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Balinese mask 3D modeling design using procedural nodes for digital preservation attempt

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Abstrak.
Digital preservation of Indonesian art and culture has become an increasingly essential practice in the era of the Internet of Things, where accessibility and longevity of cultural heritage are paramount. This research focuses on the digital preservation process through a case study of Balinese art and culture, with a particular emphasis on the iconic Balinese masks. The study involved high-resolution photography of Balinese masks housed at the Setia Darma House of Mask and Puppets, which served as the foundation for creating detailed 3D models. This digital asset will be broken down in several steps of 3D modeling using Blender software and specifically utilized the procedural nodes to achieve lower file size but maintain the image quality. The result will show the significant effort to preserve art and culture in digital media by utilizing 3D software technology to create better visuals with effective file sizes.

Keywords: Digital, 3D Modeling, Mask, Preservation, Texturing

Introduction

There are several digital preservation efforts that have been done to develop Balinese culture. One of the preservation efforts is transforming old manuscripts into digital artefacts on a website (Syamsudin & Valentino, 2022). In this research, a team was developing a digital preservation using 3D Modeling software with a goal to create a high resolution image by using procedural nodes to achieve comprehensive textures and materials. This method will minimize the unwrapping process (Wibowo, 2022) and in the end, the file will be in lower file size. This digital documentation has been done similarly by the research team from the Program Studi Sarjana Terapan Teknologi Survei dan Pemetaan Dasar UGM, where they create 3D measurement for Pantja Dharma area. The 3D scale technical expectancy can conduct and help with building maintenance and restoration faster. This similar approach will be considered by the research team to use 3D software to create high impact on preservation efforts and also create stunning images that can represent the actual object itself. Blender's Procedural Node utilization will easily apply textures and material in a shorter time. By using variation of code, the 3D Model result will be as close as the real material of the objects. The procedural node application will be helping more textures and materials in some complex polygons, such as Balinese Mask 3D Model, for example.

Nowadays, digitalization has been a fundamental process to archiving everything we have in the physical world. By doing so, we can have a complete complex library or museum about everything we have. The methods used to display works have also changed and evolved (Pratama & Rosita, 2023). In this era of Internet of Things, it becomes more possible to communicate and gather information around the world. The hope is that this communication will become a kind of cultural heritage that can continue to develop in the future. Heritage can also be defined as the knowledge and expertise passed

down through a community's way of life and beliefs. It represents the collective memory of the community and symbolizes the civilization of a society (Wan Isa et al., 2018). In Indonesia itself, cultural heritage is a blessing, and its abundance is considerable. Therefore, the most important concern is how to develop this heritage and enhance it in today's digital age. Digitalization contributes to the conservation of heritage and scientific resources; it can be used to encourage tourism, and it provides ways of improving access by citizens to their patrimony (Abdo, 2019). Therefore, it is important that the heritage can be accessed by residents and developed by local residents so that a sense of wanting to preserve and develop the arts is formed.

The advent of digital technologies has profoundly transformed cultural and heritage sectors, providing new avenues for broader access and interactions with digital collections (Pereda et al., 2025). With the technology and how to develop, it opened the opportunity to do more. With regards to art and culture's preservation, it becomes more possible and more inclusive to whoever wants to inform others, and whoever is interested in what they want to know. There are many examples that can be found today, one of the developments that is quite respected at this time is the use of 3D technology for cultural and tourism development. The 3D modeling of cultural heritage also reveals the distortion of cultural heritage objects over time and allows for the reconstruction of these objects in a timely manner over a long period of time (Caciora et al., 2023).

To this end, cultural data is considered challenging, due to its specific features; in particular, Cultural Heritage data is distinguished as multi-formatted (content exists in various media as audio or video records, text documents, images, physical and digital objects), multi-topical (topics include art, anthropology, archaeology, literature), multi-lingual (content exists in different languages as well as extinct languages), multicultural (content relates to and is being interpreted by different culture) and multi-targeted (content is targeted to laymen as well as experts, different age groups and social classes) (Ziku, 2020). Through these variations and groupings, it is clear that cultural heritage can be utilized and developed in many ways, especially in Indonesia which has a great deal of cultural heritage stored. For this particular topic, the research team has chosen Balinese Mask as its main subject. Bali in general is one of the famous places in Indonesia that is recognized around the globe. There are many arts and cultures practiced in Bali. Wooden Craft is one of the strongest forms of art in Bali, and particularly, Balinese Mask is famous. In artistic activities, masks can be classified as performing arts, while as works of art or artistic products, masks are included in sculpture because they display dimensions as a study of conventional visual language (Suardana, 2015). It is famous not just because of its detail and beautifully crafted, but it has a sacred meaning behind every design.

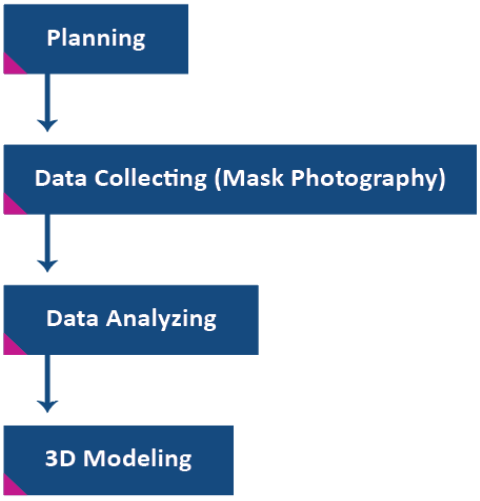
Digitalization is a fundamental process that is becoming increasingly essential in the current Internet of Things era. Digitalization provides opportunities and new possibilities for things that previously faced limitations. The digitalization of Indonesian cultural elements is becoming an increasingly important activity, especially for the purposes of preservation and widespread information dissemination. Information about Indonesia's cultural diversity is already quite well-known internationally, but accessing this information often requires significant effort. For example, to explore cultural diversity, such as traditional masks, both Indonesians and international communities must travel to museums that house mask collections. In the case of traditional masks, which are meticulously, beautifully, and uniquely crafted by artisans, they rely solely on skill and manual dexterity, coupled with intense concentration and a strong desire to achieve inner and outer satisfaction according to the demands of the soul. Therefore, mask-making is perceived as a total devotion to their ancestors (Sutiyati et al., 2015). This statement clearly demonstrates the sacredness of culture, and this can sometimes be a barrier to learning. This, of course, has its advantages, as a physical object has its own unique appeal when viewed in person. However, the challenge that digitalization seeks to address is making it easier and more accessible for the general public to obtain information about this culture. On the one hand, the limited capacity for innovation within cultural heritage institutions and other collection management organizations can be assessed by basic indicators such as digitization and appropriate online publication. These can be seen as early indicators

of an organization's capacity to innovate in developing new heritage information services, expanding audience engagement, or generating added value for their collections (Ziku et al., 2024).

Digital preservation of cultural artifacts is a crucial step in preservation because today's digital technology era makes it easier for anyone to access information. Previous research done by creating virtual reality or interactive books focusing more on the interactivities (Elian et al., 2019). By focusing on the interactivity, there will be lacks in term of providing the detail visual information of the Balinese Mask design. In this paper the research focuses on using the best method to produce 3D Modeling of the mask that can be applied in many media. By focusing on the 3D Modeling method, hopefully the result will be a detailed Balinese Mask design that can be used to represent the beauty of the real physical mask.

With this information widely accessible, the general public can seek out all kinds of information needs. Here, it will also show that the emphasis is on the importance of cultural archives, where the need for visual arts archives is because it is one way to reflect, analyze and translate social change, therefore art is a cultural driver in the development of culture and the social dynamics of society (Akbar et al., 2018). Balinese masks were chosen as the main focus this time due to their popularity. Moreover, in today's era, Balinese masks are not only used as essential props in masked dance performances. They also serve as marketing materials, such as merchandise and souvenirs, demonstrating the immense potential of Balinese mask culture for various economic sectors to visiting tourists. Starting with Balinese masks, it is hoped that they will serve as a primary attraction for international communities to become more interested in accessing information about Indonesian culture, with the further hope that they will also be interested in exploring information about other Indonesian cultures.

Methods



Planning

In this stage, the research team conducted a sequential process plan about recording data of images of Balinese Mask. This plan phase is important to prepare all the process thus the design result will be according to the expectations.

There are steps the research team have done to plan before creating a 3D Modeling of Balinese Mask which are Design Element Identification, Data recording Process Identification, Photography Images List, 3D Modeling Expectations, and Design expectations

Planning was carried out before recording the data and before going to the location where Balinese Mask collections are kept. Data recording was held two times by recording photos of all Balinese Masks and interviewing the Operational Manager of Setia Darma Museum. Interviews had

been conducted to get to know more about the reason behind the collections of the Masks and Puppets in the Museum. We tried to harmonize our work with the museum's intention in preserving arts and cultures specifically in mask and puppets form.

To address this issue, the research team aims to translate the physical and visual characteristics of Balinese masks into a three-dimensional (3D) digital representation. This transformation will allow users to explore the masks interactively through any digital media such as websites, virtual technology, things like communication, information, and even various entertainment facilities can be accessed easily online via smartphones through the development of the internet (Pratama & Nugroho, 2023). By employing digital visualization techniques, cultural heritage can be preserved more effectively while providing an engaging learning experience for users. This approach aligns with current trends in digital cultural preservation, where advanced visualization technologies such as 3D modeling and virtual exhibitions play a crucial role in safeguarding traditional art forms in the digital era (Gomes et al., 2014).

Data Collecting (Mask Photography)

This stage focuses on documenting the visual characteristics of Balinese masks through a structured and controlled photography process. Because the masks are stored and exhibited in indoor museum spaces, additional artificial lighting is used to ensure optimal exposure, color accuracy, and the preservation of intricate visual details. A carefully planned lighting setup helps avoid shadows or overexposure, allowing for a consistent and accurate digital record of each mask's features. This is especially important for masks that have complex textures, carved details, or layered paint, which must be documented clearly to support subsequent 3D modeling and digital preservation (Felicísimo & Polo, 2022).

The photography process will involve capturing multiple angles of each mask—including frontal, side, and top views—to generate a comprehensive visual dataset. Each mask will also be accompanied by a catalog entry containing descriptive information, including its visual characteristics, historical context, and the folk tales that inspired its creation. By combining technical photographic documentation with cultural storytelling, the project not only preserves the physical form of the masks but also safeguards the intangible cultural narratives embedded within them. This method aligns with recent practices in digital heritage preservation, where high-resolution photographic documentation serves as the foundation for accurate 3D digitization and virtual exhibitions.

This stage involves capturing the visual appearance of the masks through photography, using additional artificial light to achieve proper lighting, as the masks are housed in a museum with indoor rooms. Several masks, especially Balinese masks, will be photographed, necessitating the creation of a catalog containing information about each mask's visual details and the folk tales that inspired them.

Data Analyzing

For this particular research, we seek unique and insightful narratives behind the existence of the Balinese mask. To achieve this, the research team conducts an in-depth interview with the Museum Manager of the Setia Darma House of Mask and Puppets, one of the most renowned institutions dedicated to preserving traditional masks in Indonesia. Through this interview, we aim to understand not only the technical aspects of preservation but also the cultural philosophies and motivations that drive their continuous efforts. We ask essential questions such as why they remain committed to this preservation practice, how it contributes to sustaining cultural identity, and whether it creates a broader impact by inspiring people around the world to learn more about Indonesia's traditional masks. Why do they keep doing this, and does it have any impact on people around the world to know more about masks in Indonesia?

The insights gained from the museum representative provide crucial context in linking traditional heritage with contemporary cultural discourse. The museum's preservation efforts are not merely acts of storing or displaying artifacts; they are a form of cultural storytelling that connects past traditions to present and future generations. By documenting their perspectives, this research

highlights how heritage institutions play an active role in shaping collective memory and fostering cross-cultural understanding.

Based on the photographic result of Balinese Mask, the researcher team observed all unique elements of the Mask. We learned what design elements make the mask unique, the similarities between masks, and also what are the differences between mask design.

3D Modeling Design

After completing the photo documentation of the Balinese masks, the research team will proceed to the 3D modeling stage. This stage aims to transform the two-dimensional visual data obtained during the photo session into a high-resolution three-dimensional (3D) digital representation with a high level of accuracy and realism. Initially, the reference photographs will be utilized to construct the base mesh through a combination of *3D sculpting* and *mesh modeling* techniques. This approach ensures that the anatomical proportions, carved patterns, and ornamental details of the Balinese mask are faithfully represented in the digital model.

Blender software is chosen as the primary tool due to its robust capabilities in *high-resolution modeling* and *Physically Based Rendering (PBR) texturing*. Several texturing techniques, including *UV mapping*, *baking*, and the application of realistic materials, will be applied to achieve a visually accurate and detailed 3D model (Inzerillo et al., 2019). By focusing on precision and realism, the final model will not only serve as an aesthetic representation but also as a valuable medium for digital cultural preservation.

Result and Discussion

This research focuses on the creation of a three-dimensional (3D) digital model of a Balinese mask. The initial stage involves a structured photography session conducted on-site at the Setia Dharma House of Mask and Puppet in Ubud, Gianyar. This museum was selected due to its comprehensive and diverse collection—reported to hold over 1,300 masks and thousands of puppets—representing Indonesia's most extensive repository of traditional mask art thus providing an ideal variety of shapes, textures, and carving styles as a reference for digitization and selection of representative objects, such diversity provides ideal conditions for object selection, stylistic comparison, and visual documentation (Adriza, 2019).

The visual data collection phase focused on acquiring high-quality imagery for the 3D reconstruction process. To ensure the quality of the final model, the shooting session was planned with controlled lighting (avoiding direct reflections on shiny areas), the use of a tripod to maintain compositional consistency, and imagery around the object at different elevations. These techniques are common practices proven to improve reconstruction accuracy and texture on small to medium-sized cultural objects (Putra et al., 2025).

The choice of the Hanoman mask as a study object is justified by its cultural and representative aspects: Hanoman is a well-known figure in the Ramayana story and often appears in traditional Balinese performances, so the 3D model has high representational value for iconographic studies and visual preservation. Additionally—technically speaking—the contrasting shape of Hanuman's head (muzzle profile, stern expression, carved details) provides a good challenge to test the accuracy of photogrammetry techniques in capturing small details such as hair carvings, cat textures, and wood cracks.

Validation and ethical aspects are also included in the method: prior to photography, we will obtain written permission from the museum curator to document the selected objects (incl. agreement on the use of images and 3D models for publication/archives), and record the physical condition of the masks (size, material, damage) as metadata. Model validation is carried out by comparing critical dimensions (e.g., facial height, facial width, distance between landmark points) between the 3D model and physical field measurements. Finally, the research output will include a

final 3D model (mesh + texture), a process report (workflow, software parameters), and best-practice recommendations for the digitization of traditional Balinese masks (Chapinal-Heras et al., 2024).

3D Production of Mask

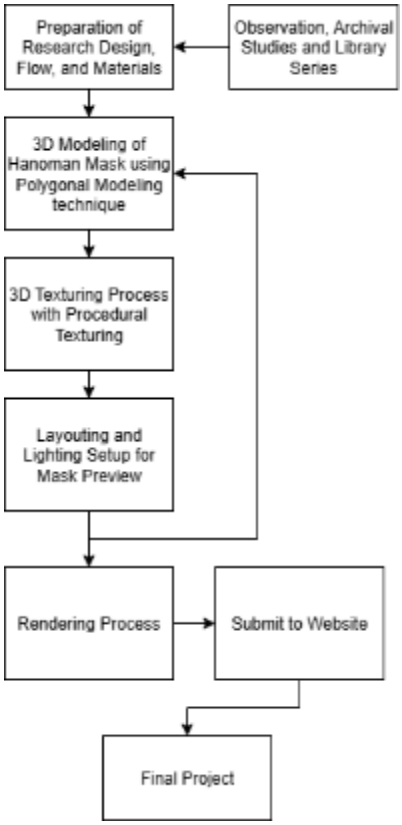


Figure 1. Flow of Production

Based on the production workflow depicted in Figure 1 above, the 3D object construction of the Hanoman Mask has a fairly lengthy production process. It begins with initial observations, data sampling, and then 3D production of the Hanoman mask, all the way from modeling the 3D based on photo reference through to the rendering and final project. Through this presentation, the researchers divided each part of the mask to maximize production performance.

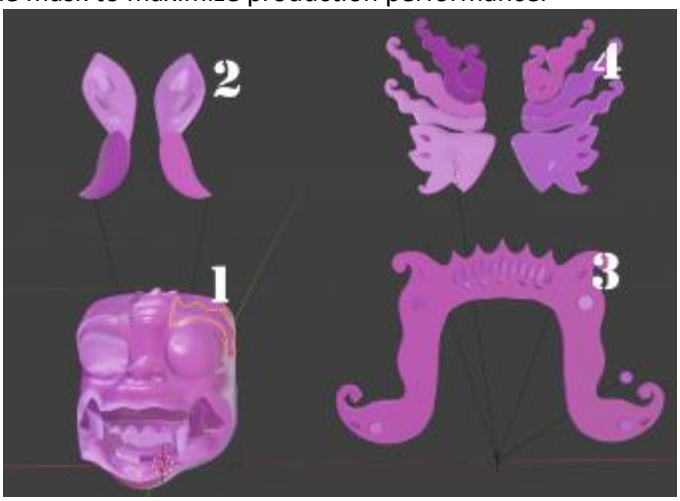


Figure 2. Four Sequential Stages of Development Modeling

Based on Figure 2, the researchers systematically divided the development into four sequential stages. Each of these stages follows a consistent methodological pattern, beginning with the establishment of a fundamental base mesh derived from a polygonal cube primitive. This cube serves as the geometric foundation from which the overall form of the mask is gradually developed.

During the initial phase, the modeler defines the primary volume and proportions of the object by manipulating the cube's topology. The subsequent process involves progressive modification of the polygonal structure, specifically through the editing of faces, vertices, and edges to refine the shape. We chose two different angles namely front and side angles for several reasons. First it will be a difficult process to ask the Museum authority to put down the Mask dan secondly at least we need different angles to understand the shape of the Mask. This procedure is important to understand, before we create the Mask in 3D Software. The purpose of capturing these different angles directly at the museum was to create a realistic 3D image that perfectly matches the original artwork.

Figure 3. Front View of Hanoman Mask

Figure 4. Side View of Hanoman Mask

Based on Figure 3 and 4, the researchers captured every detail and color that matches the original Hanoman mask. These modeling operations allow the base geometry to evolve from a simple cubic structure into a complex organic form that accurately represents the contours and features of the Hanoman mask. To ensure accuracy and consistency, each stage of modification is guided by reference images like both front and side orthographic views, taken from the original artifact. These references act as visual constraints that help maintain proportional fidelity between the digital model and the physical mask. Through iterative adjustments and topology optimization, the mesh is gradually shaped to capture the distinctive anatomical and ornamental details characteristic of Balinese mask craftsmanship.

Figure 5. 3D Modeling using Polygonal Modeling

Based on Figure 5, the researcher used the 3D Modeling method through the Polygonal Modeling approach, which prioritizes function and precision of form by editing the vertices, edges and faces. The modeling process also involves the implementation of subdivision and smoothing techniques to enhance surface curvature and realism. By strategically adding edge loops and controlling polygon density, the modeler ensures that the mesh maintains both aesthetic precision and structural efficiency, which is essential for subsequent stages such as texturing and rendering.

Ultimately, this four-step modeling workflow reflects a structured and iterative approach to digital sculpture, where the transformation from primitive geometric forms to accurate cultural artifacts is achieved through a balance of technical precision and artistic interpretation. The final form serves not only as a digital representation but also as a medium for cultural preservation and the study of traditional Balinese art.

Figure 6. Final Modeling of Hanoman Mask

Based on Figure 6, The Hanoman assets were successfully created in a representative and authentic manner from the separation of each asset described previously. Next process we conduct is unwrapping and texturing using procedural node, texturing using software adobe substance painter. The unwrapping process was carried out systematically by cutting and segmenting the 3D assets according to a pre-planned UV mapping flow. This strategy aims to ensure a clean and efficient UV layout, minimizing distortion during the texturing stage. A well-organized UV structure allows for a

more precise and controlled texturing process in Substance Painter, as each part of the surface can be assigned materials with a high level of accuracy.

At this stage, the entire asset was divided into four main sections, each with a distinct UV map. This segmentation simplifies the texturing process since each section can be independently managed without interfering with the others. Following the UV mapping stage, the next step is shading. Shading plays a crucial role in defining how a 3D object's surface interacts with light, creating the illusion of depth, texture, and realistic material properties. In Blender, the shading process is relatively straightforward due to its intuitive interface and node-based system. Shading is also useful for separating each texture ID, which will later be useful for detailed coloring and texturing in procedural and substance painter processes.

Figure 7. Shading progress in Blender

Based on Figure 7, each component and shade has a different color and ID, thus avoiding confusion for the 3D artist working on the next step. Once the shading process is completed and the material characteristics are established, the next stage involves texturing. This stage focuses on adding visual details such as color, patterns, and specific material properties to the surface of the object, resulting in a more lifelike and visually convincing 3D model. Texturing also serves as one of the key determinants of the final visual quality in the 3D production pipeline. Texturing is a crucial stage in the 3D animation production pipeline as it enables artists or animators to apply authentic and realistic surface details to digital objects (Pratama & Damanik, 2025). Through texturing, object surfaces can accurately represent various types of materials, such as skin, wood, metal, fabric, or other natural surfaces. This process adds an extra layer of visual dimension, enhances depth perception, and increases the overall believability of the rendered scene.

In this project, the texturing process was carried out using a procedural approach combined with an inter-software workflow between Blender and Substance Painter. The use of procedural texturing allows for the creation of complex surface patterns and material properties without relying solely on static image textures, providing greater flexibility for visual development. Throughout the texturing stage in Substance Painter, the entire process proceeded smoothly and efficiently. The final result closely aligned with the predetermined visual references, successfully capturing the intended material characteristics. This outcome significantly contributes to the aesthetic and technical quality of the 3D assets, reinforcing the overall visual realism of the project.

Figure 8. Texturing Progress using Substance Painter

Based on Figure 8, Substance Painter helps 3D artists to create textures, colors, and gradations that suit the researcher's wishes and support the procedural process that the researcher will carry out. After completing the texturing process in Substance Painter, the next stage involved transferring and integrating the texture maps into Blender. At this point, we began applying a pure procedural texturing approach by combining the baked textures from Substance Painter with Blender's native procedural texturing techniques. This hybrid method was intended to enrich the visual details, enhance the flexibility of material adjustments, and increase the overall depth and complexity of the 3D object's surface. During this stage, several procedural texturing elements were utilized to achieve a more dynamic and realistic visual outcome. For instance, Noise Texture was employed to create subtle dust effects and fine surface wear, adding a sense of realism to the model.

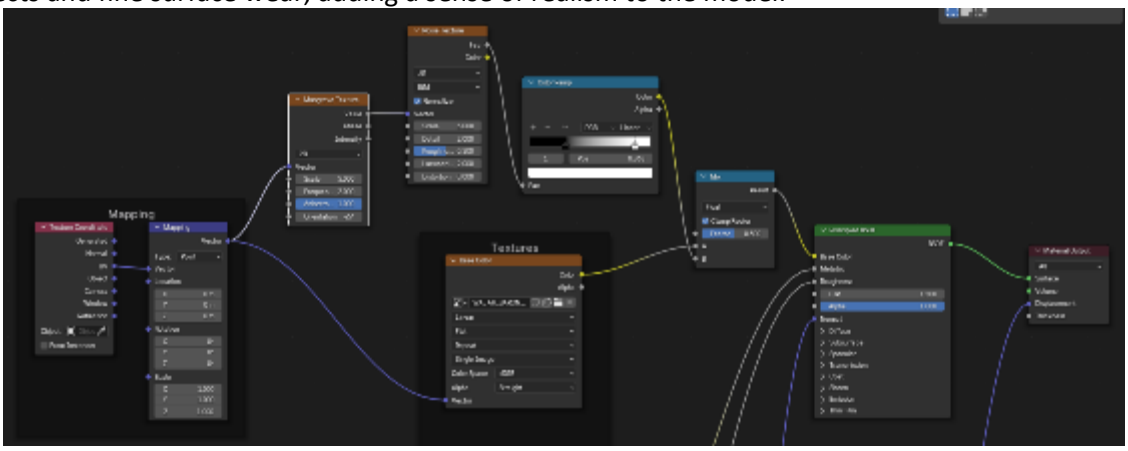


Figure 9. Example of procedural texturing in Hanoman Mask

For example, in Figure 9, where the team tried to create a procedural texture for the creation of dust and past effects on a 3D asset, namely the Hanoman mask, using Musgrave Texture. Additionally, Musgrave Texture was applied to introduce organic, non-repetitive surface variations that mimic natural imperfections. To blend and control these various texture layers, ColorRamp Nodes and Mix Shaders were used, allowing for precise control over intensity, contrast, and texture transitions. Through this procedural texturing method, we successfully produced the Hanoman mask texture with a high degree of visual complexity and close resemblance to the original reference. This approach also provided additional flexibility during the look development process, as texture parameters can be easily modified without the need to restart the texturing process from scratch. Such a workflow is highly advantageous in modern 3D production pipelines, which demand both efficiency and high visual quality.

After completing the shading and texturing stages, we proceeded to the lighting phase, which plays a crucial role in defining the final visual quality of the 3D object. In this stage, we applied a basic three-point lighting technique consisting of three main light sources: Key Light, Fill Light, and Back Light. This lighting setup is widely used in both animation and cinematography industries due to its effectiveness in emphasizing form, depth, and material characteristics in a balanced manner. Once the lighting setup was finalized, we proceeded with the rendering stage using Cycles Render Engine in Blender. Cycles is a path-tracing render engine known for its ability to produce accurate global illumination and realistic shadows (Aryanto et al., 2020).

Figure 10. Front View Final Render

Figure 11. Side View Final Render

The final results from Figure 10 (front view) and Figure 11 (side view) show the rendering quality produced by Blender Node base to enhance texture and material conditions. The 3D Modeling process, which combines polygon-based through sculpting and mesh techniques, is able to generate a form that is highly similar to the original mask as captured in photography. The texturing process utilizes photo-scanning methods, texture creation from scratch in Substance painter, and the translation of realism requirements through node-based coding. The comparison between the 3D model and photographic references shows a very close or similar result, as the approach applied throughout the 3D modeling process focuses on interpreting the requirements for achieving a realistic appearance. The objective of this method is to represent Balinese masks as closely as possible to their original form and to present them via internet media without relying on large image files, by using 3D models that maintain high visual quality while remaining lightweight in file size. Consequently, the application of node-based workflows in the creation of 3D mask models can be extended to other mask collections, supporting

broader cultural preservation efforts by leveraging 3D modeling to overcome the limitations of conventional techniques such as photography.

Conclusion

This study demonstrates that the digitalization of cultural artifacts through three-dimensional (3D) modeling plays a significant role in cultural heritage preservation, particularly in the case of Balinese masks. The use of structured photography, in-depth visual analysis, and 3D modeling techniques in Blender enables the creation of highly accurate digital representations in terms of form, proportions, and surface details. Supported by systematic unwrapping, shading, and texturing processes like procedural and through external tools such as Substance Painter. In this research, we did two methods for adding texture to the mask. One the method we use procedural nodes, the second method we use the unwrapping process first and then adding the texture in adobe substance software. Each process has its own benefits. After the modeling was done, first we did unwrapping and adding the detail texturing in Adobe Substance. This method is necessary because in Adobe Substance, the software provides us more tools and flexibility to add different kinds of materials. Secondly, after the basic color and material are complete, we continue the process inside the Blender software to add more materials using its tool called procedural node. The final model closely reflects the original material characteristics of the artifact.

Digitalization not only offers new possibilities for conserving physical objects but also expands public access to cultural information through digital platforms. As a result, cultural artifacts such as the Hanoman mask can be studied without geographical or temporal limitations. Furthermore, this effort strengthens the potential for developing digital museums, enriching cultural education, and utilizing 3D models for tourism promotion and scientific documentation.

Overall, the findings confirm that integrating 3D modeling technologies and digital visualization provides an effective strategy for sustaining cultural knowledge. Procedural nodes are a powerful visual code provided by Blender and we can utilize it to create a stunning and believable visual from this case study, a 3d model of Balinese Mask. This initiative contributes to preserving the artistic and historical values of Balinese masks while opening new avenues for creating inclusive, interactive, and sustainable cultural archives in the digital era.

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