3D Approach for Moon Guitar Digitalization

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Abstract. Moon guitar (Chinese: Yueqin), also known as Yueqin, is a traditional Chinese String instrument. As the computer technology progress, 3D modeling is nowadays a common strategy to digitalize objects in real world. To meet the demand of protecting Chinese traditional instruments, building a 3D modeling for the moon guitar is chosen as a subject to study how can people attempt to digitalize Chinese traditional instruments. To build a complete 3D moon guitar model, the following steps are followed: 1) Geometry of the moon guitar: study and break down the geometry of the moon guitar, calculate the statistics of the moon guitar, create the broken-down components in openJSCAD, union all the components into a geometry, and finally a geometry of the moon guitar can be exported in multiple 3D model formats; 2) Texture of the moon guitar: study and break down the materials of the moon guitar, create the according materials in blender, create UV map for the imported moon guitar geometry, and apply the material to the matched faces. After the 3D modeling of moon guitar is implemented, an evaluation survey is conducted to evaluate the overall geometry and texture effect, and the details of the moon guitar. The analysis of survey reflects the 3D modeling looks good overall but still needs improvement on details.

Keywords: 3D; moon guitar; openJSCAD; digitalization.

1. Introduction

Moon guitar (Chinese: Yueqin), also known as Yueqin, is a traditional Chinese String instrument that handed down from Han Dynasty (202 BC – 9 ADS, 25–220 AD). It is a type of lute that has the following features: round and hollow soundboard (estimated 36.3 centimeter in diameter), a short and curvy neck, four tuning machines, four strings, and its length is approximately 62 centimeters. Moon guitar is often used as accompaniment for opera (especially Peking opera), folk music, and ensemble. It is also known as one of the three major accompaniments for Peking Opera bands. In short, moon guitar is a valuable member of Chinese traditional instruments that has a place in Chinese culture and history.

Digitalization is the process of transforming information into computer-readable/digital format. As it is an inevitable trend of the human world development and provides a reliable and convenient source of information preservation and recalling, it challenges many traditional industries. This is because their digital formats show up as strong competitors and alternatives which weaken the role of their physical formats. However, besides challenging traditional contents, digital world also offers new opportunities. As it is being stated in a journal article [1], those new technologies have the potential to support “comprehensive knowledge environment” for art. Music, as a form of vocal art, should has the same potential. Moon guitar, as a kind of instruments, a member of traditional Chinese instruments, and, more importantly, beauty of Chinese culture and human history, should be preserved, studied, and handed down to next generation, as we will never forget William Shakespeare’s Sonnet 18. Nevertheless, unless it starts to be digitalized, it has a risk of vanishing from humans’ life and being the forgotten.

As Sen, S., and Chakraborty, R propose in their journal article, creating a traditional knowledge library to protect their traditions and cultures, Chinese traditional instrument: moon guitar, can also be protect by transforming or digitalizing it into sort of knowledge [2]. The first and one of the most important steps of moon guitar digitalization is to digitalize moon guitar’s physical body into its digital format which is its 3D modeling. Create a precise version of moon guitar’s 3D modeling is meaningful and helpful as it assists traditional instruments protection and provides an extendable foundation for future development on the digital moon guitar. In order to achieve this goal, research will be conducted based on the following topics: structures of moon guitar, 3D modeling of moon guitar, and material of moon guitar.

2. 3D Modeling Design

There are many pipelines to reconstruct a 3D modeling, the one that Vrubel, A., Bellon, O., & Silva, L. use for digital preservation is a good example [3]. There are two key elements that can be concluded from their strategies: models' generation and texture generation. In order to digitalize the moon guitar, reproducing the moon guitar into a precise 3D modeling, the geometries and materials of the 3D model also need to be researched and defined. In the following section 3.1 and section 3.2, the structures and the texture of moon guitar will be studied and drew up. That information will be meaningful to the implementation of the moon guitar 3D modeling.

2.1. Structures of Moon Guitar

In order to provide reference for the precise 3D modeling implementation, the structure of Moon guitar need to be determined. Most components of the moon guitar are served for pronouncing mechanics of the moon guitar, so they need to be reproduced completely and accurately. One of the main functions of vision is to estimate the 3D shape of objects in our environment [4]. So, a vision (Figure 1) is being employed to help with studying the structure of the moon guitar.

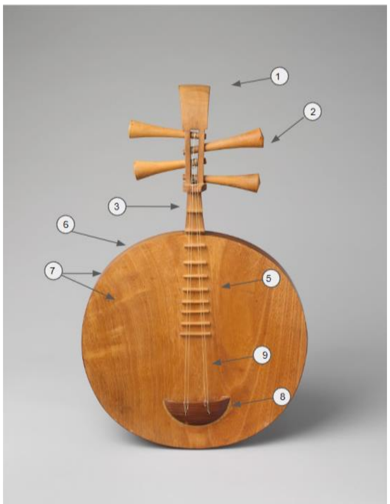

Fig. 1 Moon guitar with component numbers [5].

The structure of the moon guitar can be divided into two main parts:

- The body of moon guitar, including the cylinder soundboard, the outer ring coverage, and fuzi which is the arc shape connected the strings.

a. Soundboard

The soundboard is the cylindrical box that made up of two panels (7 from the figure 1) and the ring moon guitar frame (6 from the figure 1). The soundboard is the biggest component of the moon guitar. Its geometric shape is a cylindrical body. Since it is a soundboard, the inner part of the cylinder is hollow.

b. Fuzi

Fuzi (8 from the figure 1), also called Fushou, is the arc shape on the guitar body that connects the guitar strings.

c. The ring coverage

The ring coverage (6 from the figure 1) or the frame of the moon guitar, also known as Qinkuang, is the outer protective coverage that surrounds the soundboard.

- The upper part of moon guitar, including the guitar neck, the tuning machine, the guitar head with pearl white decoration, guitar strings, and horizontal strips, also called Ping in Chinese.

a. Guitar neck

The guitar neck (3 from the figure 1) is the rectangular strip shape handle which has a little bit curvy on its back. It is where moon guitar players support the moon guitar when they play this instrument.

b. Tuning machine

The tuning machine (2 from the figure 1) are the four waters drop shape geometries attached to the guitar head. They support the tuning mechanism of the moon guitar.

c. Guitar head

The guitar head (1 from the figure 1) is the flower-looked decoration in the figure. The decoration varies in different moon guitar, but it is essential component of moon guitar for keeping balance.

d. Guitar string

Guitar strings (9 from the figure 1) are the strings connected at the middle of the moon guitar. The important fact is the number of strings: 2 strings for 2 tuning machines, and 4 strings for 4 tuning machines. That is important to build a proper moon guitar 3D modeling.

e. Ping

The Ping (5 from the figure 1) are the short horizontal strips that evenly distributed from guitar neck to the guitar body.

2.2. Material of Moon Guitar

Fig. 2 Reference figure for moon guitar materials

The material of the moon guitar is important references for modeling a 3D moon guitar as it provides information about what textures should be applied to the 3D geometries.
The following materials are concluded from the figure 2.

1. Wood 1 (light): used for the soundboard
2. Wood 2 (dark): used for the guitar neck, tuning machines, and ring guitar frame.
3. Pearl white material: used for the guitar head and tuning machines decorations.
4. Wood 3 (light): used for the Pings.
5. Metal: used for the guitar strings.

3. 3D Modeling Implementation & Development

3.1. 3D Geometries Implementation

OpenJSCAD will be employed as a tool to create the 3D geometries for the moon guitar. The following operations will be used to create the desire moon guitar geometry:

The following A and B are geometries that created in OpenJSCAD which are able to be operated by operation commands.

1. A Union B (A.union(B)): the result is a geometry that unions geometry A and geometry B.
2. A Subtract B (A.subtract(B)): the result is a geometry using geometry A to subtract geometry B

3. A Intersect B (A.intersect(B)): the result is a geometry that is the intersection of geometry A and Geometry B.

In order to implement a precise 3D modeling of moon guitar, not only the name of different components of moon guitar need to be researched and captured, but also the operations of shapes and math of them need to be studied and defined. The following analysis will be about how those moon guitar components can be shaped by geometric shapes and what are the mathematical data of those components (Figure 3). (Since the data is used for 3D modeling, the actual length unit such as centimeter will be replaced by standard size for convenience.)

Fig. 3 Reference figure for the size of moon guitar

3.2. Soundboard

The soundboard is the biggest component of the moon guitar. Its geometric shape is a cylindrical body. Since it is a soundboard, the inner part of the cylinder is hollow. According to figure 3, the diameter of the soundboard is approximately 36.3 centimeters. In order to simplify the calculation and future implementation, the diameter of the soundboard will be defined as 36 times of a standard size, and since height is not standard in moon guitars, it is defined to be 5 standard sizes as an appropriate number (Figure 4). After acknowledging the required information, a moon guitar soundboard can be built by creating a cylinder geometry with the defined data.

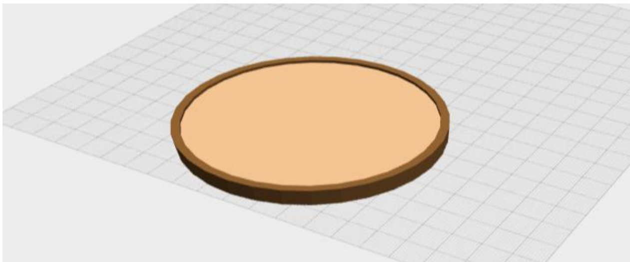

Fig. 4 Soundboard Geometry

3.3. Outer Ring

The Outer Ring is the protective outer coverage of the soundboard, refer to the moon guitar figures that are found, it has a thin thickness and the inner ring is attached to the soundboard. Thus, the Outer Ring will be a ring shape (subtraction of two cylinders) in which the inner diameter is 36 standard sizes, which is the same as the diameter of the soundboard, and the outer diameter is 38 standard sizes, slightly larger than the inner diameter. Both their height is 5 standard sizes, the same as the soundboard. The operation that will be performed is subtraction. By subtracting the inner cylinder by an outer cylinder with the same height, a ring is created (Figure 5).

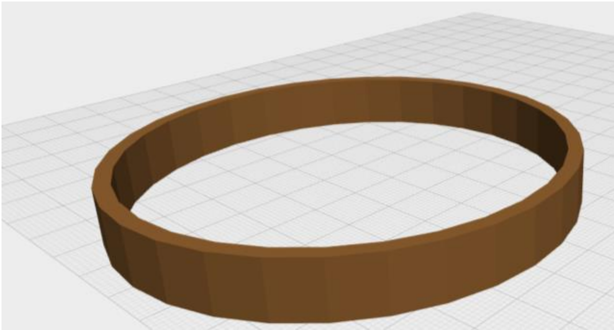

Fig. 5 Outer ring geometry

3.4. Fuzi

The Fuzi is an arc shape with no more concrete math data being found in documents. After processing through figure references, there are several things about Fuzi that can be found: 1) The arc is intercepted from a circle that is around one third of the soundboard diameter, of which its diameter is around 12. 2) The height of the arc is around one fourth of the diameter. By integrating these two pieces of information, the arc is defined to be intercepted from a 12-diameter cylinder and the height of the arc is 1.5 standard size. The height of the geometry is defined to be 0.5 standard size to create the expected thickness (Figure 6).

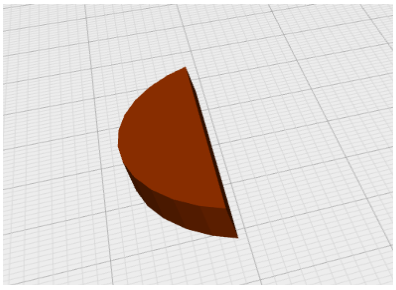

Fig. 6 Fuzi geometry

3.5. Guitar Neck

The guitar neck is a rectangular strip shape in the front, and it is curvy on the back side. To simplify the geometry, the shape of the guitar neck is defined to be a cuboid combining with the cylindrical back. Their math can be calculated from the reference figure. As the height of the whole moon guitar is 64 centimeters, and the guitar body is 38 centimeters, the length of guitar neck can be calculated as 64 centimeters minus 38 centimeters, which is 26 centimeters. The height of the neck is slightly smaller than the height of the body, which is an observable fact in reference figures, so its height is defined to be 5 minus 1 which is 4 standard sizes. The last step will be to define the width and diameter (which they are the same) of the cuboid and cylinder. After using the width of the guitar neck as standard and comparing it to the diameter of soundboard, it is known to be around one sixth of the diameter, so the width of the neck will be 6 standard sizes (Figure 7).

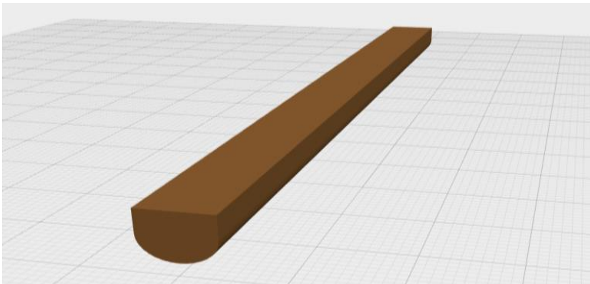

Fig.7 Guitar Neck Geometry

- Tuning Machine

The geometric shape of the tuning machine can be simplified into a cone union with a smaller proportion of guitar head. The exact shape of the guitar head will be defined later, but it is reasonable to prove that the diameter of the smaller guitar head is the same as the diameter of the cone. Then, only two numbers need to be determined: the height and diameter of the cone. The height is straightforward, as it can be compared to the width of the guitar neck and the result is around 12 standard sizes (Figure 8). The diameter is approximately equal to the height of the neck when it is being observed on the side. Thus, the diameter is 4 standard sizes.

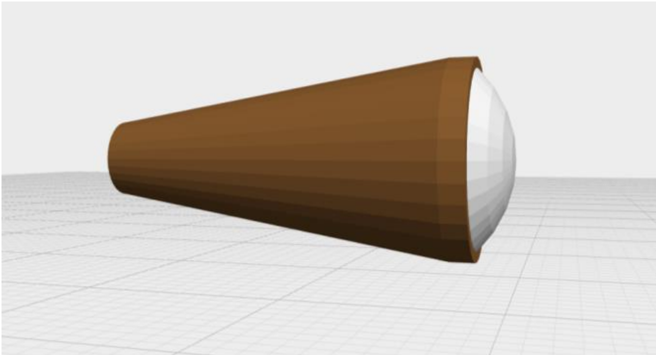

Fig. 8 Tuning Machine Geometry

- Guitar Head

The geometry of the guitar head is a cylindrical base union with part of a sphere. The basic operation that will be used here is union of a cylinder and a spherical shape. Cylinders can be created through simple commands, but to create a part of a sphere intersecting is the essential operation. By applying the intersect operation to a cube intersecting the upper part of a sphere, the expect geometry can be constructed. After acknowledging how to operate the geometry, the scale of those shapes needs to be defined. The diameter of the cylinder is around two times bigger than the width of the guitar neck, but still, it is smaller than the length of the tuning machine, whereas they share a similar height. Thus, its diameter is defined to be 10 standard sizes, and its height is 4. The base of the spherical shape has a diameter that is slightly smaller than the cylinder, so it is defined to be 9. Moreover, since the decoration is also slightly protruding from the cylinder surface, its height is defined to be 2 standard sizes (Figure 9).

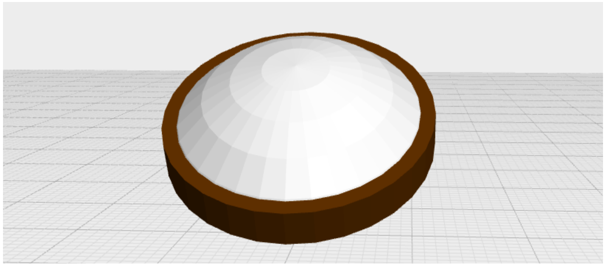

Fig. 9 Guitar head geometry

- Guitar String

The shape of the string is a cylinder only with a large height and small diameter. The diameter of these cylinders is around 0.1, so the cylinder will look like a string instead. Plus, the height of the cylinder is computable which is equal to the length of the neck plus the length of the radius of the soundboard which is 18 plus 26 equals 44 standard size (Figure 10).

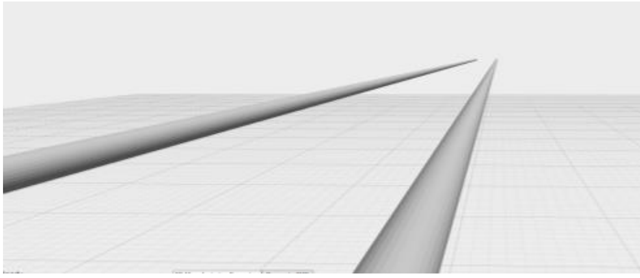

Fig. 10 Guitar string geometry

- Ping

The Pings are cylinders which have the same height as the width of the guitar neck, which is 6 standard sizes. And its diameter, which can be observed from the reference figure, is about half the width of the outer ring, so the diameter of the Ping is defined as 1 standard size.

After implementation of all eight components of the moon guitar, they can be unioned together to create the complete geometry of moon guitar (Figure 11).

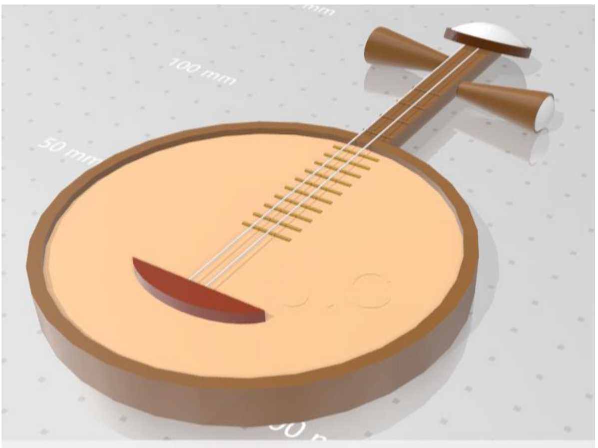

Fig. 11 3D Moon guitar in 3D viewer

3.6. Applying Textures to the 3D Geometries

After implementing 3D modeling of the moon guitar in OpenJSCAD, a 3D moon guitar modeling in the stl format can be exported. However, so far only have the geometry of the moon guitar is created. When it is being imported into blender, it is still a solid body in gray color without any texture information as Fig.12:

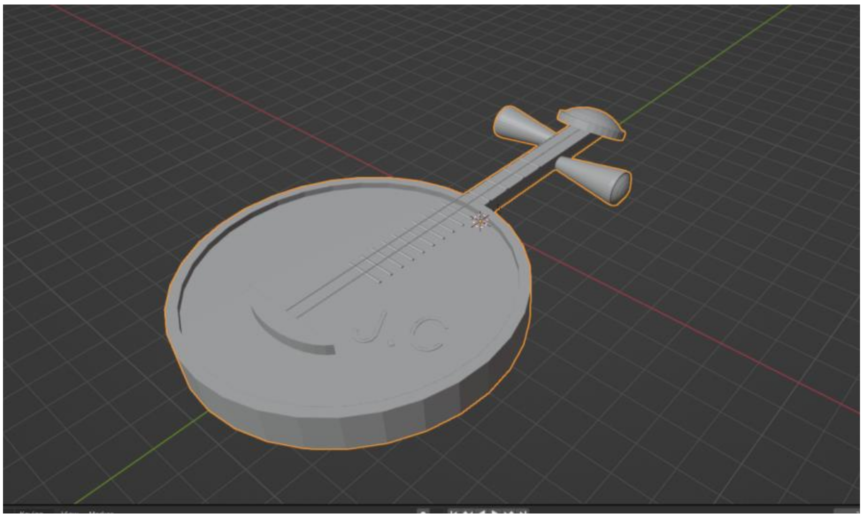

Fig. 12 Imported Moon Guitar 3D Model in Blender (1)

The geometries of the moon guitar are complicated and has a massive number of faces as Fig.13

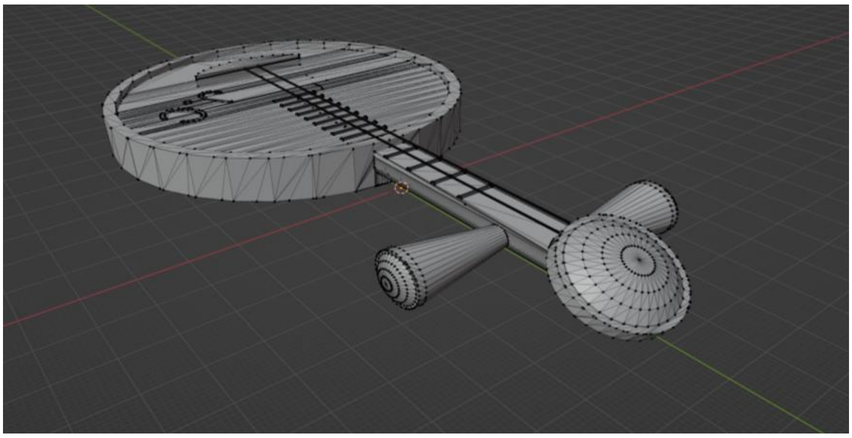

Fig. 13 Imported Moon Guitar 3D Model in Blender (2)

Thus, it is not proper to select multiple faces and directly apply materials to faces, since the tool has no instruction on how to apply texture, as consecutive patterns, to separate faces. From an article that explains how to visualize astgronomical data with blender [6], a technique called uv-unwrapping is being used. This technique helps people apply distinctive pattern to geometries instead of repetitive patterns which perfectly fits the project. By selecting the geometry and create according UV map as below, the geometry of moon guitar now has a UV map that tells the system how the pattern from the figure texture should be applied to those faces (Figure 14-15).

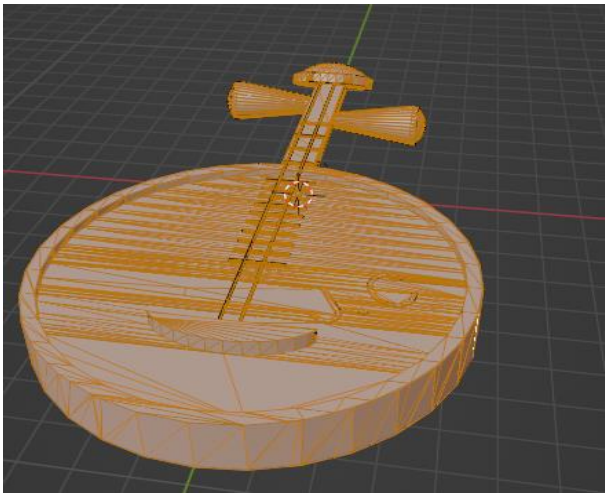

Fig. 14 Faces selection for Moon Guitar 3D Model

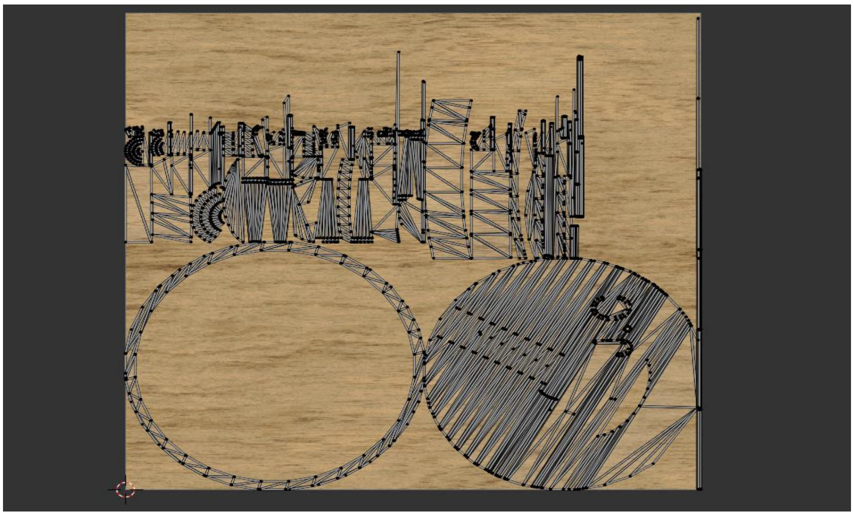

Fig. 15 UV Map for Moon Guitar 3D Model

The following step is to assign materials in section 3.2 to the according components of the moon guitar (Figure 16):

Wood (1) (light): used for the soundboard

Wood (2) (dark): used for the guitar neck, tuning machines, and ring guitar frame.

Wood (3) Pearl white material: used for the guitar head and tuning machines decorations.

Wood (4) Metal: used for the guitar strings.

(1) (2) (3) (4)

Fig. 16 Wood (1)-(4)

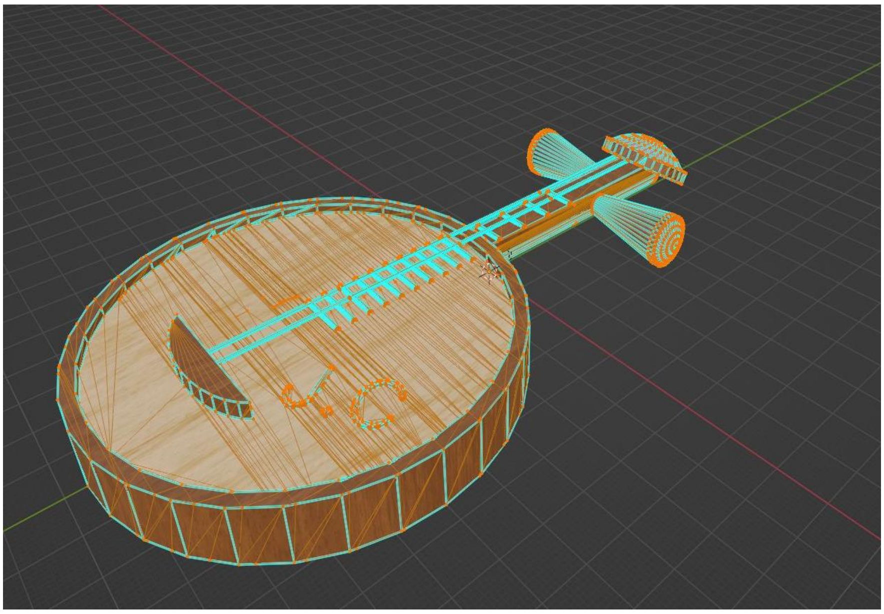

Fig. 17 Applying Material to Selected Faces

By the end, after all textures are applied to the moon guitar properly, a 3D modeling of moon guitar with correct material are implemented (Figure 18):

Fig.18 The Final Effect

4. Result

After the all the geometries and textures are being created and applied, a 3D modeling of the moon guitar is being created. In this session, its applications (5.1) and its evaluations (5.2) will be discussed.

4.1. The Application of The Moon Guitar 3D Modeling

- 3D viewer

(a) (b)

Fig. 19 (a) Online 3D viewer example example, (b) Microsoft 3D viewer example

The 3D modeling of the moon guitar can be exported into various 3D object types, such as obj, 3ds, stl, ply, gltf, glb, and they can be smoothly imported into most kinds of 3D viewer. For example, the above two figures are the example of moon guitar 3D modeling in online 3D viewer and Microsoft 3D viewer (figure 19). In this way, if any individuals or parties want to learn information about moon guitars or want to use the 3D modeling of moon guitar for any purpose, they can easily import the 3D moon guitar into their websites, their local viewers, or any other types of work. Especially for projects that are expecting to protect and preserve the moon guitar. For example, there is a concept of second life for museum [7]. In short, it is a digital scene of museum that is accessible online. If such a museum needs to exhibit a moon guitar, it definitely needs a 3D modeling version of it.

- Game Engine & 3D modeling engine

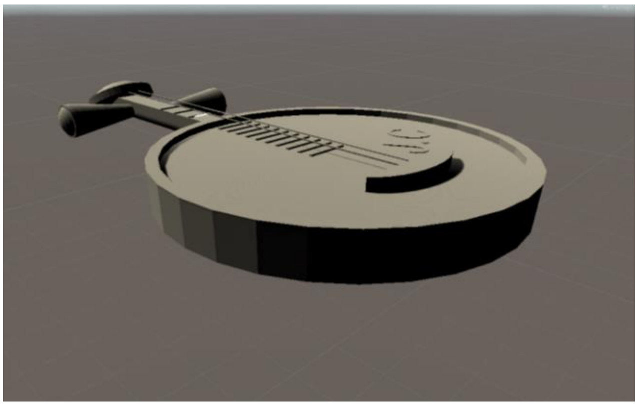

Fig. 20 3D modeling of the moon guitar in 3D Unity

The 3D modeling of the moon guitar can also be imported into 3D game engines and other 3D modeling engines (Figure 20). For example, the 3D moon guitar can be exported in the file type of fbx, which is the one exported with material information, and imported into 3D unity as an asset. This is also compatible with other game engines such as Unreal. Moreover, if any individual wants to extend or customize the 3D moon guitar, he/she can also import the 3D modeling into their own 3D modeling engine and launch the changes.

If game developers want to employ moon guitar as a content of their game, the 3D moon guitar is the proper resource. Plus, they can customize the 3D moon guitar to match their specific needs.

- 3D printer

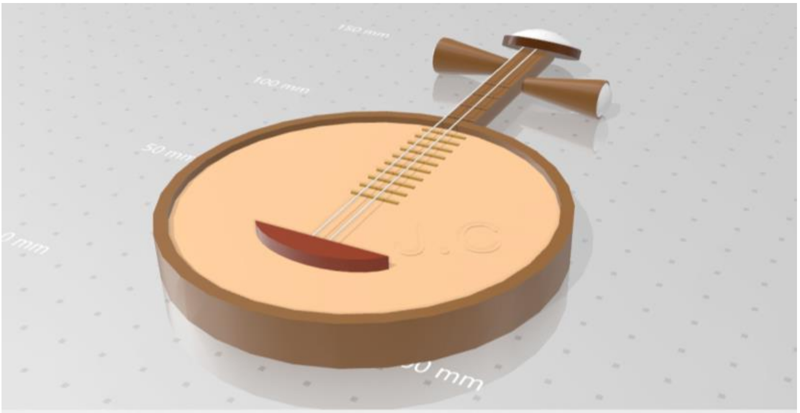

Fig. 21 3D moon guitar in print 3D

The 3D modeling of the moon guitar can also be printed in real life by the 3D printer (Fig.21). The figure in the example d is the 3D moon guitar in Print 3D. If people need a model of moon guitars instead of a moon guitar for some reasons, for example they only need to show what a moon guitar looks like, they can use a 3D printer to print out the 3D modeling in a relatively lower price.

4.2. Evaluation

The evaluation of the moon guitar 3D modeling will be based on two major aspects: geometry and texture, and two minor attributes: overall effect and details for each.
The figure 22 provides more views of the moon guitar 3D modeling:

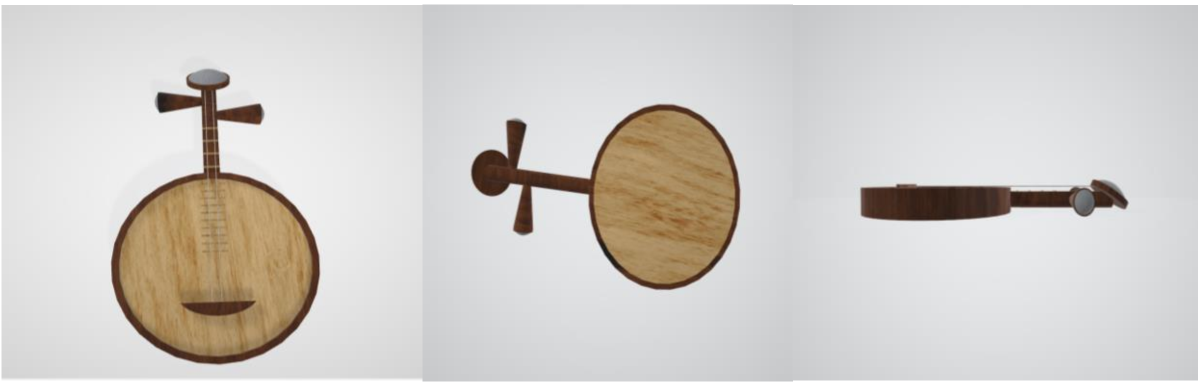

Fig. 22 The different views

The survey of evaluation is conducted on a population of 20 randomly selected people through oral presentations, the survey result is organized into the following table 1.

Table 1 The survey result

	Overall Geometry	Geometry Details	Overall Texture	Texture Details
Good	15	10	16	12
Medium	3	7	3	6
Poor	2	3	1	2

Based on the data above, several advantages and drawbacks of the 3D moon guitar can be concluded:

- Advantages

a) The overall geometry effect is good. 75% of participants think it is good.

b) In the 3D modeling design, the components that made up of a moon guitar is being researched and analyzed. Moreover, the statistics of those components are being calculated in the implementation. All these efforts contribute to the ultimate overall geometry effect.

c) The overall texture effect is good as well. 80% of participants think it is good. Only 5% of the participants think it is poor. The materials of the moon guitar are being studied in the design part. Plus, those materials of 3D moon guitar are selected face by face and applied distinctive textures to the according faces. The overall texture effect looks very similar to the real moon gutiars.

d) The details of the texture effect is decent. 60% of participants think it is good. The usage of UV Map helps the texture on multiple faces looks consecutive and coherent. As long as the material image is detailed enough, the detail effect of the texture should be no problem.

- Drawbacks

a) The details of the geometry effect need improvement. 50% of participants think it is not good (medium or poor). 15% of participants think it is poor.

b) The strategy that is being used to construct the geometry of the 3D moon guitar is conducting operations on multiple common solids (geometries such as cube, cylinder, and sphere) selections. It is good for creating a good overall effect but it also lacks details. "Mismatches between 3D models and real-world objects are quite common. It is impossible to Find the 3D model for every single instance of, say, a banana" [8-10]. The result may also vary for different impressions of moon guitars.

c) The details of the texture effect need improvement. 40% of participants think it is not good (medium or poor). Although materials on the moon guitar look coherent, they are still images that applied to selected faces in one time. It means that many details, such as the wood pattern, will not be exactly the same as the real subject.

5. Conclusion

This research paper employs openJSCAD as a 3D modeling tool to structure the geometry of a moon guitar, and uses blender to apply textures to the 3D moon guitar geometry. Building a 3D modeling of moon guitar is the process of digitalizing a traditional Chinese instrument to better protect humans' traditional cultures and histories. The survey reflects the overall effect of the moon guitar 3D modeling is good, though the details of geometry and texture are merely decent and need improvement. This can be labeled as a good start of the future development.

The future development of the moon guitar 3D development

The 3D modeling of the moon guitar is not the whole story of digitalizing the moon guitar. The 3D modeling of the moon guitar only reproduces the geometry and materials of what a moon guitar looks like. However, a real instrument can be played, can make sound, and has its history and culture behind its solid body. To fully implement the moon guitar in digital world, works need to be proceeded in the following two fields:

1) Reproduction of the animation of playing moon guitars.

2) Reproduction of the sound that can be made by moon guitars.

Some day in the future, when all works are implemented. People can access the complete moon guitar in the digital world.

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