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Behavior-Driven Design Frameworks for Virtual Heritage Experience

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Abstract

This study investigates how virtual reality (VR) and the game platform Minecraft can be employed to create an interactive digital pilgrimage experience centered on the Boudhanath Stupa in Nepal. Adopting a Behavior-Driven Design (BDD) approach, the design process focuses on modeling ritual interactions based on actual user behavior. Using Gherkin syntax with "Given-When-Then" statements, user scenarios are systematically defined to ensure that key religious actions—such as circumambulation, spinning prayer wheels, offering incense, and releasing animals—are meaningfully embedded into the virtual environment. This user-centered methodology informs not only the design of interactive features, but also the spatial configurations of the virtual environment, with each ritual scenario shaping corresponding experiential nodes. A user study involving fifteen Buddhist practitioners who had previously visited the physical site revealed that, despite Minecraft's simplified aesthetics, the virtual pilgrimage effectively evoked emotional resonance and memory recall. Participants also valued the addition of symbolic and imaginative spaces unique to the virtual setting. Overall, the study demonstrates how BDD facilitates cross-disciplinary collaboration and enables the translation of cultural and spiritual practices into interactive experiences, thus redefining digital heritage as a dynamic and participatory space rather than a static representation.

1. Introduction

1.1 Research Background and Motivation

With the development of cultural heritage digitization, virtual environments have become vital tools for both preservation and participation. These spaces go beyond static representation and enable embodied, interactive experiences. In the context of religious heritage, this transformation is particularly significant, as ritual, bodily action, and spatial practice form the core of meaning-making. It is one of the primary reasons why physical presence at the site, such as through pilgrimage, is highly valued. Yet when sacred sites are digitally reconstructed, a fundamental question arises: how can users meaningfully engage with their ritual dimensions in a virtual environment?

This study focuses on the case of the Boudhanath Stupa in Nepal, a UNESCO World Heritage Site and a major pilgrimage destination in Tibetan Buddhism. In traditional practice, circumambulating the stupa in a clockwise direction (*pradakshina*) is an essential ritual believed to generate merit, purify defilements, and deepen one's devotion. As stated in the *Right Circumambulation of the Stupa Sutra* (Sikshananda, 2021), even an unintentional act of circumambulation is said to result in boundless merit. This doctrinal perspective affirms a Buddhist merit-logic in which bodily movement and ritual engagement directly contribute to spiritual transformation.

To extend this principle into the virtual domain, the study also draws upon religious scholar Mircea Eliade's theory of sacred space. Eliade (2022) posits that sacred space is formed through a rupture in profane continuity—a manifestation of the sacred (*hierophany*)—which transforms an ordinary place into a spiritually ordered center (*axis mundi*). From this standpoint, the stupa is not merely architectural but cosmological, embodying a structure of spiritual orientation and ritual function. Therefore, any meaningful digital reconstruction must retain this sacred structure, allowing users to act as ritual agents rather than passive observers.

Despite advances in 3D modeling and scanning technologies such as drones, Matterport, and AI-based photogrammetry, these methods primarily offer visual replication and are insufficient for supporting ritual interactivity. Furthermore, their high cost and technical demands limit their accessibility for broader educational or devotional use. This research addresses this gap by proposing an interaction-first framework rooted in ritual behavior and merit-centered design.

1.2 Theoretical Framework and Design Principles

Grounded in the Buddhist doctrine of merit-generating action found in the *Right Circumambulation Sutra*, this study reinterprets virtual pilgrimage as a participatory journey. To translate religious acts into interactive elements, we adopt Behavior-Driven Development (BDD) as our design methodology. BDD (Lawrence and Rayner, 2019) is a user-centered approach from software development, begins with the intended user behaviors. It uses natural language scenarios written in the Given–When–Then format, allowing developers, cultural experts, and designers to communicate interaction goals in an accessible and testable manner.

In this study, BDD scenarios are not merely technical artifacts,they serve to ritualize digital interaction. Each user behavior is treated as a merit node within the sacred environment. Through this process, the stupa becomes not just a reconstructed space, but a performative site of karmic potential. Ritual actions such as circumambulating, spinning prayer wheels, or making offerings are incorporated into the design as integral components of interaction flow.

In terms of the technical process, the virtual environment is developed using Minecraft and integrated with Virtual Reality

(VR) technology. In addition to replicating the actual architecture of the Boudhanath Stupa, we introduce symbolic extensions such as a Bodhisattva for offering, an animal-feeding zone (symbolizing generosity), an interactive mantra player, and an accessible stupa interior chamber. These additions reflect core Buddhist values and allow for deeper immersion and spiritual reflection, potentially surpassing what is possible in the physical world.In summary, this study combines Buddhist teachings and behavior-driven design to construct a digital stupa experience that emphasizes ritual performance and spiritual participation. The result is a virtual sacred space that can be interacted with, practiced within, and used for generating merit—redefining digital heritage as a dynamic space of living faith.

1.3 Research Objectives and Problem Statement

Building upon the aforementioned frameworks, this study explores how a behavior-driven approach can inform the design of ritual-centered digital heritage experiences. Specifically, it investigates how core Buddhist practices—circumambulation, offering, and devotional acts—can be meaningfully translated into virtual interactions.

The primary objectives of this study are:

1. To analyze Buddhist ritual acts based on textual sources, and reinterpret their behavioral, symbolic, and spatial significance for a virtual context.

2. To implement BDD as a methodology for cultural interaction design, using Gherkin syntax to bridge technical specifications with ritual requirements.

3. To develop and evaluate an interactive prototype of the Boudhanath Stupa in Minecraft with VR integration, assessing users' spiritual engagement, cultural understanding, and memory activation.

While VR has been increasingly employed in cultural heritage projects, a clear gap remains in addressing ritual performance and spiritual engagement. Many digital heritage initiatives prioritize architectural fidelity or historical storytelling , often overlooking the embodied logic of religious spaces. As a result, users often become observers rather than participants. To address this issue, the study is guided by the following research questions:

- How can merit-generating Buddhist ritual behaviors be translated into interactive virtual experiences?

- How can BDD, as a design methodology, facilitate the creation and communication of spiritually resonant interactions within a digital heritage context?

Through this investigation, the study proposes an integrated framework for designing interactive sacred environments—merging doctrinal insight with interaction design—to promote spiritual participation and cultural continuity in virtual heritage.

2. Literature Review

2.1 Stupas and Circumambulation Rituals

In Buddhism, the Stupa is regarded as a sacred structure built to enshrine the relics of the Buddha and to serve as a focal point for devotion and spiritual practice. The scriptural basis for this practice is foundational, originating from the Buddha's final instructions in texts such as the Mahayana Mahaparinirvana-sutra, which record his directive to enshrine his relics in stupas so that they might inspire future generations (Yamamoto, 1973). As one of the earliest known examples, the Sanchi Stupa, dating back to the 3rd century BCE, exemplifies the archetypal hemispherical mound structure of sacred Buddhist architecture. Among these numerous holy sites, the Boudhanath Stupa in Kathmandu, Nepal, holds particular significance. Enshrining the relics of the Kassapa Buddha, it is one of the largest stupas in the world. Known as the "Wish-Fulfilling Stupa," it attracts hundreds of thousands of pilgrims annually. Its profound spiritual status, unique symbolic architecture, and geographic location make it an ideal subject for virtual pilgrimage.

The most integral ritual associated with the stupa is circumambulation—the act of walking clockwise around the structure with one's right side facing it. Deeply rooted in early Buddhist tradition, this practice is prominently depicted in ancient reliefs, most notably on the stupas of Bharhut and Amaravati. Buddhist scriptures, including the Right Circumambulation of the Stupa Sutra (Sikshananda, 2021) further affirm that this act generates boundless merit, such as liberation from hardship, the accumulation of positive karma, and favorable rebirths. This doctrine of merit is vividly illustrated and popularly transmitted through narratives in Avadāna literature, such as the *Divyavadana*, which recount numerous stories of devotees earning extraordinary rewards through the veneration of stupas (Cowell and Neil, 2021). The continuity and importance of this ritual over centuries is further attested in the travelogues of East Asian pilgrims such as Faxian (1886) and Xuanzang (1886), who documented their own experiences of circumambulating stupas across India. However, circumambulation is not merely a physical act; it is a holistic ritual involving the integration of body, speech, and mind. Unlike casual tourists who may circle the stupa out of curiosity, devout pilgrims perform this act mindfully, often while chanting mantras, reciting prayers, or making offerings and full-body prostrations. The space around the stupa is, therefore, a sacred zone that supports continuous spiritual engagement.

This process of imbuing space with meaning through ritual action aligns with the theory of sacred space proposed by religious scholar Mircea Eliade (2022). From this perspective, the act of circumambulation becomes a performance that transforms the physical space around the stupa into a spiritually charged center. As Adrian Snodgrass (1985) elucidates in his classic study, the stupa's very architecture functions as a cosmic model, making it a perfect realization of Eliade's concept of a world center. Sanctity is not static or inherent in the architecture alone; rather, it is dynamically and continuously created through the ritual participation of the faithful. The Tibetan Buddhist master Dzongsar Khyentse Rinpoche (2022) emphasizes that visiting sacred sites allows practitioners to accumulate great merit through acts such as prostrations, offerings of water, flowers, incense, and food, reciting prayers, circumambulating stupas, and dedicating merits. This emphasis on embodied ritual is not merely a contemporary view; its deep historical roots are confirmed by schol-

arly research. Drawing on archaeological and epigraphic evidence, Gregory Schopen (1997) underscores that early Buddhist practice was profoundly material and ritual-focused, centering on the tangible presence of relics. This confluence of doctrinal and historical perspectives highlights a critical gap in current digital heritage technologies: most efforts focus on visual replication but overlook interactivity and performativity—elements that position the user as a ”ritual participant” rather than a passive observer.

Given the repetitive, immersive, and embodied nature of this practice, circumambulation is especially suitable for translation into a virtual ritual mode. In this study, the ritual is reinterpreted within an interactive system designed to preserve its essential elements:circular movement, mantra recitation, sensory offerings, and devotional intent. The design aims to maintain the integrity of the ritual while enabling its practice in digital and remote settings. By doing so, the virtual pilgrimage interface allows both Buddhists and interested participants to engage meaningfully with the practice, synchronizing physical action, sound, and intentionality to complete the ritual’s spiritual purpose.

2.2 Technological Approaches with Minecraft and VR

While virtual heritage environments created through 360-degree photography or drone imagery provide accessible and visually rich representations of cultural sites, they often fall short of evoking the ritual and spiritual dimensions central to religious heritage. The design of a virtual pilgrimage site must go beyond representational fidelity to elicit emotional resonance and embodied engagement. In sacred contexts, active user participation—through movement, chanting, offering, or reflection—is essential for cultivating a sense of presence and ritual authenticity. Without opportunities for action, passive viewing remains limited in its ability to transmit the experiential and devotional depth of pilgrimage.

Minecraft has emerged as a promising platform for bridging this gap, offering interactive, user-centered environments for engaging with cultural and religious heritage. It has received scholarly attention for its potential in education and public heritage engagement. Despite its constraints in visual realism due to its modular, block-based system, Minecraft allows users to reconstruct architectural forms, navigate spatial layouts, and experiment with participatory creation. Its effectiveness as a tool for conveying architectural heritage was established in early studies, with researchers like Fernandez and Medeiros (2019) identifying it as a valuable solution for representing digital cultural assets. Several recent studies have expanded Minecraft’s application in diverse cultural heritage contexts. For example, Griffiths et al. (2021) demonstrated its utility for exploring both the technical and interpretative landscape of Bryn Celli Ddu. This work highlighted its potential for cultural heritage education. Similarly, Andrade et al. (2024) utilized Minecraft as a geo-game to support youth engagement in co-designing climate adaptation scenarios for heritage-sensitive sites, revealing its value in participatory planning and environmental awareness. Extending these applications into the domain of ritual heritage, a preliminary study by Lo (2024) constructed a Minecraft model of the Boudhanath Stupa, integrating symbolic architectural elements and ritual pathways. This work explored how designing for and from prayer can mediate virtual spiritual experiences, thereby pushing the boundary of Minecraft’s use from educational and participatory design into the realm of affective and embodied religious engagement.

Complementing this approach, VR technologies provide the immersive depth necessary for ritual experience. Unlike desktop-based interfaces, VR enables embodied navigation, multisensory input, and direct interaction with sacred objects and environments. In VR simulations, users can move through temple complexes, perform circumambulation, spin prayer wheels, offer incense, or listen to chanting—all contributing to a holistic sense of spiritual engagement. Studies such as Buragohain et al. (2025) demonstrate the transformative role of digitally conserving temple architecture, offering a resilient new frontier for cultural heritage preservation. By virtually experiencing iconic sites like Kodaiji Temple, Angkor Wat, and Shwedagon Pagoda, expanding access and enhancing educational engagement globally. Temple architecture could become central to virtual tourism, allowing users to visit, learn historical contexts, participate in rituals, and engage in interactive storytelling that brings myths and traditions to life. Mu et al. (2024) further explored a VR recreation of the Mount Wutai pilgrimage landscape, incorporating Dunhuang-inspired iconography and Buddhist chants. Their results suggest that such immersive experiences not only enhanced users’ symbolic understanding but also improved affective memory and ritual empathy.These findings support a growing consensus that immersive technologies can meaningfully simulate aspects of spiritual practice, especially when physical access to sacred sites is limited due to geography, age, or health. In educational settings, this aligns with theories of embodied learning, which argue that cognition and emotion are co-constructed through spatial movement and sensorimotor engagement.

Building on these insights, the current study merges these two technologies to create a multi-layered ritual experience. It employs Minecraft to reconstruct the architectural form of the Boudhanath Stupa, including its hemispherical dome, circumambulatory path, and symbolic features like the Buddha’s all-seeing eyes. This digital structure serves as both a visual referent and a ritual interface. A VR adaptation then builds upon this base by integrating haptic navigation, 3D audio of mantras, interactive prayer wheels, and designated spaces for smoke offerings, prostrations, and devotional lighting. By combining the participatory construction model of Minecraft with the sensory and spatial immersion of VR, this approach repositions digital heritage from static visualization to interactive ritual performance. The virtual pilgrimage becomes not only a means of preservation but also a legitimate spiritual interface—fostering devotional agency, emotional resonance, and continued engagement across cultural and geographic boundaries

3. Methodology

Our development process centered on user-driven design, using principles of BDDto ensure that interactive mechanisms within the virtual Boudhanath Stupa reflected real-world behaviors, rituals, and user expectations. BDD emphasizes communication and functionality grounded in user needs by scripting interaction scenarios in natural language from the user’s perspective. This was particularly effective for a spiritual-cultural experience, where precision in representing rituals such as circumambulation, offering, and chanting is crucial. By drafting **Given-When-Then** scenarios before implementation, we ensured that each interaction—whether devotional or exploratory—was directly tied to an observed or documented behavior within the sacred site. The result was a system in which users could intuitively begin circumambulation, engage in smoke offering, spin prayer wheels, make alms-giving offerings, enter stupa halls,

and honor the Buddha’s relics—all within a meaningful, embodied sequence.

3.1 Ritual Scenarios

Based on on-site observations and interviews conducted at the Boudhanath Stupa in Kathmandu, we identified a set of typical behavioral patterns performed by circumambulators, which were then translated into “ritual nodes” within the virtual environment to simulate a standard pilgrimage journey. The core sequence includes: starting at the sacred site, beginning clockwise circumambulation, making smoke offerings, chanting mantras, giving alms, lighting lamps, offering flowers, and finally departing the stupa. This sequence integrates bodily action, vocal expression, and devotional intention, forming a widely practiced and representative structure of pilgrimage.In more devout and advanced forms of practice, we also observed practitioners engaging in prayer wheel turning, ritual practice, mandala offerings, full-body prostrations, and seated meditation. These actions reflect a deeper level of religious commitment and embodied cultivation. However, in the present study, we focus on designing for the foundational pilgrimage flow, providing a core structure through which users can initially engage with and understand the circumambulatory ritual. This decision supports accessibility while maintaining the coherence of ritual logic, and it establishes a meaningful baseline for future expansions into more complex ritual modules. Through this approach, we aim to recreate a basic yet spiritually resonant framework of practice within the virtual pilgrimage environment.

3.2 Development Process

Below are the BDD Scenarios Based on the Virtual Pilgrimage Sequence(Table 1):

The current stage of development has established a foundational interactive structure for virtual pilgrimage at the Boudhanath Stupa. Through user-centered design and the application of BDD, we implemented a sequence of ritual nodes that reflect observed practices such as circumambulation, smoke offering, mantra chanting, almsgiving, lamp lighting, and flower offerings. Each interaction is embedded in meaningful bodily, verbal, and devotional action, creating an experiential flow aligned with actual pilgrimage behavior. These actions generate corresponding spatial forms within the virtual cultural environment, with each interaction situated in locations that mirror the spatial arrangement of the physical site. In this way, ritual behavior does not occur in isolation but actively shapes the design of the virtual space, anchoring cultural meaning through spatial embodiment.

To further validate and refine the virtual ritual experience, the next phase of the project involves a preliminary user trial. We plan to invite 15 participants to engage with the system and complete the core pilgrimage sequence. Feedback from this group will provide insights into usability, spiritual resonance, and areas for enhancement. This trial aims to assess whether the current design successfully facilitates a sense of ritual participation and emotional connection within a virtual sacred space.

4. VR Ritual Experience

After building the interactive VR experience of the Boudhanath Stupa, we conducted a user study with 15 Buddhist practitioners in a broad sense (Figure 1). Each participant was invited to explore the virtual Stupa, follow a guided circumambulation quest, and interact freely with the environment. We observed their behaviors and conducted post-experience interviews to gather qualitative feedback. Participants’ ages ranged across three groups: one participant was under 25 years old, eleven were between 25 and 55, and three were over 55. The results indicate that age did not significantly affect usability or engagement with the virtual experience. The average duration of each session was approximately 15 to 20 minutes, during which users completed the ritual journey and interacted with multiple symbolic elements embedded in the environment.

1.Begin	
Given	the user is standing at the entrance
When	the user presses the ”Start ” button
Then	the arrow shows
2.Smoke Offering	
Given	the user is walking clockwise around the stupa
When	the user reaches the incense station
Then	incense smoke appears
3.Chant Mantras	
Given	the user is reaching a player desk
When	the user presses the ”play ” button
Then	the chanting audio plays
4.Giving	
Given	the user is continuing the circumambulation
When	the user reaches a donation spot
Then	the a food offering
5.Light a Lamp	
Given	the user is going to a temple
When	the user puts a Lamp on the desk,
Then	a light effect appears
6.Offer Flowers	
Given	the user completes a full circumambulation loop
When	the user puts a plant of flower before the stupa
Then	a Bodhisattva Thangka shows

Table 1. the BDD Scenarios.

4.1 Behavioral Mapping

Analysis of the users experience questionnaires revealed a participant group highly qualified to evaluate the system’s authenticity, as all identified as cultural Buddhists and most had prior experience with stupa circumambulation. Despite over 80% being first-time users of Minecraft and VR, the system received overwhelmingly positive feedback on its usability, with the majority reporting the interface was “fun,” “easy to understand,” and “pleasant to use.” This positive reception was reflected in the quantitative data, where four-fifths of respondents gave the experience the highest possible satisfaction rating. The high satisfaction was largely attributed to the interaction points developed through the BDD process, which effectively replicated the feel of real-world ritual behaviors. Figure 2 offers a clear visual testament to this, juxtaposing the physical ritual of a

Figure 1. VR experience by practitioners.

smoke offering (top) with its corresponding interaction in the virtual environment (bottom), thereby illustrating the experiential continuity between the physical and digital. This sense of continuity was further corroborated by qualitative feedback, where users expressed experiencing a genuine ritual rhythm and inner calm. Comments such as being able to “naturally recite mantras during interaction with the stupa” or that the experience felt like “actually walking through the sacred site” underscore the system’s success in generating spiritual resonance. The intuitive nature of these interactions reflects the success of the BDD methodology itself, with remarks like “I immediately knew where to click” pointing to the cultural legibility and ritual coherence embedded in the design. Furthermore, the design proved so engaging that some users proactively suggested enhancements, such as “adding options for full-body prostrations or prayer wheel spinning,” indicating that the virtual space was perceived not as a static replica, but as a living site with potential for expanded ritual practice.

Notably, although most participants lacked a technical background, the interface received overwhelmingly positive feedback, with only two individuals reporting minor issues such as visual dizziness.

4.2 Practitioners’ Feedback

Building on on-site observations and interview data, the circumambulation process was segmented into six primary ritual nodes, each corresponding to a key moment of devotional activity. These nodes were then translated into interactive scenarios using Gherkin syntax (Given–When–Then), enabling precise articulation of user behavior within the virtual environment. Initial feedback from expert reviewers and collaborators confirmed that this scenario-based structure fostered effective communication between technical developers and researchers with ritual expertise. To further evaluate the user experience, a post-experience Likert scale questionnaire was administered to 15 participants. The instrument assessed six dimensions: ”Ease of Use” (M = 3.53), ”Spiritual Resonance” (M = 4.00), ”Cultural Understanding” (M = 4.35), ”Sense of Immersion” (reverse-coded; M = 1.65), ”Ritual Recognition” (M = 4.00), and ”Expectations for Extension” (M = 4.59). These results reflect consistently high levels of agreement across most dimensions, with particularly strong responses in cultural understanding, ritual recognition, and participants’ enthusiasm for future extensions. Although some variation was observed in ease-of-use ratings—primarily among users with less prior VR experience—the experience overall was successful in conveying the

Figure 2. Parallel enactments of smoke offering in physical and virtual pilgrimage spaces.

intended structure, affective resonance, and devotional meaning of Buddhist ritual practice.

While the quantitative data offers a broad measure of effectiveness, qualitative feedback provides deeper insight into the user experience. Many participants described the interactions as intuitive, with comments such as “I immediately knew where to click” and “when the incense appeared, it really felt like I was making an offering,” reflecting the ritual coherence and cultural legibility of the interaction design. Several users even proposed enhancements, such as extending the chanting duration or adding features for full-body prostration and prayer wheel spinning. These responses not only affirm the clarity and resonance of the existing experience but also suggest its capacity to inspire further engagement and ritual elaboration within virtual sacred environments.

5. Conclusion and Discussion

This study demonstrates that a virtual environment co-created with Minecraft and VR can successfully establish the spatial, temporal, and behavioral conditions necessary for ritual performance. The findings confirm that through intuitive spatial guidance and BDD-driven interactive triggers, participants could meaningfully simulate acts of prayer and merit-making, leading to high levels of satisfaction in cultural understanding and spiritual resonance. The efficacy of this approach lies in the use of BDD as more than just a technical tool. By translating ritual acts into structured interaction logic, BDD served as a communicative bridge between spiritual intention and technical implementation. This methodology directly addressed the dual

challenge of maintaining ritual integrity while ensuring user accessibility, proving to be a valuable framework for designing spiritually resonant digital experiences. This study therefore contributes to a broader redefinition of digital heritage—not merely as visual preservation, but as interactive and performative engagement. Through participatory platforms like Minecraft and embodied interfaces enabled by VR, sacred spaces can be reinterpreted and re-experienced in ways that maintain both symbolic meaning and affective depth. Such an approach offers a viable framework for future digital heritage projects that aim not only to represent, but to revive spiritual and cultural practices in immersive virtual environments. Future research may further explore how digitally embodied ritual practices influence long-term spiritual engagement and how such virtual environments can serve not merely as simulations, but as authentic extensions of lived religious experience across diverse cultural contexts.

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