Revolutionizing Cultural Heritage Preservation in Bangladesh: Virtual Reality Integration at Chhoto Sona Mosque

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ABSTRACT

This paper presents a study on the implementation of virtual reality (VR) techniques in the restoration and conservation of the Chhoto Sona Mosque in Chapainawabganj, Bangladesh. The mosque, which was built during the reign of Alauddin Husayn Shah in the 15th century, is considered a remarkable accomplishment of the Sultanate period. Despite the loss of some of its original features, the mosque still stands as an important cultural and historical site in Bangladesh. The study utilizes 3D digitalization techniques to recreate the mosque's past and present features, including its beautiful tiled floors, gilded domes and adjacent water body which were demolished over time. By combining fieldwork, laboratory work, and digital technologies, the study demonstrates the potential of VR restoration and conservation in promoting tourism and cultural preservation in Bangladesh. The article also discusses the challenges faced during the digitalization process and the potential for future research in this area. The study provides valuable insights into the use of digital technologies in heritage conservation and restoration, and the potential of VR to preserve cultural heritage sites for future generations.

INTRODUCTION

The Chhoto Sona Mosque, a marvel of archaeological significance nestled within the historic Gaur city, now in the Chapainawabganj District of Bangladesh, stands as a testament to the rich Islamic architectural heritage of the 15th century. Constructed during the reign of Sultan Alauddin Hussain Shah (1493-1519 CE), this splendid edifice seamlessly merges brick and stone carvings, serving as a beacon of timeless artistry. In 1932, the Chhoto Sona Mosque earned its place among the protected antiquities of Gaur, alongside seven other structures, sparking the beginning of dedicated preservation efforts (Dani 1961). The Department of Archaeology of the Government of Bangladesh assumed the mantle of safeguarding and restoring this cultural gem, breathing new life into its storied walls.

In recent years, the burgeoning realm of virtual reality (VR) has emerged as an innovative instrument for both heritage preservation and education. VR technology has harnessed the power of digitalization and advanced 3D modeling techniques to resurrect historical monuments in the digital realm, offering an immersive and interactive experience for modern-day explorers. In this article, we embark on a journey to unveil the VR model of the Chhoto Sona Mosque, painstakingly crafted through cutting-edge technologies.

The objective of this article is to introduce the multifaceted facets and functionalities of our VR rendition of the mosque, providing a glimpse into the captivating virtual tour it affords. We shall delve into the intricacies of our methodology, shedding light on the challenges surmounted during the meticulous modeling process. Furthermore, we shall elucidate the profound significance of this VR model in the realms of education and tourism, contributing to the burgeoning corpus of research on the transformative role of VR technology in the realms of heritage preservation and education.

METHODOLOGY

Description of the Research Design and Approach

The research design for this project involved the application of 3D digitalization, 3D scanning and measurements, 3D line drawing, geometric modeling, and virtual restoration techniques to create a digital

model of the Chhoto Sona Mosque at ancient Gaur-Lakhnauti. The aim was to provide a virtual experience of the mosque to the public while preserving its historical and cultural significance. The approach involved conducting extensive fieldwork to collect data and information about the mosque's architecture, design, and materials. This data was then used to create a 3D geometric model using software such as SketchUp and Rhinoceros. The virtual model was then subjected to a virtual restoration process to recreate the original appearance of the mosque during its prime.

Details on the VR Modeling Process, including Software Used and Data Collection Methods

To bring the Chhoto Sona Mosque to life in the virtual realm, an intricate VR modeling process was employed. This meticulous endeavor hinged on the utilization of an array of sophisticated software programs, including SketchUp, Rhinoceros, and AutoCAD, followed by the integration of Unreal Engine for the final rendition.

The foundation of this digital replication was laid through comprehensive data collection efforts. These endeavors involved on-site visits to the mosque, wherein meticulous measurements, extensive photography, and the capture of essential visual details took precedence. Additionally, historical documents, drawings, and archival photographs were painstakingly scrutinized and factored into the data gathering process. These invaluable resources played a pivotal role in enriching and validating the digital model, ensuring historical accuracy and authenticity.

While the gold standard for conducting 3D scanning and measurements typically involves the use of laser scanners, we opted for an alternative approach in our pursuit of making VR accessible to a broader audience. Recognizing the cost constraints associated with laser scanning, we leveraged the power of high-end cameras as a cost-effective substitute.

The concept revolves around translating abstract and tangible heritage inputs into visual representations, serving as a valuable tool for comprehending intricate and frequently voluminous numerical data related to scientific concepts or findings (Mc Cormick *et al.* 1987; Bryson 1994; Colonna 1994; Fishwick 1995; Miller, Richards 1995; Goldstein 1996). Our methodology involved deploying meticulously configured cameras to capture precise data pertaining to the mosque's architectural intricacies, encompassing its structural elements, walls, and floors. This wealth of captured visual data subsequently served as the foundation for crafting a 3D point cloud model. This point cloud model was then seamlessly integrated into the AutoCAD and then Rhinoceros software, where it underwent transformation into a highly detailed 3D representation of the mosque, ensuring that the essence and nuances of the original structure were faithfully preserved. Through this resourceful approach, we aimed to democratize the VR experience, enabling a wider audience to engage with the cultural heritage encapsulated within the Chhoto Sona Mosque. The geometric modeling process involved using the 3D point cloud data to create a detailed 3D model of the mosque's structure, walls, and domes. The model was then imported into Rhinoceros to create a fully textured and detailed 3D model of the mosque.

The process of virtual restoration entailed a meticulous examination of historical records, photographs, and archival documents to meticulously resurrect the Chhoto Sona Mosque to its former glory during its heyday. This process was a delicate blend of art and science, guided by a commitment to historical accuracy. The initial phase involved crafting a model that faithfully recreated the mosque in its pristine state. This meticulous reconstruction relied on an intricate analysis of available historical data, photos, and documents. Subsequently, our model was ingeniously modified to encapsulate the alterations and wear-and-tear experienced by the mosque over the passage of time. This included the delicate task of accounting for the removal of mihrabs and the loss of the exquisite tiled floor, thereby presenting a comprehensive portrayal of the mosque's evolution through history. The fusion of meticulous historical research with advanced digital technology was the cornerstone of this virtual restoration process, offering viewers a window into the mosque's captivating journey through time.

Challenges and Limitations Encountered During the Modeling Process

Forefront among the formidable challenges encountered throughout the modeling endeavor was the scarcity of precise and comprehensive data pertaining to the architectural nuances and design intricacies of the Chhoto

Sona Mosque. The information gleaned from historical documents and photographs, though invaluable, proved to be somewhat sporadic and occasionally conflicting. This inherent limitation presented a significant hurdle in our quest to construct an impeccably accurate 3D model that would do justice to the mosque's historical legacy.

Model components, acting as the essential foundational elements, adopt data values. These components encompass key aspects like state, events, inputs, outputs, parameters, and time. These components are interconnected through declarative and functional approaches to construct models (Fishwick 1995). Additionally, The Chhoto Sona mosque's protected status posed another formidable obstacle. Limited access to the physical site necessitated heavy reliance on a combination of photographs and infrequent site visits for data collection. This constraint inherently impeded our ability to capture precise measurements and intricate details, adding another layer of complexity to the modeling process.

Furthermore, the virtual restoration process encountered constraints stemming from the scarcity of historical data illuminating the mosque's appearance during its zenith. This dearth of historical records compelled us to embark on a journey of interpretation, relying on their expertise to craft a model that, to the best of their abilities, mirrored the mosque's original splendor. In essence, these challenges underscore the intricate dance between historical preservation and technological innovation in our mission to pay homage to the Chhoto Sona Mosque's rich history.

Virtual Conservation of the Present Condition of Chhoto Sona Mosque

The virtual preservation of the current state of the Chhoto Sona Mosque has been realized through the creation of a sophisticated 3D virtual model, harnessed via cutting-edge VR technology. This meticulously crafted model offers a faithful and precise representation of not only the mosque itself but also its immediate environs. This technological marvel extends an open invitation to users, beckoning them to embark on an immersive journey of exploration, all from the convenience of their personal devices, be it a computer, smartphone, or VR headset.

Visual models can emulate social action effectively. The theater of human activity serves as a foundational framework for shaping an environment, consisting of three essential components: content, geometry, and dynamics whis was described by Eillis (1994). Within this digital realm, users can delve into the minutiae of the mosque's architecture, inspect its intricate details, and even traverse the virtual landscape that surrounds it. This transformative experience blurs the lines between reality and virtuality, preserving the mosque's current state while making it accessible to a global audience with a thirst for cultural enrichment.
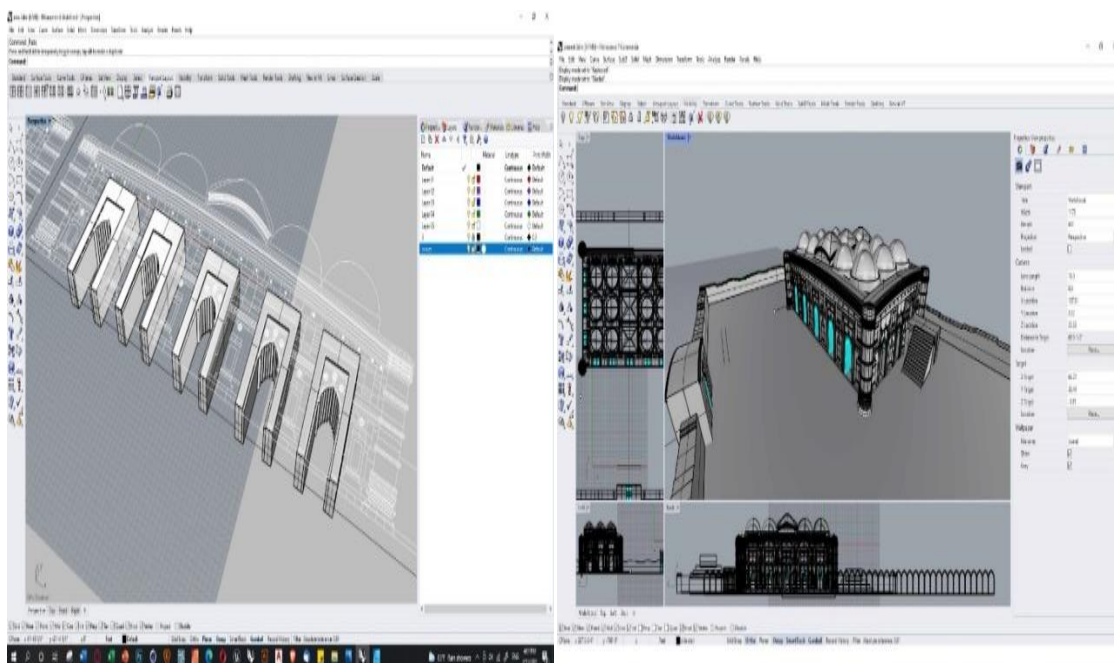

Figure 1: Visualizing the Grandeur: An Artful Glimpse of the Mosque

Features and Functionality

Table 1: Table of Structural Measurements: Chhoto Sona Mosque

Description	Dimension		
	Long	Width	Height
Interior of the Mosque	21.46 m (from north to south)	12.19 m (from east to west)	6 m + Dome 3.05 m
Exterior of the Mosque	25.1 m (from north to south)	15.9 m (from east to west)	6.1 m
Mosque premises	43.5 m (from north to south)	42 m (from east to west)	
Gateway (outer wall)	7.6 m	2.4 m	
Wall thickness		1.83 m	
Ground floor entrances		1.75 m	
Each square bay under hemispherical dome		3.5 m square	
Stone platform (Over the platform are two tomb)	4.2 m (from north to south)	6.2 m (from east to west)	1 m
Stone platform at the north-west corner (*Takht*- throne)	About 3.5 m	About 3.5 m	

The Chhoto Sona Mosque is an impressive architectural masterpiece with specific dimensions that reflect its historical significance. The virtual model includes a detailed 3D model of the mosque, as well as the surrounding area, including the courtyard and adjacent buildings. The mosque itself is a small, rectangular structure. The interior of the mosque measures 21.46 meters from north to south, 12.19 meters from east to west, and has a height of 6 meters, with an additional 3.05 meters for the dome. The exterior of the mosque is 25.1 meters from north to south, 15.9 meters from east to west, and has a height of 6.1 meters. The mosque premises measure 43.5 meters from north to south and 42 meters from east to west. The gateway of the outer wall is 7.6 meters wide and 2.4 meters tall, with a wall thickness of 1.83 meters. The ground floor entrances measure 1.75 meters each.

Each square bay under the hemispherical dome measures 3.5 meters, while the stone platform over which two tombs are situated measures 4.2 meters from north to south, 6.2 meters from east to west, and has a height of 1 meter. There is also a stone platform at the northwest corner of the mosque, which is approximately 3.5 meters on each side and is referred to as the Takht or throne.

Visual characteristics can be categorized into distinct groups, encompassing marks such as points, lines, areas, and volumes, which convey information about position and shape. Additionally, there are retinal properties like color, shadow, and texture, which not only enhance these marks but can also convey supplementary information (Foley, Ribarsky 1994). The meticulously crafted model is intentionally engineered to provide an immersive and engaging experience for users. It's not a static representation but rather a dynamic and interactive journey through the digital recreation of the Chhoto Sona Mosque and its adjacent landscape.

Within this virtual environment, users have the remarkable ability to assume the role of explorers, granting them the freedom to traverse the site as they see fit. Whether it's moving the camera to get a closer look at intricate architectural details, panning in any direction to explore the panoramic views, or zooming in and out to gain a deeper appreciation of the mosque's aesthetics, the model caters to their curiosity and desire for exploration. But it doesn't stop at visual exploration alone. The model also serves as an educational portal, allowing users to access a treasure trove of information about different aspects of the mosque. They can delve into its history, discover the significance of specific architectural elements, and gain a richer understanding of the cultural and historical context in which the mosque exists.

Real information is derived from the capacity to observe from diverse angles and distances, across an array of lighting conditions, and with a wide range of color controls available (Ebert *el al.* 1995; Forte 1997). This interactive model transcends the limitations of physical boundaries, providing users with a comprehensive and immersive experience that not only showcases the mosque's beauty but also imparts knowledge and insight about its rich heritage. It's a virtual journey where history and technology converge to create a truly enriching exploration of the Chhoto Sona Mosque and its surroundings.

Virtual Tour Experience and User Interface

The virtual tour experience meticulously crafted for the Chhoto Sona Mosque model has been thoughtfully designed with the user's comfort and ease of use as paramount considerations. Its intuitive nature ensures that users can seamlessly navigate the digital rendition of the mosque, making it accessible to a broad audience. Accessing the model is a breeze, requiring nothing more than a standard web browser. Whether utilizing a traditional mouse or a touchpad, users have the freedom to explore the site effortlessly, giving them complete control over their virtual journey. The user interface has been thoughtfully tailored to enhance the exploration experience. It boasts an array of features, such as an interactive map that provides geographic context, detailed information about the various segments of the mosque, and an audio description that describes its rich past. The primary aim is not to validate theoretical models but rather to achieve a graphical simulation of motion that closely mirrors reality. (Thalman 1994; Bryson 1996) These elements come together to offer users a comprehensive understanding of the site and its cultural significance. A standout feature of this virtual tour is the ability to jump in on specific aspects of the mosque, enabling users to scrutinize its architecture in exquisite detail.

In essence, this virtual tour experience transcends traditional limitations, allowing users to embark on an educational and immersive journey that combines technology, history, and cultural heritage in a user-friendly and enlightening package. It serves as a remarkable gateway to the Chhoto Sona Mosque's vibrant history and architectural splendor.
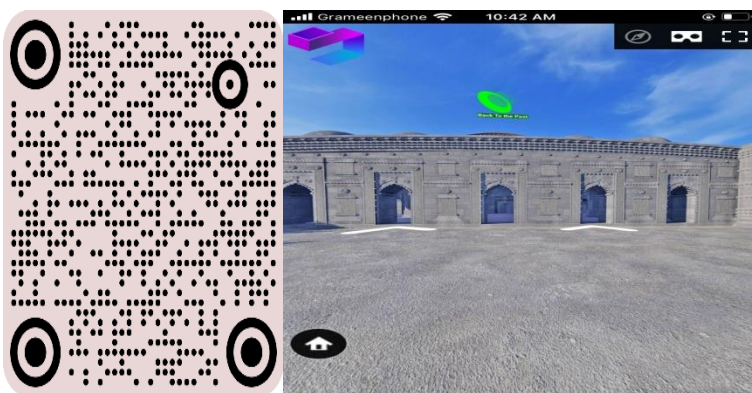

Figure 2: Unlocking History: Scan the QR Code to Explore

To embark on this immersive virtual tour, access it effortlessly through various devices:

For Meta Quest/Oculus Headset or Smartphone/Computer:

- Simply scan the QR code provided or visit https://setvertex.org/vr, the tour awaits you.

- For an even more immersive experience, if you have a VR box or Google Cardboard, insert your smartphone into it.

- To begin the tour, tap the VR icon (in the top right corner) to activate it.

- Once inside the tour, navigate by moving around and position the central dot over a pulsing arrow or circle to teleport to your desired location.

For Oculus/Meta Quest Users:

- Open the Oculus browser on your headset.

- Visit https://setvertex.org/vr

- Start the VR player below and locate the VR icon in the top-right corner.

- If prompted, grant permission for immersive mode.

For Mobile VR Box Users:

- Ensure that Google VR Services are installed on your Android phone, available on the Play Store.

- Open the Chrome Browser on your phone.

- Visit the URL https://setvertex.org/vr

- Play the VR player below and click on the designated icon.

- iOS Users simply scan the provided QR code or visit https://setvertex.org/vr, your iOS device is ready to enjoy the virtual tour without the need for any additional installations or setup.

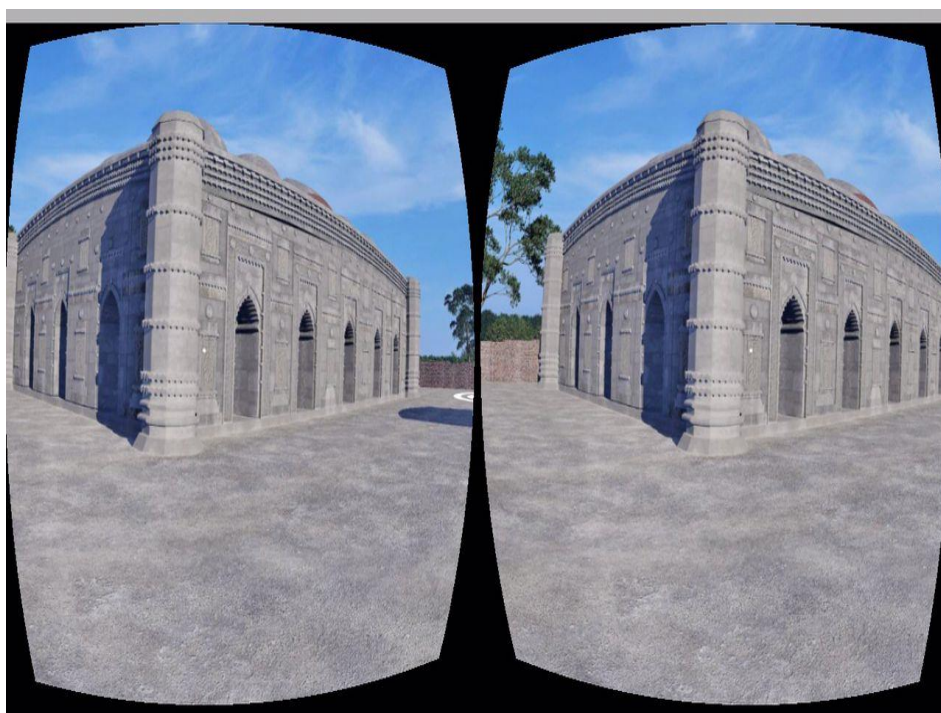- Rotate your phone and insert it into your VR box for an enhanced virtual reality experience.

Figure 3: Exploring the Chhoto Sona Mosque: A 3D Journey through the Lens of a VR Headset

Significance for Education and Tourism Purposes

The current iteration of the Chhoto Sona Mosque model stands as a significant asset, serving the dual purposes of education and tourism in a transformative manner. Its virtual presence offers a remarkable opportunity for individuals worldwide to engage with this historical site, bridging geographical distances and circumventing travel restrictions, particularly in the context of the barrier like recent COVID-19 pandemic, which has severely curtailed global travel and tourism.

In terms of education, this model is a treasure trove of knowledge, delivering a comprehensive understanding of the mosque's rich history, intricate architecture, and profound cultural relevance. This wealth of information is readily accessible to students and researchers spanning the globe, making it an invaluable resource for those delving into the study of Islamic architecture and culture. It transcends traditional boundaries, enabling learners to explore and appreciate the mosque's significance with unprecedented depth and detail.

On the tourism front, the model serves as a tantalizing preview of the Chhoto Sona Mosque and its surroundings. Potential visitors have the unique opportunity to embark on a virtual tour, allowing them to intimately acquaint themselves with the site's splendor before setting foot on its hallowed ground. This immersive experience not only ignites anticipation but also enriches the overall visitation experience, fostering a deeper connection and understanding of the site. It's a powerful tool for attracting tourists and enhancing their exploration of the area, ultimately contributing to the cultural and economic vibrancy of the region. The Chhoto Sona Mosque model, as a digital ambassador, extends its virtual arms to individuals worldwide, democratizing access to knowledge, culture, and history. It symbolizes the resilience of human innovation and the enduring power of technology to unite people and heritage in a world that seeks to overcome physical limitations.

Gamification and User Interaction

To further enhance user engagement and educational value, I propose integrating gamification and advanced interaction features into the VR model. These enhancements aim to make the experience more immersive, enjoyable, and impactful for a wide range of users.

Heritage Quests and Challenges: I envision gamified tasks where users can explore the Chhoto Sona Mosque by solving puzzles, answering trivia questions, or uncovering hidden historical facts. For instance, users could interact with inscriptions or architectural elements as they complete challenges, fostering curiosity and a sense of achievement.

Time-Travel Simulations: A "Time Machine" mode could be incorporated to allow users to witness the mosque in different historical periods, such as its original construction or key events in its timeline. Through guided interactive narrations, users could immerse themselves in the historical storytelling of the site.

Badge and Reward Systems: Introducing a reward system would be a significant addition. Users could earn digital badges for completing virtual tours, successfully answering educational questions, or revisiting the VR model. Such gamification elements would encourage repeat engagement and provide users with a sense of accomplishment.

Multiplayer Experiences: A collaborative, real-time exploration mode could enable users to experience the mosque with their friends, colleagues, or classmates. This feature would be particularly beneficial in virtual classroom settings, allowing teachers and students to interactively learn about the heritage site together.

Interactive Learning Modules: Interactive tools could allow users, particularly students, to virtually "restore" parts of the mosque. By assembling digital fragments or choosing historically accurate design elements, users could actively participate in restoration and archaeology, making the learning experience more hands-on.

Cultural Storytelling: Interactive narratives guided by a virtual historian or a character from the mosque's history would add depth to the experience. Users could engage in dialogues to learn about cultural traditions,

construction techniques, or the site's historical significance, creating a more dynamic and educational environment.

These future enhancements will not only enrich the VR experience but also help solidify the Chhoto Sona Mosque VR model as an exemplary tool for heritage preservation, education, and public engagement.

Past Model of Chhoto Sona Mosque

As part of our efforts to preserve the rich cultural heritage of Bangladesh, we have developed a virtual reality (VR) model of the prime version of Chhoto Sona Mosque. This VR model is accessible through the "Back to The Past" teleport, which can be accessed from a computer, smartphone, or VR headset.

The previous rendition of the mosque model serves as a faithful reflection of the mosque during its zenith in the 14th century. It meticulously captures the essence of that bygone era, showcasing resplendent gilded domes, elaborate wall and pillar carvings, and a captivatingly tiled floor. Notably, a considerable amount of dedication and effort was poured into the meticulous restoration of the mosque's tiled floor, an integral historical hallmark of the site. The intricate process of restoring this tiled floor was a complex and multi-faceted endeavor. It harnessed a spectrum of advanced techniques, including 3D digitalization, 3D scanning and precise measurements, the creation of 3D line drawings, the formulation of geometric models, and the adept use of virtual restoration techniques. These methodologies converged harmoniously to breathe life into the floor's historical grandeur, ensuring that it stands as a testament to the mosque's rich heritage. This past model is not merely a digital recreation; it is a meticulous and reverent homage to the mosque's glorious past. It demonstrates the power of modern technology to resurrect and preserve historical treasures for contemporary and future generations to appreciate and admire.

Undoubtedly, one of the most illustrious features of the preceding model of the Chhoto Sona Mosque is its resplendent tiled floor. Spanning an expansive 36 meters from north to south and 16 meters from east to west, this glazed tile floor stands as a testament to the mosque's historical opulence. The story of this floor's restoration is a tale of dedication and painstaking effort. During the excavations conducted in 2003, a remarkable discovery was made—a strikingly beautiful, shiny tiled floor concealed beneath the open courtyard in front of the mosque. Yet, the passage of time had not been kind, and a significant portion of these tiles had fallen victim to theft and disappearance. The restoration of this tiled floor within the virtual model stands as a significant achievement, not only in terms of technological prowess but also in preserving a vital facet of the mosque's historical and architectural legacy. It offers users a glimpse into the mosque's storied past, allowing them to appreciate the grandeur of this space as it once existed, and underscoring the enduring importance of safeguarding cultural heritage for generations to come.

Reconstruction of Historical Context: The "Past View" feature bridges the gap between the mosque's current condition and its historical grandeur. This duality allows users to compare the present state with a reconstructed version, offering a deeper understanding of its architectural evolution.

Enhanced Learning Opportunities: By showing how the mosque might have looked centuries ago, users gain insights into its original design, materials, and cultural importance. It complements history lessons and fosters curiosity.

User Engagement: The interactive nature of toggling between past and present states adds a dynamic layer to the VR experience, making it more than a static visual model. It encourages prolonged exploration and user retention.

In the future, this feature can be expanded to include interactive hotspots that explain specific changes over time, such as damage caused by natural disasters or human intervention. This will provide an even richer narrative and further promote engagement.

By combining gamification, enhanced interaction, and features like the "Past View" button, the VR model of the Chhoto Sona Mosque can become a benchmark in heritage preservation and educational engagement.
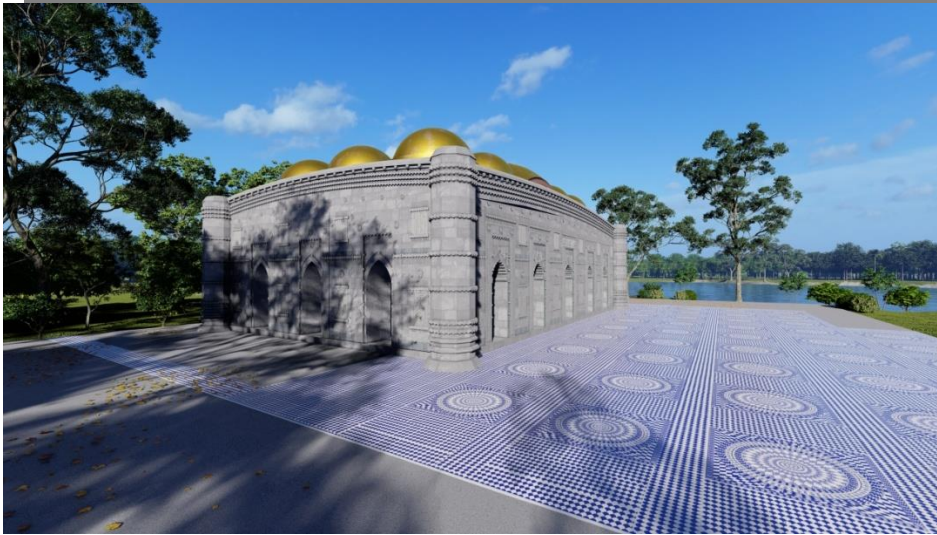
Figure 4: Reviving History: Immaculate Virtual Restoration of the Courtyard's Tiled Floor at the Mosque and gilded domes.

Figure 5: Impeccable Virtual Restoration: Resurrecting the Tiled Floor Inside the Mosque's

The virtual tour of the Chhoto Sona Mosque offers a truly immersive experience, inviting visitors to embark on an in-depth exploration of both its interior and exterior. Designed with utmost user-friendliness and intuition, the user interface ensures that visitors can effortlessly navigate every nook and cranny of the mosque. This interactive journey empowers them to move freely within the mosque's digital realm, while also enabling them to zoom in on specific features, revealing the intricate details that grace its architecture. The past model of the Chhoto Sona Mosque is a pivotal instrument in the ongoing preservation of the mosque's rich cultural heritage and the provision of profound insights into its historical significance. Leveraging cutting-edge VR technology, we've been able to meticulously recreate the mosque's features and functionality as they stood in the past. This model serves as a veritable treasure trove for educational and research purposes, affording students, researchers, and tourists alike the opportunity to delve into the mosque's architectural marvels and historical tapestry with an unprecedented level of detail and authenticity. This prime model transcends the boundaries of time and space, fostering a deeper connection between people and the mosque's legacy. It epitomizes the symbiosis of technology and cultural preservation, ensuring that the Chhoto Sona Mosque continues to inspire and educate generations to come.

DISCUSSION

Analysis of Research Findings and Implications:

The devastating Assam earthquake of 1897 left a trail of destruction in its wake, particularly affecting the Chhoto Sona Mosque. Three of its iconic hemispherical domes succumbed to the tremors, along with significant portions of the west wall. The central aisle also suffered, as three of the *Chauchalas* within it

collapsed. In the wake of this calamity, the British government, recognizing the historical and cultural significance of the mosque, embarked on a restoration effort in 1905-06, allocating Rs. 7165 for the endeavor (Marshall 1905). This marked the beginning of efforts to breathe new life into the mosque. In 1932, a pivotal milestone was achieved when eight structures in Gaur, including the Chhoto Sona Mosque, were officially designated as protected antiquities. This designation heralded a period of preservation and protection for these historical treasures. However, it wasn't until a century later, in the early 2000s, that a concerted effort by the Department of Archaeology of the Government of Bangladesh was launched to comprehensively conserve and renovate the mosque and its adjacent ancient monuments. This undertaking, carried out during 2003-05, represents a vital chapter in the ongoing efforts to safeguard and celebrate the cultural heritage encapsulated within the Chhoto Sona Mosque.

The excavation in 2001, led by Dr. Shafiqul Alam, the Regional Director of Rajshahi Division, and Mr. Md. Abdul Khaleq, who served as the Assistant Director at the time, unveiled a remarkable discovery—a brilliantly shiny tiled floor nestled within the open courtyard in front of the mosque. This glazed tile masterpiece stretches across an impressive expanse, spanning 36 meters from north to south and 16 meters from east to west. However, the passage of time had taken its toll, and regrettably, a significant portion of these tiles had been pilfered. Intriguingly, the excavation revealed a mosaic of tiles, boasting about 25 distinct varieties of blue and white designs. The tiles were ingeniously laid atop a foundation of lime-brick beaten floor, designed with holes in the lower back to facilitate installation. Notably, historical accounts and sources suggest that similar tiles adorned the floor of the mosque's prayer room. Former Director of the Department of Archaeology, Nazimuddin Ahmed, attested to the presence of tiles within the mosque during his visit to Gaur. He even took the initiative to collect some of these tiles from the Chhoto Sona Mosque, subsequently depositing them in the Lalbagh Fort Museum (Shafiqul 2004). The site director at that time also echoed the existence of tiles within the mosque. Nevertheless, the concept of adorning the courtyard with an exquisite tiled floor while utilizing ordinary stone and bricks for the main mosque structure raises intriguing questions, sparking curiosity about the historical motivations and artistic choices that have left their indelible mark on the Chhoto Sona Mosque.
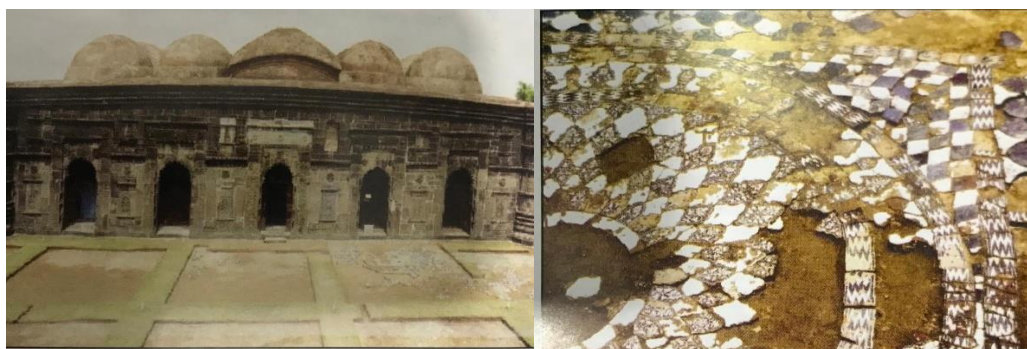

Figure 6: Unearthing the Treasures: Tiles Discovered During Excavation of Chhoto Sona Mosque at 2001

Scholars hold varying perspectives regarding the origins of tile usage in Bangladesh. While some propose that the introduction of tiles to the subcontinent can be traced back to Turkey, many contend that their roots lie in Persia. Nevertheless, irrespective of their origins, historical records unequivocally establish the extensive utilization of glossy tiles in religious and ceremonial contexts spanning several centuries during the Sultanate and Mughal eras in Bengal, as well as in other regions across India.

The existing section of the tile floor within the mosque had deteriorated significantly over time. However, it was deduced that the floor had undergone extensions, spanning five additional blocks along the primary entrance to the mosque and two more blocks on each side of the turret situated in the northeast and northwest corners of the mosque. The discernible part of the floor can be clearly identified by its layout, featuring tiles arranged in four-row square blocks, each encircled by uneven rectangular blocks. Notably, there were three more square blocks positioned adjacent to a concentric circle near the primary arch, with two non-circular squares interspersed in between. The corner turret of the mosque displayed symmetry, boasting two identical square blocks on either side. This configuration contributed to a total of 39 concentric circle square blocks and

four non-circular blocks, with the tiles arranged in an array of unequal rectangular blocks around them (Shafiqul 2004). The result was a stunning and intricate floor, characterized by diverse tile layouts, colors, and designs, which added to the mosque's overall visual allure.
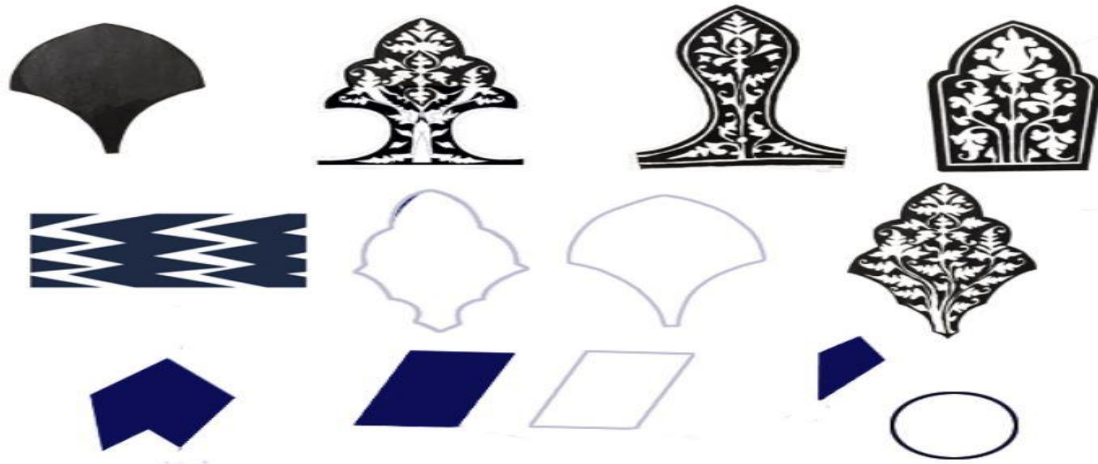

Figure7: Diverse Tile Shapes Unearthed in Archaeological Excavation

The meticulous restoration journey embarked upon a multifaceted approach, commencing with the resplendent re-painting of the mosque's domes in a brilliant golden hue, reinstating their former grandeur. However, the true marvel of the restoration process lay in the painstaking revival of the mosque's tiled floor, a task that demanded a blend of artistic vision and digital precision. To rekindle the charm of the tiled floor, a methodical approach was employed. Small tiles were meticulously arranged in phases, a process facilitated by the adept use of software tools like Adobe Photoshop and Illustrator. This endeavor led to the creation of a rectangular floor block, capturing the essence of the original design. However, the challenges of restoration extended beyond the courtyard. A total of 39 blocks outside the mosque and 15 blocks within its sacred confines required virtual restoration. These endeavors were made possible through the use of Illustrator-designed files, with the final touch of texture mapping being skillfully executed in Rhino. It was imperative that the Illustrator files were of high quality, available in JPJ, GIF, or PNG formats, to ensure the accuracy of texture mapping and maintain the fidelity of the restoration.

The resulting VR model of the Chhoto Sona Mosque emerges as a testament to meticulous craftsmanship and technological prowess. It transcends the boundaries of time and space, offering users a profound understanding of the mosque's architectural intricacies and design elements. The restoration, spanning the tiled floor, gilded domes, and the adjacent pond, breathes life into the historical narrative, underlining the significance of this sacred site. Accurate measurements, as meticulously detailed in Table 1, have played a pivotal role in ensuring the faithful replication of the mosque's dimensions within the VR model. This VR model is more than a digital recreation; it is a celebration of heritage, an educational tool, and a testament to the enduring commitment to preserving the legacy of the Chhoto Sona Mosque for generations to come.

The VR model has also enabled us to identify several design elements that were not visible in the current state of the mosque. For instance, the use of different types of blue and white tiles on the floor and the intricate designs on the gilded domes provide a glimpse into the artistic and architectural sensibilities of the people who built the mosque. The virtual tour experience of the mosque provides an immersive experience to the users, which is not possible with traditional methods of presenting historical sites. The ability to move around the site and view it from different angles and perspectives makes the experience more engaging and informative.

Insights on the Potential Applications of VR Modeling in Archaeology and Cultural Heritage Preservation:

The use of Virtual Reality (VR) modeling in archaeology and cultural heritage preservation presents transformative possibilities with far-reaching applications.

First, VR modeling serves as a vital tool for documenting and preserving historical sites at risk of damage or destruction. By creating detailed digital replicas, VR ensures that these sites can be studied and experienced virtually even if the physical structures become inaccessible or are irreparably damaged. For instance, the VR model of the Chhoto Sona Mosque safeguards its architectural and cultural essence against potential threats such as natural disasters or anthropogenic pressures. Situated in an earthquake-prone region, the mosque faces substantial risks of structural damage. Moreover, a major road in front of the mosque frequently bears heavy truck traffic transporting stone from the Sona Mosque port, causing continuous vibrations. These vibrations, compounded over time, pose a significant threat to the structural integrity of the mosque. The VR model acts as a digital conservation measure, ensuring that this treasured heritage is preserved in its pristine form for future generations.

Secondly, VR modeling enables the resurrection of historical sites as they existed in their prime, offering immersive and interactive experiences that connect the present to the past. The VR reconstruction of the Chhoto Sona Mosque provides a vivid glimpse into its historical grandeur, transcending the limitations of its current state. This approach can be applied to other sites suffering from centuries of decay, environmental changes, or human intervention. By virtually restoring these sites, researchers, historians, and enthusiasts gain access to an invaluable tool for in-depth study and exploration, offering a unique opportunity to visualize and understand the past in ways that physical restoration may not always achieve.

Thirdly, VR modeling offers a revolutionary solution for creating virtual exhibitions of historical artifacts and sites. Museums and cultural institutions often face spatial limitations that hinder the display of their entire collections. VR technology circumvents this challenge, enabling the creation of dynamic and immersive virtual exhibitions accessible to anyone with a basic smartphone or internet connection. In the context of Bangladesh, where technological access and infrastructure vary significantly, the VR model of Chhoto Sona Mosque has been designed to operate efficiently on low-bandwidth internet and standard smartphones, making it a cost-effective and inclusive tool. This democratizes access to cultural heritage, allowing students, researchers, and global audiences to explore these treasures irrespective of geographical or financial constraints.

Finally, VR modeling acts as an essential educational and awareness-raising tool. By making the Chhoto Sona Mosque's VR model widely accessible, the initiative promotes public appreciation of heritage conservation and fosters a deeper understanding of the risks these historical sites face. It encourages the integration of digital technologies into cultural heritage preservation, blending tradition with innovation to secure our shared history for future generations.

The VR model of the Chhoto Sona Mosque is more than a digital artifact; it is a beacon of sustainable preservation. By addressing immediate threats, offering immersive educational experiences, and ensuring accessibility, it sets a benchmark for the virtual conservation of endangered heritage sites, inspiring similar efforts both locally and globally.

Contributions of the Study to the Field of Archaeology and Digital Humanities:

The study conducted holds significant implications and contributes substantially to the dynamic realms of archaeology and digital humanities in several notable ways.

First and foremost, the creation of the VR model of the Chhoto Sona Mosque stands as a pioneering achievement. It serves as a meticulously detailed and immersive resource that imparts a profound comprehension of the mosque's architectural intricacies and design elements. This invaluable asset not only enriches our understanding of the site but also extends an inviting hand to further research endeavors. Researchers, historians, and scholars now have an unprecedented tool at their disposal, one that can be harnessed to delve deeper into the historical and cultural tapestry encapsulated within the Chhoto Sona Mosque. It opens doors to new avenues of investigation and analysis, fostering a more nuanced and comprehensive grasp of this treasured heritage.

Secondly, the study's application of VR modeling in the context of archaeology and cultural heritage preservation is groundbreaking. It unveils a spectrum of possibilities and potentialities for the field. The use of

VR modeling goes beyond mere representation; it emerges as a powerful instrument for the documentation and preservation of historical sites. By virtually resurrecting sites that have succumbed to time's relentless march or alterations, it bridges the temporal chasm between past and present, offering a lifeline to researchers and enthusiasts eager to explore history's mysteries. Moreover, the creation of virtual exhibitions brings artifacts and objects to life in ways that transcend the confines of physical space. It democratizes access to cultural treasures, rendering them accessible to a global audience. These applications underscore the transformative role that digital technologies can play in safeguarding and celebrating our shared heritage.

Lastly, the study shines a spotlight on the imperative of integrating digital technologies into the discipline of archaeology and cultural heritage preservation. The use of VR modeling redefines the boundaries of engagement and education. It fosters a more immersive and interactive experience for users, be they students, researchers, or the general public. This heightened engagement, in turn, has the potential to raise public awareness and appreciation for historical sites and artifacts, kindling a renewed sense of reverence and curiosity for our shared past. In essence, the study illuminates the path forward, one where technology and tradition coalesce, enriching our collective understanding and connection with the treasures of yesteryears.

Scaling the VR Model to Other Heritage Sites

Building on the success of the Chhoto Sona Mosque VR model, there is immense potential to expand this initiative to other heritage sites in Bangladesh and beyond, creating a comprehensive virtual repository of cultural and historical significance. This approach could transform how heritage is preserved, accessed, and experienced globally.

National Expansion

Bangladesh is home to a vast array of heritage sites, including the ancient city of Mahasthangarh, the terracotta temples of Kantanagar, the Paharpur Buddhist Vihara, and the mosques of Bagerhat. By applying the VR technology used for the Chhoto Sona Mosque to these sites, it would be possible to create a cohesive digital archive of the nation's rich cultural history. This archive could serve as a platform for educational institutions, tourists, and researchers to explore and engage with Bangladesh's heritage in a meaningful way.

Creating a Virtual Heritage Repository

A long-term vision would be to establish a virtual heritage repository that digitally documents and preserves multiple historical sites. This repository would:

- Provide global access to Bangladesh's cultural treasures, removing barriers related to geography, cost, and accessibility.

- Serve as a valuable resource for educators, historians, and researchers interested in studying cultural heritage.

- Act as a conservation tool, ensuring that digital records remain intact even if the physical sites face threats from natural disasters, urbanization, or neglect.

Regional and Global Integration

Scaling this VR initiative globally could foster international collaboration and cultural exchange. By digitizing heritage sites from different countries, it would be possible to create a shared platform where users can explore the diversity of human history and culture. For example, integrating Bangladesh's heritage sites into a global VR repository could highlight their unique contributions to world history while connecting them to larger narratives in Asian and Islamic art and architecture.

Opportunities for Tourism and Education

Expanding the VR model would also boost the tourism industry by offering immersive experiences of heritage sites to a global audience. For students, such a repository could provide a virtual classroom experience that spans cultures and geographies, allowing them to "visit" historical landmarks worldwide without leaving their homes.

Collaboration and Partnerships

Achieving this vision will require collaboration with various stakeholders, including government agencies, cultural organizations, educational institutions, and private technology companies. Partnerships can help secure funding, ensure historical accuracy, and leverage cutting-edge technologies such as AI, AR, and 3D scanning to enhance the virtual models.

A Sustainable Future for Heritage Preservation

Scaling the VR model to other sites aligns with global efforts to preserve cultural heritage through technology. By creating a digital repository of heritage sites, we can ensure their legacy for future generations while promoting cross-cultural understanding and appreciation on an unprecedented scale.

Through these efforts, the VR initiative can evolve into a transformative tool that not only preserves history but also makes it accessible, engaging, and relevant in the digital age.

User Feedback

A survey was conducted among 300 people. Here's the breakdown of responses we can use for the visualization:

- Education: 240 respondents (80%) found it effective.

- Tourism: 210 respondents (70%) found it effective.

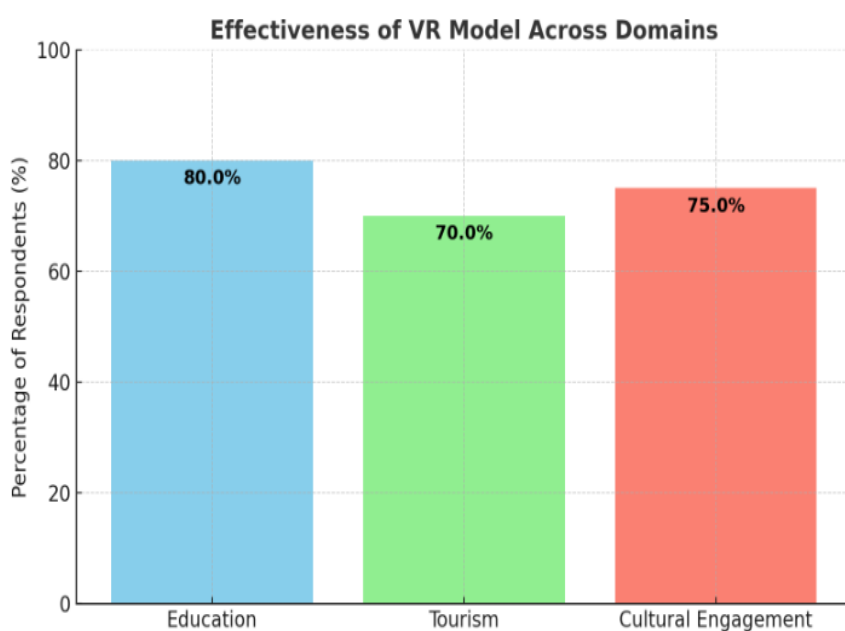- Cultural Engagement: 225 respondents (75%) found it effective.

Figure 4: the bar chart showing the effectiveness of the VR model across education, tourism, and cultural engagement based on survey responses from 300 participants.

CONCLUSION

In this study, a virtual reality model of the Chhoto Sona Mosque in Bangladesh was meticulously developed using a combination of 3D digitalization, scanning, geometric modeling, virtual restoration, and VR technology. This model was created with the primary objective of preserving and presenting the cultural heritage of this historical monument for educational and tourism purposes. The findings of this research underscore the effectiveness of VR modeling in cultural heritage preservation. By immersing users in an interactive virtual experience, it successfully transports them to the past, allowing for a deeper appreciation of the mosque's architectural and historical significance. The meticulous restoration of the tiled floor serves as a testament to the craftsmanship of a bygone era and fosters a meaningful connection between present generations and their cultural heritage. Furthermore, this study highlights the vast potential of VR modeling in archaeology and cultural heritage preservation. Beyond offering virtual tours, it demonstrates the technology's capacity to aid in the restoration and conservation of cultural sites, particularly through the recreation of lost or damaged elements. This application presents a cost-effective and efficient solution for experts and archaeologists engaged in the restoration process.

This study constitutes a substantial contribution to the fields of archaeology and digital humanities. It underscores the pivotal role of VR modeling in preserving cultural heritage by creating an immersive platform for education and tourism, thereby safeguarding the legacy of the Chhoto Sona Mosque. For future research, it is recommended to explore avenues of interactivity and user-generated content, potentially integrating gamification elements. Additionally, the incorporation of AI and machine learning into the VR modeling process warrants further investigation to enhance the accuracy and efficiency of restoration and preservation efforts.

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