ISVS e-journal, Vol. 10, Issue 12

December, 2023

Preserving History in The Metaverse: A Platform to Digitize the Campus Cultural Heritage in Indonesia

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Received	Reviewed	Revised	Published
16.10.2023	18.11.2023	22.12.2023	31.12.2023

https://doi.org/10.61275/ISVSej-2023-10-12-43

Abstract

This study examines the innovative application of metaverse and light detection and ranging (LiDAR) technologies in safeguarding the digital assets of the East Hall, a historical building situated within the Bandung Institute of Technology's Ganesha Campus. Through the metaverse, the preservation of heritage buildings takes on a new meaning, as it allows us not only to preserve them as physical structures but also to capture their historical significance as digital assets.

The design process of the proposed method is structured into three key phases: (1) pre-production, which entails the acquisition of data from LiDAR, unmanned aerial vehicles, blueprints, and location photos; (2) production, which involves the meticulous creation of 3D assets through the utilization of SketchUp and Blender software; and (3) post-production, where the metaverse platform is developed using Unreal Engine for the metaverse local network, whereas the VR-based metaverse online network relies on Spatial.io, reflecting its current limitations.

This workflow ensures efficiency, while also preserving accuracy and detail in representing assets, effectively bridging the gap between the metaverse's local and online platforms, which are yet to be fully supported.

Keywords: Metaverse, LiDAR, Unreal Engine, Workflow, Campus, Cultural heritage.

1. Introduction

Bandung Institute of Technology is one of the oldest universities in Indonesia, renowned for its iconic building, the East Hall, which stands out among all of its buildings. According to Kusno (2010), the East Hall building (Fig. 1), also known as "Barakgebouw B" in Dutch, showcases a blend of Indonesian architecture and tradition by incorporating vernacular forms to create a new architectural style known as "Indische Architectuur." In designing the East Hall, Maclaine Pont drew inspiration from authentic Indonesian visual culture, making it a valuable technological and cultural heritage asset. Besides being a cherished historic building on one of the oldest colleges in Indonesia and an iconic structure, the East Hall serves as a versatile venue, frequently hosting exhibitions, workshops, seminars, and various other events throughout the year. Its accessibility extends not only to campus academics but also to people from different walks of life who attend the events held within its premises.

One way to showcase the value of the East Hall, both domestically and internationally, is through the metaverse. The integration of renewable technology with the metaverse not only facilitates the replication and documentation of physical and historical artifacts but also aids in their preservation. In line with this concept, Lee et al. (2021) has highlighted that the metaverse with the incorporation of new and progressive technologies, as well as ecosystem refinement will undergo significant transformations in the next few years. Digitized representations will become more interactive, lively, embodied, and multimedia-rich.

Fig. 1: The East Hall of the Bandung Institute of Technology
Source: Author, 2023

The design of the campus metaverse for the East Hall of the Bandung Institute of Technology is based on 3D-asset modelling. This modelling involves the creation of 3D objects (i.e., assets) using computer design software. This process encompasses the development of geometric shapes and polygons, which are further refined into intricate models with textures, colors, lighting, and visual effects. To enhance data accuracy during the 3D-design phase, advanced technologies such as light detection and ranging (LiDAR) terrestrial laser scanners (TSLs) are employed to retrieve ground-surface mapping data, while LiDAR unmanned aerial vehicles (UAVs) are used to capture roof data. The actual processing of 3D-asset data is conducted using software such as SketchUp and Blender, which serve as the primary tools for shaping 3D objects before they are integrated into the metaverse platform.

The design of the metaverse effectively addresses the limitations of current virtual dimensional technology, which often falls short of delivering an immersive sensory experience. The restricted perception offered by 2D virtual technology hinders users from fully engaging with the virtual space. However, the shift from 2D to 3D technology has led to more realistic visual stimuli because 3D models provide a heightened sense of realism. It is important to note that metaverse technology differs fundamentally from virtual reality (VR). According to Indarta et al. (2022), three key differences exist between the metaverse and VR. First, whereas VR-related studies concentrate on physical and rendering approaches, the metaverse serves as a more comprehensive service with sustainable content and social significance. Second, the metaverse is not reliant exclusively on VR technology. Thus, platforms that do not support VR may still function as metaverse platforms. Finally, the metaverse offers a scalable environment capable of accommodating a large number of users—a crucial feature that underscores the social significance of this technology (Xi et al., 2022; Abd Al-Rahman and Ghafoor, 2023).

Nonetheless, incorporating VR technology into visualization stimuli within a virtual space can help bridge the gap between users and designers (Adharamadinka and Junaidy, 2023) when presenting a metaverse platform. Accordingly, a metaverse for the Ganesha Campus has been developed; this was achieved by establishing an efficient workflow process while preserving the accuracy and intricacy of interior assets of its buildings, which have outstanding architectural heritage. To this end, we employed a metaverse local network, which served as a bridge for online platforms that may not yet fully support the unrestricted size of 3D objects due to processing limitations in a web-based environment.

The objective of creating the campus metaverse for the East Hall of the Bandung Institute of Technology is to present the building as a heritage asset in architecture and interior design, open for visits, exhibitions, events, and collaborative endeavors on a larger scale without the constraints of physical space. It promotes the use of metaverse technology workflows by researchers to showcase cultural assets like furniture, sculptures, and carvings, which may have deteriorated over time. This facilitates their examination, presentation, and appreciation, serving not only the current generation but also preserving them as historical assets for the future.

2. Theoretical Framework

Preserving Indonesia's historical treasures is underscored as essential by Djukardi, Rachmi and Sumiarni (2020), Pranajaya and Dwijendra, (2021), and Winardi and Basani (2022). They emphasize the importance of safeguarding historical edifices, encompassing their architectural styles, as a testament to a nation's past and to bolster national identity and values. However, Drianda, Zohrah and Aritenang (2022) observe that, despite Indonesia's rich cultural heritage, preserving this legacy encounters numerous challenges. This is due to historical buildings being less popular than other urban attractions. To tackle this issue, digitalization practices, the definition of cultural identity, and collaboration with creatives become imperative.

Hence, archival processing plays a pivotal role in conserving Indonesia's cultural structures. Nonetheless, Safira et al. (2020) highlights a deficiency in cultural heritage documentation. To address this concern, the combination of LiDAR technology and UAV photogrammetry is proposed to generate 3D models of historical architectural buildings. This method facilitates comprehension of their measurements, dimensions, and areas without causing harm to these assets (Andaru et al., 2019; Arrofiqoh et al., 2022; Arrofiqoh and Muryamto, 2023);

Doughan et al. (2022) propose that the Metaverse offers a virtual environment for constructing collective architecture and preserving historical heritage. Zhang et al. (2022) suggest that digitizing cultural heritage within the Metaverse can enhance tourism guides, site maintenance, and object conservation. Both authors underscore the potential advantages of the Metaverse in these areas. Similarly, Franco, Plata and Bernal (2022) contends that the Metaverse enables universal accessibility, eradicating spatial and temporal barriers in various fields, including cultural heritage. Integrating Metaverse-based cultural elements within campuses holds the potential to enrich campus culture by amalgamating campus spirit and cultural components, and expanding cultural constructions (Han et al., 2022).

This design endeavor was undertaken in response to the demand of the Bandung Institute of Technology, the oldest technical university in Indonesia, to evolve in alignment with the requirements of the era known as Society 5.0. This era revolves around the concept of utilizing various innovations stemming from the Industrial Revolution to address diverse societal challenges and issues. Society 5.0 marks a significant convergence between virtual and real spaces, where the Internet serves not only as a platform for sharing information and analyzing data, but also as an integral part of daily life. In line with this vision, the Bandung Institute of Technology is becoming increasingly interconnected with the world through the development of the campus metaverse of the Bandung Institute of Technology, preserving its cultural heritage through the integration of LiDAR technology and Unreal Engine.

3. Review of Literature

The metaverse campus is an emerging concept that combines the virtual world and the physical environment to create a digital representation of the campus in a virtual realm. According to Han et al. (2023), metaverse technology overcomes spatial barriers, enabling virtual roaming, human-computer interaction, and the promotion of campus culture within the virtual environment. Apart from enriching the campus experience for academics, this technology serves as a platform to globally showcase universities and their campuses. Within the metaverse campus, academics can interact using their chosen avatars, attend lectures virtually, participate in discussions, and collaborate with fellow students and staff. This approach generates new opportunities for interactive, enjoyable, and flexible learning experiences, providing easy access to educational resources and online campus activities.

Nagao (2023) emphasizes that collaboration between digital campuses increases the content available to students and helps shore up the weaknesses of each campus. Syndication serves as a mechanism for sharing resources and minimizing risks by configuring and connecting networks. By linking digital campuses, sharing educational resources becomes intuitive, allowing users to move seamlessly from one campus to another. Although the concept of the metaverse campus is still in its early stages, Ling et al. (2022) posit that it encompasses a vast framework with numerous potential digital features, offering benefits such as interaction, authenticity, and portability. Moreover, the metaverse has the potential to revolutionize higher education by leveraging the advantages of cyberspace, enabling the creation of innovative and inclusive learning experiences. Consequently, the education system must be reorganized to maintain accessibility and extend its existence into the metaverse era. Described below are several metaverse campuses currently in development.

3.1 CUHKSZ-Metaverse

The Chinese University of Hong Kong, Shenzhen’s metaverse campus (CUHKSZ-Metaverse), as described by Duan et al. (2021), serves as a prototype campus based on blockchain technology, exemplifying a system for future demonstrations and social experiments. CUHKSZ-Metaverse’s 3D model was developed using Blender software and was subsequently enhanced using Unity Engine to present a semi-realistic low-polygon graphical presentation. The platform emphasizes user-generated content, fostering interaction not only through communication but also through customized assets in a 3D environment. In terms of typology, the digital metaverse building is a digital twin. Accordingly, the virtual buildings featured in this application mirror their physical counterparts found in the real world (Table 1).

3.2 MetaHKUST

MetaHKUST, owned by the Hong Kong University of Science and Technology (HKUST), is a metaverse platform currently undergoing long-term development based on an extended reality foundation that combines VR and augmented reality technologies. Like CUHKSZ-Metaverse, this platform also constitutes a digital twin of its respective university campus (HKUST Public Affairs Office, 2022). The development of the metaverse is closely intertwined with the real-world construction of buildings, allowing interactions among academics in the physical world to influence it. MetaHKUST adopts a user-generated content-based approach, enabling the seamless integration of digital content with the real world. The platform is designed to enable users to create their own avatars, non-fungible tokens, tokens, or virtual artworks once the system becomes operational (HKUST Public Affairs Office, 2022) (Table 1).

3.3 The University of Tokyo metaverse

The University of Tokyo Metaverse is an ongoing project that aims to create a virtual space within the campus premises. The project was initiated by a specific department on the campus. As a starting point, the University of Tokyo organized a new-year celebration using a replica of the historic Yasuda Auditorium, renowned for its significant historical value (The Yomiuri Shimbun by The Japan News, 2022). The metaverse platform is presented through a web-based environment and features semi-realistic graphic quality. A scanning system with 80 cameras is being employed for its development (Fujii, 2022) (Table 1).

3.4 HKU AlumniLand

HKU AlumniLand, affiliated with the University of Hong Kong (HKU), serves as a platform for celebrating the 25th HKU Mentorship Program Inauguration Ceremony, as described by the HKU (2022). This metaverse platform is accessible through a web-based platform named Spatial.io, which provides access to various devices and supports VR capabilities. HKU AlumniLand presents the main building of the HKU as its key feature, showcasing a realistic building base achieved through LiDAR scanning technology, which enables the acquisition of precise building data. Additionally, 3D modelling was performed using specialized software to further enhance the visual representation (HKU, 2022) (Table 1).

3.5 ASUniverse

ASUniverse, affiliated with Arizona State University is a metaverse product created using a digital twin approach. This platform utilizes a combination of two game engines, Unreal Engine and Unity Engine, allowing it to dynamically adapt and change in real time, considering factors such as cloud cover, time of access, and the number of people present in the campus, all with just a click of the mouse (Pirehpour, 2022). ASUniverse integrates a Zoom room that serves as a virtual meeting space in which students can interact via their personalized avatars. This approach provides an immersive experience and introduces students to the campus, offering a platform for socializing and exploring various interactive experiences (Table 1).

3.6 HUT metaverse

The HUT Metaverse, as described by Han et al. (2023), is an application designed to introduce campus culture through the integration of VR and metaverse technologies, utilizing 3D modelling based on UAV LiDAR data. The development of this application involves the use of SketchUp software for processing 3D-asset modelling, whereas the Unity Engine serves as the primary game engine for creating both mobile and VR applications (Table 1).

Table 1: Metaverse Campuses
Source: Author

Name	Year	Characteristics			Game Engine	Existing Building Type	Release Status
		VR	Graphics	Digital Typology			
CUHKSZ-Metaverse(Chinese University of Hong Kong, Shenzhen)	2021	Non-VR Android version	Semi realistic	Digital twin	Unity Engine	√	In development
MetaHKUST (The Hong Kong University of Science and Technology)	2022	XR (XR and VR)	Semi realistic	Digital twin	Unity Engine	√	In development
University of Tokyo Metaverse	2022	Non-VR (web-based)	Semi realistic	Digital model	Unity Engine	√	In development

HKU AlumniLand (The University of Hong Kong)	2022	VR and web-based	Realistic	Digital shadow	Unity Engine	√	In development
ASUniverse (Arizona State University)	2022	VR and web-based	Semi realistic	Digital shadow	Unity Engine and Unreal Engine	√	In development
HUT Metaverse (Hubei University of Technology)	2023	VR and mobile apps	Realistic	Digital shadow	Unity Engine	√	In development

Note. VR = virtual reality; XR = extended reality.

3.7 Summary

The development of campus-based metaverses is currently in its early stages and these applications are yet to be fully established as integrated 3D world platforms. The process of creating metaverse products poses various challenges, as each campus and researcher may have their own preferences for, and approaches to, metaverse development. Several characteristics must be carefully considered in the development of these platforms.

One crucial aspect is the use of VR to create metaverse applications, aiming to immerse users in a new virtual space using a head-mounted display (HMD) for a more engaging experience. Graphics also play a significant role in defining the metaverse's characteristics. The graphical style employed in a metaverse application can influence the extent to which users perceive the virtual world as similar to the real world. Different styles, such as realistic, semi-realistic, pixel blocks, and cartoons offer varying levels of realism and aesthetics. Digital typologies have also played a key role in the development of metaverse applications. These typologies include digital twins, shadows, and models. Van der Aalst, Hinz, and Weinhardt (2021) explained that a digital twin is a virtual representation directly connected to a real-world object, whereas a digital shadow features only attachments from the real world to digital objects, and digital models lack direct attachments between digital and virtual objects. Each digital typology has advantages and disadvantages that influence metaverse design.

A game engine is a vital component in the development of a metaverse—it comprises the software used to design and create games. In the context of metaverses, game engines are employed to construct virtual environments that incorporate 3D-asset modelling and other essential elements. One prominent game engine, Unreal Engine, is well suited for metaverse development—although it demands high computer performance, its advantages, including a thriving community, an extensive array of plugins, visual scripting capabilities, and lighting settings, make it a favorable choice for metaverse development.

In developing the metaverse of the Ganesha Campus, the primary focus was to preserve the historical value of the East Hall and accurately represent its interior in a realistic style, mirroring its original form as it stands today. The development process prioritizes an ideal characteristic approach whilst considering existing conditions. In line with this, Yanti, Satwiko, and Setyohadi (2023) asserts that the incorporation of distinct cultural elements improves the representation of traditional architecture. Overall, campus metaverse development remains in its early stages, necessitating careful attention to the various aspects discussed. By considering the characteristics, digital typology, and game engine utilized, campus metaverses can yield products that are well suited for their intended purpose.

4. Methodology

Metaverse development is categorized into three distinct phases: Pre-production, production, and post-production (Fig. 2). This division allows for a comprehensive examination of the processing details and optimization of workflows for each phase. This study focuses on the 3D team responsible for developing 3D-asset modelling for metaverse products and presents the workflow from the 3D team's perspective, encompassing the journey from the initial design to the final product. The term "workflow" refers to the process and steps undertaken by the research team to achieve its intended objectives and captures the approach adopted by designers and researchers to document the development process from inception to completion.

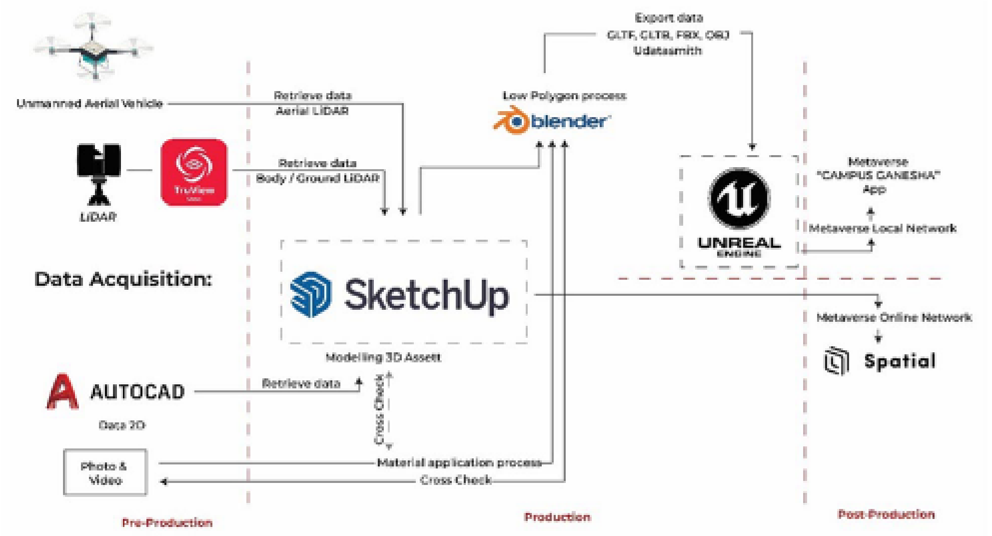


Fig. 2: Workflow
Source: Author, 2023

4.1 Pre-production

The pre-production phase of the Ganesha Campus Metaverse commenced with dividing the developers into teams based on their respective fields, namely, the 3D, LiDAR scanning, and computing teams. This division ensured efficient data acquisition and processing based on the expertise of each team. The 3D team was responsible for collecting and processing LiDAR data for 3D-asset modelling. The LiDAR scanning team focused on gathering scanning data and converting them into point-cloud data products, which were subsequently processed for 3D-asset modelling. The computing team played a vital role in assembling the models, conducting simulations, utilizing game engines, and exporting them to the Ganesha Campus Metaverse application.

During the initial stage, the entire team, led by the LiDAR scanning team, scanned the gate area of the Bandung Institute of Technology, Ganesha Campus, extending to the East Hall. The scanning process was divided into ground and aerial surveys. The ground survey utilized a Leica RTC360, whereas the aerial survey employed a DJI M300 RTK with a LiDAR scanner Geosun GS-100C. Concurrently with the scanning process, other teams captured photos, videos, drawings, and blueprint archives of the scanned objects. In the second stage, the LiDAR scanning team processed the LiDAR data by employing equipment and software to analyze the East Hall LiDAR data and obtain detailed information on the area's topography, surface, and existing structures. The final stage involved crosschecking the data with existing photos, videos, and 2D plans.

4.2 Production

The production phase was crucial in establishing 3D-asset modelling for the metaverse. This phase was further divided into several stages, namely, the modelling process, low-poly, exporting, re-setting, 3D-asset modelling, and HMD setting.

In the modelling-process stage, LiDAR data processing and cross-checking were utilized for 3D modelling, texturing, and arrangements to conduct 3D-asset modelling using SketchUp software. The low-polygon modelling process was then conducted using Blender software, focusing on reducing the polygon count of the 3D-asset modelling and re-texturizing the mapping, if necessary. This stage helped improve data computation efficiency when reading 3D assets.

Exporting was divided into two categories: the metaverse online network and the metaverse local network. This division was meant to determine the current state of the metaverse and conduct 3D-asset modelling specifically. The online metaverse used Spatial.io as a web-based platform and Unreal Engine to design metaverse products, ensuring that they aligned with our metaverse expectations. In the metaverse online network, the exporting stage emphasized meeting the requirements needed for Spatial.io, whereas the metaverse local network used the Udatasmith plugin to integrate the data assembled in Unreal Engine.

The re-setting stage for the metaverse online network involved a few in-game adjustments and simple settings for spatially positioning the 3D assets. Further, the metaverse local network reprocessed the data to determine the quality of 3D assets, reset textures, and applied lighting adjustments.

Finally, in the HMD settings stage, the use of the HMD was matched to the metaverse local network stage to identify the blueprints required to process the data into a metaverse. Conversely, the metaverse online network did not require any settings because Spatial.io directly reads and translates metaverse products into VR form.

4.3 Post-Production

The post-production phase entailed collaboration between the 3D and computing teams to create the metaverse application, which was divided into two main parts: the metaverse local network and the metaverse online network.

The metaverse local network utilized the Unreal Engine 5.1 game engine as the foundation for developing and creating local area network-based applications, focusing on detail, and providing an optimal presentation for metaverse applications. Further, the local network metaverse was divided into two parts: applications that concentrated on realistic design concepts and VR sections targeting mid-end users, with a focus on usability when using HMDs. Conversely, the online network metaverse utilized the web-based platform Spatial.io to assess whether 3D-asset modelling can be effectively applied to the existing web-based metaverse.

5. Discussion and Analysis

5.1 Pre-production

The data acquisition process is a crucial pre-production step involving the collection of data from various sources, such as LiDAR, blueprints, photos, and videos, which serve as primary data for modelling 3D assets. Data acquisition is performed through a combination of manual effort and technological assistance, depending on the type and source of data being collected. This process is of utmost significance because it underpins accurate decision-making and analysis.

5.1.1 LiDAR

LiDAR technology focuses on retrieving data from the surface of an object or area using laser scanning. LiDAR generates data in the form of point clouds, which are composed of a collection of point data in a 3D coordinate system representing an object or scene (Otepka et al., 2013). Different LiDAR scanning devices lead to variations in the density and output of data. The accuracy and level of detail of the results obtained by a specific LiDAR device depend on its capabilities and precision in capturing data.

LiDAR data collection in the East Hall employed two methods: the terrestrial laser scanner (TLS) method using the LEICA RTC 360 tool, and the DJI M300 RTK UAV LiDAR method. The TLS method utilizes points as positions to obtain accurate data. The points taken do not have specific parameters because of the flexibility of the scanning position, ensuring the desired spatial details. The positioning of the TLS played a pivotal role in retrieving detailed data on various building aspects, such as pillars (Fig. 3), ceilings (Fig. 4), carvings (Fig. 5), and windows (Fig. 6). Each scanning process lasted 5–10 minutes at each point, encompassing the steps of device placement, scanning, and setting. The retrieval of these data demonstrated high accuracy and data density, as shown in Table 2.

Table 2: LEICA RTC 360 data accuracy
Source: LEICA Specifications

Accuracy	1.9 mm	2.9 mm	5.3 mm
Shooting range	1 –10 m	10–20 m	20–40 m

Assuming a noise range of 0.4 mm at a distance of 10 m, as well as 0.5 mm at a distance of 20 m, based on RTC 360 specifications, the Leica RTC360 device offers a significant advantage in scanning results. Each scanning point was directly connected to adjacent points, facilitated by the geospatial program embedded in the Leica RTC360 device. The TSL data products were subsequently processed using TrueView, a review application that reads scanning data and assists in the creation of 3D assets using SketchUp.

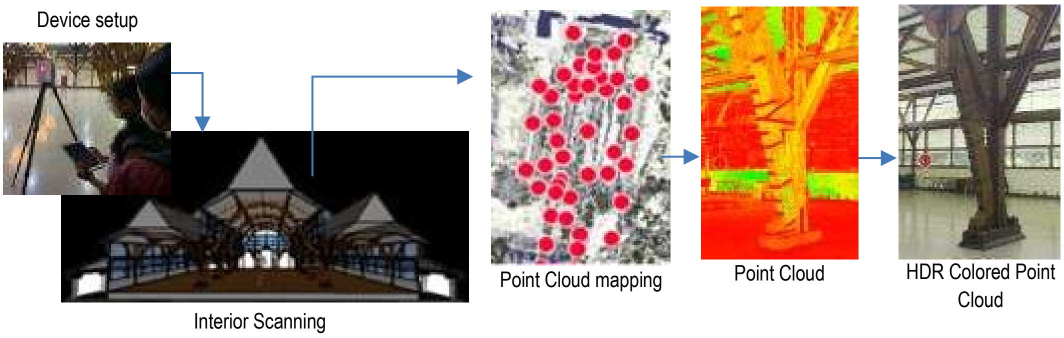

Device setup
Interior Scanning
Point Cloud mapping
Point Cloud
HDR Colored Point Cloud

Fig. 3: Pillar scanning process (device setup, interior scanning, scanning point, point cloud, and point cloud with texture).
Source: Author, 2023

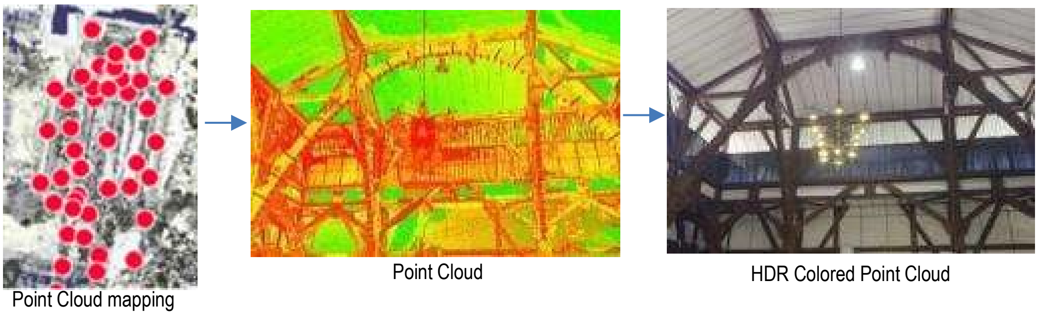
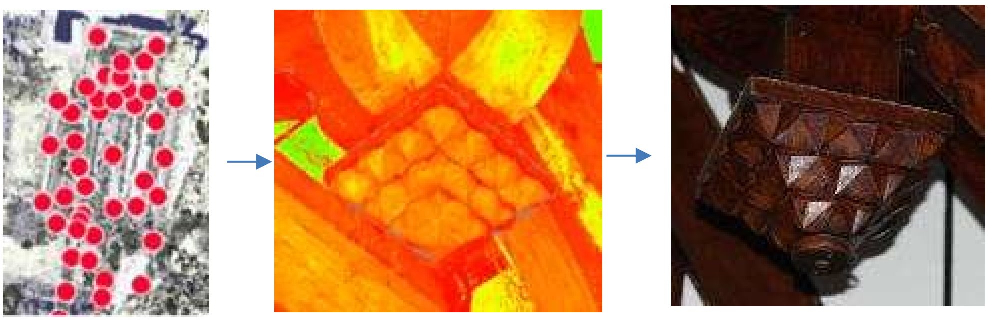

Point Cloud mapping
Point Cloud
HDR Colored Point Cloud

Fig. 4: Ceiling scanning process (scanning point, point cloud, and point cloud with texture)
Source: Author, 2023

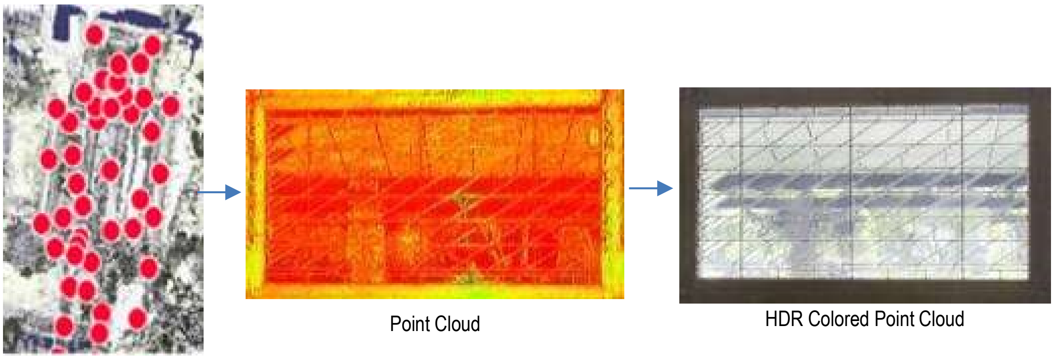


Point Cloud mapping

Point Cloud

HDR Colored Point Cloud

Fig. 5: Carving scanning process (scanning point, point cloud, and point cloud with texture)
Source: Author, 2023



Point Cloud

HDR Colored Point Cloud

Point Cloud mapping

Fig. 6: Window scanning process (scanning point, point cloud, and point cloud with texture)
Source: Author, 2023

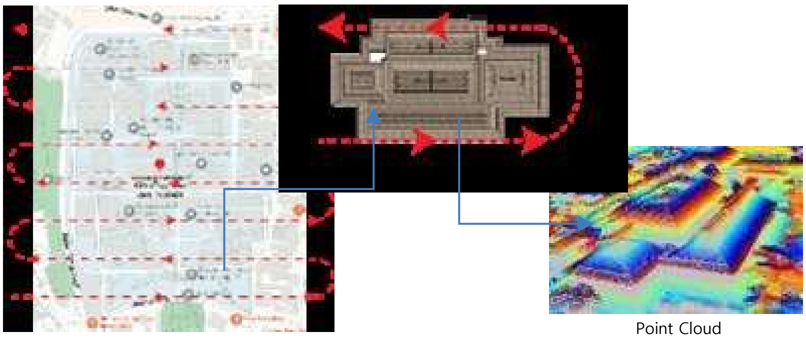
Aerial data collection involves the utilization of UAV and LiDAR technologies to acquire high-resolution topographical data and altitude information. This cutting-edge technology enables the gathering of exceptionally detailed topographical data, including vegetation, and has applications in various fields such as mapping, environmental monitoring, and scientific research. For the LiDAR UAV data collection, a DJI M300 RTK with a LiDAR scanner Geosun GS-100C was employed. Data were collected at a flight height of 150 m above the ground level. The flight path followed a west-to-east direction using the repeated snaking method to ensure complete coverage of the Bandung Institute of Technology, Ganesha Campus, and to obtain comprehensive field and topographical data (Fig. 7).

To focus on the roof and topography of the East Hall, the Trimble Scan SketchUp plugin was used to process the point-cloud data. This plugin not only facilitated cutting point-cloud data, but also aided in the manual connection of point clouds within the SketchUp application to form the shape of the East Hall’s roof. Data collection adhered to the accuracy approach presented in Table 3.

Table 3: Geosun GS-100C data accuracy
Source: Geosun GS-100C Specifications

Accuracy	≤ 5 cm	≤ 7 cm	≤ 10 cm
Shooting range	50 m	70 m	110 m

UAV LiDAR was employed to obtain aerial data that could not be acquired using TSL. The use of the UAV was not solely focused on capturing contours from all areas of the Bandung Institute of Technology but also involved obtaining point-cloud data of the iconic East Hall's roof shape.



Flying Movement

Point Cloud

Fig. 7: UAV LiDAR scanning process (flying around the Bandung Institute of Technology, flying over the East Hall, and point-cloud data)
Source: Author, 2023

Note: that point clouds cannot be used directly as 3D objects and are not pursued for hyperrealism in 3D-asset modelling.

5.1.2 2D Plans, Photos, and Videos

The design process involved a measured drawing technique for the interior elements of the East Hall at the Bandung Institute of Technology, focusing on achieving high data accuracy. To accomplish this objective, a laser meter was used to measure the dimensions of the East Hall's rooms. The laser meter provided precise data on the room dimensions, including length, width, height, and other interior elements. The re-measurement technique was essential to ensure the precision and accuracy of the data used in the planning, 3D modelling, and texturing of building assets. With high data accuracy, the risk of errors in decision-making or design could be reduced, enhancing the efficiency and reliability of building management.

In addition to using a laser meter, photos and videos were captured from the existing East Hall area as a cross-checking method and to support remote work processes. Photos and videos were used for documenting the details of objects or artifacts in rooms. Using this technology, the dimensions, shape, texture, and condition of the interior elements measured by the laser meter could be easily confirmed and verified. This visual documentation provided an added advantage in the re-measurement process, allowing for a more detailed analysis and a better understanding of the East Hall's interior elements.

Moreover, the use of photos and videos enabled the research team to work remotely, reducing the dependence on physical presence at the research site. This flexibility was particularly beneficial in situations where access was limited or travel restrictions were in place, facilitating more efficient collaboration among research team members in different locations.

5.1.3 Data Comparison

Data were compared upon completion of data acquisition from both sources. This comparison aimed to assess the accuracy of the data size for each scan before undergoing TSL and UAV LiDAR data processing. The obtained comparison served as a reference point for designers when working on precise and optimal 3D shapes using SketchUp.

5.2 Production

During the production process, several significant challenges arose due to technological limitations and the complexity of LiDAR data. The heavy data and high computational processing involved in LiDAR point-cloud data made it impractical for use as the main reference for automatic metaverse formation. Consequently, manual 3D modelling using SketchUp became the preferred approach for processing LiDAR data from the East Hall.

The SketchUp process was facilitated by the Trimble Scan plugin in SketchUp 2022, which proved to be immensely helpful in manually modelling LiDAR point-cloud data. This plugin enabled the reading of point-cloud data obtained through the LiDAR UAV, serving as a benchmark for forming the roof and the upper shape composition of the East Hall. Additionally, the process of modelling the interior of the East Hall utilized LiDAR TSL data combined with manual data from blueprints and manual measurements. This amalgamation of data sources aimed to achieve high-quality realistic 3D-asset modelling. The focus was on capturing the intricate details of each asset in the field and meticulously translating them into the metaverse.

5.2.1 Modelling Process

In the context of the metaverse, 3D-asset modelling plays a crucial role in creating realistic and appealing virtual environments. It involves designing virtual objects, such as buildings, characters, cars, and land contours, which comprise integral elements of the metaverse environment. For an efficient metaverse experience, 3D-asset modelling must strike a balance between high detail and lightweight construction to ensure fast loading times and optimal system performance. Additionally, these models should be adaptable to various platforms, including desktop and mobile setups, as well as VR headsets, and should be seamlessly integrated with different metaverse software.

To achieve this, SketchUp was utilized based on LiDAR data and East Hall size data. As noted by Li (2008), SketchUp offers functions that facilitate the creation of detailed and accurate 3D assets, emphasizing both modelling speed and application convenience. The software's operational efficiency and accuracy allow for easy comparison checks before and after model modification, as highlighted by Li (2022). This aids in gradually adjusting the asset-formation scheme during on-site revisions and investigations.

The process of working on 3D-asset modelling is significant in the Ganesha Campus metaverse design workflow, as these assets will be showcased and integrated into the virtual world. Thus, meticulous attention to detail and shape accuracy is given the utmost priority to ensure the precise representation of the East Hall of the Bandung Institute of Technology (Fig. 8).

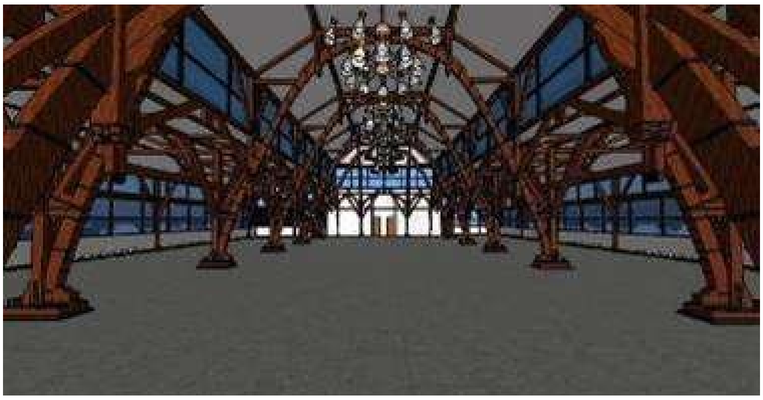
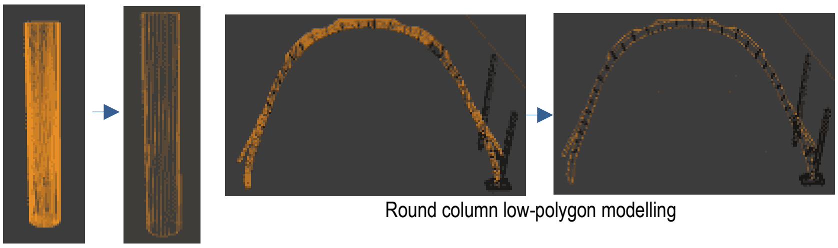


Fig. 8: The East Hall interior's 3D-asset modelling process
Source: Author, 2023

5.2.2 Low-Polygon Modelling

Following the completion of 3D asset modelling for the building and interior details of East Hall, the team proceeded with a low-polygon modelling process using the Blender application. This step aims to optimize the model assets for an Unreal Engine, reduce computational complexity, and ensure smoother performance in the metaverse. Low-polygon modelling primarily focused on selected assets and was not applied to the entire model. This involved simplifying the geometry and rematerializing objects based on existing data in Blender software.

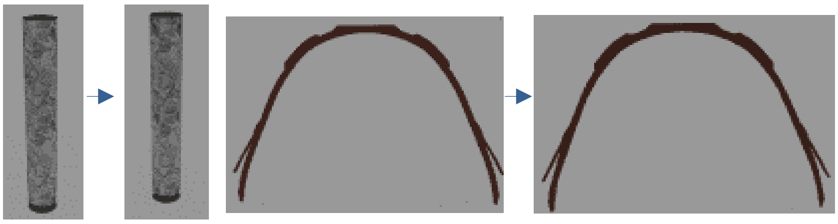
During low-polygon modelling, the outer pillar columns were optimized, resulting in a reduction from 200 to 128 vertices, 594 to 152 edges, 396 to 26 faces, and 396 to 252 triangles (Fig. 9). Similarly, the curved pillar columns underwent optimization, decreasing from 2,030 to 899 vertices, 6,418 to 1,345 edges, 4,390 to 448 faces, and 4,390 to 1,918 triangles. This optimization significantly reduced the polygon count while preserving visual appearance (Fig. 10).



Circle column low-polygon modelling

Round column low-polygon modelling

Fig. 9: Low-polygon modelling
Source: Author, 2023



Before circle column low-polygon modelling

After circle column low-polygon modelling

Before round column low-polygon modelling

After round column low-polygon modelling

Fig. 10: Low-polygon modelling
Source: Author, 2023

5.2.3 Exporting

The file exporting process was divided into two parts based on the target platforms: the metaverse local network version using Unreal Engine and the metaverse online network version using Spatial.io.

For the metaverse local network version, the data and plugins were integrated by importing pre-made 3D assets (embedded with texture data) into Unreal Engine. The file formats *.glTF, *.GLB and the Udatasmith plugin were used to export data from SketchUp and Blender to Unreal Engine. While there were no specific file limitations required by Unreal Engine, the exporting process required a computer with a capable graphics processing unit for efficient computation.

In contrast, the metaverse online network version required exporting 3D assets into Spatial.io using the recommended *.glTF and *.GLB file formats, along with various texture features carried by the asset data (Table 4). This export process had specific file limitations that affected the design process. The accepted 3D files were limited, and there were file size limitations, which reduced the freedom to use and optimize 3D assets in the Spatial.io metaverse application. Additionally, the content limits in the file were regulated, imposing various restrictions that necessitated the optimization of 3D assets to be compatible with the metaverse web-based aspect (Table 5).

Table 4: Supported File Types
Source: Spatial.io, July 2023

Format	Maximum size
OBJ	100 MB
glTF	100 MB
GLB	100 MB
FBX	100 MB
DAE	60 MB
PCD	10 MB
ZIP	500 MB

Table 5: File Optimization
Source: Spatial.io, July 2023

Textures	Recommended: 1024x1024 px, and a maximum of eight textures per file.
	Maximum: 1024x1024 px, up to 16 textures OR 2048x2048 px, maximum of four textures per file
Object Count	Recommended: For environment object: < 10 For single object: < 3
	Maximum: For environment object: 20 For single object: five
Vertex Count	Recommended: For environment object: < 100k For single object: < 30k
	Maximum: For environment object: 300k For single object: 50k
Triangles	Recommended: For environment object: < 60k For single object: < 15k
	Maximum: For environment object: 180k For single object: 30k
Shaders	Recommended: Unlit
	Supported: Unlit, Metallic/Roughness and Specular/Glossiness PBR
Shadows	The application support real-time shadows only on mobile devices (Android/iOS), but they do not have the best quality
	We recommend baking lighting into textures for a more impressive model

5.2.4 3D Asset Re-setting Modelling

The re-setting process of 3D-asset modelling in Unreal Engine involved an approach that considered the existing conditions of the East Hall. This included re-texturing, placing lighting, setting sunlight, and configuring collisions to ensure that objects did not intersect during interactions within the metaverse. The file equalization approach was executed through a workflow process that involved observing the existing conditions based on the acquired data and adjusting the texture parameters in Unreal Engine to match them as closely as possible (see Figs. 11, 12, & 13). This re-setting process was specifically conducted to identify any changes that occurred during the export process from SketchUp to Unreal Engine.

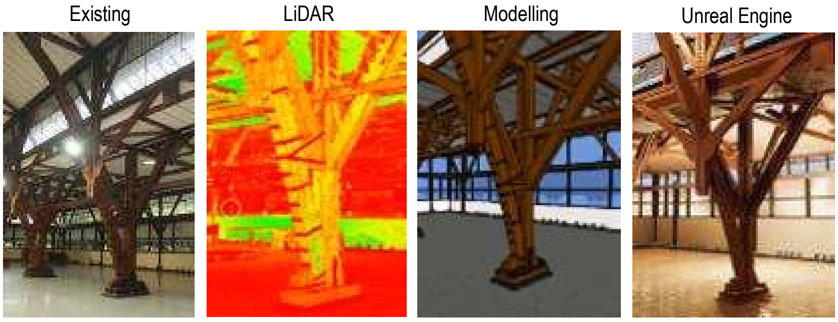


Fig. 11: East Hall Column
Source: Author, 2023

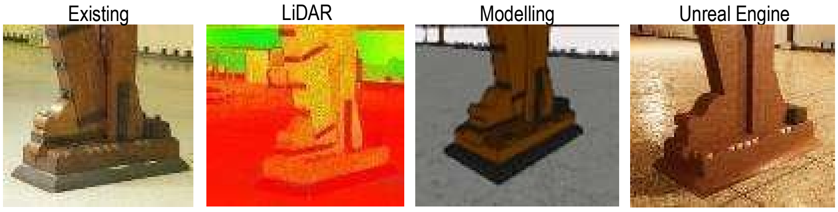


Fig. 12: Column Detail 1
Source: Author, 2023

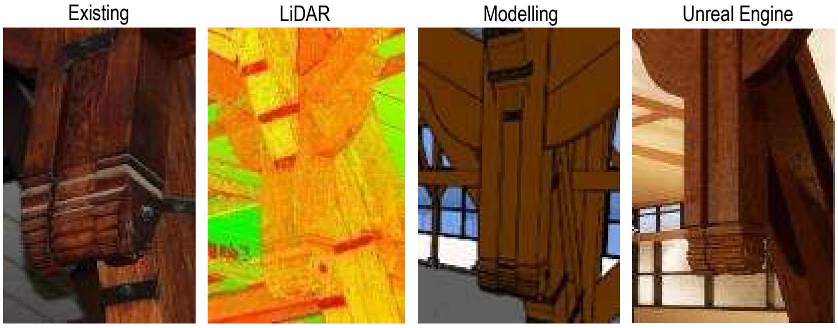


Fig. 13: Column Detail 2
Source: Author, 2023

In the metaverse local network, the re-setting process focused on setting the coordinates for the placement of the 3D assets after completing the import process from the existing data. This step was crucial for determining the entrance points and ensuring proper positioning within the virtual environment.

5.2.5 HMD Setting

The utilization of HMD technology in the metaverse aimed to provide users with an immersive spatial experience that differs from conventional spatial environments. The development process for both the online and local metaverse data shared the same foundation in 3D-asset modelling but diverged in their presentation methods.

In the metaverse local network, Unreal Engine served as the primary processing platform for the data, where the existing 3D-asset modelling was transformed into a 3D environment that closely resembled real-world conditions. The workflow process for 3D-asset modelling extended to the aspects of usability, control using HMDs, and playability. Unreal Engine's versatility allowed for compatibility with various types of HMDs from different brands on the market; however, for the metaverse local network, the team specifically utilized the Oculus Rift S (Fig. 14). Each HMD required specific computation and configuration within

Unreal Engine, and optimizing the use of the Oculus Rift S was a priority in the metaverse local network (Fig. 15).

For the metaverse online network, Spatial.io was used as the web-based configuration for the development. Configuring the HMD in Spatial.io could be performed directly because of the limitations of its application, as it only supported Meta Quest and Meta Quest 2 HMD devices.

Fig. 14: Testing HMD-based VR in Unreal Engine
Source: Author, 2023

Fig. 15: Testing HMD-based VR in Unreal Engine
Source: Author, 2023

5.3 Post-Production

The post-production phase involved the final stages of data export and publication, focusing on both the metaverse local and online networks.In the metaverse local network, Unreal Engine served as the central platform for processing computer data, forming the basis for the Ganesha Campus Metaverse. Two different product prototypes were generated as a result. The first application offered a third-person perspective, allowing users to navigate the campus gate area and part of the East Hall's interior with maximum-quality visuals accessible through computer-based devices (Fig. 16). The second part presented the prototype using an HMD, targeting mid-end users (Fig. 17). At this early stage, the focus was on functionality rather than intricate details, and 3D-object processing was limited to accommodating device capabilities. Although some textures and assets were reduced in detail due to device limitations, the emphasis remained on the functionality of the product features.

Fig. 16: Metaverse local network walkthrough
Source: Author, 2023

Fig. 17: Metaverse VR local network walkthrough.
Source: Author, 2023

The metaverse online network used Spatial.io, which is a web-based metaverse. During the structuring process in Spatial.io, several factors were considered, such as adequate Internet connectivity and establishing a system for 3D-asset placement on the web platform. The user interface in Spatial.io facilitated interactions between users and offered additional configurations for enhancing the metaverse web experience. However, due to the limitations of the web-based platform, some textures and assets had to be reduced and optimized, resulting in a tradeoff between quality and performance. Additionally, the VR system in this context was not yet fully optimized, leading to minor issues such as lag, blur, and motion sickness during use (Fig. 18). Despite these limitations, the web-based metaverse Spatial.io was optimized to the best of its capabilities (Fig. 19).

Fig. 18: Metaverse VR Spatial.io walkthrough
Source: Author, 2023

Fig. 19: Metaverse Spatial.io walkthrough
Source: Author, 2023

6. Conclusions and Recommendations

In the development of the East Hall in the Ganesha Campus Metaverse, the workflow process and various opportunities to develop the metaverse campus in a realistic manner in the future are showcased. It can be used as an exhibition platform or as an educational medium, introducing aspects of the campus, its culture, and historical values, as well as to present the campus to the world. Further, the development of this campus metaverse can effectively enrich the campus life for academics at the Bandung Institute of Technology. This study focused on the design and workflow processes involved in the creation of a metaverse campus, while shedding light on the advantages and disadvantages of using an existing platform, which can provide valuable insights for researchers aiming to develop metaverse products using LiDAR data and Unreal Engine.

To enhance the efficiency and detail in processing digital assets of historical buildings, we propose employing this method. However, it's crucial to acknowledge that the final product is confined to offline platforms exclusively. This restriction arises from the constraints imposed by Spatial.io on the types of files that can be uploaded, processed, and displayed within the web interface.

Acknowledgments

We would like to express our sincere gratitude to all individuals and organizations that contributed to the ITB Metaverse Project. This work was supported by the Institute of Research and Community Services, Bandung Institute of Technology (ITB) Riset Unggulan ITB 2023.

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