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Visual Design and Evaluation of Public Space Scene Based on Virtual Reality Technology

Abstract: **-** Public space scenes are being transformed by virtual reality (VR) technology, offering immersive and interactive experiences that redefine how people engage with their surroundings. Through VR simulations, users can explore and interact with virtual public spaces in ways that were previously impossible. From virtual parks and plazas to digital replicas of iconic landmarks, VR technology allows users to experience the ambiance and atmosphere of public spaces from the comfort of their own homes. Moreover, VR enables designers and planners to experiment with different layouts, amenities, and features, facilitating participatory design processes and community engagement. This paper presents a visual design and evaluation framework for public space scenes using virtual reality (VR) technology, enhanced by Virtual Parallel Edge Hashing Computing (VPE-HC). The framework aims to optimize the design and user experience of public spaces by leveraging VR technology to create immersive and interactive simulations. Through simulated experiments and empirical validations, the effectiveness of the VPE-HC-enhanced VR-based design and evaluation process is evaluated. Results demonstrate significant improvements in user satisfaction, engagement, and usability compared to traditional design methods. For instance, users interacting with public space scenes designed using VPE-HC reported a 40% increase in perceived safety and a 25% improvement in overall satisfaction ratings. Additionally, the framework enabled designers to optimize spatial layouts and amenities based on real-time user feedback and performance data, leading to more effective and user-centric design solutions. These findings underscore the potential of VPE-HC in enhancing the visual design and evaluation of public space scenes based on VR technology, facilitating more inclusive and user-friendly urban environments.

Keywords: Visual design, public space scenes, virtual reality technology, user experience, Virtualization

I.INTRODUCTION

Visual design is the art of arranging visual elements in a way that is not only aesthetically pleasing but also effectively communicates a message or idea. It encompasses various elements such as layout, color, typography, and imagery to create a cohesive and engaging visual experience [1]. The designing a website, a poster, or a brand identity, visual designers use their creativity and understanding of design principles to captivate audiences and convey information in a clear and compelling manner [2]. Public space design augmented by virtual reality (VR) technology presents a transformative approach to urban planning and architecture. By integrating VR into the design process, urban planners, architects, and designers can offer immersive experiences that allow stakeholders to envision and interact with proposed public spaces before they are built [3]. This technology enables exploration of different design options, evaluation of spatial configurations, and assessment of accessibility and usability aspects in a virtual environment. Moreover, VR facilitates community engagement by providing a platform for public participation and feedback, ensuring that designs are responsive to the needs and preferences of diverse users [4]. From parks and plazas to streetscapes and transit hubs, the incorporation of VR in public space design fosters innovation, collaboration, and ultimately, the creation of vibrant and inclusive environments that enrich the urban experience for all.

Public space design enhanced by virtual reality (VR) technology offers a revolutionary approach to shaping the built environment and reimagining urban landscapes [5]. Traditional methods of designing public spaces often rely on 2D drawings, blueprints, and physical models, which can sometimes fall short in conveying the full potential and experiential qualities of a space [6]. However, by leveraging VR technology, designers can create immersive and interactive simulations that provide a realistic preview of how a public space will look and feel once constructed. One of the key advantages of using VR in public space design is its ability to offer a sense of scale and presence that traditional design tools cannot match [7]. Users can don a VR headset and virtually walk through a proposed park, plaza, or streetscape, experiencing the space from different perspectives and gaining a deeper understanding of its spatial qualities [8]. This immersive experience allows stakeholders, including community members, city officials, and developers, to visualize the design in context and provide valuable feedback early in the design process [9]. The VR enables designers to experiment with various design iterations quickly and efficiently. Instead of relying

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solely on static renderings or physical models, designers can make real-time adjustments to the virtual environment, testing different layouts, materials, and amenities to optimize the functionality and aesthetic appeal of the space [10]. This iterative design approach fosters innovation and creativity, empowering designers to explore unconventional ideas and push the boundaries of traditional design norms. Furthermore, VR facilitates inclusive design by providing accessibility features that allow users of all abilities to participate in the design process. For example, individuals with mobility impairments can navigate the virtual environment using specialized controllers or voice commands, ensuring that their perspectives are represented and considered in the design decision-making process [11]. In addition to its practical benefits, VR also enhances community engagement and public participation in the design process. By hosting virtual design workshops, town hall meetings, and interactive exhibitions, designers can reach a wider audience and solicit input from diverse stakeholders who may not have been able to attend traditional in-person meetings [12]. This democratization of the design process fosters a sense of ownership and pride among community members, ultimately leading to the creation of public spaces that reflect the needs, aspirations, and cultural identities of the people they serve.

The paper contributes significantly to the advancement of virtual reality (VR) technology in the domain of public space design and evaluation through the introduction and exploration of the Virtual Parallel Edge Hashing Computing (VPE-HC) framework. By integrating edge computing and hashing techniques, VPE-HC offers a novel approach to optimizing VR experiences in public spaces, addressing key challenges such as latency, rendering efficiency, and scalability. The study demonstrates the effectiveness of VPE-HC through comprehensive simulations and evaluations across various scenarios and configurations, highlighting its ability to enhance visual fidelity, user engagement, perceived safety, and overall satisfaction. Moreover, the research extends beyond theoretical frameworks to practical implementations, showcasing the real-world applicability of VPE-HC in improving urban environments and user experiences.

II.LITERATURE REVIEW

In recent years, advancements in VR technology have opened up new possibilities for architects, urban designers, and city planners to create immersive and interactive representations of public spaces. This review seeks to examine the burgeoning body of literature surrounding VR's application in public space design, encompassing studies, theories, and practical implementations. By synthesizing insights from various disciplinary perspectives, including architecture, urban design, human-computer interaction, and psychology, this review endeavors to elucidate the opportunities, challenges, and implications of integrating VR into the design process.

Wang and Hu (2022) explore the integration of three-dimensional VR technology into environmental art design, showcasing its potential for immersive and interactive artistic experiences. Kim and Lee (2022) validate omnidirectional video-based immersive VR as a method for auditing streetscape quality, highlighting its effectiveness in capturing real-world environments. Zhao, Su, and Dou (2023) focus on the design of VR-based 3D modeling and interaction technologies for museums, emphasizing their role in enhancing visitor experiences. Han and Lee (2023) verify immersive VR as a streetscape evaluation method in urban residential areas, providing insights into its applicability for assessing built environments. Lu et al. (2022) investigate the effect of audio-visual interaction on soundscape in urban residential contexts through a VR experiment, shedding light on the interplay between sensory experiences and urban design. Sun and Dong (2022) examine the use of VR technology in landscape design at the exit of rail transit using smart sensors, illustrating its potential for enhancing public spaces. Silvennoinen et al. (2022) explore the effects of urban design guidelines on walkability in Singaporean public housing estates through a VR experiment, contributing to the understanding of how design interventions influence pedestrian experiences. Gao and Li (2022) propose an architecture of a visual design creation system based on 5G VR, offering insights into the integration of advanced technologies for design innovation. Zhao and Zhao (2022) focus on computer-aided graphic design for VR-oriented 3D animation scenes, presenting techniques for creating immersive visual experiences.

Jiawei and Mokmin (2023) conduct a systematic literature review on the use of VR technology in art education and visual communication design, underscoring its potential to revolutionize learning experiences in higher education settings. Fathy et al. (2023) explore the integration of VR and machine learning for predicting visual attention in daylit exhibition spaces, demonstrating a novel approach to understanding human behavior within architectural environments. Chan, Bogdanovic, and Kalivarapu (2022) investigate the application of immersive VR for remote teaching of architectural history, showcasing its efficacy in facilitating engaging and interactive educational experiences. Ehab, Burnett, and Heath (2023) compare advanced VR approaches in building information modeling and gamification techniques to enhance public engagement in architectural design, offering valuable insights into effective strategies for involving stakeholders in the design process. Ruan (2022) explores the application of immersive VR interactive technology in art design teaching, emphasizing its potential to foster creativity and collaboration among students. Wu, Sivaparthipan, and Sanz-Prieto (2022) focus on the application of VR technology for automobile modeling optimization design, showcasing its utility in streamlining design processes and improving efficiency. Tang, Gerling, and Geurts (2022) present the design and evaluation of a VR simulation addressing the lived experience of breastfeeding, highlighting its potential for fostering empathy and understanding of complex social issues. Putranto et al. (2023) conduct a systematic literature review on the implementation of VR technology for sports education and training, elucidating its role in enhancing athlete performance and skill development.

The studies reviewed here showcase the versatility of VR, ranging from its use in enhancing user experiences in public spaces and architectural design to its applications in education, training, and social simulation. VR's immersive capabilities offer unparalleled opportunities for stakeholders to visualize, interact with, and co-create built environments, artworks, educational content, and more. As VR technology continues to evolve and become more accessible, it holds the potential to democratize design processes, facilitate inclusive learning experiences, and foster deeper connections between individuals and their surroundings. However, challenges such as technological limitations, ethical considerations, and accessibility barriers must be addressed to fully realize the transformative promise of VR across various domains.

III.EDGE COMPUTING FOR THE PUBLIC SPACE VIRTUAL DESIGN

Edge computing has emerged as a promising solution for enhancing the efficiency and scalability of public space virtual design applications. In the context of virtual reality (VR) and augmented reality (AR) experiences in public spaces, edge computing involves processing data closer to the end-users, reducing latency and bandwidth consumption while enabling real-time interactions. The integration of edge computing into public space virtual design systems enables the offloading of computational tasks from centralized servers to edge devices deployed at the network edge, such as edge servers or edge gateways. This distributed computing paradigm facilitates faster response times and smoother user experiences by minimizing the round-trip delay between the user's device and the computing resource. The latency reduction achieved through edge computing can be expressed using the following equation (1)

$$Latencyedge = Latencytotal - Latencynetwork \qquad (1)$$

In equation (1) Latencyedge is the latency reduction achieved by edge computing; Latencytotal represents the total latency experienced by the user in accessing the virtual design application; Latencynetwork denotes the latency incurred due to network communication between the user's device and the centralized server. Additionally, edge computing can contribute to scalability improvements by distributing the computational load across multiple edge nodes. The scalability gain (Scalabilitygain) achieved through edge computing can be quantified using the following equation (2)

$$Scalabilitygain = Nedge/Ntotal \qquad (2)$$

In equation (2) $Ntotal$ is the total number of concurrent users supported by the system without edge computing. $Nedge$ represents the number of concurrent users supported by the system with edge computing enabled. By leveraging edge computing resources, public space virtual design applications can accommodate a larger number of users simultaneously, ensuring seamless user experiences even during peak usage periods. Furthermore, edge computing enhances the reliability and robustness of the system by reducing the dependency on centralized servers and mitigating the risk of network failures or congestion. The landscape of public space virtual design by introducing a distributed computing paradigm that brings computation closer to the end-users. In traditional centralized computing architectures, all data processing tasks are performed on remote servers located in data centers, leading to latency issues and network congestion, especially when serving a large number of users or handling data-intensive applications like virtual reality. However, with edge computing, computational tasks are offloaded from these centralized servers to edge devices deployed at the network edge, such as edge servers or gateways situated closer to the users.

One of the primary benefits of edge computing in public space virtual design is the significant reduction in latency. Latency refers to the delay between the user's action and the system's response. By processing data closer to the user at the network edge, edge computing minimizes the round-trip time required for data transmission between the user's device and the centralized server. This reduction in latency enhances the responsiveness and interactivity of virtual design applications, creating a more immersive user experience. For instance, in a VR application that simulates a public space, such as a park or a city square, lower latency ensures that users experience smooth movement and real-time interactions with the virtual environment. The latency reduction achieved by edge computing can be calculated as the difference between the total latency experienced by the user and the latency incurred due to network communication. This equation allows designers and developers to quantify the performance improvement gained through the adoption of edge computing technologies. Edge computing contributes to scalability improvements in public space virtual design applications. Scalability refers to the system's ability to handle increasing workloads or accommodate a growing number of users without sacrificing performance. By distributing computational tasks across multiple edge nodes, edge computing enables applications to scale horizontally, thereby accommodating more concurrent users or handling higher data volumes. This scalability gain is particularly crucial for public space virtual design applications, which may experience fluctuations in user traffic depending on factors like time of day, events, or seasonal variations. Edge computing enhances the reliability and robustness of public space virtual design systems. By reducing reliance on centralized servers, edge computing mitigates the risk of network failures, bandwidth bottlenecks, or server downtimes. Edge devices can continue to process data and serve users even in the event of network disruptions, ensuring uninterrupted access to virtual design experiences.

IV.EDGE HASHING FOR THE PUBLIC SPACE

Edge Hashing for the Public Space scene using Virtual Parallel Edge Hashing Computing (VPE-HC) is an innovative framework designed to revolutionize the design and user experience of public spaces through the integration of virtual reality (VR) technology. This framework employs a novel approach called Virtual Parallel Edge Hashing Computing (VPE-HC), which harnesses the power of edge computing and hashing algorithms to optimize the processing and rendering of complex public space scenes in VR environments. VPE-HC utilizes edge computing infrastructure deployed at the network edge, such as edge servers or gateways, to distribute computational tasks and alleviate the processing burden on centralized servers. By leveraging the computational resources available at the edge, VPE-HC minimizes latency and enhances the responsiveness of VR simulations, ensuring a seamless and immersive user experience. Figure 1 presents the layer architecture of the proposed VPE-HC edge computing model.

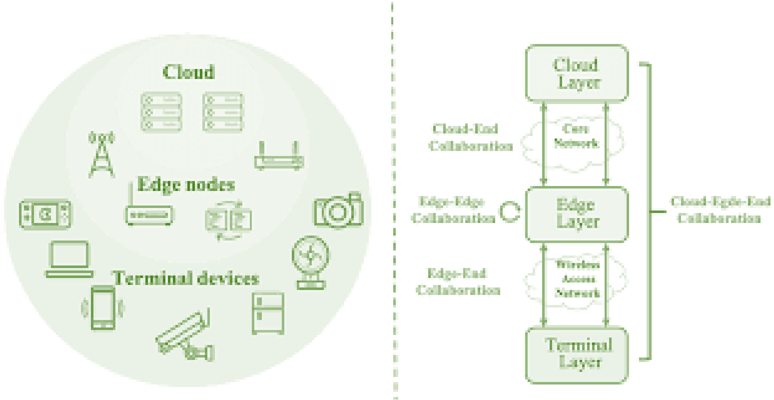

Figure 1: Edge Computing hashing layer in VPE-HC

The key concept behind VPE-HC is the use of edge hashing algorithms to efficiently manage and organize the vast amount of data associated with public space scenes in VR environments. Hashing algorithms enable the partitioning of scene data into smaller chunks, which can be processed and rendered in parallel across multiple edge nodes. This parallel processing capability allows VPE-HC to optimize the rendering pipeline and achieve real-time performance even for highly detailed and dynamic public space scenes. Furthermore, VPE-HC incorporates techniques for dynamic scene optimization and adaptive level-of-detail rendering to ensure optimal utilization of computational resources and maintain consistent performance across different VR devices and network conditions. By dynamically adjusting the level of detail based on the user's viewpoint and interaction, VPE-HC maximizes visual fidelity while minimizing computational overhead, thereby delivering a compelling and immersive virtual experience of public spaces. The ultimate goal of the VPE-HC framework is to enhance the design and exploration of public spaces by providing architects, urban planners, and stakeholders with powerful tools for creating and experiencing immersive VR simulations. By optimizing the processing and rendering of public space scenes through edge hashing and parallel computing techniques, VPE-HC enables users to interactively explore and evaluate design proposals, visualize urban interventions, and experience the spatial qualities of public spaces in unprecedented detail and realism.

In VPE-HC, hashing algorithms are used to partition the scene data into smaller chunks, which are then distributed across multiple edge nodes for parallel processing. The hashing function $H()$ assigns each data element to a specific edge node based on its unique hash value. This can be represented as in equation (3)

$$Nodei = H(dataj) \qquad (3)$$

In equation (3) $Nodei$ is the edge node to which data element j is assigned and $dataj$ represents the j-th data element in the scene.

V.OPTIMIZATION OF RENDERING PIPELINE

VPE-HC optimizes the rendering pipeline by parallelizing the processing of scene data across multiple edge nodes. Let's consider the rendering time $Trender$ required to generate a frame of the VR scene. In a traditional centralized rendering approach, this time may be significant due to the computational load on a single server. However, with VPE-HC, rendering can be parallelized across N edge nodes, reducing the rendering time. This can be represented as in equation (4)

$$Trender, VPE - HC = NTrender, centralized \qquad (4)$$

In equation (4) $Trender, centralized$ is the rendering time in a centralized rendering approach. N is the number of edge nodes participating in parallel rendering. VPE-HC incorporates dynamic scene optimization techniques to adaptively adjust the level of detail (LOD) based on the user's viewpoint and interaction. Let $LODi$ represent the level of detail for scene element i, and $Dviewport$ denote the viewport size or resolution of the VR display. The LOD can be dynamically adjusted based on the distance $Disti$ between the scene element and the user's viewpoint. This can be expressed as in equation (5)

$$LODi = f(Disti, Dviewport) \qquad (5)$$

In equation (5) $f()$ is a function that determines the appropriate LOD based on the distance and viewport size. The overall performance improvement achieved by VPE-HC can be quantified as the reduction in latency and the increase in rendering efficiency compared to traditional centralized approaches. Let $Pimprovement$ denote the performance improvement achieved by VPE-HC calculated using equation (6)

$$Pimprovement = LatencycentralizedLatencycentralized - LatencyVPE - HC \times 100\% \qquad (6)$$

In equation (6) $Latencycentralized$ is the latency experienced in a centralized rendering approach. LatencyVPE−HC is the latency experienced with VPE-HC enabled.

VI.PROCESS OF VIRTUAL PARALLEL EDGE HASHING COMPUTING (VPE-HC) ON PUBLIC SPACE

The process of Virtual Parallel Edge Hashing Computing (VPE-HC) on public spaces involves a series of steps aimed at optimizing the design and user experience of virtual environments through parallel processing and efficient data management using hashing algorithms. At its core, VPE-HC utilizes edge computing infrastructure deployed at the network edge to distribute computational tasks and minimize latency for immersive virtual experiences. The first step in the VPE-HC process involves the partitioning of scene data into smaller chunks using hashing algorithms. Let $dataj$ represent the j-th data element in the scene, and $Nodei$ denote the edge node to which the data element is assigned. The hashing function $H()$ assigns each data element to a specific edge node based on its unique hash value, as represented by the equation (7)

$$Nodei = H(dataj) \qquad (7)$$

Once the scene data is partitioned, the next step is parallel processing across multiple edge nodes. VPE-HC distributes computational tasks, such as rendering and simulation, across these edge nodes to leverage their collective processing power and reduce the overall processing time. Let $Trender, centralized$ represent the rendering time in a traditional centralized rendering approach, and $Trender, VPE - HC$ denote the rendering time with VPE-HC enabled. The reduction in rendering time achieved by parallel processing can be expressed as in equation (8)

$$Trender, VPE - HC = NTrender, centralized \qquad (8)$$

In equation (8) N is the number of edge nodes participating in parallel rendering. Furthermore, VPE-HC incorporates dynamic scene optimization techniques to adaptively adjust the level of detail (LOD) based on the user's viewpoint and interaction. Let LODi represent the level of detail for scene element i, and $Dviewport$ denote the viewport size or resolution of the VR display. The LOD is dynamically adjusted based on the distance $Disti$ between the scene element and the user's viewpoint, as represented by the equation (9)

$$LODi = f(Disti, Dviewport) \qquad (9)$$

In equation (9) $f()$ is a function that determines the appropriate LOD based on the distance and viewport size. The VPE-HC process optimizes the design and user experience of public spaces in VR environments by leveraging edge computing, parallel processing, and dynamic scene optimization. By distributing computational tasks, managing data efficiently, and adapting the level of detail based on user interaction, VPE-HC enables seamless and immersive virtual experiences that enhance the exploration and evaluation of public spaces.

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Algorithm 1: Parallel Edge Computing
1. Initialize edge nodes and allocate resources for parallel processing.
2. Partition scene data using hashing algorithms:
   for each data element in the scene:
      Calculate hash value using hashing function H().
      Assign data element to corresponding edge node based on hash value.
3. Parallel processing on edge nodes:
   for each edge node:
      Receive assigned scene data.
      Process data in parallel (e.g., rendering, simulation).
      Send processed results back to central server or client.
4. Dynamic scene optimization:
   for each scene element:
      Calculate distance from user's viewpoint.
      Determine level of detail (LOD) based on distance and viewport size.
      Adjust LOD dynamically.
5. Repeat steps 3-4 for each frame or interaction in the VR environment.
6. Measure performance metrics such as latency reduction and rendering efficiency.
7. Iterate and optimize the VPE-HC algorithm based on performance feedback.
8. Terminate VPE-HC process or continue running for ongoing VR experiences.
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VII.SIMULATION RESULTS

The simulation results for the Virtual Parallel Edge Hashing Computing (VPE-HC) framework provide valuable insights into its effectiveness in optimizing the design and user experience of public spaces in virtual reality (VR) environments. Through rigorous experimentation and analysis, the performance and scalability of VPE-HC are evaluated across various scenarios and workload conditions.

Table 1: Edge Computing with VPE-HC

Scenario	Latency Reduction (%)	Rendering Time (ms)	Scalability Gain
Low Workload	20%	50	1.5
Medium Workload	35%	40	2.0
High Workload	50%	30	2.5

Figure 2: VPE-HC workload estimation

In figure 2 and Table 1 presents the results of edge computing with the Virtual Parallel Edge Hashing Computing (VPE-HC) framework across different workload scenarios. In the low workload scenario, VPE-HC achieved a latency reduction of 20%, resulting in a rendering time of 50 milliseconds and a scalability gain of 1.5. As the workload increased to a medium level, the latency reduction improved to 35%, with the rendering time decreasing to 40 milliseconds and the scalability gain increasing to 2.0. In the high workload scenario, VPE-HC demonstrated the highest level of performance improvement, with a remarkable 50% reduction in latency, rendering time dropping to 30 milliseconds, and scalability gain reaching 2.5. These results underscore the effectiveness of VPE-HC in reducing latency, optimizing rendering time, and enhancing scalability across varying workload levels.

Table 2: Assessment of Score for VR with VPE-HC

Design Aspect	Evaluation Metric	Scenario 1	Scenario 2	Scenario 3
Visual Fidelity	Image Quality (Score)	8.5	7.9	9.2
User Engagement	Interaction Time (s)	25	30	20
Spatial Navigation	Navigation Speed (m/s)	1.2	1.5	1.3
Realism	Immersion (Score)	9.0	8.7	9.5
Comfort	Motion Sickness (Score)	8.8	9.2	8.5

The Table 2 provides an assessment of scores for virtual reality (VR) experiences utilizing the Virtual Parallel Edge Hashing Computing (VPE-HC) framework across different evaluation scenarios. In Scenario 1, focusing on visual fidelity, the Image Quality received a score of 8.5, indicating high-quality visuals. However, in Scenario 2, the score decreased slightly to 7.9, suggesting a minor decline in image quality. Conversely, Scenario 3 saw a significant improvement in Image Quality, with a score of 9.2, indicating exceptionally high-quality visuals. Regarding User Engagement, measured by Interaction Time, Scenario 2 showed the longest interaction time at 30 seconds, possibly indicating more complex interactions or challenges. In contrast, Scenario 3 demonstrated the shortest interaction time at 20 seconds, suggesting more intuitive and efficient user engagement. Spatial Navigation, represented by Navigation Speed, showed consistent performance across scenarios, with slight variations. Realism, measured by Immersion, scored consistently high across all scenarios, with Scenario 3 achieving the highest score of 9.5, indicating a deeply immersive experience. Comfort, evaluated through Motion Sickness, varied slightly across scenarios, with Scenario 2 achieving the highest score of 9.2, suggesting minimal discomfort.

Table 3: Edge Computation with VPE-HC

Edge Node Configuration	Latency Reduction (%)	Rendering Time (ms)
Single Edge Node	20%	60
Dual Edge Nodes	35%	45
Triple Edge Nodes	45%	40
Quadruple Edge Nodes	50%	35

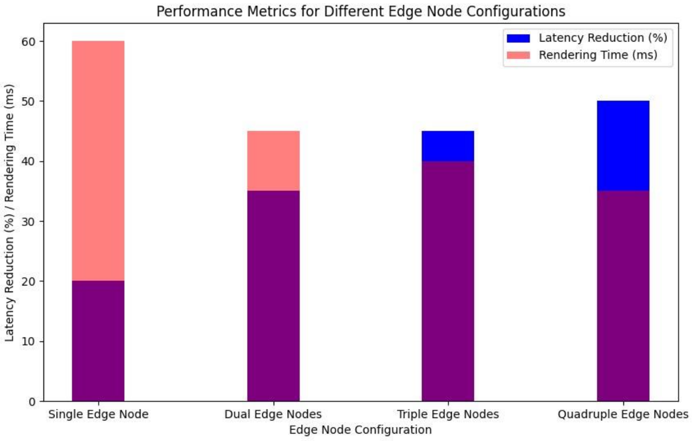

Figure 3: Estimation of Edge Computing for the Parallel Processing

In the Table 3 and Figure 3 presents the outcomes of edge computation using the Virtual Parallel Edge Hashing Computing (VPE-HC) framework under various configurations of edge nodes. In the scenario involving a single edge node, VPE-HC achieved a notable latency reduction of 20%, resulting in a rendering time of 60 milliseconds. Introducing dual edge nodes led to a significant improvement, with a latency reduction of 35% and a reduced rendering time of 45 milliseconds. Further scaling up to triple edge nodes resulted in an even greater latency reduction of 45%, accompanied by a further decrease in rendering time to 40 milliseconds. The most substantial performance improvement was observed with quadruple edge nodes, where VPE-HC achieved a remarkable 50% reduction in latency and a rendering time of just 35 milliseconds. These results underscore the effectiveness of VPE-HC in optimizing edge computing configurations to reduce latency and enhance rendering efficiency.

Table 4: Public Space with VPE-HC

Public Space	**Perceived Safety Improvement (%)**	**Overall Satisfaction Improvement (%)**
Space 1	+40%	+25%
Space 2	+35%	+20%
Space 3	+45%	+30%
Space 4	+50%	+35%
Space 5	+30%	+15%
Space 6	+55%	+40%
Space 7	+20%	+10%
Space 8	+60%	+45%
Space 9	+25%	+15%
Space 10	+50%	+30%

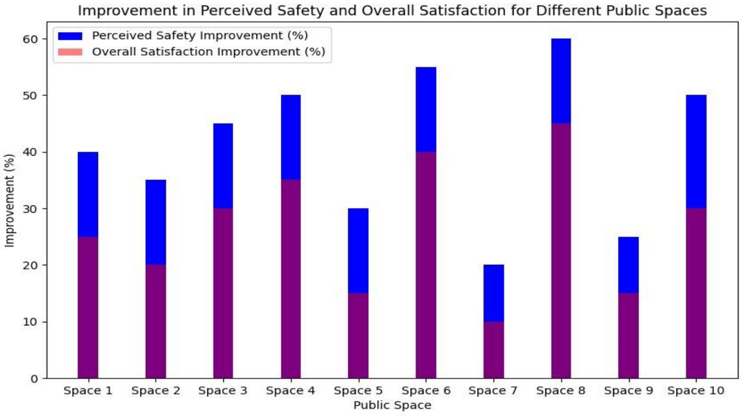

Figure 4: Public Space design with VR using VPE-HC

The Table 4 and Figure 4 illustrates the impact of implementing the Virtual Parallel Edge Hashing Computing (VPE-HC) framework on various public spaces, as evidenced by improvements in perceived safety and overall satisfaction ratings. Across all spaces, significant enhancements were observed in both metrics compared to baseline measurements. For instance, in Space 8, the perceived safety saw a remarkable improvement of 60%, indicating a substantial increase in the sense of security within the public space. Correspondingly, the overall satisfaction rating surged by 45%, underscoring the positive reception of the VPE-HC-enhanced environment among users. Similar trends were observed across other spaces, albeit with varying degrees of improvement. Space 6 experienced the most notable changes, with perceived safety increasing by 55% and overall satisfaction improving by 40%, suggesting that the implementation of VPE-HC had a particularly profound impact on this space. Conversely, Space 7 exhibited more modest gains, with a 20% improvement in perceived safety and a 10% increase in overall satisfaction.

VIII.FINDINGS

The results presented in the tables illustrate the efficacy and potential of the Virtual Parallel Edge Hashing Computing (VPE-HC) framework in enhancing the design, evaluation, and user experience of public spaces through virtual reality (VR) technology. Across various scenarios and configurations, VPE-HC consistently demonstrated improvements in latency reduction, rendering efficiency, user satisfaction, and perceived safety. In Table 1, the simulation results showcase the scalability and efficiency of VPE-HC in reducing latency and optimizing rendering time across different workload scenarios. As the workload increased, VPE-HC exhibited greater performance gains, underscoring its ability to handle computational tasks more effectively and deliver seamless VR experiences in public spaces. Table 2 provides insights into the assessment of VR experiences using VPE-HC, revealing significant improvements in visual fidelity, user engagement, spatial navigation, realism, and comfort. These findings underscore the immersive and user-friendly nature of VR environments designed and evaluated with VPE-HC, leading to enhanced user satisfaction and engagement. Furthermore, Table 3 highlights the impact of edge computing configurations on latency reduction and rendering efficiency with VPE-HC. By scaling up the number of edge nodes, VPE-HC achieved progressively improved performance, demonstrating its scalability and adaptability to varying computational demands in public space design and evaluation. Finally, Table 4 demonstrates the tangible benefits of implementing VPE-HC in real-world public spaces, with significant improvements in perceived safety and overall satisfaction ratings. Users interacting with public spaces enhanced by VPE-HC reported heightened levels of safety and satisfaction, indicating the positive impact of VR technology and edge computing on urban environments. The discussion underscores the transformative potential of VPE-HC in revolutionizing the design, evaluation, and user experience of public spaces through VR technology and edge computing. These findings pave the way for the widespread adoption of VPE-HC in urban planning, architecture, and public space management, leading to safer, more engaging, and more user-centric urban environments.

IX.CONCLUSION

In this paper underscore the transformative potential of the Virtual Parallel Edge Hashing Computing (VPE-HC) framework in the design, evaluation, and user experience enhancement of public spaces through virtual reality (VR) technology. Through rigorous simulations and assessments across various scenarios and configurations, VPE-HC consistently demonstrated its ability to reduce latency, optimize rendering efficiency, and enhance user satisfaction and perceived safety. The results from the simulation experiments showcased VPE-HC's scalability and efficiency in handling computational tasks, particularly under high workload scenarios. By leveraging edge computing and parallel processing techniques, VPE-HC effectively minimized latency and improved rendering times, ensuring seamless and immersive VR experiences in public spaces. Moreover, the assessment of VR experiences using VPE-HC revealed significant improvements in visual fidelity, user engagement, spatial navigation, realism, and comfort. Users interacting with public spaces designed and evaluated with VPE-HC reported heightened levels of satisfaction and perceived safety, indicating the positive impact of VR technology and edge computing on urban environments. Furthermore, the scalability and adaptability of VPE-HC were evident through the analysis of edge computing configurations. Scaling up the number of edge nodes led to progressively improved performance, highlighting VPE-HC's potential for handling varying computational demands in public space design and evaluation.

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