# 3D INDOOR DOCUMENTATION OF THE WINTER GARDEN IN THE EARTHENWARE MUSEUM AT SARREGUEMINES (FRANCE)

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**ABSTRACT:**

This paper presents the work accomplished in order to digitize and model the Winter Garden of the Earthenware Museum at Sarreguemines (Moselle, France). The objectives were to create a digital archive of this cultural heritage place and to find appropriate ways of promoting it. Topographic, photogrammetric and lasergrammetric methods were used to model the Winter Garden. Different virtual reality tools enabled us to spotlight some of its parts and to offer an immersive visualization. Several challenges had to be taken up during this project. We first had to find out the best processing workflow to model earthenware, which is a highly reflecting material. Image processing was also needed for aesthetic reasons and we finally had to find methods to reduce the size of the models.

## 1. CONTEXT OF THE STUDY

In 1880, the earthenware manufactory at Sarreguemines (Moselle, France) was a flourishing company, employing several thousands of workers and exporting its products throughout the world. Winter gardens were in vogue at that time among wealthy people and Paul de Geiger, director of the manufactory, decided to build one in his private apartments. Nowadays, this room is a listed building and the heart of the city's museum. This has led the town of Sarreguemines, on the initiative of Olivier Reis, to scan this local heritage jewel in the aim of creating a digital archive also usable for touristic purposes. The task was entrusted to the Photogrammetry & Geomatics Group of INSA Strasbourg. So 3D indoor documentation of the Winter Garden at Sarreguemines (Figure 1) became the Master project of Valentin Girardet.

Figure 1. Winter Garden at Sarreguemines (France) (www.sarreguemines-museum.eu)

Beside the fountain (its most remarkable piece), the Winter Garden also shelters vases, portraits of former directors, views of the city of Sarreguemines in late nineteenth century as well as two allegories representing fire and earth, which are the two major elements needed for ceramic art.

The project has two main objectives:
- to record and model the entire Winter Garden with a satisfying result from an aesthetic point of view and to create a virtual archive in case of destruction or relocation of the entire room (heritage conservation);
- to consider virtual and recreational means of visualization and spotlighting 3D models in accordance with the museum's and public's expectations (immersive virtual visit, videos, interactive digital space, 3D printing).

Photogrammetric and laser scanning methods were used to build the 3D model of the Winter Garden. The project was georeferenced in the French official geodetic system (RGF93-CC49 in planimetry and NGF-IGN69 in altimetry). The challenge was to digitize earthenware, which is a highly reflective material causing highlights on the images as well as noise in the processed point clouds. Concerning the visualization aspect, various experiments were made with a Virtual Reality system.

## 2. STATE OF THE ART

As mentioned, digitizing earthenware was the main issue in this project. On the basis of its extensive experience in 3D laser scanning and photogrammetry recording (Grussenmeyer et al., 2016), the INSA Photogrammetry and geomatics Group team saw the key to success in the control of light conditions (Tucci et al. 2015) and the homogenization of light to avoid specular reflections in photogrammetry (Nicolae et al., 2014). Due to technical reasons (large glass walls on both ends of the Winter Garden), it was impossible to regulate or homogenize the amount of light entering the sensor, but the camera chosen (Canon EOS 5DSR) allowed us to take images in RAW format and reprocess them afterwards. In laser scanning, the higher the intensity of light, the deeper the laser penetration into the material (Guidi et al., 2009) and that can potentially cause biases in distance measurement and increase noise in the point cloud. Data from several 3D recording systems was combined (Faro Focus 3D X330 Scanner, Faro Freestyle 3D hand scanner, Canon EOS 5DSR camera, Iphone 8S).

## 3. 3D MODELLING WORKFLOW

A well-controlled workflow (Murtiyoso & Grussenmeyer, 2018) made it possible to obtain point clouds with an accuracy of 2 to 3 mm after registration and georeferencing. In order to manage large datasets, the Winter Garden has been subdivided into 6 main parts, which in turn are subdivided into 10 sub-parts. The commercial software 3DReshaper was used for the meshing job, as it allows to build a manual mesh. The final result was achieved by refining a coarse mesh (with an average distance of 1.5 to 2 cm between future mesh points) and applying afterwards a smoothing process along with manual corrections.

Corresponding tools are available in 3DReshaper. All are explained in the software user manual [TECHNODIGIT, 2016]. Set to an empirically defined value of $10^{-5}$, the function "Refining to rope error/ from a point cloud" allowed in particular to minimize errors in the mesh by taking false points into consideration. The minimum size of triangles was set to 1 mm (which is the resampling value of the global point cloud) in order to avoid too small triangles. A local smoothing was also applied to reduce the noise impact. The best way of doing so is to retain the same refining and smoothing parameters in order to finally get a uniform overall mesh. As 3DReshaper is a commercial software, we had no access to the algorithms implemented and can therefore not explain in detail how they work. After having done so for the 6 main parts, all were put together and combined to form a single block, i.e. the Winter Garden (Figure 2).

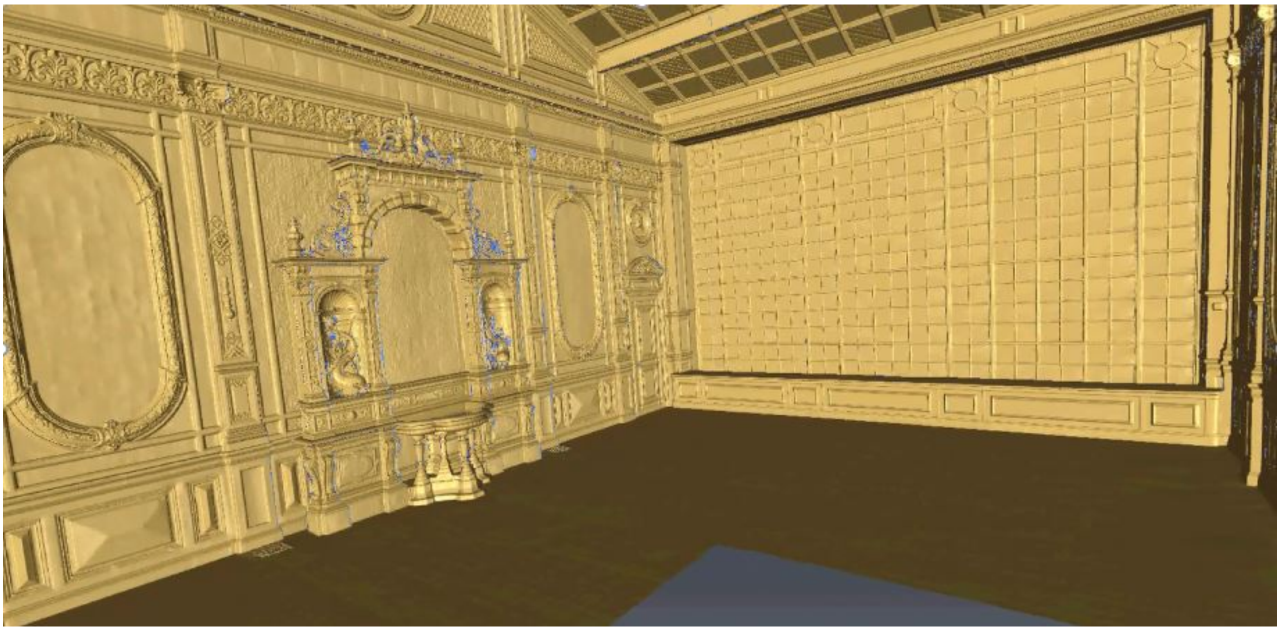

Figure 2. Accurate meshed model of the Winter Garden

The last processing step consisted in texturing the model by applying the images acquired with the SLR camera. This operation was not carried out globally (for the Winter Garden as a whole). The different files of the remarkable objects and the volumetry were imported separately in OBJ format into the PhotoScan software. The pre-processed georeferenced texture was then applied. An adequate texture able to maintain all the details without producing too large files was chosen with great care, as well as the sizes (10000x10000 pixels for remarkable objects to get sufficient detail on each one of them, 40000x40000 pixels for the volumetry because it is the maximum texture size that can be calculated by PhotoScan) (Figure 3).

The main disadvantage of textured mesh models lies in the large size of the resulting files. Two solutions were tested in order to optimize the models. The "Reduce" function of 3DReshaper was the first one, based on a deviation criterion. It was set to $10^{-5}$ m. This empirically defined value enabled us to reduce the model without affecting shapes. Doing so, the model was reduced in size by 25% in RSH format (specific to 3DReshaper) against 9.5% only in standard OBJ format. When visualizing it, it appeared clearly that the mesh size was relatively unaffected by the reduction in size of the model and its homogenization. On the other hand, the reduction achieved in OBJ format was clearly not sufficient to be really profitable. That is the reason why another method of reduction based on the "Quadric Edge Collapse Decimation" tool from MeshLab was tested, allowing to reduce the size of the model and more particularly the number of triangles while preserving the actual shape of the object [Rodríguez-Gonzálvez et al. 2015]. Although providing the same advantages as the "Reduce" function of 3DReshaper, it only cut the size of the OBJ file by 11.5% for half as much triangles.

Besides, this type of reduction has also a strong impact on texture: the higher it is, the more texture is degraded. It was therefore rejected and the FBX file format was used for all exports and imports to overcome the problem. It actually compresses the files in such a way that they take up less space. This compression is about 40% for the models of the remarkable objects and about 70% for the volumetric model of the Winter Garden.

Figure 3. Accurate 3D textured model of the Winter Garden

## 4. PHOTOGRAMMETRIC RECORDING OF A SELECTION OF ARTIFACTS OF THE WINTER GARDEN

In order to improve the models, photogrammetric experiments were carried out on some remarkable objects.

### 4.1 Experiments based on Smartphone data

Smartphone photogrammetry has experienced a dramatic development in recent years due to the integration of increasingly high-performance sensors and components. During this project, a smartphone was consequently used to conduct photogrammetric tests, mounted on a gimbal stabilizer to get the sharpest possible pictures and the smoothest possible videos.

Figure 4. Textured model of the upper part of the fountain (extracted from a video)

Several tests were carried out, concerning both photo and video on the left fish of the fountain and video alone on the top of the fountain. For that last one, we managed to extract 172 pictures from the video at a rate of one per second. After a classical photogrammetric modelling process with PhotoScan, the rendering obtained was quite interesting. The texture quality was good (Figure 4) and the accuracy was satisfying, as the comparison between the photogrammetric point cloud used to build the model and the reference TLS point cloud on Cloud Compare led to a standard deviation of 2.3 mm, with a difference being below 3 mm for 75% of the points (Figure 5). This is close to the theoretical accuracy of laser point clouds. Therefore, the smartphone texture was used to overcome shortcomings and fill gaps on top of the fountain, because it was impossible to take pictures at that height with the SLR camera.

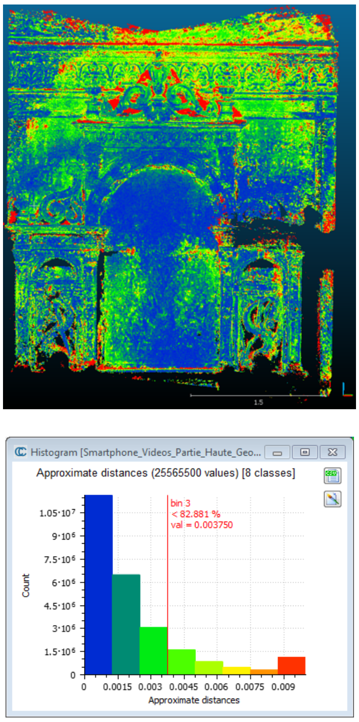


Figure 5. Histogram of the number of points according to the laser-point distance (bottom) and associated 3D map (top)

### 4.2 Programming Image Processing

Image processing solutions aim at correcting the model's texture. This can either be done by programming means (on Matlab, using dedicated toolboxes) or with specialized software such as the open source GIMP Tool. A histogram equalization was applied to the RAW images taken with the Canon EOS 5DSR camera at the bottom of the fountain to lighten them because they were too dark.


Figure 6. Fountain without (left) and with (right) histogram equalization

The image processing toolboxes of Matlab were used for that purpose, the goal being to smooth out the differences between the textured model at the top (smartphone data acquisition) and at the bottom (Canon pictures processed) of the fountain (Figure 6).

## 5. VISUALIZATION AND VIRTUAL REALITY

After the completion of the textured lasergrammetric models (Winter Garden and remarkable objects), the next objective was to find out how to best spotlight them. Different visualization tools such as Sketchfab, Faro Scene VR and Unreal Engine were taken into consideration here (Kersten et al., 2018).

### 5.1 Uploading 3D models to Sketchfab

The first solution consisted in importing the models of 9 remarkable objects in FBX format on the Sketchfab platform. This allowed us to respect the maximum import file size rule (50 MB at the most) applying to a free basic account. The light can be fine-tuned to make the models more photorealistic. It is possible to set the scale to 1:1 in the virtual reality options, enabling thus the user to see objects in real size (Figure 7).

By doing so, the user has two different ways of visualizing models:
- either from his smartphone by downloading the Sketchfab app and wearing suitable glasses (such as Google Cardboard, Homido headset, Samsung VR headset, etc.) for a quick viewing;
- or from his computer by navigating to the website and using a more advanced virtual reality headset (HTC Vive, Oculus Rift) offering better rendering.

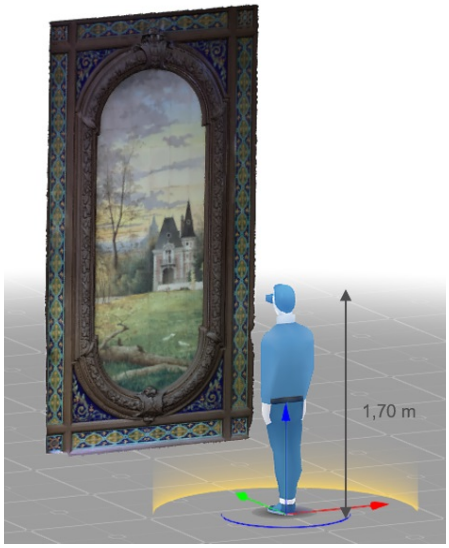


Figure 7. Setup of the Virtual Reality Tool for the "Pavillon de Geiger" model

### 5.2 Virtual Reality Viewer for an immersive point cloud visualization

The second solution consisted in using the point clouds of the Winter Garden and its surroundings for an immersive visualization. The FARO SCENE software and the HTC Vive system made that possible (Figure 8). The immersion was implemented by registering point clouds progressively with the cloud to cloud method as no sphere was placed inside the Winter Garden.

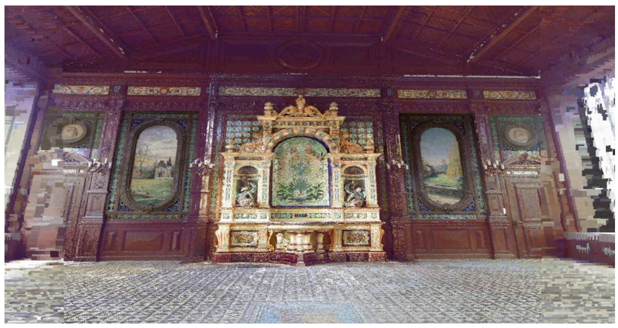

Figure 8. Immersion in virtual reality in the Winter Garden

An average deviation of 1.3 mm resulted from that registration with a difference being below 4 mm for 79% of the points. This is rather satisfying, considering that the point clouds used came from different acquisition campaigns. The user can thus move freely in all three dimensions to appreciate the feeling of space as well as the detail refinement that the cloud offers.

### 5.3 Interactive virtual visit with Unreal Engine

The third option consisted in setting up a virtual visit scenario in the textured model of the Winter Garden and using a video game engine for that, able to manage large files. Interactivity has played an important part since buttons have been created especially to enable the user to consult information about remarkable objects of the Winter Garden and its history (Figure 9). Consequently, the HTC Vive system has been fine-tuned with Unreal Engine to allow a model-user interaction and to program the movements inside the room.

### 5.4 Printing of 3D objects

The Photogrammetry & Geomatics Group has recently acquired a 3D printer and the project gave us the opportunity to conduct some tests. Both the left fish of the fountain (Figure 10) and the fountain as a whole were printed.

This booming technology will allow the museum to better address different audiences. Those 3D printed objects will enable a tactile discovery of the Winter Garden for blind people. For children, it could be a recreational way of approaching local heritage.


Figure 9. Virtual visit with Unreal Engine

## 6. CONCLUSION AND OUTLOOK

### 6.1 Conclusion


Figure 10. Example of 3D printed fish (on the left side of the fountain)

The work done allowed us to produce a complete 3D indoor documentation of the Winter Garden at Sarreguemines. The difficulties related to the highly reflective nature of earthenware were bypassed by combining photogrammetric and lasergrammetric techniques. Aesthetic reasons have led to the use of up-to-date photogrammetric methods such as smartphone acquisition. This solution, currently fast developing, provides rather good results and can replace traditional methods when those ones are unusable or unsuitable (for the upper part of the fountain, for example).

Images were additionally processed in two different ways in order to correct the model's texture: by programming, to equalize the histogram of dark pictures (Canon) as well as manually, by the means of specialized editing software for touching up isolated defaults. A meshed and textured 3D model of the Winter Garden has been released with an accuracy of 2 to 3 mm. As aesthetics is the top criterion for the museum, such an accuracy is more than enough. The model will be archived and ready for use in the case of damages, whatever their cause may be.

Beyond heritage conservation, the project also gave us the opportunity to test various ways of spotlighting, promoting and visualizing this heritage to show it to a large audience. Two interactive virtual tours have been created, one in the point cloud and one in the model. The Earthenware Museum plans to develop an area dedicated to digital technologies in near future with the support of the City of Sarreguemines. The interactive virtual tours will of course be part of it.

### 6.2 Outlook

Further modelling work can be undertaken at Sarreguemines. A second project is on-going at present and will shortly be completed, focussing on two more listed buildings, i.e the “Casino des Faïenceries” and the nearby “Pavillon de Geiger”. Other remains of the earthenware industry can be found here and there in the city and it could be interesting to digitize them. We are discussing the matter as well as other options with the city’s authorities.

On the technical level, it may be interesting to try to automate several steps of the lasergrammetric modelling process as it is particularly long and tedious. Other methods may also be tested to reduce the size of models. It could be possible, for example, to create hybrid models, consisting of geometric primitives. They could be useful for plain parts (without particular details) and repetitive elements. Finally, it may be necessary to improve user movement with virtual reality system controllers in Unreal Engine for greater fluidity.

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