevant and aesthetically pleasing color palettes. The objective was to transform this urban space into a harmonious extension of the marine environment. The research elucidated the pivotal role of the Zhuhai Shijingshan Park case study in validating the effectiveness of our interactive genetic algorithms (IGAs) within the broader experimental design. This case study not only informed but also confirmed the practical application of our algorithms in the field of urban ocean color design.

A core feature of this experiment was the iterative nature of IGAs. The color schemes evolved based on user feedback and preferences. The algorithms refined and adapted color combinations, systematically optimizing the aesthetic appeal and contextual relevance. Throughout the process, the specific urban context of Zhuhai Shijingshan Park remained a focal point. This encompassed recognizing the dynamic nature of coastal environments, harmonizing with natural surroundings, and addressing the unique color durability challenges posed by saltwater exposure. The participatory approach resulted in heightened community satisfaction, as residents and stakeholders felt a genuine connection to the color schemes that adorned their urban environment.

The analysis reveals the significance of the park's landscape color, primarily conveyed through greenery and the main building. The extensive presence of greenery creates a serene and visually appealing environment that contributes to visitors' spatial perception and spiritual fulfillment. The quantitative analysis further emphasizes the dominance of greenery in the park's vegetation, with other colors complementing and harmonizing with the primary green hue. The smaller footprint of the main buildings allows for a rich variety of colors, adding architectural character and visual interest. The hardscape elements provide a neutral backdrop, while garden vignettes serve as decorative accents with white as the dominant color. Together, these components create a harmonious and visually captivating color composition within the park, enhancing the overall aesthetic quality and creating a delightful experience for park visitors.

3.3. Research on Shijingshan Park Square Landscape Color Design Method

Upon conducting a comparative analysis of the color space within the square, it becomes evident that architecture and greenery play crucial roles as the primary spatial carriers. Their purpose is to cater to people's psychological need for a sense of belonging to a place, fostering a connection between individuals and their environment. However, the main color space carrier within the square is the hard ground, which serves multiple purposes. It not only satisfies visual requirements but also contributes to spatial perception and environmental identification [25]. This analysis highlights the similarities between architecture and greenery as spatial carriers, revealing that the color design of the plaza-style ground landscape primarily focuses on meeting people's psychological and behavioral needs through the hard ground. The design places greater emphasis on evoking a sense of belonging and attachment to the place. In contrast, the green landscape assumes a somewhat weaker role, with greenery primarily serving as the main color element rather than directly addressing the psychological aspects of belonging [26].

Further analysis and generalization provide deeper insights into the color design of the square. Specifically, the color scheme of the greenery is predominantly influenced by the presence of tree pools, accounting for approximately 7% of the total green area. These tree pools contribute significantly to the overall visual impact and aesthetic composition of the greenery within the square. On the other hand, the square area is dominated by square signs or buildings, which occupy around 15% of the square as a background. The color choices and design of these structures significantly contribute to the overall ambiance and character of the square. The hard landscape elements, such as pavements and pathways, assume a prominent role in the square's color composition, occupying a substantial portion of approximately 76% of the entire square area. These elements not only serve practical functions but also significantly impact the visual experience and overall color scheme

of the square. Additionally, the garden accessories, including rubbish bins and signage, constitute a relatively small portion, making up only 2% of the total space. Despite their small scale, these accessories play a significant role in maintaining cleanliness, organization, and providing essential information within the square [27]. The findings from this analysis, as presented in Table 2, provide valuable insights into the distribution and composition of colors within the square. They enhance our understanding of the overall color palette, the significance of different spatial elements, and the design elements that contribute to the visual and experiential aspects of the square.

Table 2. Proportion of square landscape color carriers.

	Proportion of Floor Area
Greenbelt plant	7%
Building	15%
Hard garden	76%
Pieces of garden	2%

3.4. The Process of Urban Color Design Based on Interactive Genetic Algorithms

1. Coding:

This study harnessed the capabilities of industry-standard software, including Adobe Photoshop CS6 and Adobe Illustrator CS5, as our primary extraction tools for creating a comprehensive pattern database. These tools afforded us a versatile platform to capture an extensive array of floral and geometric patterns found in the natural world.

The pattern extraction process was a meticulous endeavor, involving not only the capture but also the transformation of these patterns. Techniques, such as simplification, addition, and exaggeration, were meticulously applied to deform and model these patterns effectively [28]. This intricate process aimed to ensure that the patterns were not only visually appealing but also adaptable to the interactive genetic algorithm.

2. Binary Encoding:

Our approach to binary encoding was methodical and aimed at maximizing the encoding capabilities of our pattern database. Consecutive Arabic numeral numbers, which played a pivotal role in Chapter 3, were systematically represented as binary strings, composed of "0" and "1".

A critical aspect of our encoding strategy was the establishment of a diverse and expansive pattern database. To achieve this, an 8-bit binary code was utilized, resulting in a total of 256 distinct patterns. Each pattern was associated with a unique binary code, ranging from 00000000 to 11111111.

To further augment our encoding capabilities, this study employed a 16-bit binary code, created by combining two 8-bit binary code strings. This approach facilitated a seamless one-to-one correspondence between individual geometric and floral patterns and the comprehensive search space of the interactive genetic algorithm [29,30].

3. Selection:

The selection process was a pivotal phase in our research, guiding the algorithm's decision-making process regarding which patterns to prioritize for subsequent variations and crossovers. The process was informed by the pattern designer's evaluation of each geometric and floral pattern initialized by the system.

Through a meticulous scoring process, the algorithm identified and selected the highest-scoring individuals. This approach ensured that the most promising patterns were granted precedence in the evolutionary process [31].

4. Adaptation Evaluation:

Within the realm of interactive genetic algorithms, the evaluation process held profound significance in determining the algorithm's fitness value. Our interactive geometric floral pattern design program streamlined this evaluation into a multi-step procedure.

The initial step involved decoding the geometric floral pattern string to ascertain the pattern's expression type.

Subsequently, the program calculated the objective function value of each individual pattern based on subjective scoring provided by the designer for the initial values selected by the program.

Further refinement was achieved through the application of a linear fit of the objective function value using an RBF neural network agent model, ultimately determining a fitness value for each individual pattern [32,33].

5. Hybridization:

Hybridization served as a pivotal process aimed at fostering the evolution of new patterns. This intricate procedure involved the replacement and recombination of coded binary codes from two parent geometric and floral pattern individuals.

A notable advantage of hybridization was its capacity to pass on desirable aesthetic properties approved by the designer from the previous pattern generation to the next. This inheritance allowed newly decoded binary strings to combine inherited stylistic beauty with unique characteristics.

This harmonious blend enhanced the adaptability of individual pattern elements, contributing to a more diverse and aesthetically pleasing pattern repertoire [32,33]. The hybridization of binary strings promoted an exchange between geometric and floral patterns, ultimately resulting in the emergence of patterns with enhanced aesthetics and improved global search performance of the algorithm [34].

6. Variation:

While the variation operator procedure was not the primary driver of generating new individual geometric and floral patterns, it played a crucial role in maintaining the algorithm's exploration of the entire pattern library.

This operator prevented premature convergence to local optima within the geometric and floral pattern library, ensuring the algorithm's continued exploration of a global search space.

By doing so, the variation operator facilitated the discovery of more diverse and innovative patterns, preventing the algorithm from falling into a local optimum and contributing to the algorithm's robust global search capabilities [35].

These methodological components, with their intricate details and strategic applications, underpinned our research's ability to harness interactive genetic algorithms for sustainable urban color pattern design. The flowchart of the algorithm is shown in Figure 2.

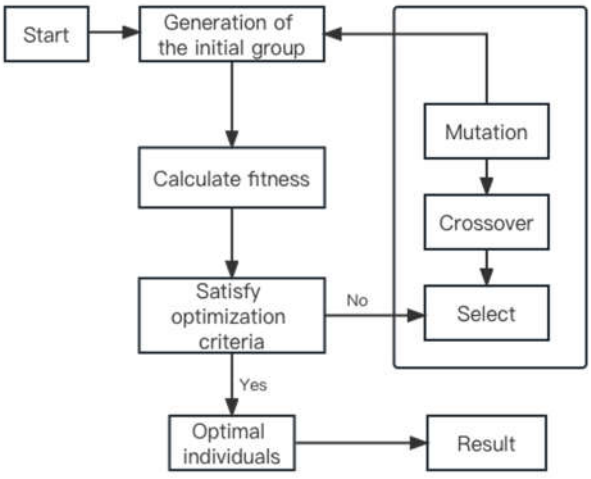

Figure 2. Algorithm flow chart.

4. Experimental Analysis of Urban Ocean Color-Aided Design Based on the Interactive Genetic Algorithm

4.1. Survey Analysis

On the premise of not disturbing the people in Zhuhai Shijingshan Park and Shijingshan Park Square, they were photographed and analyzed, and people around were talked to, to understand their views on the colors of the square, and a questionnaire survey was conducted to find out the problem areas, from which 100 questionnaires were distributed in Square (92 were validly returned). The selection of 92 valid responses was based on a careful consideration of statistical power and the desire to provide meaningful insights. There were eight unqualified questionnaires due to incomplete answers and other reasons. This sample size was deemed appropriate for our research objectives, as it allowed for a robust statistical analysis and the detection of significant correlations between color preferences and psychological needs. Additionally, this research applied rigorous quality-control measures to ensure the validity and reliability of the responses, further enhancing the credibility of the research survey results. The basic information of the survey respondents included where the respondents came from and their age; the survey was mainly about the general impression of the Square and the general feeling of the colors of the urban landscape; the colors of the garden elements were assessed in detail, taking Shijingshan Park Square as an example. To comprehensively capture visitor preferences and contextual insights, our research employed a multifaceted data collection approach. Firstly, we administered surveys to visitors, both in situ and through online channels, with the aim of soliciting their opinions, preferences, and emotional responses concerning the color palette prevalent in the urban milieu. To ensure the representativeness of our sample, this research employed a stratified sampling technique. This involved categorizing potential respondents into distinct demographic groups, including age, gender, occupation, and residence location. Within each stratum, participants were randomly selected to participate in the survey. The survey aimed for a sample size that would provide statistically significant results while ensuring diversity. The rationale behind this diversity was to capture a comprehensive spectrum of perspectives on urban color design, ensuring that these research findings are robust and applicable across different demographic segments. These meticulously constructed questionnaires are thoughtfully designed to elicit specific feedback pertaining to the visual, psychological, behavioral, and spiritual dimensions of their color-related experiences. Secondly, we executed extensive field surveys across various marine cities, exemplified by our focal case study, Zhuhai Shijingshan Park. These field investigations entailed systematic observations of extant color schemes, their interactions with the natural and built environment, and their consequential effects on the overall visitor experience. By synergizing these complementary methodologies, our research endeavors to cultivate a diverse and information-rich dataset, fostering a nuanced comprehension of the role and implications of color in the context of marine cities.

Through the analysis of the survey results, it was found that there are many people flowing through Zhuhai Square, and they are divided into three types, one is local residents, one is foreign visitors, and another is residents of the province. The majority of the survey respondents were middle-aged and elderly people, followed by teenagers, with a diversified target of visitors.The visitor survey and analysis table is shown in Table 3.

In this paper, the researchers focused on the color elements of the landscape in Zhuhai Plaza and conducted five evaluations: very satisfied, satisfied, ordinary, bad, and very bad. By utilizing post-evaluations, the researchers aimed to understand the satisfaction levels of tourists regarding the color of Zhuhai Plaza's landscape. The analysis of user feedback and satisfaction with the color of the plaza's landscape provides valuable insights for planning and designing landscapes, facilities, and buildings in the area. By setting up these five evaluation categories, the researchers were able to capture a wide range of responses and opinions from tourists visiting Zhuhai Plaza. The inclusion of "very satisfied" and "very bad" categories allows for extreme responses, highlighting the potential for both positive and negative experiences with the color elements of the landscape. This comprehensive

evaluation approach enables a more nuanced understanding of user preferences and satisfaction levels.

Table 3. Investigation and analysis of tourists.

	Proportion of Floor Area	Proportion
Place of ownership	Native Person	76%
	Outsider	23%
	Foreigners	1%
Age	Below 18	4%
	18–35	19%
	36–50	36%
	50–60	15%
	Above 60	26%

Moreover, the analysis of user feedback and satisfaction levels contributes to an understanding of the public opinion. By summarizing the color preferences and satisfaction levels of visitors to Zhuhai Plaza, the researchers can gain insights into the preferences of the local community and tourists alike. This information is crucial for future planning and design endeavors in the area, as it allows decision-makers to align their color choices with the desires and expectations of the public.

Figure 3 provides a visual representation of the satisfaction levels of tourists regarding various categories of the square space color in Zhuhai Plaza. The horizontal axis depicts specific categories of color design, including the overall color design of the square, ground pavement color design, building facade color design, landscape color design, and green plants and flower color matching. The numerical axis represents the satisfaction levels, with a range from −2 to 2, where negative values indicate dissatisfaction and positive values indicate satisfaction. The numerical axis represents the satisfaction of the tourists; −2 to −1.1 means very bad, −1–0.1 means bad, 0 means average, 0.1–1 means satisfactory, and 1.1–2 meets the standard very satisfactory.

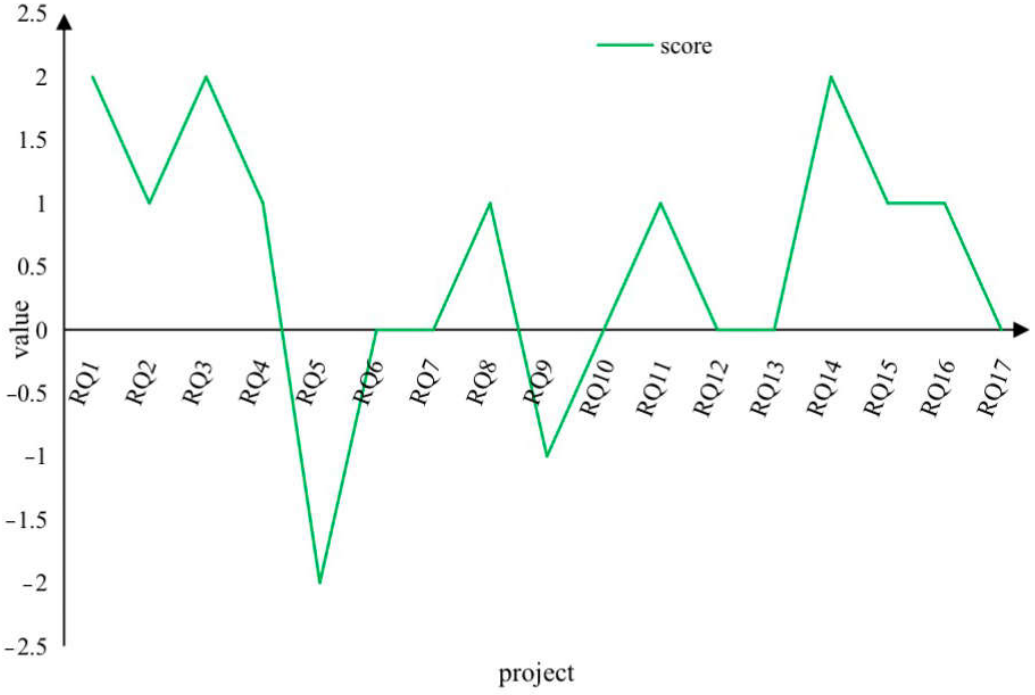

Figure 3. Landscape color evaluation form of the plaza.

The results from Figure 3 highlight the overall satisfaction levels of tourists with the color design of Zhuhai Plaza. The highest satisfaction levels were observed in the

overall color design of the square (category 'RQ1'), the landscape color design (category 'RQ3'), and the color design of the building facades (category 'RQ14'). These findings indicate that tourists found these aspects of the color design to be particularly appealing and visually pleasing.

Conversely, when analyzing the survey results, there was a contrasting trend in categories that garnered the lowest satisfaction levels, specifically concerning the cultural infrastructure color scheme design (category "RQ5") and the ladder color design (category "RQ9"). The data highlight that tourists expressed notably lower levels of satisfaction when evaluating the color choices and design implementation in these specific areas of Zhuhai Plaza. To better understand these results and derive meaningful insights, it is essential to delve into potential explanations for the lower ratings.

In the case of the cultural infrastructure color scheme design ("RQ5"), the diminished satisfaction levels could be attributed to a disconnect between the color choices made for these elements and their intended cultural significance or historical context. It is plausible that tourists expected a more harmonious integration of colors that resonate with the cultural heritage of the area, and the discrepancies in this regard might have led to the lower satisfaction scores. This points towards the importance of aligning color schemes for cultural elements with the broader narrative and identity of the urban environment.

Similarly, in the case of ladder color design ("RQ9"), the lower satisfaction levels may signify a misalignment between the ladder designs and the overall aesthetic vision of Zhuhai Plaza. Tourists may have perceived the ladder color choices as incongruent with the plaza's overarching design language, leading to a sense of visual dissonance. Addressing this aspect might require a more cohesive approach to color selection and design implementation across various architectural elements within the plaza.

These insights into the specific areas of lower satisfaction offer valuable guidance for potential improvements in Zhuhai Plaza's urban color design. By reevaluating and potentially realigning color schemes and design choices in cultural infrastructure and ladder elements, this research can strive for a more coherent and culturally resonant urban landscape. This, in turn, has the potential to enhance the overall tourist experience and create a stronger sense of place within the plaza.

In gardens, the recognition of color space plays a significant role, particularly in the design of public facilities. Different functions of these facilities prompt people to engage in various behaviors. For example, the color design of the guide system (category "RQ9"), bulletin boards (category "RQ11"), and bathroom facades (category "RQ10") all influence visitors' actions and experiences within the garden. Moreover, the ability to distinguish colors is influenced by distance, which is an important factor to consider. Therefore, when making enhancements, color methods that enhance visibility can be employed. On the other hand, in weakening design, the desired landscape effect is achieved by reducing the brightness of colors.

The color (category "RQ13") of sewage treatment facilities has a significant impact on the environmental quality of the city. However, despite being integrated with the surrounding environment, the low brightness and poor functionality of their color design can hinder the effective guidance of tourists towards adopting civilized behaviors. To address this, it is recommended to harmonize the color with the surrounding environment while increasing the brightness and purity. This adjustment would enable people to locate the facilities from a distance, facilitating standardized hygiene and civilized behavior.

In the context of squares, lighting facilities serve the purpose of night lighting. The color design of these facilities tends to have a relatively thick appearance with low brightness, maintaining a natural harmony. The success of the square's color design lies in its ability to create a balanced and visually pleasing atmosphere during nighttime activities.

The survey conducted among the population provides an overall positive assessment of the use of colors in the park. The strengths and weaknesses of the park's color design are summarized based on the survey's rating criteria. The numerical axis represents the satisfaction of the tourists; -2 to -1.1 means very bad, -1–0.1 means bad, 0 means

average, 0.1–1 means satisfactory, and 1.1–2 meets the standard very satisfactory. Figure 4 demonstrates that the overall landscape color feeling (category "RQ1"), the landscape color design along the walkway (category "RQ9"), the perception of the four-season lawn (category "RQ6"), the richness of flower matching (category "RQ14"), and the compatibility of tall greenery (category "RQ15") receive satisfactory ratings. On the other hand, the color design of facilities in the cesspool (category "RQ13"), guide signs (category "RQ11"), and basic cultural facilities (category "RQ7") have average scores in the negative range. The color of the entrance gate (category "RQ3") received the lowest average score.

Figure 4. Landscape color evaluation form of the park.

4.2. Survey Results

The findings from Figure 3 have important implications for color design in urban spaces. They provide specific insights into the strengths and weaknesses of the color design in Zhuhai Plaza, allowing designers and planners to identify areas for improvement and enhancement. By focusing on the aspects that received the highest satisfaction levels, such as the overall color design of the square, the landscape color design, and the building facade color design, future color design endeavors can build upon these successful elements. Additionally, the categories with lower satisfaction levels, such as the cultural infrastructure color scheme design and the ladder color design, present opportunities for targeted interventions. By reassessing and refining the color choices and design approaches in these areas, it is possible to enhance the overall satisfaction levels of tourists and create a more cohesive and visually pleasing environment. The numerical scale used in the evaluation provides a quantitative measure of satisfaction, enabling a more nuanced analysis of tourists' perceptions.

The results of the evaluations indicated that tourists were generally satisfied with the color of the landscape in Zhuhai Plaza. This finding suggests that the color design of the plaza successfully resonates with the preferences and expectations of the visitors. The positive feedback from tourists regarding the landscape color of Zhuhai Plaza provides valuable evidence of its success in creating an aesthetically pleasing and enjoyable environment.

The findings of this study have practical implications for the planning and design of landscapes, facilities, and buildings in Zhuhai Plaza. The analysis of user feedback and

satisfaction with the color of the plaza's landscape can inform future color design decisions. By taking public opinion into account, planners and designers can create environments that are more engaging, visually appealing, and capable of fostering positive experiences for both residents and tourists.

The color space recognition and design of public facilities influence people's behaviors and experiences within these spaces. Visibility, brightness, and harmony with the environment are key considerations in color design. The study shown in Figure 4 shows that the survey results indicate an overall positive effect of color use in Zhuhai Shijingshan Park, while also highlighting areas for improvement. By understanding and addressing these factors, designers can create visually appealing and engaging urban landscapes that promote positive experiences and behavior among visitors.

The analysis results are shown in Table 4.

Table 4. Genetic iteration evaluation form.

Color Type	Options	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7	RQ8	RQ9	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17
Square Landscape Color	Evaluation value	2	1	2	1	−2	0	0	1	−1	0	1	0	0	2	1	1	0
	Genetic Iterative Selection	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	No	No	Yes	Yes	Yes	No
Park Landscape Color	Evaluation value	2	2	−1	1	0	2	1	0	2	1	2	2	1	2	2	1	0
	Genetic Iterative Selection	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

The dissertation research approach hinges on the invaluable input provided by tourists when rating the colors used in parks and squares. These critical data play a pivotal role in guiding our decision-making process concerning the selection of subsequent genetic iterations. By incorporating these color rating values into our iterative design methodology, we can make more informed and data-driven choices in the evolution of urban color schemes.

In essence, the color rating values serve as a form of a quality control mechanism for our design process. Parts of the color scheme that receive high evaluation scores are accorded greater selectivity during subsequent genetic iterations. This strategic prioritization ensures that elements of the design garnering positive feedback from the public undergo further refinement. Consequently, the resulting color scheme is inherently more harmonious with public preferences, contributing to its widespread acceptance and appreciation.

Conversely, sections of the design with lower evaluation values may not progress through the iterative cycle. Instead, these areas are earmarked for comprehensive improvements and considerations in future urban planning and design endeavors. This adaptive approach underscores our commitment to continuous enhancement, allowing us to progressively fine-tune the color scheme based on real-world feedback. By systematically integrating tourist opinions and preference data into our iterative process, the capacity to create urban environments that not only exhibit aesthetic excellence but also resonate deeply with the broader public is fortified, thereby fostering more vibrant, engaging, and community-centric urban spaces.

The effective design of urban environments holds significant importance as it directly influences the well-being and satisfaction of residents. Colors play a crucial role in shaping urban aesthetics and can have profound effects on human emotions, behavior, and the overall urban experience. Therefore, optimizing urban color design is a pertinent area of research with far-reaching implications. By optimizing urban color design, this research contributes to enhancing the aesthetic appeal and livability of urban spaces. Aesthetically pleasing environments have been shown to positively impact people's mood, productivity, and overall quality of life. Additionally, well-designed urban colors can create a sense

of place, identity, and community cohesion. Moreover, this study holds the potential for practical applications beyond color optimization. By leveraging interactive genetic algorithms, it may be possible to extend this approach to other factors that shape urban environments. For instance, exploring the relationship between color design and education levels within a community could shed light on the impact of visual aesthetics on learning environments. Similarly, investigating the link between color design and poverty rates may provide insights into how color can influence perceptions of safety, inclusivity, and social equity.

In a quest to comprehend the holistic dynamics of urban design, this research ventured beyond the realm of color to consider broader factors. This inclusive approach led us to explore variables, such as education levels and poverty rates. The selection of these factors stems from their recognized significance in shaping urban landscapes and the quality of life within cities. Education levels can profoundly influence community engagement, cultural enrichment, and the appreciation of urban aesthetics. Poverty rates, on the other hand, bear a direct relationship with the availability of resources for sustainable and vibrant urban design initiatives. By delving into these variables, this research aim to shed light on their potential roles in urban design and their interplay with color, fostering a deeper understanding of the multifaceted nature of urban environments.

By venturing into the exploration of factors beyond color, this research can broaden its scope and relevance. Examining the influence of education levels or poverty rates on urban design can offer valuable insights for policymakers, urban planners, and designers. Understanding how these factors interact with color and other design elements can aid in the development of more inclusive, equitable, and socially sustainable urban environments.

In conclusion, optimizing urban color design using an interactive genetic algorithm holds immense potential for enhancing urban aesthetics, well-being, and community satisfaction. This study's significance lies in its broader implications for urban design and the potential to extend the approach to factors beyond color, such as education levels or poverty rates. Expanding the scope and relevance of the research can provide valuable insights for creating more vibrant, inclusive, and socially sustainable urban environments.

4.3. Mitigating Color Design Evaluation Fatigue in Interactive Genetic Algorithms

The interactive genetic algorithm is a unique approach that incorporates subjective evaluation from humans to find optimal solutions for individual design needs. This algorithm takes into account user preferences and emotions, allowing designers to actively participate in the evolutionary fitness process [35,36]. However, a potential challenge with this approach is the user fatigue that arises from repeatedly evaluating design options.

In response to the challenge of user interaction fatigue within the interactive genetic algorithm, this paper introduces two distinct yet complementary methods aimed at alleviating this issue. These methods not only address the fatigue factor but also contribute significantly to enhancing the overall efficiency and effectiveness of the algorithm.

Resetting the Interaction Evaluation Step: In this approach, the interaction evaluation step is strategically reset to occur before the operation of the genetic operator. This means that, initially, the designer evaluates and selects individuals from the interaction interface before any further processing through the algorithm takes place. The pivotal advantage here lies in the reduction of the designer's evaluation burden. By focusing on a smaller set of individuals during the initial evaluation, the designer can allocate their attention more effectively, resulting in a streamlined and less burdensome evaluation process [37,38].

Introduction of Model: To further enhance the algorithm's efficiency, an agent model is seamlessly integrated into the process. This agent model functions as an invaluable tool for capturing and analyzing the designer's interaction patterns, preferences, and behaviors. By gaining a deep understanding of the designer's unique evaluation approach, the agent model actively assists in curbing the evaluation burden placed on the designer. This is achieved through adaptive adjustments and real-time insights derived from the designer's actions, ultimately simplifying and optimizing the overall evaluation process [39].

The effectiveness of these strategies in reducing user interaction fatigue is substantiated by experimental results. By implementing the reset of the interaction evaluation step, the designer's task is streamlined to involve the comparison and evaluation of just six individuals from the interaction interface. From this focused evaluation, the best individual is selected. Subsequently, the optimal design solution is determined by choosing the best combination from the location layout interface. This entire process encompasses a mere six evaluation actions, leading to the generation of one optimal solution for each evolutionary generation [40]. Importantly, this approach minimizes the generation of sub-optimal solutions, thus significantly alleviating the burden on the system.

The strength of this approach lies in its remarkable ability to strike an equilibrium between designer involvement and computational efficiency. By significantly reducing the number of evaluations required and ensuring a more targeted evaluation process, designers can actively engage in the algorithm without succumbing to excessive fatigue. Moreover, the reduction in sub-optimal solutions generated by the system substantially enhances the efficiency and effectiveness of the algorithm and translates into a more productive and fatigue-resistant design process [41].

This research contributes to the field of urban color design by providing a practical solution to mitigate user interaction fatigue within the interactive genetic algorithm. By streamlining the evaluation process, designers can actively engage in the optimization of urban color design without being overwhelmed by the task. The proposed methods enhance the usability and efficiency of the algorithm, making it a valuable tool for designers, urban planners, and policymakers seeking to create visually appealing and satisfying urban environments.

5. Discussion

Koma S, Yamabe Y, and Tani A used an optimization system for urban landscape design, which was proposed using an interactive genetic algorithm (IGA) in the article "Research on urban landscape design using the interactive genetic algorithm and 3D images" [42]. Huang W and Xu W expressed in the paper "Interior color preference investigation using interactive genetic algorithm" that an IGA interior design system was used to investigate the interior color preference of Beijing residents' apartments. A typical living room interior is composed of five factors of a sofa, and participants are instructed to use the IGA system to find the ideal color combination of these five factors [43]. Fan Z, Liu J, Wang L, and other scholars proposed a new method of an MHRB automatic layout based on genetic algorithm in the paper "Automated layout of modular high-rise residential buildings based on genetic algorithm" [44]. These studies have shown the application prospects of interactive genetic algorithms in architectural design, urban planning, and other fields.

The field of mathematics offers a plethora of intelligent algorithms, each with unique characteristics and applications. The refinement and application of different algorithms hold significant promise for enhancing urban color design by approaching the task from diverse design perspectives, consequently yielding a variety of pattern effects [45]. As mathematics continues to evolve, an increasing number of mathematical algorithms is being developed and integrated into various domains of art and design. The inherent artistic beauty of mathematics remains a subject of ongoing exploration, revealing new avenues for creative expression [46]. Importantly, the research presented in this article serves as a replicable model that opens the door for future applications of interactive genetic algorithms in urban planning and design. The iterative selection of optimal solutions, guided by the principles of interactive genetic algorithms, represents a promising direction for further advancements in the field [47].

While this paper focuses primarily on the utilization of the interactive genetic algorithm in the context of urban color design, it is essential to acknowledge that numerous other mathematical algorithms hold potential applicability within the realm of art and design. The exploration of alternative algorithms, coupled with strategic combinations, has

the potential to yield distinct and innovative art designs [48]. To facilitate further research, several suggestions and perspectives are offered:

Building upon the foundation laid by this research, the incorporation of various intelligent algorithms into pattern design can be explored. Integrating algorithm theory with the specific design objectives and steps can lead to the creation of design solutions that cater to the aesthetic preferences and needs of the public. By diversifying the algorithmic approaches employed, the field of urban color design can expand its creative horizons and accommodate a wider range of design possibilities.

While this study primarily addresses the layout of geometric patterns and their spatial configurations to achieve aesthetic variations, it is important to note that the inclusion of color schemes for individual urban elements remains an unexplored territory. Future research endeavors should consider integrating color elements into the sample space, allowing for the generation of patterns that are not only visually appealing but also versatile in their functionality. This extension of the design process can enhance the practicality of urban color design, aligning it more closely with the multifaceted needs of urban environments [49].

The application of intelligent algorithms, such as interactive genetic algorithms, in the domain of urban color design represents just one facet of the potential synergies between mathematics and art. By diversifying the range of algorithms employed and expanding the scope of design considerations, future research can contribute to a more nuanced, versatile, and aesthetically satisfying urban landscape, while further illuminating the intrinsic artistry of mathematics in design disciplines [50].

6. Conclusions

The passage discusses the exploration of suitable design methods or patterns for marine cities' parks and squares, considering the spatial carrier needs, environmental psychology, and the relationship between the color of the urban landscape. Typical examples are used to illustrate the recommended color schemes for each context [51]. For urban parks, the main color scheme should revolve around shades of green, with similar or analogous hues selected for the green system and a medium color contrast [52]. On the other hand, for squares, the pavement color takes precedence, with low brightness or neutral color schemes deemed appropriate. A medium color contrast should be maintained. The study incorporates the use of interactive genetic algorithms, which have already proven to be effective in image processing, image retrieval, and color scheme selection. Building upon previous research methods, the paper examines and applies the theory of interactive genetic algorithms to urban color design [53]. Through this interactive process, users can select the color scheme that best meets their needs.

This research covers a wide range of disciplines, delving into the intricate relationship among people, color, and scenery [54]. It adopts a multidisciplinary approach to refine and validate the findings. It is important to note that the color of a marine city's cityscape is subject to temporal changes, influenced by various factors. Therefore, the study acknowledges the potential perturbations that may occur during the research process and emphasizes the need to eliminate any such disturbances to ensure accurate and reliable results [55].

The paper highlights the exploration of design methods and patterns suitable for marine cities' parks and squares, with specific attention given to color schemes. It introduces the application of interactive genetic algorithms in urban color design, emphasizing coding, selection, hybridization, and mutation processes. The study employs a multidisciplinary approach to refine and validate the findings, acknowledging the time-sensitive nature of cityscape colors and the need to address potential perturbations.

Furthermore, the research conducted in Zhuhai Plaza can serve as a model for similar evaluations in other Marine Cities. The methodology used to assess color satisfaction can be replicated in different contexts, allowing for a comparative analysis of public opinion regarding the landscape color. This broader application of the research can contribute to the development of standardized approaches to color design in urban planning, enabling

the creation of more harmonious and culturally appropriate environments [56,57]. This paper's analysis of user evaluations and satisfaction levels with the color of Zhuhai Plaza's landscape provides valuable insights for planning and designing landscapes, facilities, and buildings. The positive feedback from tourists indicates that the color design of the plaza is successful in meeting user expectations. The understanding of public opinion gained from this analysis can guide future color design decisions, promoting the creation of visually appealing and user-centric urban environments. Additionally, the research's methodology can be applied to other contexts, facilitating the development of standardized approaches to color design in marine city planning [58].This paper is written to address the problems of few references and few examples to draw on in terms of research on color design in marine cities. The research of this thesis is conducive to the progress of marine cities in terms of urban development, urban image and urban culture construction.

Future research directions include the following. Firstly, an exploration of cross-cultural color preferences within diverse marine cities could shed light on the universality or cultural specificity of color choices in urban landscapes. Secondly, the integration of emerging technologies, like augmented and virtual reality, into the interactive color design process presents an exciting frontier for investigation. Additionally, there is a need to assess the environmental implications of urban color schemes, examining their influence on factors, such as microclimates and ecological sustainability. User-centered design approaches that actively involve residents and visitors in color decision-making could be further refined and studied. Longitudinal studies may reveal how chosen color patterns evolve over time in response to changing socio-cultural and environmental contexts. Collaborative interdisciplinary research could lead to holistic strategies that consider urban aesthetics alongside broader societal and ecological impacts. Lastly, the role of color design in smart city initiatives and its contribution to climate change adaptation in coastal urban areas warrant focused inquiry. These future research directions hold the potential to advance our understanding of color's multifaceted role in creating sustainable, vibrant, and psychologically enriching marine cities.

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