ISSN: 2690- 912X

Research Article

Journal of Genetic Engineering and Biotechnology Research

Digital Restoration and 3D Printing of Porcelain - A Case Study of Double-Ear Clashing Color Vase with Lotus Design

Jie Lv, Jingjing Fu*

Anhui Wenda University of Information Engineering, Hefei 230026, PR China

***Corresponding Author**
Jie Lv, Anhui Wenda University of Information Engineering, Hefei 230026, PR China.

Submitted: 02 Dec 2022; **Accepted:** 06 Dec 2022; **Published:** 24 Jan 2023

Citation: Lv J, Fu J.* (2023). Digital Restoration and 3D Printing of Porcelain - A Case Study of Double-Ear Clashing Color Vase with Lotus Design. *J Gene Engg Bio Res*, 5(1), 14-19.

Abstract

Porcelain is a precious historical and cultural heritage of China and the world as a whole as well as a treasure inherited from ancient Chinese art. Nevertheless, due to human activities, environmental changes and other factors, a multitude of porcelain cultural relics are undergoing destroy. Therefore, how to use modern science and technology to effectively inherit and protect this precious cultural heritage has become a major concern in human society. Digital protection of porcelain has attracted a board attention with the progress of 3D scanning modeling and 3D printing technology. Double-ear clashing color vase with lotus design is an elaborate Qing Dynasty porcelain unearthed in Anqing City, Anhui Province. Unfortunately, the bottleneck is defective, but its artistic value can be restored via 3D modeling, digital repair and 3D printing. This study attempts to display more historical information on this double-ear clashing color vase by 3D modeling and 3D printing technology, and to unveil the historical connotation behind this cultural relic.

Keywords: Porcelain, Double-ear Clashing Color Vase with Lotus Design, Digital Restoration, 3D modeling, 3D printing

Introduction

Porcelain ware is a precious historical and cultural heritage of our country and the world, as well as a treasure of ancient Chinese art. Due to human activities, environmental changes, natural disasters, conservation capabilities etc., many cultural relics are undergoing rapid destruction and disappearance in an irreversible manner. Hence, the application of modern science and technology to effectively inherit and protect this precious cultural heritage for better inheritance of human civilization has emerged as a problem requiring collective measures of all humankind [1-3]. In general, a large number of damaged cultural relics can be unearthed in archaeological excavations; especially it has rarely seen that the wares and ornaments of porcelain are well preserved. To complete the restoration of cultural relics by traditional working methods, series cumbersome restoration procedures should be finalized such as recording, numbering, storing, measuring, drawing and splicing. The progress of restoration will be affected in face of a large number of fragments or complex ornamentation of cultural relics. Sometimes the improper restoration will even cause secondary injury to cultural relics. Consequently, the traditional means of restoration is unable to satisfy the need of conservation restoration of cultural relics any more. How to provide new methods and support for the protection of cultural relics with the application advanced technology has become a major challenge over the years.

With the advancement of cartographic technology, 3D scanning modeling and computer application science, digital protection of cultural relics has been practical applied. For instance, the project of "computer storage and reproduction system of endangered precious cultural relics information" undertaken by Dunhuang Research Institute has realized the preservation of cultural relics information of Dunhuang murals and similar cultural relics. The digital Imperial Palace project, implemented by The Palace Museum in partnership with Japan's letterpress Co., Ltd., allows people to travel across time and space in "the digital Imperial Palace", making it a reality to visit the Palace Museum without leaving home. The virtual appreciation and restoration system of Dunhuang grottoes developed by Zhejiang University has achieved the actual scene visit of the cave murals by vividly reproducing the site on the computer [4]. However, the above cases still focus on digital image generation and virtual display, while the more crucial original 3D data and texture information in the protection of cultural relics are not sufficiently studied, which compose of the key part in 3D digital model. Foreign scholars have yielded some research results and relevant accumulation in the digital protection of cultural relics such as three-dimensional information retention of cultural relics and high-precision three-dimensional modeling of cultural relics, which makes it possible to digitize the protection of related cultural relics based on high-precision 3D models [5]. Stanford University in the United States is a case in point, it adopted laser rangefinder to digitize Michelangelo statues; Canada developed a NRC's 3D imaging system to collect raw data from cultural relics and art galleries [4]. K a Robson Brown and so on applied 3D laser scanning and modeling software to build a 3D model for the surface of grotto Cap Blanc in the late Paleolithic period. However, these researches mainly focused on the establishment of geometric models, involving little information about 3D printing [6]. Combined with the traditional method of cultural relics restoration, the utilization of virtual restoration and 3D printing of high-precision 3D models of cultural relics with computer virtual reality technology can effectively reduce the frequent contact in the actual restoration work, avoiding the potential secondary damage to cultural relics caused by improper restoration [7].

Double-ear clashing color vase with lotus design, is a porcelain found from Qing Dynasty in Anqing, Anhui Province in 1974. Its body is designed with a total of 9 layers patterns, with the theme decoration as lotus. This vase is regarded as a precious historical and cultural heritage as a fine work produced by Jingdezhen blue-white porcelain kiln in the Qing Dynasty with gorgeous colors and exquisite patterns. However, it is a great pity that when the bottleneck of the vase was broken when the porcelain was unearthed. To better restore the original appearance of this artwork, Anhui Provincial Museum embarked on digital restoration of 32 broken porcelain pieces represented by this double-ear clashing color vase with lotus design in May 2019.

3D Digital Modeling for Double-ear Clashing Color Vase with Lotus Design

The most direct approach to extract 3D digital data of cultural relics is laser-scanning measurement, which is featured by fast speed and high precision without secondary damage to cultural relics, so as to record and preserve the original information of cultural relics to the greatest extent [8]. In terms of the Qing Dynasty double-ear clashing color vase with lotus design, this research obtained the 3D digital model of porcelain bottle with the help of laser 3D modeling technology, and mapped the texture information. Finally, 3D printing was completed to realize the virtual reproduction of double-ear clashing color vase with lotus design. The modeling process was based on the Rapid Form XOS2 laser data processing software, the collected point cloud data were automatically spliced to obtain the 3D model of cultural relics with texture information, and then combined with reverse engineering software Geomagic Studio was, the missing part was patched or scanned, and the texture image was used to make up for the defective texture, which eventually ensured the acquisition of 3D data model of cultural relics. Currently, 3D scanners are divided into two categories, one is airborne (LiDAR) type, which is mainly aimed at large ground scenes such as cemeteries, and the scanning accuracy is relatively low. The other is terrestrial type (TLS), which is mainly used for small objects [7, 9]. Compared to LIDAR, TLS scanning is of higher accuracy and easier operation. This research has chosen the TLS for 3D scanners. The principle of TLS is to veritably reproduce the three-dimensional landscape of the measured object by transmitting and receiving pulsed laser to collect point cloud data [10]. However, it is noteworthy that as to porcelain, the ground laser scanner is incapable of obtaining complete and uniform point cloud data due to disparate angle reflection caused by light. Therefore, in addition to Free Scan X3, contacting three-dimensional laser scanner, NikonD850 digital camera for cultural relic data collection and high-resolution texture information extraction, the process of obtaining three-dimensional data also employed software such as 3DMAX, CINEMA 4D fir denoise and elimination of redundancy, then extracted the three-dimensional point cloud data of double-ear clashing color vase with lotus design [14, 16]. The 3D data acquisition process consists of three procedures: data acquisition, data editing and data storage, as the detailed flows shown in figure 1.

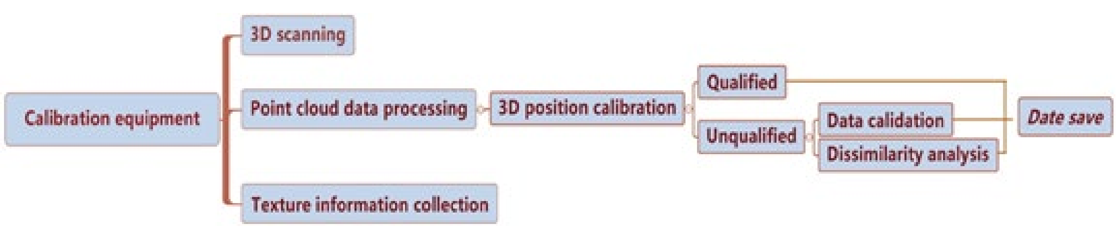

Figure 1: Flow Chart of Point Cloud Data Processing

3D Data Collection

The data acquisition includes three aspects, namely, regular equipment debugging, data acquisition, point cloud data preprocessing and storage. For data acquisition, a quick look 3D model was obtained by rough data processing to ensure the integrity of data. For data processing, the laser data optical data obtained from 3D model were verified each other to make sure the 3D accuracy of the results. The inserting value calculation was conducted to the data at all levels, to count the accuracy and diminish the accuracy loss in data processing [11]. Lastly, the fusion processing of texture information obtained by optical camera and texture information in laser data guaranteed the texture accuracy of the final model [18-20].

Equipment debugging refers to the sensor equipment, such as laser scanner and digital camera, used in the experiment, which is affected by the transportation, storage environment or other conditions, causing deviation in accuracy. To ensure the accuracy of cultural relics data acquisition, the sensor needs to be calibrated before application [12, 13 and 15].

After completing the sensor, debugging is to carry out data acquisition. The high-density laser data collected from double-ear vase and data-entry mainly operated by FreeScan X3 scanners and NikonD850 digital cameras. The cultural relic was placed on the rotating platform; the appropriate measuring station position was selected according to the size of the double-ear vase, and the scanning density parameter was set to the sampling point of each scanning laser line in760 points / line. The relative position of the sensor and the cultural relic was adjusted in line with the lens parameters of the sensors, and then the two sensors collected data in the directions of the transverse R (rotation of platform) and longitudinal H (height), respectively. In the meantime, adopting 3D laser scanner and digital camera to collect 3D coordinates and texture information of cultural relics, the number of points obtained is 286578, and the average point spacing is about 0.2mm.

In 3D data acquisition, the selection of coincidence rate is crucial to the quality and efficiency of the model. Several groups of point cloud data can be obtained after multiple scans of a complete 3D model, the higher the coincidence rate of these groups of data, the more accurate the data acquisition, the better the effect of the model after the later splicing, and the lower the efficiency of data acquisition. On the contrary, if the coincidence rate is too low, even if the extraction is highly efficient, later it may result in large amounts of errors in the calculation of point cloud data, causing large broken surface in the model [19]. Therefore, data acquisition needs to strike a balance between the quality and efficiency, to intentionally select proper coincidence rate. During the data acquisition process, the vase was placed vertically on the turntable, and a 30° was rotated each time to obtain one-stop data. The 360° rotating was defined as R, then the data lift scanner acquired in 360° rotation was defined as H. R scanning only required turning the turntable, given it did not involve the position coordinates movement of the scanning device, the extraction image is of high coincidence rate, while H needed to adjust the height of the scanning device up and down, and the absolute position of its X Z axis would also change after moving the scanner Y axis, so the extraction image repetition rate was relatively low. Since the later splicing process began with transverse direction before longitudinal direction, though the longitudinal coincidence rate was small, the data involved in the splicing were fixed as the data between the two strip transverse acquisition bands, so it can ensure the accuracy of the splicing. The final data comparison shows that, as long as R≥75%, HR≥45% the data coincidence rate, it can meet the requirements. as shown in Figure 2.

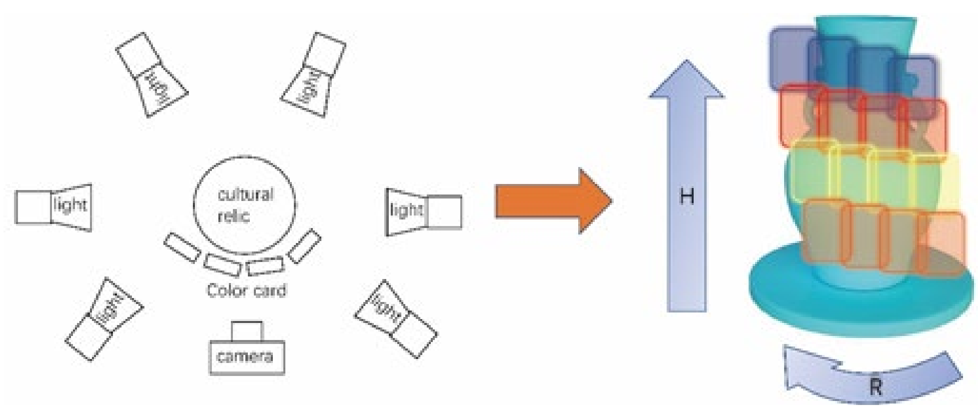

Figure 2: The Schematic Diagram of 3D data's Collection on Cultural Relic

The last procedure was point cloud data preprocessing and storage. Data preprocessing is to check the quality of data acquisition. In order to improve the efficiency of model acquisition, plus the necessary gaps in scanning process, the initial point cloud data will inevitably be incomplete. The missing point cloud data, reflected in the 3D model, is the broken surface of the model. To this end, it is necessary to preprocess the collected data in the field of data acquisition for the integrity of the collected data.

Above all, the obtained pre-processed 3D point cloud data should be further refined. The initial point cloud data acquired by 3D scanning is liable to be rough, which is suitable for the 3D splicing of some complicated ornaments, such as porcelain. To solve this problem, three stages are needed, including laser data processing, digital photogrammetry processing and data fusion. Laser data processing refers to the automatic and manual trimming of point cloud data obtained by each scanning station, and the registration processing of all point cloud data of porcelain, in which obtain the connection points of all two coincidence data and coincidence areas, and then connect the points to form a spatial transformation equation. Subsequently the point cloud data is converted into a plane by computer automatic settlement.

Considering the collected data will appear partial overlap, the data calibration must be carried out by manual calibration, and ultimately make gridding for the whole model after calibration to obtain the quadrilateral model. Owing to the four sides of the whole model, the four sides grid reconstruction was carried out in accordance with the curvature geometric characteristics of the double-ear vase surface and the automatic calculation method of the software, to obtain the micron-scale 3D model in four sides, and finally, the high-precision three-dimensional model was realized followed by model grid optimization.

Digital Photogrammetry

Digital photogrammetry processing is to determine the relationship between images by human-computer interactive editing, and then obtain dense connection points by R, H image registration for dense connection points. In addition to the accuracy and integrity of basic data, the degree of color restoration, the difference of image data and acquisition data in texture accuracy and photo color also have direct impact on the data quality of 3D reconstruction. NikonD850 was selected in this digital photogrammetry, it is also the current mainstream photogrammetry camera, with CCD sensor size of 35.9*23.9 mm, the highest resolution 8256*5504, and the effective pixels 45.75 million, after installing the MD-18 handle, the NikonD850 can reach about 9 beats per second in continuous spots, which can fully support the texture information collection. NikonD850 camera can start to collect the texture information of the double-ear vase, after correcting the color card, then calculate the camera focal length and determine the shooting position in the resolution of no less than 300 dpi. At the premise of keeping the focal length and shooting distance unchanged, the coincidence rate of the upper and lower, left and right adjacent was not less than 45% and 75%, respectively, then the target object was photographed. Finally, the 76 sequence photos of no less than 300 dpi were extracted to form the texture information of the cultural relic. Four pairs of points of the same name were selected as the control points on the sequence photos and the obtained high precision 3D model. The (x, y) coordinates of the same name points on the photos and the (X, Y, Z) coordinates on the 3D model were recorded for registration to acquire the 3D model with texture information.

Considering the influence of ambient light on the double-ear vase, all the images were processed in uniform color. Due to the different light intensity on each side of the vase, the uniform light source should be set before adjusting the texture information. As for color texture information, stable light source serves as a vital component. After laser data processing, a 3D model with high precision artifacts was obtained. However, the texture information cannot be directly mapped to the 3D model, because the chromaticity of the same area will produce different effects due to different angles of light, that is, the same vertex of the cultural relic grid model is given different color values. In this case, direct mapping of texture information will result in unidentical texture information calculation. Hence, light source in uniform brightness and saturation should be set around the cultural relic before the texture information extraction, to create a uniform color temperature and unified light source, and then adjust the texture picture [16]. Table 1 is a reference of light source and projection relation of 3D reconstructed artifacts, among which, "Spatial mean resolution (mm)" is a key index to identify the accuracy of texture mapping data, and "Projection error" is a crucial index to judge the accuracy of projection matching.

Table 1: Reference of Light Source and Projection Relation of 3D Reconstructed Artifacts

project	Amount	Spatial mean resolution (mm)	Photo-control-point	error of the average projection(mm)	square root of error(mm)	connection points	error of the average projection(mm)	square root of error(mm)
internal	84	0.034	4	0.0027	0.0519	48.211	0.018	0.1341
external	42	0.051	4	0.0145	0.1204	23.653	0.025	0.1581
bottom	36	0.034	4	0.0211	0.1452	32.332	0.015	0.1224
integral	162	0.0396	12	0.0421	0.2051	173.523	0.019	0.1378

By digital photogrammetry, the data with high accuracy and rich texture information will be obtained. However, the data points are relatively dense, which requires data fusion processing. The purpose is to inspect the overall 3D precision of the model and supplement the texture information of the cultural relic model, so that enable the shape and color of the double-ear vase to reach the effect closest to the entity.

Findings and Significance

Model Classification

The true 3D data of the established model can be divided into four grades based on varied accuracy and use. Level L0: the original data obtained for scanning, which is kept by cultural relic preservation unit as the fundamental of 3D model, but solely for storage backup, rather than direct application. L1:general 3D model with high 3D accuracy, but mainly targeted at visitors in general display, to pursue a better display effect, texture color data of this level of cultural relics is more close to that in the original scene when the cultural relics were made, some seriously damaged parts can be properly repaired. L2 : high-precision 3D data model, the optimized virtual reality data packets based on the high-density 3D data at L0, which is mainly used in science, teaching and research, all texture information is restored in line with the original when unearthed. L3 thumbnail model of 3D data, which is simplified based on L1 level data and used to match the 3D thumbnail of the corresponding cultural relic. After completing the three-dimensional model data of four levels, the data is entered into the three-dimensional data management system of museum cultural relics. The function of the database system realizes the whole stereoscopic display, data calculation and cultural relic protection monitoring of cultural relics. Meanwhile, a variety of data about cultural relics, such as isoline map, profile map and so on, can also be obtained. It not only provides a innovative approach to the display of cultural relics, but also offers new means for cultural relics experts to study cultural relics, novel technology for the protection and management of cultural relics, and a basis for the restoration of cultural relics.

3D Printing Application

The ceramic materials used for 3D printing in china are still limited. This experiment chose alumina ceramics (Al2O3), which bears the advantages of high strength, high hardness, tight structure, good thermal stability, strong corrosion resistance and superior wear resistance, as the most widely used ceramic materials at present. Ceramic 3D printing, eliminating the traditional ceramic production process such as engraving, kilning, painting and other procedures, only requires digital modeling of the product without previous steps such as firing and drying. To this end, 3D ceramic printing is highly effective in application.

Before printing, the adjusted model should be entered into 3D printer, and then inject the alumina ceramic material. This stage can be divided into 3 steps, setting the printing parameters, preparing suitable printing materials and performing printing tasks. In high precision model printing, the printer parameters should be set to advanced, the printing is expected to be longer, and the printing process needs to guarantee stable power supply, to avoid power failure or machine failure resulting in task disruption.

Figure 3: 3D-printed renderings of Double-ear Clashing Color Vase

During the execution of the printing task, it's not allowed change the setting parameters, otherwise it may lead to printing fault; after setting the printing parameters and printing materials correctly, the model of the cultural relic is finally obtained, as shown in Figure 3.

Conclusion

The main objective of this study is to create a 3D color model with high precision 3D and texture information. In the process of 3D reconstruction, the high precision characteristic of 3D laser data processing is fully utilized to make the 3D model more accurate in geometric detail. During the process of texture reconstruction, the high-definition texture model is developed by using the texture model of the reconstructed object by digital photogrammetry. Finally, the fine texture reconstruction of the high-precision 3D model is realized by means of data fusion UV vertex alignment. This method greatly improves the 3D accuracy of the model and the registration quality of the texture color model. The reconstruction efficiency has been significantly improved compared with other 3D reconstruction methods. The construction of high-precision 3D model and texture color model not only provides a more intuitive stereoscopic visual effect for the display of cultural relics, but also greatly promote the data preservation of cultural relics objects, cultural relics entities and digital restoration and scientific monitoring and other fields, so as to truly realize the digital protection of cultural relics.

Acknowledgements

The research work was financially supported by the Quality Engineering project of universities in Anhui province (Nos. 2019XJY25; XYS2019B01). The publication costs of this article were partially covered by the Estonian Academy of Sciences.

Notes

The authors declare no competing financial interest.

References

1. Leonov, A. V., Anikushkin, M. N., Ivanov, A. V., Ovcharov, S. V., Bobkov, A. E., & Baturin, Y. M. (2014). Laser scanning and 3D modeling of the Shukhov hyperboloid tower in Moscow. Journal of Cultural Heritage, 16(4), 551-559.
2. Koller, D., & Levoy, M. (2006). Computer-aided reconstruction and new matches in the forma urbis romae. Comput-

er-aided Reconstruction and new Matches in The Forma Urbis Romae, 103-125.

3. Lerones, P. M., Llamas, J., Gómez-García-Bermejo, J., Zalama, E., & Oli, J. C. (2014). Using 3D digital models for the virtual restoration of polychrome in interesting cultural sites. Journal of Cultural Heritage, 15(2), 196-198.
4. Wang Ting. (2012). Application of 3D digital modeling technology to cultural relics in the Museum of the Terra-Cotta Warriors and Horses of Qin Shihuang. J. Sciences of conservation and archaeology. 24:103-108.
5. Brown K., R Chalmers. A., Saigol, T., Green, C., & D'errico, F. (2001). An automated laser scan survey of the Upper Palaeolithic rock shelter of Cap Blanc. Journal of Archaeological Science, 28(3), 283-289
6. Zeng Yiguo,. Chen Shuang. (2019). Research on the digital display and propagation of cultural relics in museums Taking the Taipei palace museum as an example. J. Journal of GuangZhou University. 1, 29-37.
7. Wang, S. (2012). Special issue on real-time 3D imaging and processing. Journal of Real-Time Image Processing, 7(1), 1-2.
8. Wang, J., Qian, W., Liu, H., & Ji, K. (2019). Quantitative analysis of pottery from the Tianma-Qucun site based on 3D scanning and computer technology. Archaeological and Anthropological Sciences, 11(10), 5645-5656.
9. Akoglu, K. G., Kotoula, E., & Simon, S. (2020). Combined use of ultrasonic pulse velocity (UPV) testing and digital technologies. A model for long-term condition monitoring memorials in historic Grove Street Cemetery, New Haven. Journal of Cultural Heritage, 41, 84-95.
10. Bernardi, L., Busana, M. S., Centola, V., Marson, C., & Sbrogiò, L. (2019). The Sarno Baths, Pompeii: architecture development and 3D reconstruction. Journal of Cultural Heritage, 40, 247-254.
11. Koller, D., Frischer, B., & Humphreys, G. (2010). Research challenges for digital archives of 3D cultural heritage models. Journal on Computing and Cultural Heritage (JOCCH), 2(3), 1-17.
12. Min, P., Kazhdan, M., & Funkhouser, T. (2004, September). A comparison of text and shape matching for retrieval of online 3D models. In International Conference on Theory and Practice of Digital Libraries (pp. 209-220). Springer, Berlin, Heidelberg.
13. Mulrenin A., Szauer, A. (2002). The DigiCULT Report. Technological Landscapes for Tomorrow's Cultural Economy. Unlocking the Value of Cultural Heritage. A. The European Commission, Directorate-General for the Information Society.
14. Di Angelo, L., Di Stefano, P., Fratocchi, L., & Marzola, A. (2018). An AHP-based method for choosing the best 3D scanner for cultural heritage applications. Journal of Cultural Heritage, 34, 109-115.
15. Balletti, C., D'Agnano, F., Guerra, F., & Vernier, P. (2016). From point cloud to digital fabrication: A tangible reconstruction of Ca'Venier dei Leoni, the Guggenheim Museum in Venice. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci, 3, 43.
16. Nex, F., & Remondino, F. (2014). UAV for 3D mapping applications: a review. Applied geomatics, 6(1), 1-15.
17. Hendrickx, M., Gheyle, W., Bonne, J., Bourgeois, J., De Wulf, A., & Goossens, R. (2011). The use of stereoscopic images taken from a microdrone for the documentation of heritage– An example from the Tuekta burial mounds in the Russian Altay. Journal of Archaeological Science, 38(11), 2968-2978.
18. McCarthy, T., O'Riain, G., & Fotheringham, S. (2007). Compact Airborne Image Mapping System (CAIMS).
19. Wang, Z. F., & Zheng, Z. G. (2008, June). A region based stereo matching algorithm using cooperative optimization. In 2008 IEEE Conference on Computer Vision and Pattern Recognition (pp. 1-8). IEEE.
20. Zhang, Z. (2000). A flexible new technique for camera calibration. IEEE Transactions on pattern analysis and machine intelligence, 22(11), 1330-1334