A Comparison of Selected Photogrammetric Techniques for Creating 3D Models of Cultural Objects with Specular Surface

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Introduction

As specular surfaces present a known challenge for most scanning and surface capturing technologies in terms of 3D model creation, the purpose of this study is to present, explore and compare three selected approaches for creating digital 3-dimensional representations of existing historical liturgical objects which have a specular (i.e. reflective, mirror-like) surface.

The framework of this study was established by the intention of the Hospitaller Order of St. John of God in Bratislava, Slovakia to have their object inventory digitized for their internal documentation purposes. As many of these objects are made of metals (mostly ecclesiastical artefacts), they have a shiny surface and therefore present a known challenge for most scanning or surface capturing technologies in terms of 3D model creation (this issue is discussed further in greater detail). Thus a kind of a feasibility study was to be executed, in order to establish if and how the digitization of these artefacts can be performed, by selecting two specular objects out of the inventory of the Order and subjecting them to the trial, so as to explore the applicability of available digitizing approaches (using a digital camera) for the creation of 3D model of the objects.

Study Objectives

This study deals with the problematics of glossy objects made out of metal creating light reflections when subjected to image acquisition. The objectives comprise a theoretical and practical exploration of the selected methods on how to approach the phenomenon of specular surfaces (shiny metal, mirror-like), as a known issue and based on the comparison of their outcomes to draw conclusion which of these approaches produces the most accurate results when comparing the final 3D models of the given objects.

Furthermore, the goal was to establish if and how the digitization of these artefacts can be performed using a digital camera and available equipment producing 3D object models with sufficient quality for internal digital documentation purposes.

The selected methods were chosen according to the following considerations: the accessibility of equipment, the restrictions on the treatment and manipulation of the borrowed objects and the purpose to mitigate the reflective effects of the specular surfaces. Therefore in an effort to meet the objectives the conditions for the three methods were set while the only light source used was diffused light (photo shooting was taking place in a completely dark studio), with employing the use of polarization filters and scanning spray.

Materials – Study Objects

For this study two historical liturgical objects borrowed out by the Order of St. John of God are being studied: a silver-plated brass ciborium and a stainless-steel crucifix. They were chosen for this purpose as they are difficult to be captured being made of materials with reflective surfaces generating highlights generally unsuitable for photogrammetry such as glossy metal, marble, etc.

Fig. 1: Object 1 – Ciborium

Fig. 2: Object 2 - Crucifix

Methods

Two studied objects, depicted in Fig. 1. And Fig. 2., were subjected to image capturing by a digital camera under three different conditions in an effort to minimize the effect of the reflected light. The first approach was using diffused light only, then cross-polarization was applied, while for the third approach a scanning spray was used. The acquired data was used for the creation of the respective 3D models of these objects. In the first two cases the data was used for both the model and the texture, whereas for the third option the data was used for creating the model only, while data from CPL (cross-polarization) was utilized for the texture due to the real surface being covered in white layer created by the spray.

Results

The reconstruction from the diffused light photos delivered results of good quality, similar to the CPL method. Despite having used diffused lighting of the studied objects, there were some specular reflexions visible in the photos. The produced mesh however is of a good standard, although there is some noise on the surface. Overall, it confirms that the image acquisition has been performed correctly with high overlapping, which proves that good input can produce a similarly good result.

The scanning spray applied in the third method created additional 'material' layer on the surface of the object. This spray was used on both objects twice – for the top and also for the bottom part photo acquisition, thus creating two different surfaces with different thickness, texture and characteristic points, which resulted in problems during the alignment process, when RC tried to find the mutual features between both surfaces while the resulting alignment was not very satisfactory. The seams on the surface are visible.

Another determined issue with the Aesub scanning spray was the applied layer not having vanished completely, despite the official claim of the producer that the coating will self-disappear. This was not the case, as on both objects, some parts were covered with white layer even after a few weeks and it was necessary to carefully clean the surfaces.

Comparison of the Methods

The final accuracy of these three reconstructed models of both objects made by comparison with an independent technique was unfortunately not possible. Micro-CT scanner didn't provide any reference data. All created models of both objects 1 and 2 were compared between each other in CloudCompare software.

Comparing the CPL model and scanning spray model of Object 1 - Cimborium shows that there is a good match between both models, below 0,2 mm. The maximum difference is on the top of the object, 0,4 mm. Comparing these models with scanning spray model shows that in some places of the bottom part of the model is a higher deviation, the difference being more than 0,5 mm. Generally, the scanning spray model turned out to be the least accurate.

Object 2 was a crucifix, consisting of the top cross and bottom base. It was found out that these two parts were not connected firmly and the top part was a little bit loose, therefore the angle was changing. Although this movement was not very substantial, it created two different sets of photos during photo shooting of the top and bottom part separately which caused the noise in the connection of the top and bottom part during the 3D model creation process. It is visible the deviation of 3 mm of the top part when comparing the diffused light and CPL models. For this reason, the base and the cross were split and in CloudCompare aligned and compared separately. The comparison of the base between all 3 models shows minimal deviation between the diffused light and CPL models.

Both diffused light and CPL models of the cross show minimal differences between them. The scanning spray model has on the other hand the minimal difference with the CPL model of the base.

Conclusions

Based on the observations described above, the cross-polarization technique delivered the best results, producing the most accurate 3D object models, while considerably exceeding the set resolution parameters for the texture. The diffused light method likewise delivered very good results, however with a little more noise in the surface of the model, but again surpassing the optimal criteria for the texture resolution. The scanning spray method supplied acceptable results, albeit with lower accuracy of the 3D model surface, as the spray created a new layer with variable thickness, which was to be expected to a certain extent.

According to the overall results we conclude that the digitization of the inventory of the Order can be realized with the equipment available for this study. Some problematic objects should be excluded however – mostly those having some very thin parts, which as this study confirmed, also represent a serious difficulty for photogrammetric methods.

The results of this study will be presented to the Hospitaller Order while concrete suggestions for possible cooperation on digitizing of their artefact collection will be discussed. For the excluded problematic objects other methods of digitization will be proposed and/or tested. The produced 3D models will be digitally delivered, for the purpose of their internal inventory documentation. Even though it was excluded from the subject of this study, the following step of post-processing of the 3D models, i.e. smoothing, retouching and closing the holes, in an external 3D modelling software (e.g. Blender, Meshlab, etc.) could be suggested. The original models should be kept however for archiving as well as preservation purposes allowing the possibility for the objects to be examined in detail or reproduced in the future according to their accurate representations.