Acta Technica *62* No. 1A/2017, 289–300

Research and application of virtual reality technology in the restoration of ancient buildings in Huizhou[1]

Jing Dong[1]

Abstract. This paper introduces the concept of virtual reality technology, current situation and future development trend, and the ancient buildings in Huizhou as an example, a detailed description of the specific process of virtual reality technology in the restoration of ancient buildings in the ancient buildings, including basic data collection, collation, 3D modeling, lighting, rendering and baking processing process and system debugging process, analysis of the specific application of virtual reality technology in the architectural restoration of the particular school of ancient, to provide some references to provide a theoretical basis and reference for the research and application of virtual reality technology in the restoration of ancient buildings in the implementation of virtual reality technology in the application of the restoration of ancient buildings in the city, in order to better promote the construction of and development.

Key words. Virtual reality technology, Huizhou architecture, VR rendering, 3DMAX.

1. Introduction

Virtual reality technology is a hot research topic at present. Virtual reality technology can realize the three-dimensional visual environment, auditory effects, three-dimensional, friendly interaction, and many other functions, so that the past exists only in the two-dimensional plane of the object can be presented in three-dimensional form, at present, virtual reality technology has been applied in many fields such as architectural design, industrial design, communication, aerospace and so on.

Based on the principle of virtual reality technology and the starting point, J. Wang explored the application of virtual reality technology in the visual and urban planning, it provides a real, objective and effective reference value for the user to provide the user with a real, objective and effective design, and it provides a lot of reference for applying the virtual reality technology in the field of urban planning

[1]School of Liberal Arts, Xi'an University of Finance and Economics, 710100, China

[1]. X. Yu pointed out that the virtual reality technology can not only be used in the traditional manufacturing industry, but also has a great application value in disaster protection engineering, for example, in the emergency drill, it is not needed to put a lot of manpower and material resources to imitate the disaster scene, it can be through the virtual scene to do some man-made accidents, this not only can save costs, but also can ensure personnel safety to the greatest degree [2]. Through the analysis of the application of computer network technology in the ancient Greek theater restoration project, C. J. Liu points out that virtual reality technology can not only realize the restoration of monuments, but also can achieve its permanent preservation and resource sharing, virtual reality technology can make quick access to the information industry of Archaeology and Museology Era [3]. D. L. Jia and others proposed the application of virtual reality technology in geographical science, which can meet the development needs of digital city technology from 2D GIS to 3D virtual reality visualization, such as high-definition Google maps street view is the application of 3D visualization map currently which is used most widely, is most famous, and has most of the audience [4]. H. U. Feng-Lian pointed out the application of virtual reality technology in mechanical manufacturing industry, it can greatly shorten the equipment manufacturing time, simplify the manufacturing process, ensure the accuracy of parts manufacturing, installation, shorten the design cycle, and improve the reaction ability of the market [5].

In this paper, the definition of virtual reality technology, the specific operation process in the restoration work of ancient architecture, and the realization of the algorithm are introduced, taking the Huizhou architecture as the research object. The restoration of ancient buildings was implemented successfully, a certain reference value for the restoration of ancient buildings in the virtual reality technology was provided, and a new case for the virtual reality technology in the field of architectural design was provided.

2. State of the art

2.1. Virtual reality technology

Virtual reality is an advanced intelligent human computer interaction technology based on the characteristics of immersion, interactivity and imagination. It uses the computer software modeling, the plane two-dimensional drawings three-dimensional, simulation, and finally generates a realistic 3D virtual 3D scene model. Experience person use certain devices, such as VR glasses, to achieve real-time interaction with the scene model, and generate the same feedback as the real world, this makes people no longer on the scene only two-dimensional sense, but a three-dimensional, realistic. Virtual reality technology is widely used in communication, architectural design, urban planning, network games, product simulation and other fields. As shown in Fig. 1, it is the application of virtual reality technology in the interior design. The application of virtual reality technology in the restoration work of ancient architecture cannot destroy the original building site, but also restore the real ancient buildings. This will not only give people an immersive sense of reality,

but also can store the history of building information stored in the computer, through the transmission of the mobile network, so that people can also travel to the building within the building [6].

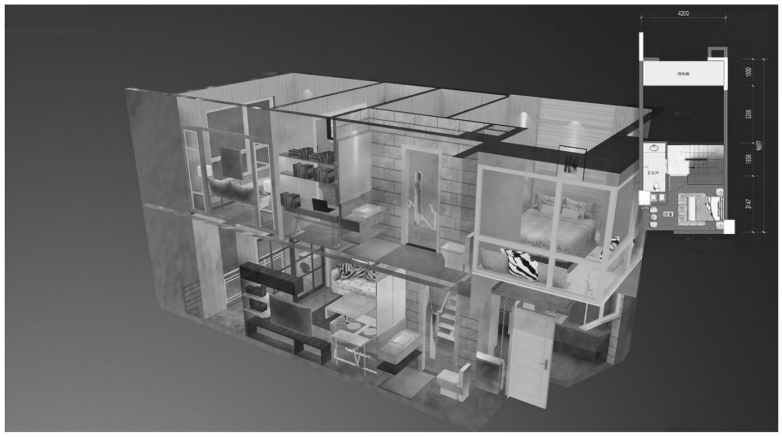

Fig. 1. Application of virtual reality technology in interior design

2.2. The process analysis of computer virtual reality technology in the digital restoration of ancient buildings

In the use of virtual reality technology for restoration of ancient buildings, the first work should be done to restore the work of the project, this need to collect information and data collection, and draw the plan. The parties involved in the restoration work of ancient buildings are designed and repaired on the basis of the ancient architectural sites, the repair work of ancient buildings need to meet the needs of history, aesthetics and other aspects in line with the historical appearance, in the early stage, historians also should strengthen communication with other historians to ensure the scientific nature and rationality of the design scheme. The preliminary planning work includes: Engineering surveying, ancient photo shoot, graphic drawing, ancient building repair technique to determine the repair, software selection, computer configuration setting, restoration of ancient buildings display and display device, virtual ancient architecture of the size, resolution, clarity and other factors.

The construction of ancient architecture determines the difficulty of restoration work. The building process of the 3D model of the ancient building is the process of restoring the ancient building system by using the virtual reality technology. Through the data collection and sorting of project planning work, this stage bases on its basis, using model to make software, for example, the establishment by using models of 3DMAX and other ancient buildings. After the completion of the ancient architecture model, the complex model needs to be optimized and designed, which is used for real time rendering, scene rendering, image rendering, and so on. And this need to control the distance between the elevation model, scheduling model in architecture, scene and other equipment to ensure the appearance of the scene, the

density of the important scene can be cut, in order to reduce the memory, and reduce the system pressure. After completing the above steps, it needs to make the scene map, light and baking process. This step has the significance that ancient buildings through the wind and rain erosion, wall color, pattern and detail components are incomplete and damaged to different extent, scene mapping, processing and baking processing effect are the results of using modeling software, this can realize the construction model in the natural light under the shadow processing and daylight effect, can map the form of virtual interactive software, and can get a better sense of reality and the improvement of the art. Ancient architecture 3D model establishment, rendering and baking all completed, followed by archaeologists, architects and other professionals to make corrective recommendations, according to historical data, determining the architectural style, details and other factors, to ensure the authenticity and artistry of ancient building model, adjusting the rectification, finally getting the draft of the restored model.

Virtual roaming refers to the establishment of a virtual character model, importing virtual environment, users can interact through the module, through the mouse, keyboard or other control keys, to move the virtual character in the virtual change of the upper and lower, this establishment of this step can be used by the user to obtain a more intuitive, three-dimensional experience of the building.

The latter part of the virtual reality technology is to test, adjust and improve the system. The main purpose of the system testing is to test the stability of the model, the compatibility of the system, and the requirements of the equipment configuration, the ability to successfully transplant to other equipment and run the test. The main contents include: the operation model of computer detection test of different hardware configurations, inviting users to try different education model, operating model under different operating platform, and crossing the three categories of the above test. Through testing, we can find problems, solve problems, and ensure that people with different levels of education can easily operate the model to achieve virtual roaming.

2.3. The characteristics of Huizhou ancient architecture

Huizhou architecture is an important part of China's architectural style, Huizhou culture is one of the three major regional cultures in china, Huizhou people pay attention to the attitude of no mountain and water cannot form a home. Therefore, Huizhou architectures emphasize the integration of the living environment and the natural ecological environment and ecology, being situated at the foot of a hill and beside a stream becomes a typical feature of Huizhou architectures.

3. Methodology

3.1. Realization process of virtual reality technology

As shown in Fig. 2, it is the process of achieving the virtual reality technology of building. According to Fig. 2, in the whole process of the realization of building

a virtual reality, aerial photography, the photography and other modes should be used to collect building, the image data can be obtained through the photography scene in the city side of the building; the recognition of buildings can be realized by aerial image technology, and it can be separated from the surrounding trees and other natural environment; by collecting the data of buildings, after the aerial image edge information extraction of three-dimensional 3D information and building body, we can start the construction of three-dimensional model building by using the three-dimensional information. In the use of virtual technology to restore ancient buildings, urban planning applications, usually require the building to rebuild the model as close to reality as possible, with a sense of reality, and therefore it needs to map the model information. Map baking technology is the key to the restoration design of ancient architecture, so in the specific modeling process, we should pay special attention to it. Because of the large scale of ancient buildings, more details, with a large number of data, so in order to meet the requirements of the virtual reality repair work, it is necessary to deal with the data processing, detail planning and so on; secondly, the model should be classified and corrected in order to achieve the effect of real recovery.

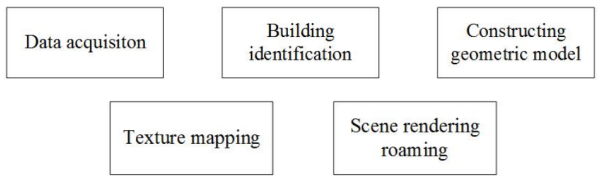

Fig. 2. Realization process of building virtual reality

3.2. Collection of data on restoration of ancient buildings

The sampling point set collected in the collection of data of buildings through aerial photography, ground photography and many other ways is called point cloud $p_i = (x_i, y_i, z_i)^t$. Supposing that the n data points which describe an elevation of the building model are $p_i = (x_i, y_i, z_i)^t$, $1 \leq i \leq n$, and the bounding set $x_{\min} \leq x \leq x_{\max}$, $y_{\min} \leq y \leq y_{\max}$ of the entire point set after traversing all data points can be obtained. In the formula, $x_{\min}$ and $x_{\max}$ are the minimum and maximum values of the point cloud coordinate x, respectively; similarly, $y_{\min}$ and $y_{\max}$ are the minimum and maximum of the point cloud coordinate y. Then the length of the grid element can be calculated, and the formula is

$$\text{size} = \sqrt[3]{(x_{\max} - x_{\min})(y_{\max} - y_{\min})(z_{\max} - z_{\min})/n} \tag{1}$$

The number of grid cells in the three directions x, y, z are, respectively:

$$\begin{aligned} x_{\text{res}} &= \left[\tfrac{x_{\max}-x_{\min}}{\text{size}}\right] + 1, \\ y_{\text{res}} &= \left[\tfrac{y_{\max}-y_{\min}}{\text{size}}\right] + 1, \\ z_{\text{res}} &= \left[\tfrac{z_{\max}-z_{\min}}{\text{size}}\right] + 1, \end{aligned} \tag{2}$$

Each data point in cloud p_i is put into a grid cell (u, v, w), among them:

$$\begin{aligned} u &= \left[\tfrac{x_i-x_{\min}}{\text{size}}\right] + 1, \\ v &= \left[\tfrac{y_i-y_{\min}}{\text{size}}\right] + 1, \\ w &= \left[\tfrac{z_i-z_{\min}}{\text{size}}\right] + 1. \end{aligned} \tag{3}$$

As far as there are duplicate points p_i in the cloud, p_i can be ignored.

Suppose that the plane S represents a plane with a boundary and there is a field which is homeomorphic with open disk $D^2 = \left\{x \in R^2 | \, \|x\| < 1\right\}$, in which, R is the unit circumference. At the same time, there is a field on the boundary point of plane S, which is homeomorphic with half circular disc $D^2 \cap H_+^2$ in which the half space $H_+^2 = \left\{(x, y) \in R^2 | x \geq 0\right\}$ and R in the formula is the unit circumference. The set of all boundary points constitutes the boundary of the plane S.

The complete least square plane fitting point set $N(p)$ is used to establish a local plane coordinate system OXY is established in the fitting plane, and the projection $\bar{p}'$ of $\bar{p}$ in the plane is taken as the origin O, where

$$\bar{p} = \frac{1}{k} \sum_{i=1}^{k} p_i \, .$$

The X axis and Y axis are the feature vectors e_1 and e_2, which correspond to the maximum and secondary eigenvalues of scatter matrix S, respectively.

Each point $p_i, \ 1 \leq i \leq k$ in $N(p)$ is projected onto the fitting plane, then the coordinates of the projection $p_i^{'}$ in the local plane coordinate system are, respectively

$$S = \sum_{i=1}^{m} (p_i - \bar{p})(p_i - \bar{p})^{\mathrm{T}} \, . \tag{4}$$

$$\begin{aligned} x_i^{'} &= e_1^{'}(p_i - \bar{p}), \\ y_i^{'} &= e_2^{'}(p_i - \bar{p}). \end{aligned} \tag{5}$$

Then, the origin of the local plane coordinate system is translated to the projection p' of the point p, so that a new local plane coordinate system $O'X'Y'$ is obtained, the polar coordinates (r_i, α_i), of each projection point are calculated $0° \leq \alpha_i \leq 360°$ and all projection point are sorted according to the order of angles from small to large. The maximum difference β between the two adjacent α_i is found, and the

boundary probabilities of point p_i can be expressed by the following formula:

$$\text{angle}\Pr(p_i) = \min\left(\frac{\beta - 2\pi/k}{\pi - 2\pi/k}, 1.0\right). \tag{6}$$

The formula for the boundary probability value of point p_i on the basis of the half disk metric algorithm is

$$\text{halfdisk}\Pr(p_i) = \min\left(\frac{3\pi\,\|\bar{p}' - p'\|}{4\bar{r}}, 1.0\right), \tag{7}$$

in which,

$$\bar{r} = \frac{1}{k}\sum_{i=1}^{k} r_i$$

and the distance between the barycenter and the center of half circular disc with the radius of $\bar{r}'$ is

$$\frac{4\bar{r}}{3\pi}$$

.

The boundary probability value of p_i is determined as follows by shape measurement method: the scatter matrix S of $N(p_i)$ describes the three-dimensional shape of the approaching $N(p_i)$ and its shape can be determined by three eigenvalues. According to the characteristic values $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq 0$ and their eigenvectors e_1, e_2, e_3, the scatter matrix S can be expressed as $S = \lambda_1 e_1 e_1^{\mathrm{T}} + \lambda_2 e_2 e_2^{\mathrm{T}} + \lambda_3 e_3 e_3^{\mathrm{T}}$. The three eigenvalues are normalized to form a judgment vector

$$(\lambda_1', \lambda_2', \lambda_3'),\ lambda_i' = \frac{\sqrt{\lambda_i}}{\sqrt{\lambda_1} + \sqrt{\lambda_2} + \sqrt{\lambda_3}}, i = 1, 2, 3\,.$$

Therefore, the probability formula of the point p_i belonging to the boundary point can be expressed as:

$$\text{shape}\Pr(p_i) = \min\left(\frac{(\lambda_1' - \lambda_2')(\lambda_2' - \lambda_3')}{1/9}, 1.0\right). \tag{8}$$

The classification is carried out on the basis of Table 1.

Table 1. Judgment vector of characteristic points

Characteristic value	Judgment vector
Interior point	$\lambda_1' \approx \lambda_2' \gg \lambda_3'$
Corner or noise point	$\lambda_1' \approx \lambda_2' \approx \lambda_3' \approx 1/3$
Points on a straight line	$\lambda_1' \approx 1,\ \lambda_2' \approx \lambda_3' \approx 0$
Boundary points	$\lambda_1' \gg \lambda_2' \gg \lambda_3'$

Based on the above three calculation methods, the probability that the calculated

point p_i belongs to the boundary points is

$$\Pr(p_i) = \frac{1}{3}(\text{angle}\Pr(p_i) + \text{halfdisk}\Pr(p_i) + \text{shape}\Pr(p_i)) . \tag{9}$$

Point cloud is used as the vertex set V of $G = (V, E)$ and the local adjacency relation of the points in the point cloud set is taken as the boundary point set E of the planar graph G, so the weight formula of the boundary line (p_i, p_j) of a planar graph is

$$w(p_i, p_j) = \frac{\Pr(p_i) + \Pr(p_j)}{2 * d(p_i, p_j)} , \tag{10}$$

where, $d(p_i, p_j)$ is the Euclidean distance between the two points.

The weight of an arbitrary section of a planar graph G is defined as $w(C) = \sum_{(u,v)\in C} w(u, v)$, and the closed curve with the largest weight is the largest circle.

The perfect matching value M of a planar graph is a subset of its set of edges, and each vertex of the planar graph has only one associated boundary line that belongs to M. The weight of perfect matching M is defined as $w(M) = \sum_{(u,v)\in M} w(u, v)$, and the perfect matching with the maximum weight is called the maximum perfect matching.

3.3. Calculation of the vector of point cloud data

Set plane equation as $ax + by + cz + d = 0$, $a^2 + b^2 + c^2 = 1$, normal vector is defined as $n = (a, b, c)'$, fitting point cloud data set as $\{p_1, p_2, \cdots, p_k\}$. Among $p_i = (x_i, y_i, z_i)'$ the least square method is used to calculate the distance between the surface point and point of the surface

$$E(a, b, c, d) = \sum_{i=1}^{k} (ax_i + by_i + cz_i + d)^2 . \tag{11}$$

Formula (11) meets the minimum value $\frac{\partial E}{\partial d} = 2\sum_{i=1}^{k}(ax_i + by_i + cz_i + d) = 0$, hence $d = -(a\bar{x} + b\bar{y} + c\bar{z})$. Let $\bar{u} = \frac{1}{k}\sum_{i=1}^{k} u_i$. From formula (10) we obtain

$$E(a, b, c, d) = \sum_{i=1}^{k} [a(x_i - \bar{x}) + b(y_i - \bar{y}) + c(z_i - \bar{z})]^2 = |U_n|^2 . \tag{12}$$

Here,

$$U = \begin{pmatrix} x_1 - \bar{x} & y_1 - \bar{y} & z_1 - \bar{z} \\ \cdots & \cdots & \cdots \\ x_k - \bar{x} & y_k - \bar{y} & z_k - \bar{z} \end{pmatrix} .$$

.

The minimum singular value U corresponds to the unit vector $n = (a, b, c)'$.

4. Result analysis and discussion

According to the third section of the image point cloud acquisition and location, the location of the plane map stitching algorithm, in this chapter, we designed a virtual reality restoration system based on the image of the ancient buildings. The system uses the C++ Visual language programming, combines with 3DMAX, Photoshop and Unity3D software combination, finally the program is applied to the restoration process of ancient architecture in Huizhou and achieved good results.

Huizhou ancient building restoration processes are as follows: First, collecting data of drawing plane graphics, as shown in the figure, according to the model plane and aerial data, as shown in figure, the map is a map rendering effect, the final completion of the map. It can be seen that the use of virtual reality technology to restore ancient buildings can achieve very good visual effect.

Figures 3 and 4 show the use of computer virtual reality technology. Virtual reality technology through the interaction of the way, you can simulate the restoration of ancient buildings, and it does not produce any two damages. Virtual reality technology in the record of the cultural heritage monomer at the same time, you can also save the surrounding environment together. The application of virtual reality technology, makes the building is no longer alone in a fixed place, and you can share in the computer equipment through the mobile network, so that people do not have to go personally, you can feel the magnificent grand buildings. The emergence and application of virtual reality technology can be stored and spread in a digital way. Virtual reality technology is the technical guidance and support after the ancient restoration work, it plays a decisive role.

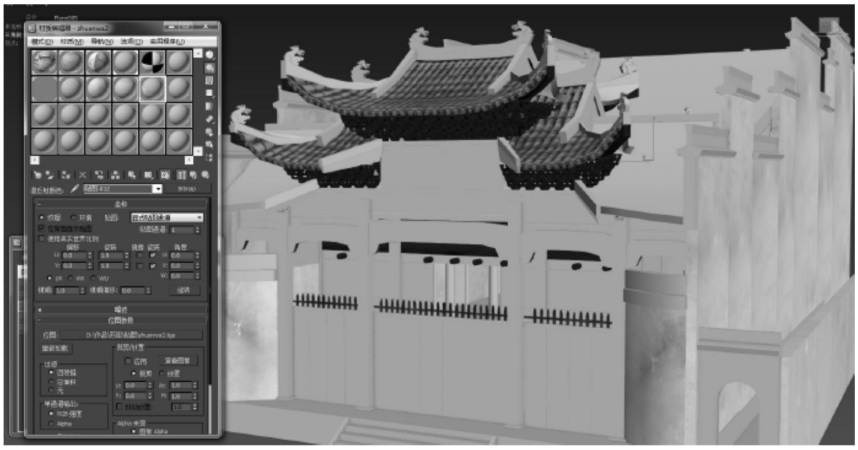

Fig. 3. Map processing

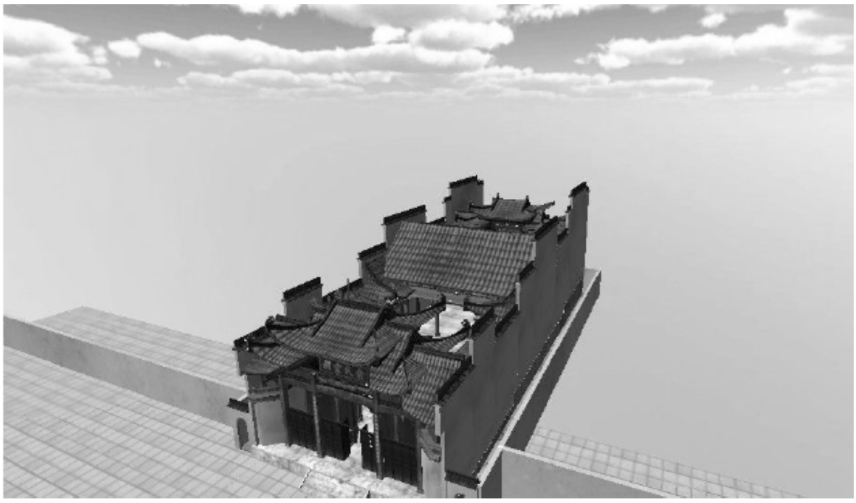

Fig. 4. Final effect charts

5. Conclusion

In this paper, the concept, current situation and future development trend of virtual reality technology were introduced, the application of virtual reality technology in the restoration work of ancient buildings was introduced, and the description of the virtual reality technology in the restoration of ancient buildings of the specific process was described carefully, the basic data collection, arrangement, the establishment of three-dimensional model, the model of light and shadow, rendering, baking, and the system debugging process were introduced. After introducing the basic algorithm of modeling, this paper took the Huizhou architecture as the research object, and the Huizhou architecture of the repair process. It is proved by an example that the application of virtual reality technology in the restoration of ancient buildings, it provided some reference suggestions for the application of virtual reality technology in the restoration of ancient buildings, and provided some technical support for the future research and application of virtual technology in the restoration of ancient buildings.

With the development of virtual reality technology, the rising and the extensive use of virtual reality technology, using virtual reality technology to demonstrate the performance of architectural design and housing design have become more and more popular among the people. The rapid development and experience of VR technology in architectural design also provide a lot of reference opinions to the restoration of ancient buildings, and reduces the design risk. However, the virtual reality technology in our country is still in the beginning of the stage of research, restoration of ancient buildings now needs to put energetic research to get more and better applications. This paper studied conditions and equipment constraints, only the Huizhou architecture is the appearance of a general repair, Huizhou architecture constructions are exquisite, many details of the decoration processing are not repaired, and

we look forward to having further studies.

References

[1] J. Wang: *Research on application of virtual reality technology in competitive sports.* Procedia Engineering *29* (2012), 3659–3662.

[2] X. Yu: *Research and practice on application of virtual reality technology in virtual estate exhibition.* Procedia Engineering *15* (2011), 1245-1250.

[3] C. J. Liu: *Research on application and development of competitive sports simulation based on virtual reality technology.* Advanced Materials Research *179–180* (2011), 1063–1068.

[4] G. Peng, G. Wang, W. Li, H. Yu: *A desktop virtual reality-based interactive modular fixture configuration design system.* Computer-Aided Design *42* (2010), No. 5, 432–444.

[5] R. Moreno: *Does the modality principle hold for different media? A test of the method-affects-learning hypothesis.* Journal of Computer Assisted Learning *22* (2006), No. 3, 149–158.

[6] C. Z. He: *The application of computer virtual reality technology in ancient buildings digital restoration.* Journal of Guangxi University for Nationalities (Natural Science Edition) (2013), No. 02, 15.

Received May 22, 2017