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Applied Practices on Digital Historical Data Transformation based on Intangible Cultural Heritage with Metaverse Approach

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Abstract

The preservation and transmission of intangible cultural heritage, such as traditional martial arts, have historically relied on manual processes that are both resource-intensive and costly. Due to budget limitations, many of these cultural assets are at risk of deterioration or remain hidden in museum storage, inaccessible to the public. To address these challenges, we propose a Digital Historical Data Transformation mechanism utilizing metaverse development techniques. This innovative approach converts 2D images into 3D representations, allowing for the extraction and visualization of associated actions in a three-dimensional space. By applying this methodology to the "Muyedobotongji," a classic text on traditional martial arts, we aim to digitally preserve these practices in a way that is both immersive and interactive. The transformation of static 2D images into dynamic 3D visualizations will not only enhance the restoration process but also make these cultural assets more accessible and engaging for future generations. This digital approach promises a more efficient and sustainable means of preserving intangible cultural heritage, ensuring that these traditions continue to thrive in the modern world.

Keywords: *2D Image to 3D Object Transformation, Metaverse, Digital Twin, Digital Historical Data Transformation*

1. Introduction

Currently, Korea's intangible cultural heritage is facing difficulties in preservation and transmission. The loss of traditional culture bearers leads to the serious problem of cultural extinction. Experts emphasize the need for creative succession methods to preserve traditional culture [1]. Historically, the restoration and transmission of cultural properties have relied on methods such as literature review of historical documents, interviews, oral histories, and archival records. However, these methods still present challenges in accurately reconstructing ancient cultures. Moreover, the restoration of intangible cultural properties often requires

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manual labor, demanding significant costs, manpower, and resources. Limited budgets create gaps in management, resulting in damage and loss of cultural properties. Additionally, many tangible and intangible cultural assets are stored in museum repositories, making restoration and research challenging [2].

To solve problems, we propose a Digital Historical Data Transformation method that utilizes virtual reality technology based on the metaverse for public accessibility, converting 2D images into 3D models. The proposed method applies metaverse techniques to the "Bon-guk Geom" from the "Muyedobotongji (Comprehensive Illustrated Manual of Martial arts)" in Korea. It animates each martial arts movement according to its characteristics, extracting actions from 2D images to create 3D object behaviors, resulting in skeletal animation 3D object models. To ensure smooth transitions between actions of 3D objects within the metaverse, animation interpolation techniques are employed to connect unit movements.

This paper aims to present a guide for developing functional programs using metaverse platforms as a novel method for preserving intangible cultural heritage. We expect this approach will contribute to the preservation and transmission of various intangible cultural properties, including not only martial arts but also traditional dance, music, and performances.

Chapter 2 discusses related research on 2D to 3D conversion. Chapter 3 elaborates on the proposed Digital Historical Data Transformation using virtual reality technology based on the metaverse for public accessibility. Chapter 4 presents a case study applying the method to the "Bon-guk Geom" from the "Muyedobotongji". Finally, Chapter 5 concludes the paper and suggests directions for future research.

2. Related Works

2.1 2D to 3D Transformation Approach Using Graphs and Neural Networks

There are several approaches to transform a 2D images to 3D object. A notable aspect of Wu's research is the method of identifying key joints in the human body from 2D images and connecting them into a graph structure. This approach plays a crucial role in converting 2D images into 3D object [3].

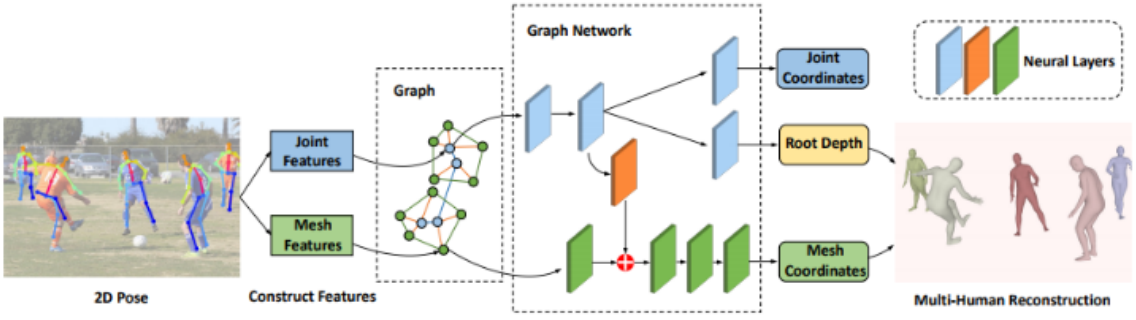

Figure 1. 2D to 3D Transformation approach using graphs and neural networks [3]

Figure 1 shows the process to transform from 2D image to 3D object using Graph theory and neural network. First, it identifies main joint points of the human body in 2D images. These joint points include, for example, shoulders, elbows, wrists, hips, knees, and ankles. Then, these joint points are interconnected to create a graph structure. This graph roughly represents the skeletal structure of the human body and shows the connections between each joint. The resulting graph structure serves as input for an AI-based single graph neural network. This artificial intelligence neural network performs the task of transforming the 2D graph into 3D space.

During this process, the 3D position of each joint is estimated, and based on this, an overall 3D human body model is constructed. The advantage of this method is that it can generate 3D models directly from 2D images.

However, accuracy may decrease in cases of complex poses or when multiple people overlap. Additionally, it is challenging to infer continuous actions of individuals. While this approach shows promise, it has limitations in accurately reconstructing 3D models from 2D images in more complex scenarios. Further research is needed to improve performance in these challenging situations and to develop methods for inferring continuous actions from static poses.

2.2 Methods of Digitizing Tangible Cultural Assets using Digital Technology

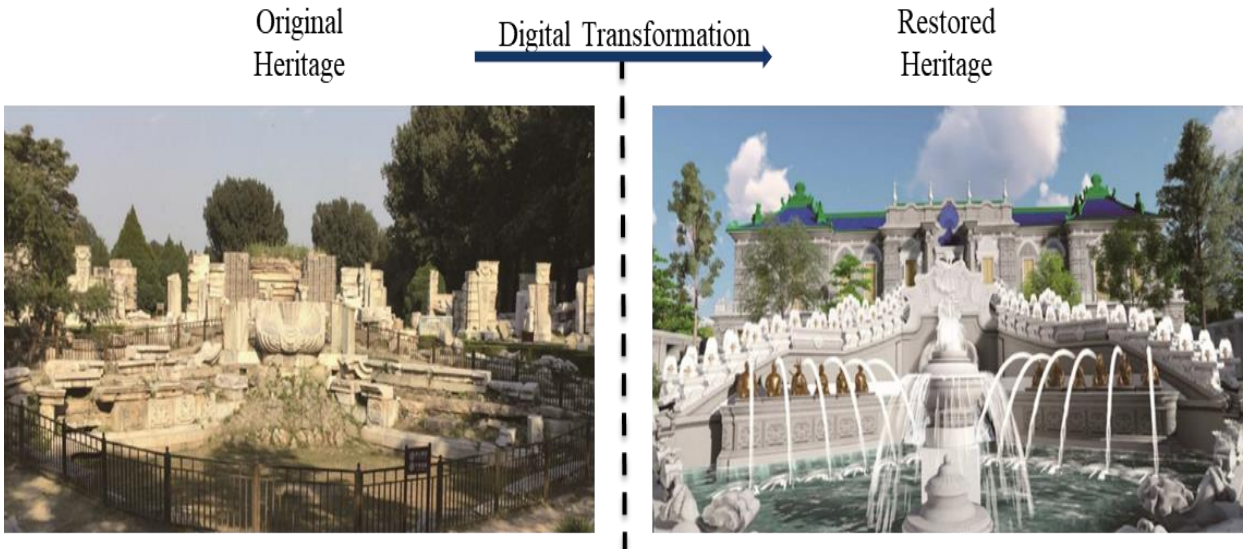

Figure 2. Example of digitization for a tangible heritage

Recent research on the digitization of tangible and intangible cultural heritage has been progressing rapidly, yet these approaches still face significant limitations. Figure 2 shows an example of digitation of tangible culture Asset. Jin et al. demonstrates that digital simulations of cultural heritage using virtual reality technology can improve traditional methods of transmission [4]. However, this paper remarks several challenges.

Firstly, there are current technological limitations in perfectly reproducing the intricate details and textures of cultural heritage. As Yu. points out, high-resolution digitization of large-scale heritage sites requires substantial time and resources, which affects the feasibility of such projects [5].

Secondly, there is a risk of losing the essential context and atmosphere of cultural heritage during the digital reproduction process. Maintaining a balance between tangible and intangible elements is particularly challenging, yet crucial for conveying the holistic value of cultural heritage.

Thirdly, as mentioned in Minli Shi et al. study, many people hope that digital technology will make culture available to everyone. However, in reality, not everyone has equal access to this technology. This creates a problem where some people can easily learn about and enjoy cultural content online, while others are left out. This gap between what we want (everyone having access) and what's happening shows that making culture truly open to all is still a challenge [6]. The unequal access to advanced VR devices may create new forms of cultural disparity, presenting the challenge of ensuring universal accessibility to digital cultural heritage

experiences.

These limitations suggest that research into the digitization of cultural heritage must consider not only technological innovations but also cultural, ethical, and economic aspects comprehensively. Future studies will likely require multifaceted approaches to address these complex challenges in preserving and transmitting cultural heritage through digital means.

3. Process of restoring Intangible Cultural Heritage with Metaverse Technology

Figure 3 illustrates the process of converting 2D images into 3D objects, detailing the steps involved in identifying and representing behaviors in three dimensions. This conversion is critical for transforming flat, two-dimensional representations into three-dimensional models that can be manipulated and viewed from various angles.

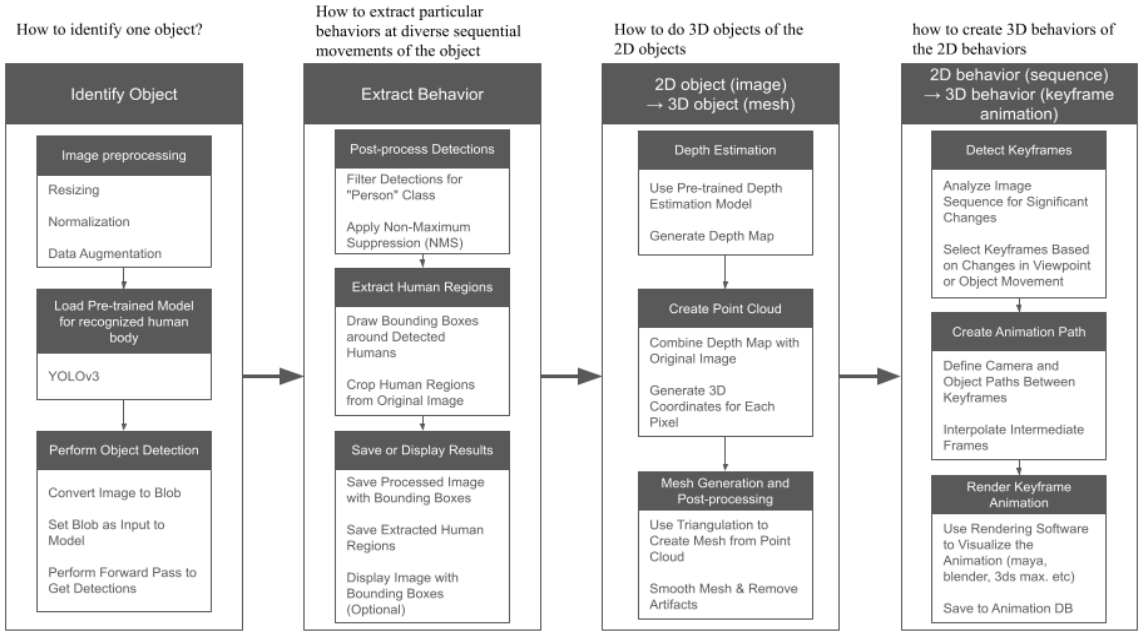

Figure 3. 2D image to 3D object transformation process on Metaverse

The workflow describes in Figure 3 demonstrates a systematic approach to extracting depth information and behavioral cues from 2D images. By employing this method, it is possible to recreate the three-dimensional structure and associated behaviors, providing a more comprehensive representation of the original subject. Researchers can use this conversion technique to create 3D models that retain the intrinsic characteristics of the original 2D images while adding depth and the potential for animated movement. This process opens new possibilities in various fields, including cultural heritage preservation, virtual reality experiences, and interactive educational tools.

1) Identifying objects from 2D image

The first stage involves object recognition from 2D images. To achieve this, techniques such as resizing, normalization, and data augmentation are employed to process the images into data suitable for input into

artificial intelligence models. Subsequently, a pre-trained object detection model, such as YOLOv3, is loaded to convert the image into a blob and set it as the model's input. The model's forward pass is then executed to obtain detected objects, during which the Non-Maximum Suppression (NMS) technique is applied to select only high-confidence detection results. Finally, bounding boxes are drawn around the detected objects to extract the corresponding regions from the original image, which are then displayed.

This process utilizes advanced computer vision techniques to accurately identify and isolate objects within 2D images. The use of pre-trained models like YOLOv3 allows for efficient and reliable object detection, while the application of NMS ensures that only the most relevant detections are retained. This approach provides a robust foundation for further analysis and transformation of 2D image content into 3D representations.

2) Extracting behaviors at diverse sequential movements of the object

The second stage focuses on extracting specific actions of objects from a sequence of consecutive images. To accomplish this, features of the detected objects are extracted from each image, and these features are used to analyze the object's movement. The position, pose, and joint angles of the object are calculated in each image to determine changes in motion. This extracted data allows for visual analysis of the object's continuous movement, and specific action sequences can be selected for use as foundational data in 3D animation generation.

This process involves advanced image processing and motion analysis techniques. By examining the changes in an object's characteristics across multiple frames, it becomes possible to reconstruct the object's movement patterns. This approach not only provides valuable insights into the dynamics of the object but also creates a bridge between static 2D representations and dynamic 3D animations. The resulting data serves as a crucial input for creating realistic and accurate 3D representations of the original 2D image sequences, enabling a more comprehensive and interactive visualization of the subject matter.

3) Transformation 2D objects into 3D objects

The third stage involves the process of converting objects extracted from 2D images into 3D objects. In this stage, a depth estimation model is employed to calculate depth values for each pixel, which are then used to generate 3D coordinates. The resulting depth map is combined with the original image to create a point cloud, which is subsequently used to construct a 3D mesh through triangulation techniques. The generated mesh undergoes post-processing to smooth it and remove artifacts, resulting in the final 3D object [7].

This process utilizes advanced computer vision and 3D modeling techniques to transform flat 2D representations into fully realized 3D objects. The use of depth estimation models allows for the accurate inference of spatial information from 2D images, while the point cloud and mesh generation steps create a detailed 3D structure. The post-processing phase ensures that the final 3D object is refined and free from computational artifacts, resulting in a high-quality 3D representation of the original 2D image content. This approach enables the creation of interactive and immersive 3D models from static 2D images, opening up new possibilities for visualization and analysis in various fields of study.

4. Case Study on Digital Historical Data Transformation with Muyedobotongji

The Muyedobotongji is a comprehensive martial arts manual published in 1790, during the 14th year of King Jeongjo's reign in the Joseon Dynasty. This text provides a systematic record of military training and traditional martial arts practices of the Joseon dynasty [8].

This historical document serves as a valuable resource for understanding the martial culture and military strategies of 18th-century Korea. The Muyedobotongji not only catalogues various martial arts techniques but also offers insights into the military philosophy and training methodologies of the time. Its compilation represents a significant effort to preserve and standardize martial knowledge, reflecting the importance placed on military preparedness and martial traditions in Joseon society.

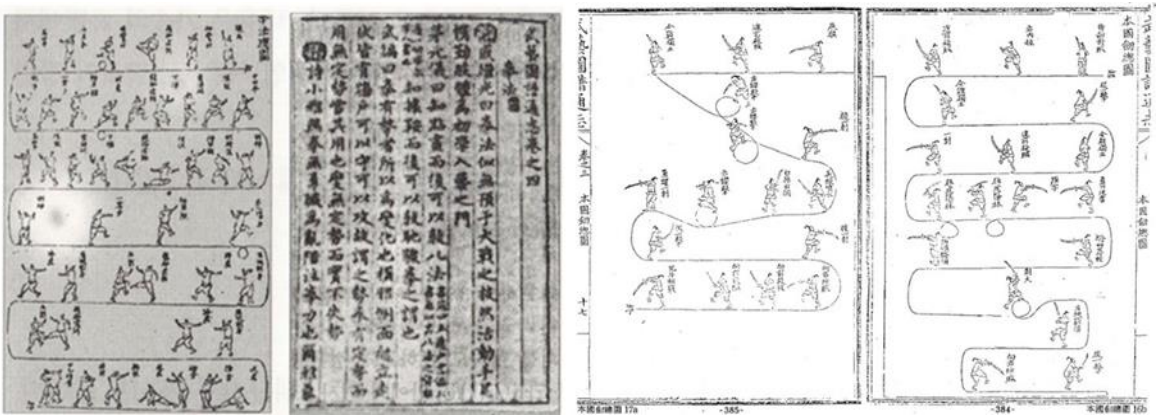

Figure 4. The Muyedobotongji(a) and The Bon-guk Geom(b)

Figure 4 (a) describes historical artifacts: the 'Muyedobotongji' and figure 4 (b) the 'Bon-guk Geom'. The Muyedobotongji meticulously documents various martial arts techniques, from basic to advanced, through illustrations and explanations. It includes detailed instructions on weapon usage and served as a crucial guide for martial arts education and training in the Joseon Dynasty [9].

However, the majority of existing research has focused primarily on textual interpretation, limiting the development of concrete methodologies necessary for the accurate recreation and preservation of martial arts movements. To address this limitation, this paper employs digital technology to recreate the 'Bon-guk Geom', a martial art form recorded in the Muyedobotongji, within a digital environment.

This approach aims to transcend traditional textual analysis by providing a three-dimensional, interactive representation of historical martial arts techniques. By leveraging digital technologies, we seek to offer a more comprehensive and accessible method for preserving and transmitting this important aspect of cultural heritage. This digital recreation not only aids in the accurate preservation of traditional martial arts but also enhances the potential for broader public engagement and educational applications.

The 3D object model is first created and then animated using the action model extracted in the previous stage. This process is applied to all 34 poses of Bon-guk Geom, bringing them to life in a virtual environment. This digital recreation allows users to study Bon-guk Geom from various angles in a 3D virtual space, providing a more comprehensive learning experience compared to traditional text and image-based study methods.

This approach significantly enhances the learning process by enabling users to observe and understand the correct postures and forms from multiple perspectives. It transcends the limitations of static illustrations and textual descriptions found in historical documents, offering a dynamic and interactive method for studying traditional martial arts techniques. This innovative use of digital technology not only aids in the preservation of cultural heritage but also provides a more engaging and effective means of transmitting historical martial

arts knowledge to modern learners.

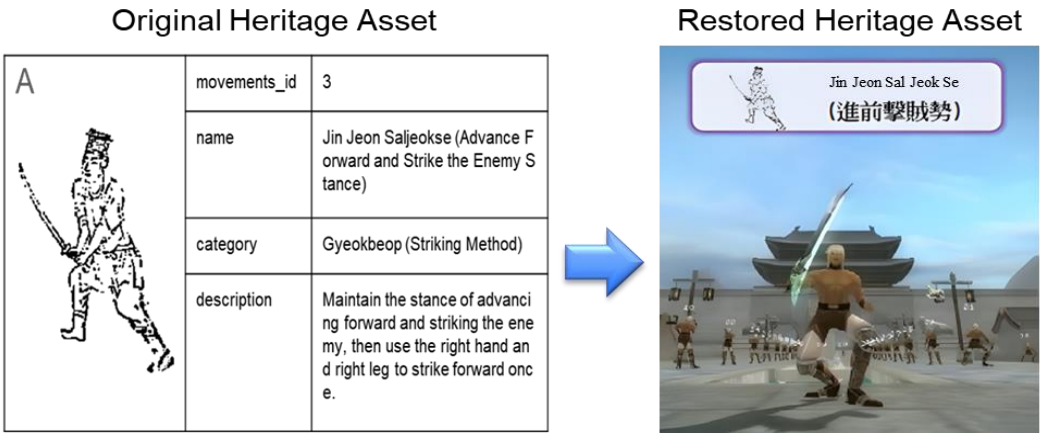

Figure 5. Example of digital historical data transformation on Metaverse [10]

Figure 5 illustrates the implementation of 'Jin jeon Sal Jeok se', the 20th poses among the 34 positions of Bon-guk Geom, in a virtual environment using metaverse techniques [10]. 'Jin Jeon Sal Jeok se' represents a vertical cutting motion where one advances forward and strikes downward at the opponent's upper body. Unlike the head strike in modern Kendo, this technique involves a straight vertical cut that can target the wrist or continue down to the torso.

5. Conclusion

This paper presents a novel approach to preserving Korean intangible cultural heritage using metaverse-based digital technology. Using the 'traditional martial arts' from Muyedobotongji as a case study, we propose a process for generating 3D object from 2D images and implementing them in a virtual environment. Through this, we offer guidelines for developing functional programs for the preservation and transmission of intangible cultural heritage using metaverse platforms, demonstrating potential applications across various forms of intangible cultural heritage.

However, attempts to create 3D objects at low cost have resulted in persistent issues with reduced resolution of these objects. Future research should focus on strengthening the theoretical foundation through diverse case studies and exploring the sustainability of metaverse-based digital technology and its potential applications across various fields.

This research explores new ways to preserve cultural heritage using digital technology. We combine traditional methods with modern tech to create 3D animations of historical martial arts. While our approach shows promise, there's room for improvement, especially in 3D image quality. As technology advances, we expect to find better and more cost-effective ways to digitally preserve culture. This could change how we learn about and interact with our heritage. Future studies will focus on improving our methods and exploring how this technology can be used in different areas of cultural preservation.

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