A Study on the Design and Production of 3d Traditional Stone Pagoda Dataset for Artificial Intelligence Learning

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Big data in the form of DataSets is crucial for artificial intelligence learning. Currently, while 2D artificial intelligence restoration algorithms are extensively studied and applied, there is still a deficiency in 3D artificial intelligence training data. In this research, we studied the process of designing and creating AI learning data for traditional towers configured in 3D. In the case of 3D AI learning data, the number of points, lines, and surfaces significantly influences the learning speed and accuracy of AI. In this paper, we analyzed and designed traditional stone towers in 3D, resulting in the creation of an optimized dataset based on points, lines, and surfaces. Thus, we propose a method of optimizing the production of datasets required for AI learning from 3D objects. This approach is anticipated to contribute significantly to future 3D artificial intelligence learning.

Keywords: Artificial Intelligence Learning, 3D Dataset, Traditional Towers, Data Optimization, Points, Lines, and Surfaces.

1. Introduction

Recently, due to the development of artificial intelligence and technology, research on the restoration of 3D cultural assets reflecting existing 2D data is being actively conducted (C. Zeyu et al.,2021; T. Hattori et al 2020). Restoration technology using artificial intelligence technology is increasing in accuracy by converging high-speed computer processing speed and media technology. Previous restorations were restored by remaining data and records, but currently, many efficient methods of restoration using artificial intelligence learning based on various data are being proposed. The 3d object restoration proposed in this study is to create a data-set by designing and manufacturing using computer graphics technology. In other words, the performance speed and accuracy of artificial intelligence learning are higher than before. However, artificial intelligence learning from 2-dimensional space to 3-dimensional space takes a remarkably long time due to the calculation of 3-dimensional data. In order to solve this problem, this study created a dataset necessary for artificial intelligence learning through the process of designing and manufacturing a traditional stone pagoda using a 3D graphic production tool. In the 3D object production process of this study, an optimized

3D modeling was designed and manufactured to maintain the original shape of the tower while minimizing the number of points, lines, and planes that affect learning. The composition of this study is to analyze the composition and characteristics of traditional stone pagodas as related research in Section 2, design and production process using 3D graphic production tools in Section 3, and point, line, and analyze the side. Section 5 analyzes and concludes the results.

2. Literature Review

2.1 The form of a Pagoda Related Works

The shape of pagodas in Korea can be largely divided into wooden pagodas, stone pagodas, and brick pagodas (塼塔) according to the material of the pagoda(T Aung et al.k,2018;Lee Ji-hyun.,2006). Most of Korea is made up of stone pagodas, and wooden pagodas also account for a significant portion. Stone pagodas in Korea are stone pagodas, and there are many granites, so most of them are used to build stone pagodas. In the Baekje era, there are the five-story stone pagoda at Jeongnimsa Temple Site and the stone pagoda at Mireuksa Temple Site in Iksan, which imitated wooden pagodas. In addition, there was a stone pagoda at Bunhwangsa Temple Site in Gyeongju during the Silla Dynasty, and four-story pagodas were popular in the Unified Silla Period, so various types of pagodas remain in Gyeongju. In the Goryeo Dynasty, there were many pagodas with various styles, and the representative pagoda is a wooden pagoda made of wood (M.-j et al.,2010; S. Usui., 2021). This wooden pagoda is one of the types of pagodas that have grown greatly in China. In Korea, there are the 9-story stone pagoda of Hwangnyongsa Temple and the twin pagodas of Sacheonwangsa Temple in the form of wooden pagodas. Given that there are not a few wooden buildings in Korea, there are wooden pagodas that preserve the ancient Korean style. Brick Pagoda (塼塔) is a pagoda made of bricks. In China, wooden pagodas were the basic form of pagodas, but from the period of the Northern and Southern Dynasties, Brick Pagodas (塼塔) that imitated the dugong and eaves of wooden buildings began to become popular, and later Brick Pagoda (塼塔) began to be built. Brick Pagoda (塼塔) remaining in Korea includes the 7th-floor Brick Pagoda (塼塔) in Shinse-dong, the 5-story Brick Pagoda (塼塔) in Dongbu-dong, and the 5th-floor Brick Pagoda (塼塔) in Songrimsa Temple, Chilgok, in Andong, Gyeongsangbuk-do. The Brick Pagoda (塼塔) is a single-story stylobate made of granite. It has supports on the top and bottom of the roof stone, and a tabernacle is installed on the stone god. Table 1 shows the shape of the pagoda in Korea.

Table 1: Characteristics by Pagoda shape

Type	Characteristics	image
Stone pagoda	It is a stone pagoda, and there is also a basic stone pagoda and a parent stone pagoda with bricks.	
Wooden pagoda	It refers to a wooden tower and mainly means Buddhist architecture.	

Brick Pagoda	It is a tower built of bricks, and it is a rare tower in Korea.	

2.2 3D Modeling Tools

3D modeling tools include Blender, Maya, 3d Max, Sketchup, Zbrush, Solidworks, Fusion 360, etc. Table 2 shows the characteristics of 3D modeling tools. In this study, a traditional stone pagoda was designed and manufactured using Blender, a free and open-source software(D. Gitlin et al.,2017;Rui Wang et al.,2008;Spencer Grey et al.,2021).

Table 2: 3D Modeling Tools

Tool	Characteristics
Blender	It can use functions such as animation, particle, texture painting, fabric simulation, and sculling, and it is widely used and easy in various places such as mobile game development because it has its own game engine of cross platform.
Maya	It is an optimized program for high-quality image effects because it has integrated interfaces such as modeling, rendering, animation, and V-RAY and the program speed is very fast.
3D MAX	Basically, it works with mesh, polygon modeling and is useful for performance that modifies multiple polygons.
Sketch Up	Simple and intuitive tools are the strength and tools are easy to design.
Zbrush	It is often used in 3D game production or character design using a mouse or tablet.
Solid Wicks	It is easy to use, intuitive, and has abundant domestic books and video courses for learning, making it easy to access.
Fusion 360	Unstructured modeling can be easily designed, and rendering, assembly, and simulation are also built.

2.3 The Structure of Korean Stone Pagoda

In this section, the detailed structure of stone pagodas in Korea is analyzed. As shown in Table 3, stone pagodas in Korea are composed of (1) upper part, (2) body part, and (3) stylobate part (W. Guo et al.,2008;M.Z. Patoli et al.,2009).

Table 3: The Composition of the Pagoda

Names by structure	Image by Structure	
	Image	Explanation
The upper part (1)		The upper part of the tower is the part that decorates the tower magnificently at the top of the tower.
A Pagoda priest (2)		The pagoda body can be said to be the most central body of the pagoda, and it is a place where sarira is enshrined.
The base of the Pogoda(3)		The base part supports the tower from the bottom of the tower and serves as the foundation of the tower.

The structure of the tower divided into three parts has a name for each part, and various types of towers were produced as shown in Table 4 for each period. In Table 4, the characteristics of the stone pagodas of the Goryeo Dynasty are that they inherited the stone pagodas of the United Silla Dynasty, and various types were erected. The stone pagodas of Silla were expanded nationwide and produced in various styles. In particular, compared to the Three Kingdoms period, the scale was reduced, the height was lowered, and the composition of the floor was made of one stone. Also, at the end of Silla, statues appeared on the face stone of the stylobate and the surface of the stupa body stone on the first floor. During the Joseon Dynasty, stone pagodas were built for the purpose of sponsoring the king and the royal family, as the construction of stone pagodas was low due to religious activities centering on Buddha statues. In addition, the scale as a whole is reduced, the number of floors is increased, the stylobate tends to be simplified, the stone body of the pagoda body is lowered, and the roof stone is erected low. The stone pagodas of Baekje started with a low foundation above the ground without a high double stylobate, and tried to imitate a wooden building by assembling many small stones. In addition, the width and height of the second floor or higher are rapidly reduced compared to the beginning, and the roof stone is flat and thin, and the four ears are lightly raised.

3. Research Methodology

The 3D modeling design and production of Korean traditional pagodas are shown in Table 4. In the basic windows environment, open-source Blender 3.4 was used, and Unity 2021 was used to check the produced objects. 3D authoring tools include CINEMA 4D, Z-brush, Sketch UP, 3D MAX, Inventor, Rhino, CATIA, and Solidworks.

Table 4: Implementation Environment

Element	Version
Window	10.0

CPU	11th Gen Intel(R) Core(TM) i7-1165G7
Graphcard Memory (GPU)	16383MB
Blender	3.4
Unity3d 2021.23f	2021.

Stone pagoda modeling requires an understanding of the history of the stone pagoda and analysis of the top and sides of each floor. Figure 1 is the result of analyzing the structure of stone pagodas in Korea and the characteristics of each floor and period.

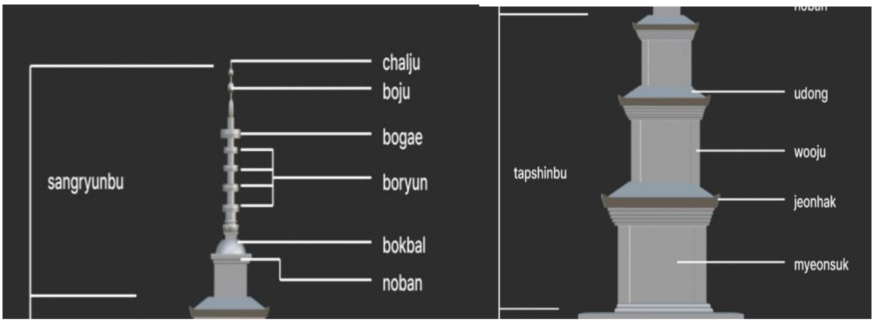


Fig. 1: Name of each floor of the stone pagoda

Figure 1 is Korea's representative "Gyeongju Bulguksa Stone Pagoda", which is divided into three parts: the upper part, the body of the pagoda, and the stylobate, and consists of a total of 23 pagodas. The uppermost part of the stone pagoda is the uppermost part of the pagoda located above the roof stone. Based on the 'three-story stone pagoda of Bulguksa Temple in Gyeongju', the composition of the upper part consists of a total of 9 'Chalju', 'Boju', 'Yongcha', 'Suyeon', 'Bogae', 'Boryun', 'Yanghwa', 'Bokbal' and 'Roban'. In other words, 'Chalju', which is located on the uppermost layer of the Sangryunbu, is also called Chalkan. 'Orb' is a bead-shaped sculpture that surrounds a chalju. The 'Yongcha' located at the bottom is a round ornament made of iron, located between the Suyeon and the orb at the head of the pagoda, and the 'Suyeon' below is a flame-shaped decoration. Suyeon is located between the boju and the boryun, and the 'boryun', which is separated into five layers, is a square decoration on the roof, and there is a cover called 'bogae' on the boryun. Yanghwa' is an ornament with a flower pattern engraved on it, and 'Bokbal' is located on top of the 'Roban' at the top of the pagoda The body of the pagoda is divided into 'Udon', 'Okgae', 'Okgae support', 'Pagoda body', and 'Universe'. The okgae is made up of udon, naksu-myeon, jeomgak, and okgae support. The dripping surface of the roof is a slope made to allow rainwater to flow down. Udon refers to the four corners of the falling water surface, and there are seals and roof support underneath. The stylobate is the lowest structure and is the stylobate of the pagoda, and is classified into 'one-story stylobate' and 'two-story stylobate'. The first floor stylobate is classified into 'Hadae Gapseok', 'Hadaeseok', 'Jidaeseok', and 'Ground', and the '2nd floor stylobate' is the 'Tangju' that acts as a support for the tower.

The 3D modeling of Korean traditional stone pagoda was done using blender graphic tool. The process is to create a cube by selecting Object Mode - Add - Mesh - Cube, and reduce the Z-axis of the created cube(M. Bailey et al.,2014;U. MavinKurve et al.,2016). After selecting the cube, considering the size of the cube, the scale of the cube was worked on, the cube object was converted to Shading mode, and Material Properties were applied by activating the +new trigger button at the bottom of the mode screen.

Table 5: Apply a texture to the cube object

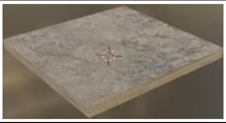
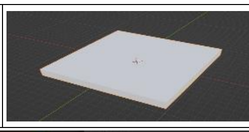
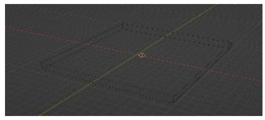
Object			
Material			

Table 5 is the texture applied to the Cube Object and worked in Layout - Edit Mode. In Eidt Mode, I selected the face of the cube object using Select Mode (Face select) and added a mesh by creating a curve in Bevel mode. Finally, I proceeded to modify the sharp edges into curves to adjust the Z-axis scale, and moved to Layout - Object Mode to additionally copy the cube object to which the bevel was applied. After scaling the copied second cube object using the method described above, it was placed to resemble the shape of the base of the original three-story stone pagoda of Bulguksa Temple in Gyeongju.

Table 5: Stone Pagoda Modelling

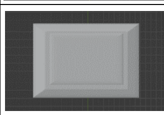
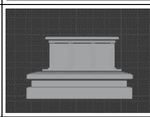
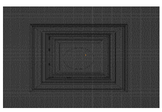
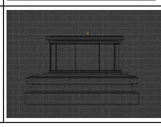
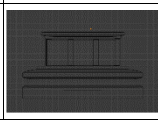
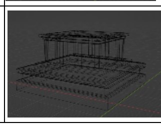
Div	Left	Right	Botton	Perspective
Texturing				
Shading				
Wireframe				

Table 6 is the result of the completed modeling work of the body of the three-story stone pagoda of Bulguksa Temple in Gyeongju. The body of the pagoda additionally models the universe, face stone, roof support, previous work, and udon, and works while checking the number of roof support during work. The three-story stone pagoda of Bulguksa Temple in Gyeongju has a total of 5 roof supports and the ends of the seals placed above have an upward shape. (After moving to Select Mode in Edit Mode, select Mesh. Implemented by moving the mesh in the z-axis).

Table 6: Stone Pagoda Seal Modelling

Div	Left	Right	Botton

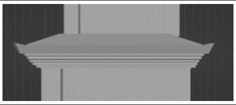
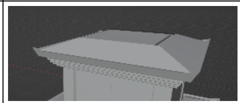
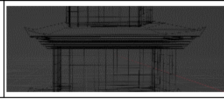
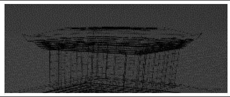
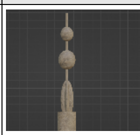
Texturing			
Shading			
Wireframe			

Table 7 is a 3D modeling of the bokbal, which was modeled based on a cube object. A cylinder object was created for the column located in the center of the beam, and the Z-axis Scale tool was used.The bolsters surrounding the pillars were created in the same way, scaled up and down in the Z axis, and then remade to be the same as the original. The three-story stone pagoda of Bulguksa Temple in Gyeongju consists of a total of five rings, and the orb located at the top of the rings was modeled after the scale of the UV sphere was reduced in the x-axis and enlarged in the z-axis.

Table 7: Stone Pagoda Seal Modelling

Div	Front	Top	Left	Right
Texturing				

The final 3D modeling file is exported for external use in the form of Export - OBJ. The exported 3D object file uses the Rendering function to adjust the light and direction(I. A et al.,2022;M. Ouza et al.,2017;G.V. Patil et al.,2016). As for the environment configuration, I modified the max samples value of sampling - render to 1024, changed the setting of Render Properties -> output Properties -> output location, and saved the file format as png. Now, the shortcut F12 of Render has been activated, and the finalized modeling is shown in Figures 7 and 8. Various types of files such as *.gltf, *,glb, *.obj, *.fbx are supported, and *.stl file is a format used for 3D printers.

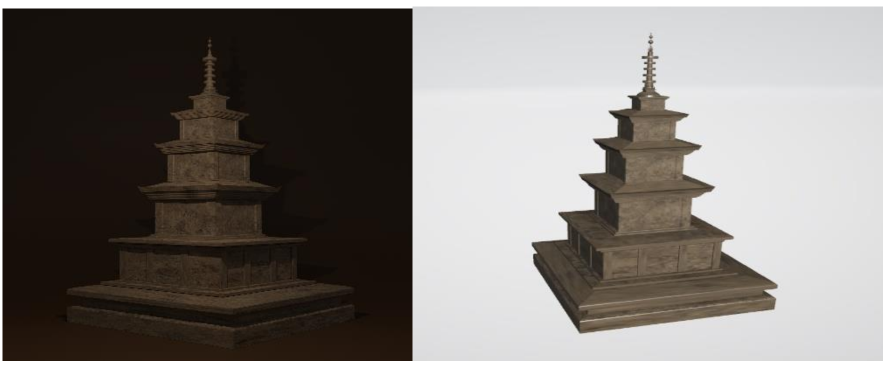
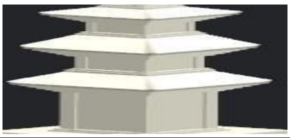


Fig. 2: Stone Pagoda Rander and Obj Export file

4. Result and Discussion

Table 8 is a 3D modeling of the original shape of the stone pagoda using a 3D scanner. It compares faces 16,499,292 and tris 11,852,734. Due to the large number of verts, faces and tris, AI training takes a lot of time. In order to compensate for these shortcomings, 3D modeling was performed in this study.

Table 8: Stone Pagoda made with 3D Scanner

Category	Existing pagoda made with 3D Scanner			
	image	verts	faces	tris
Sangryunbu		250,094	499,462	499,462
Tapshinbu		3,093,425	10,836,988	6,190,430
Gidanbu		2,583,180	5,162,842	5,162,842

In the study, a direct 3D model was created to improve the AI learning speed due to a lot of learning data. The total number of verts, faces, and tris of the stone pagoda produced in this paper is shown in Table 9 above. All verts, 8,326 faces, and tris 17,814 of the upper part, the body of the pagoda, and the base end were noticeably reduced.

Table 9: The newly created stone pagoda modelling

Category	Newly pagoda made with Blender tools			
	image	verts	faces	tris
Sangryunbu		5,511	5,103	10,766
Sapshinbu		3,654	2,954	6,580
Sidanbu		314	234	468

Table 10: Comparison between the created modelling and Scan modelling

Category	image	verts	faces	tris	full
Scan Modelling		5,926,699	16,499,292	11,852,734	36,957,363

Created Modelling		9,479	8,291	17,814	35,584

Table 10 compares modeling produced using a 3D scanner and stone pagoda modeling produced using a graphic authoring tool (Blender tool). Verts, faces, and tris were compared as targets for comparison. As a result of comparison, the total size decreased by about 1000 times from 36,967,363 to 35,584. The existing method takes a long time to learn artificial intelligence due to the large number of pages and a phenomenon in which learning accuracy is reduced occurs.

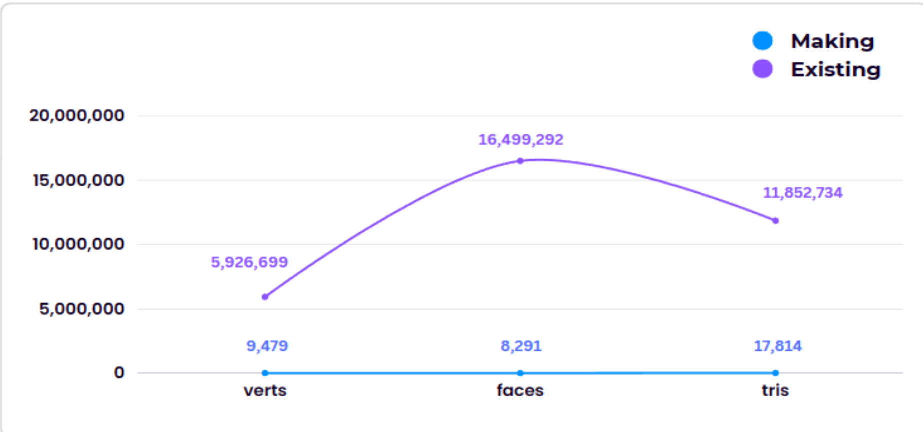


Fig. 3: Comparison diagram graph of generated modelling and existing

Figure 3 is a newly created modeling by reducing the number of vertices of the existing stone pagoda 3D model created through a 3D scanner.

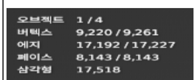
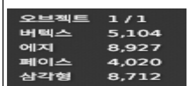
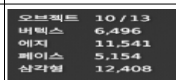
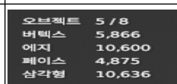
Table 11: Image of stone pagoda Modelling by Angle

Era		x-axis rotation				y-axis rotation			
		0°	15°	45°	80°	15°	40°	80°	120 °
gol yeo									
									
	In the Golyeo Dynasty, unlike the previous era, it was made of a polygon rather than a quadrangle, and the number of floors was made of several stone pagodas rather than three stories.								

SIlla	
	
	Silla's stone pagodas have not only become smaller, but there are also stone pagodas that are making great changes in their style. First, the number of stone materials decreased at the base, and the tangju of each side stone was simplified, and second, the number of support layers of roof stones on each floor is decreasing at the pagoda body.
Chosun	
	
	The overall size was reduced, the number of floors increased, and the base was simplified. It can be seen that the pagoda body stone of the pagoda body is lowered, and the roof stone is low.
Baekje	
	
	Baekje stone pagodas are characterized by a lower base than the pagoda body and a narrower base from side to side, and a wider roof stone from side to side than the base of the member.

Table 11 is a modeled stone pagoda, rotated by 0°, 15°, 45°, 80° on the x-axis and 15°, 45°, 80° and 120° on the y-axis. It was built based on representative stone pagodas from the Goryeo, Silla, Joseon and Baekje dynasties. Table 11 is a process of making 3D modeling by selecting representative towers for each era to suit the characteristics of each era. The Korean traditional tower models produced in this way were compared based on the number of vertices as shown in Table 12 so that they could be used in research. Through the number of vertices, you can see which towers have a complex structure, and you can learn about the structure of towers by era. As a result of comparing the number of vertices, the pagodas of the Goryeo Dynasty are generally monotonous, and the heights of the Silla Dynasty are lower, but they are complex structures as various styles and special-type stone pagodas are built. Also, in the Joseon Dynasty, the scale was reduced, and tall stone pagodas appeared mainly. During the Baekje era, it was confirmed that pagodas were built with excellent technology and proportions and balance.

Table 8. Model by Age Top Vertex

Era	Modeling Stone Pagoda	Modeling Image	Vertex
Golyeo Dynasty (高丽王朝)	Nine-story Stone Pagoda in Seojeong-ri, Cheongyang		 4,320
	Five-story Stone Pagoda in Wanggung - ri, Iksan		 1,827
Silla Dynasty (新罗王朝)	Gyeongju Bulguksa Three-story Stone Pagoda		 9,220
	Changnyeongsuljeongri-dong Three-story Stone Pagoda		 5,104
Joseon Dynasty (朝鲜王朝)	Yangyang Naksansa Seven-story Stone Pagoda		 6,496
	Hamyang Byeoksongsa Three-story Stone Pagoda		 5,866
Baek jae Dynasty (百济时期)	Iksan Mireuksaji Stone Pagoda		 3,382
	Jeongnimsa Five-story Stone Pagoda		 6,594

Most of the traditional pagodas in Korea produced by era showed that the number of peaks was different for each era. The number of pagodas composed of the top part, the body part and the base part was monotonous and constant in the case of the Goryeo Dynasty. In addition, in the case of the Joseon Dynasty, there were many tall towers, so the number of vertices and faces increased, and in the case of Baekje, it was more related to floors. Influenced by decoration, the tower had many additional aspects. In the study, Unity 2021 was used to organize the restoration and modeling work in this study by era.

After placing the modeling in Unity, I checked the modeling in virtual reality using VR equipment. Fig. 3 shows the Pagoda shape by era arranged in Unity and Web Publishing by Aframe Platform (B. Sheng, et al.,2017; L.Pan, et al.,2012).

Fig. 3: Modelling Result Using Unity and Web Publishing

5. Conclusion and Future Work

Currently, there is a lack of data on cultural properties in Korea, so 3D modeling is needed for restoration. In this study, the characteristics of pagodas by era were analyzed, and a 3D traditional pagoda, a graphic authoring tool, was designed and produced. Currently, most restorations using artificial intelligence are in the form of 2D images. In the case of 3D, the data-set for restoration is insufficient, and the complexity increases and the operation speed decreases due to the 3-dimensional restoration progress based on the three axes of X, Y, and Z, and research is insufficient. In addition, it is difficult to secure data based on past data for the current restoration. In this study, we proposed a way to secure a data-set necessary for artificial intelligence learning that is similar to the real thing for the tower in Korea. As a result of the study, the results of analyzing the number of vertices of Korean traditional pagodas by era are as follows. The Goryeo Dynasty had a simple tower structure and the number of vertices was small. In the Shilla Dynasty, as the number of floors decreased, the number of vertices was smaller than in other eras. The Joseon Dynasty had many vertices as a characteristic of high-rise buildings with splendor. In the Baekje era, the number of vertices increased as a feature of splendid decoration rather than the height of the number of floors of stone pagodas.

It is believed that the researched contents will be used as data for restoration that can be actively utilized in the restoration of Korean cultural heritage (Pagoda). It is considered that it can be actively utilized for building big data based on modeling derived from future research.

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