Church Heritage Multimedia Presentation

Case study of the iconostasis as the characteristic art and architectural element of the Christian Orthodox churches

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This paper is part of ongoing research which aims is to develop the methodology for the church heritage digitization and visualization. The subject of the presented work is the iconostasis, as a significant part of the Christian Orthodox church heritage, distinguished by its bilateral character, as an architectural element of a church interior and an art piece composed of icons. Considering that iconostases can be seen only in situ, we developed the methodology for its digitization and virtual representation dissemination, which provides a user with the possibility to visualize iconostases outside the physical borders of sacral interiors. The proposed methodology relies on techniques for photogrammetric surveying, 3D modeling, and augmented reality visualization, and it is presented in a particular case study of the iconostasis. An outcome is shown as the multimedia presentation of an exhibition, realized throughout collaboration between the university and the museum.

Keywords: *church heritage, iconostasis, multimedia presentation, photogrammetry, AR*

INTRODUCTION

In terms of modern technologies, a virtual representation of cultural heritage has the major and an essential role for the purposes of preservation, conservation, as well as a promotion of tradition and national identity, in the context of globalization. 3D reconstruction methods for digital preservation of cultural heritage, such as photogrammetry, have become increasingly used as a low-cost method for documenting and analyzing of cultural heritage. According to the plenty researches and case studies that use photogrammetric approaches, the main subjects of cultural heritage digitization can be classified by the type of cultural heritage as: archeological sites (Böhler and Marbs 2004; Sapirstein 2016); architectural objects (Yastikli 2007; Nagakura et al. 2015; Webb et

al. 2016; Böhler and Marbs 2004); statues and sculptures (Böhler and Marbs 2004; Heinz 2002; Pieraccini et al. 2001); and museum artefacts (Nicolae et al. 2014; Böhler and Marbs 2004).

This research focuses on church heritage digitization and visualization. In particular, the subject of the paper is the iconostasis as a distinctive element of the cultural heritage of the Christians, distinguished by its bilateral character, as an architectural element and an art piece composed of the religious paintings.

The iconostasis is one of the most notable features of the interior of the Orthodox and Eastern Christian churches, characterized by the specific artistic, architectural, visual and theological significance. As a characteristic art piece, it represents a richly decorated vertical frame (solid screen) composed of the religious paintings (icons). As an architectural element which dominates the interior of the Orthodox churches, it serves as a visual as well as the physical division between the sanctuary containing the altar area and the nave in a church. By the theology meaning, it separates the layman in the nave from the priest in the sanctuary (Melvani 1981) and represents the symbol of the division between holy and profane, heaven and earth, divine and human (Fanny 2017).

This work presents the workflow which aims to create a museum multimedia presentation of the iconostasis, as the specific art and architectural element of the cultural heritage of the Christian Orthodox churches. It is an outcome of the university and the museum collaboration.

Since the iconostases present unique elements of the monumental interior, and as such can be seen only in situ, the multimedia presentation is significant as it bridges physical gaps and provides a user with the possibility to visualize one of the most valuable cultural heritage of Orthodox Christians outside the physical sacral interiors. For that purpose, the virtual representation of the iconostasis is created by using photogrammetric methods for surveying and 3D modeling. Since the iconostasis can be simultaneously considered as an altar barrier in a church interior, as well as the screen of the religious art paintings, different photogrammetric approaches for surveying are required. An outcome of the surveying, 3D modeling and visualizing of the iconostasis is shown as the multimedia presentation of the museum paintings exhibition.

CASE STUDY OF THE ICONOSTASIS AS THE CHARACTERISTIC ART AND ARCHITECTURAL ELEMENT OF THE CHRISTIAN ORTHODOX CHURCHES

Iconostases initially evolved from the low altar barrier with an architrave, known as a Byzantine templon (Melvani 1981; Fanny 2017). High iconostases, in the form of solid screens with large icons, are developed in Russia in the late 14th and 15th centuries and probably spread thence to Mount Athos, and further to Greece and the Balkans (Fanny 2017). In the 18th century, iconostases became the most decorative elements of the Christian Orthodox churches, with the highly decorated carvings and icons, made by the most influential artists of that time.

The subject of this research is the iconostasis located in the Serbian Orthodox Church of St. Procopius the Great Martyr situated in a village Srpska Crnja, in central-east Banat, alongside the border with Romania, which dates from the period of the 18th-19th century. Besides its religious value, it is also the significant cultural heritage of Serbia since contains rear sacral paintings of the Georgije "Đura" Jakšić (1832-1878), one of the most expressive representatives of the 19th-century Serbian art. The first large painting commission that young Đura Jakšić received involved replacing and copying the icons on the iconostasis in the Church of St. Procopius the Great Martyr in Srpska Crnja. He painted eight icons of the iconostasis during 1853 and 1854: the central icon of the iconostasis, four throne icons, icons on the Royal Doors, and on the North and South Door (see numbered icons in figure 1a).

As opposed to the most of objects of cultural heritage that have a distinctly organic and three-dimensional shape, the iconostasis is characterized

by a notable flat shape distinguished by ornamental decoration and materialization. Except the icons surrounded with the highly decorated frame, other important elements of the iconostasis are richly carved doors: one located in the center and known as a Royal Door, and two on each side, called Deacon's Doors (see figure 1).

Besides the primary architectural function as an altar barrier that separates the altar apse from the nave in a church, iconostases also hold the rare and unique works of artists in the field of sacral painting. As such, iconostases can be also considered as the museum art pieces.

METHODOLOGY

This research focuses on the multimedia presentation of the iconostasis. According to that, a methodology for the 3D digitization and visualization of the iconostasis, as the specific part of the church heritage, is created. The methodology for the iconostasis digitizing and visualization is designed considering three main parameters:

- the iconostasis shape and the size,
- church interior conditions,
- 3D model application.

The methodology is based on the few main steps:

1. Iconostasis surveying;
2. Data processing;
3. 3D modeling;
4. 3D visualizing.

Considering the large dimensions of the iconostasis, situated inside a constrained church interior, the main challenge was to achieve iconostasis 3D representation by using a photogrammetric approach. The proposed photogrammetric approach arises from the specific bilateral character of the iconostasis, as well as from its large dimensions and a flat, yet complex shape. Since it can be considered as an architectural element and the museum art piece composed of the religious paintings, as well, a complete 3D reconstruction with detailed texture was required. Thereby, one of the main parameters that were taken into account during designing the methodology was the required level of detail of the iconostasis 3D model visualization, needed for further application. The result of the proposed methodology for the iconostasis digitization is shown as the multimedia presentation of the museum paintings exhibition in the Gallery of Matica Srpska ([1];[2]) in Novi Sad, Serbia. The museum multimedia presentation consists of two different types of iconostasis visualization:

1. Augmented reality (AR) application for a total 3D representation of the whole iconostasis;
2. Web application which allows a detailed 3D representation of part of the iconostasis that contains icons painted by Đura Jakšić, as well as the high-resolution visualization of the images of that particular icons.

This paper presents the designed methodology for the 3D digitization and visualization applied to the particular iconostasis of the Church of St. Procopius the Great Martyr in Srpska Crnja. However, on the basis of the detailed study of the surveying parameters related to the iconostasis structure and dimensions, its position inside the church, and a characteristic location conditions of church interiors, as the main parameters that affected image-based modeling approach, we propose the methodology that can be repeated the same in the similar surveying scenarios of other iconostases, with changing only a few parameters of the surveying process, according to a specific case study.

Iconostasis surveying

Taking into consideration the bilateral character of the iconostasis and its ornamental shape, as well as its specific position in the church interior, the surveying is split into two main workflows:

1. Total 3D representation of the iconostasis;
2. Detailed 3D representation of single iconostasis elements, such as icons, framed with a gilded carving, and the doors.

Two pipelines based on *SfM* (structure from motion) photogrammetric method for surveying are designed. Each of two main workflows relies on two different *GSD* (ground sample distance) values, initially determined in order to achieve the desired level of detail of the iconostasis reconstruction. Ground sample distance is the distance between adjacent pixel centers measured on the ground, and as such it presents pixel size expressed in an object scale.

First, we determined surveying parameters mutual for both workflows. Due to the notable flat nature of the iconostasis structure, distinguished by significantly lower object depth in relation to its width, the photos were taken in a parallel fashion. In order to introduce detailed iconostasis depth into the 3D model, the parallel mode is combined with divergent camera locations, rotated in the right and left direction by the angle of approximately 10°. The complete iconostasis surveying is performed using the tripod and the camera NIKON D7000 (pixel number: 4928x3275; pixel size: 4.78µm; sensor size: 23.6x15.6mm; focal length: 18-109mm). In order to measure a proper exposure, based on the church interior lighting condition, characterized by a very low illumination, the *Aperture priority* mode is employed to determine correct exposure time, while the values *f-stop* = f/8 and the default *ISO speed* = 100 were manually fixed. The value *shutter speed* = 1 second, selected by the camera as the most suitable exposure time, is fixed and used throughout the whole project. This way, the internal camera parameters, based on the church interior conditions were determined for both workflows.

Figure 1
a) Scheme of the iconostasis in the Orthodox Church of St. Procopius the Great Martyr in Srpska Crnja (author: Vladimir Petrović, The Provincial Institute for the Protection of Cultural Monuments, Petrovaradin, Republic of Serbia); Icons painted by Đura Jakšić: the central icon of the iconostasis (1), four throne icons (2,4,6,8), icons on the Royal Doors (5a,5b), and on the North and South Door (3,7); b) the iconostasis; c) the Royal Door; d) the framed icons of the Royal Door

The second part of the surveying planning is related to the geometric, as well as the location characteristics of the iconostasis. As the typical architectural element of the Orthodox church interiors, the iconostasis is positioned in between an altar apse, behind it, and the church chancel, in front of it. The chancel area includes the side choirs, which slightly occlude the iconostasis on both sides, while the unconstrained space in front of the iconostasis stretches 11m in length to the western main entrance. The iconostasis dimensions of 6,64 (width) x 6,41 (height) meters mainly follow the width and the height of the church.

Since the camera position in relation to the object is not restricted in terms of the limited distance, we designed a methodological approach which depends on the desired level of detail of the representation. In order to achieve different levels of detail of the iconostasis 3D representation, we determined desired *GSD* values: in the range of 0.6-0.8mm for the detailed 3D representation, and 0.9-1,1mm for the total 3D representation, accordingly.

Detailed 3D representation. In this case, the first and the second floor of the iconostasis consisted of the Royal door and gilded carving frames which hold the icons painted by Đura Jakšić were surveyed separately, according to the previously obtained camera parameters, orientation and the position relative to each of them. In order to achieve surveying of the full height of one floor in one stripe of photographs, we used wide angle lens with the 24mm focal length (*c*). By setting the value *GSD*=0,6mm, the distance (*D*) covered on the iconostasis with photograph is determined by considering a particular camera pixel number (formula 1).

$$D = \text{pixel number} \cdot GSD \quad (1)$$

Accordingly, the distance (*D*) is calculated as follows: $4928 \cdot 0,6 = 2,956mm = 2,9m$ (portrait mode); $3275 \cdot 0,6 = 1965mm = 1,9m$ (landscape mode), where the pixel number corresponds to 4928x3275. Since the obtained value of 2,9m covers the first-floor height (2,5m), the appropriate camera orientation resulted in the portrait mode. Further, values for the scale (*m*), as well as the distance from the camera to the object (*h*), are calculated in the following way (formula 2 and 3):

$$m = GSD/\text{pixel size} \quad (2)$$

$$h = m \cdot c \quad (3)$$

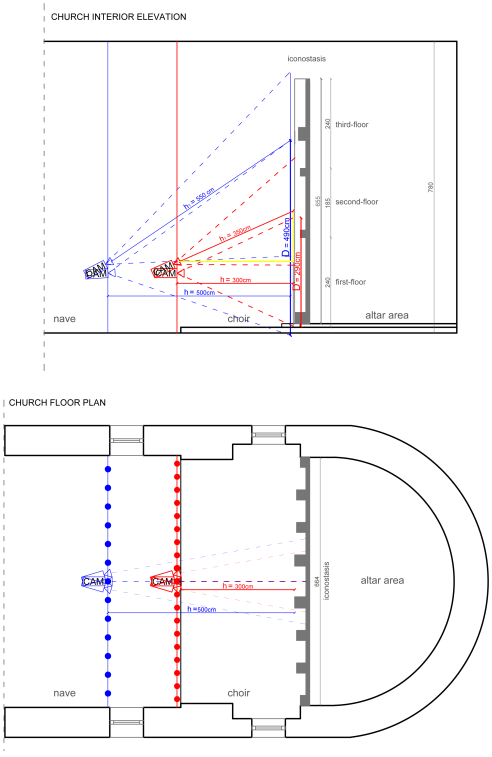
The scale (*m*) was $0,6/4,78 = 0,1255 \cdot 10^{-3}$, and the distance from the camera to the object (*h*) resulted in $0,1255 \cdot 10^{-3} \cdot 24 \Rightarrow h = 3m$, where the focal length (*c*) is 24mm. The survey of the first iconostasis floor is carried considering the constant distance of 3m and the baseline (*b*) of 0,3m providing an average overlapping of 80% between photographs.

The same methodology is applied to the second iconostasis floor surveying scenario, since, in this case, the camera was oriented at a certain angle in order to fully cover by photographs the second-floor height. This resulted in the predefined value of the distance of the camera to the object (*h1*), which was expressed as the mean value of shorter and longer distance hypotenuse (see figure 2). According to this, first, the scale is calculated (see formula 3) as: $m = h/c = 3500/24 = 1,458 \Rightarrow GSD = 0,7mm$, obtaining the *GSD* value which is appropriate for the given scale, and consistent with the initially determined range of values.

The third floor was not surveyed separately since it does not contain the particular icons of the painter, so the detailed reconstruction was not required. However, since it stands on the height of 3,95m, for its detailed representation, the drone should be employed.

Total 3D representation. For the total 3D reconstruction, the iconostasis is surveyed in two stripes, using the *GSD* value initially set in the range of 0,9-1,1mm. Setting the value *GSD*=0,9mm, the first stripe of photographs had covered the first and the second-floor height simultaneously. The same way, the second stripe had covered the second and the third floor, obtaining the *GSD* of 1,1mm, due to the certain angle of the camera position. The same methodol-

ogy for the surveying parameters calculations, used for the detailed 3D representation is performed. Figure 2 illustrates the surveying processes, created for both scenarios.



By taking into consideration the particular distances from the object and the fixed aperture, the depth of field (*DoF*) is checked for every single case, with the aim to achieve a correct sharpness of the photographs. In the case of the detailed 3D representation surveying scenario, the nearest distance of the camera to the object was 3m and the far limit was 4m, so we first checked the *DoF* for the focus of 3m distance. Since for the *f/8* and the distance of the 3m, *DoF* is 1,64m at near limit, and 17,3m at the far, (15,7m in total), so the focus in front of the subject is 9%, the nearest distance of the 3m was used as the appropriate camera focus point. For the total 3D representation surveying scenario (nearest distance to the object = 5m; the far limit = 5,8m), the camera was focused at the subject distance of 5m, which covers the depth of field of 2m in front of the iconostasis, up to infinite behind it. The calculated parameters for two different surveying scenarios are shown in table 1.

Data processing

Data processing was done using automatic, photogrammetric software, based on the depth map method, which generates mesh directly with depth map data, allowing a reconstruction of exceptionally detailed geometry.

The photographs acquired by each of the surveying scenarios were processed separately in order to estimate error and the reconstruction accuracies (see table 2). In addition, the stripes of images were linked and processed mutually, creating two different 3D models. The detailed 3D representation consisted of the particular icons painted by Đura Jakšić, is created by simultaneously processing photographs related to the first and the second iconostasis floor. The total 3D representation of the iconostasis is based on the mutual processing two stripes of photographs of the linked first and the second floor, and the second and the third floor, respectively.

By studying the specific church interior conditions, as well as the iconostasis structure and its characteristic position inside the church, we designed a methodological approach which depends on the desired level of detail of the reconstruction. The proposed methodology is evaluated by comparing the *GSD* value resulted by processing data with the one initially established for each of the surveying scenarios, individually, as well as in their compatible combination. The achieved accuracies and the reconstruction parameters, resulted by using high-quality processing settings are shown in table 2. For the total 3D reconstruction the masks were applied to the photographs, which reduced the number of points and polygons. It can be concluded, that re-

Figure 2
Scheme of the surveying process, created for both scenarios (red line - detailed 3D representation; blue line - total 3D representation)

Table 1
Surveying parameters for detailed and total 3D iconostasis representation surveying scenarios: D = distance covered by photograph; h = distance of the camera to the object; b = baseline.

Surveying parameters	Detailed 3D representation		Total 3D representation	
	1st floor	2st floor	1st + 2st floor	2st + 3rd floor
focal length (c)	24 mm	24 mm	24 mm	24 mm
GSD	0,6 mm	0,7 mm	0,9 mm	1 mm
D	2,9 m	2,9 m	4,9 m	4,9 m
h	3 m	3,5 m	5 m	5,5 m
b	0,35 m	0,35 m	0,50 m	0,50 m
focus point	3 m	3 m	5 m	5 m

Table 2
Estimated error and the achieved accuracies and reconstruction parameters, resulted by using high-quality processing settings

Data processing	Detailed 3D representation		Total 3D representation		
	1st floor	2st floor	1st + 2st floor	2st + 3rd floor	1st + 2st floor + 2st + 3rd floor
GSD (mm)	0,59	0,85	0,90	1,16	0,95
Mean error (mm)	0,082	0,024	0,018	0,024	0,039
Depth maps	58	37	48	23	71
Dense points	24,858,174	4,074,637	10,669,166	8,358,967	10,837,310
Polygon count	1,120,750	273,331	978,557	832,972	1,601,083

gardless of the height of the iconostasis (6,5m), the ground photogrammetry provides satisfying results in two different levels of details. Figure 3 shows the orthophoto obtained after detailed 3D reconstruction. Total 3D representation of the iconostasis obtained by using the proposed methodology and automatic photogrammetric approach is illustrated in figure 4a. Considering that the data processing results are consistent with the previously determined surveying parameters, it can be concluded that the same methodology could be adapted to a number of similar iconostasis surveying scenarios, which is the subject of the future research.

3D modeling

The meshes are automatically created by the generating mesh from depth maps tool in photogrammetric software, providing a high level of detail (see figure 4a). According to the needs of the further 3D model application, the mesh is additionally edited using a few different digital tools. Software for digital sculpting is used with the aim to improve the 3D model, in terms of editing geometry, cleaning redundant faces and closing holes (see figure 4b). In order to prepare the 3D model for its visualization in the augmented reality environment, the mesh polygon count is optimized by performing retopology techniques. Given that the iconostasis is composed of the religious paintings, notable attention is dedicated to detailed texturing. Since the poor lighting conditions of the church interior caused uneven exposure between images, as well as an overexposure on side photo areas, the photographs, taken in *RAW* format were manually edited prior to the automatic texture generation inside the photogrammetric software. The image exposure was manually improved by exposure correction toolset in a photo editing application. Furthermore, the texture was un-

Figure 3
Orthophoto of the detailed iconostasis 3D representation

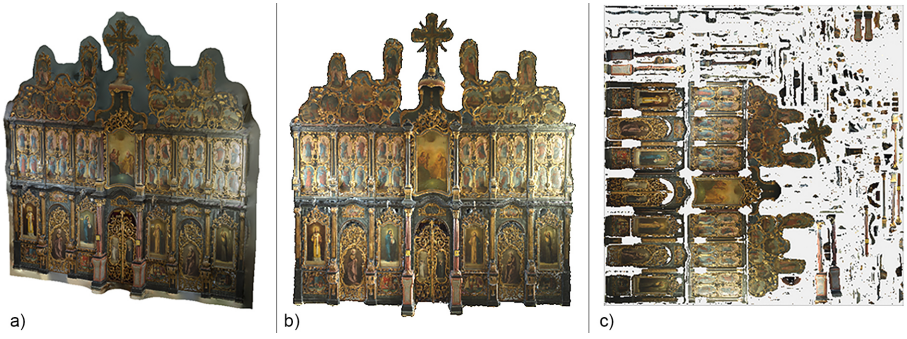


Figure 4
Total 3D representation of the iconostases: a) automatically generated 3D model; b) improved 3D model; c) unwrapped texture map

wrapped and exported into 3D texture painting software, whereas the specular and normal maps, were created, in order to refine the visual quality of the iconostasis 3D model material appearances (see figure 4c).

3D visualizing

3D models with additional options and information are visualized throughout the virtual environment made for the museum exhibition of paintings. The 3D visualization of the iconostasis can be split into two main parts:

1. Augmented reality (AR) visualization of the whole iconostasis;
2. Web application which allows detailed 3D model visualization of the linked first and the second iconostasis floors, consisting of particular framed icons painted by Đura Jakšić, and the carved doors.

AR application. Since the iconostases, as unique architectural elements of the church interior can be seen only in situ, the main idea of the AR application is to allow a user with the possibility to visualize it outside the physical borders of the monumental interior.

Regardless the large dimensions of the iconostasis, in this way, the visualization of the entire structure of the iconostasis construction, as a big frame which, visually and physically, supports the icons, as well as the visualization of single icons, is allowed.

For this purpose, the previously optimized 3D model of the total iconostasis representation is used. AR application is developed using the Vuforia SDK that comes integrated with the Unity game engine. The whole application is made inside one scene in the Unity engine, while the changing between the AR scene and the main application page is performed only by switching between AR and the main camera, with the aim to achieve optimized processing time. This way, the whole iconostasis is visualized by detecting the printed marker throughout the camera of the tablet device (figure 5a).

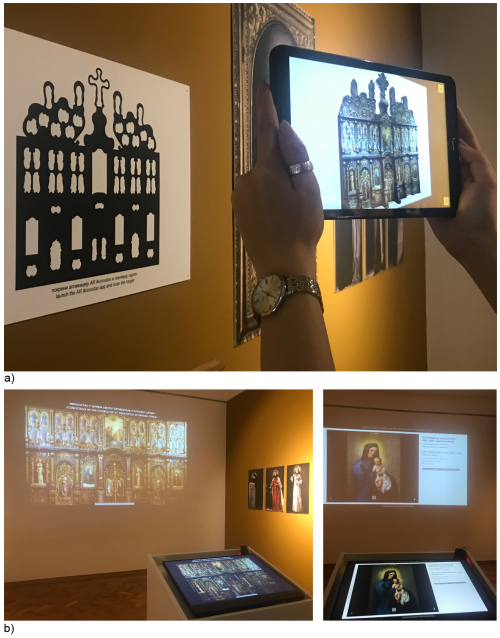


Figure 5
Multimedia presentation of the iconostasis at the museum painting exhibition of the Gallery of Matica srpska (Mišić 2019; [1]; [2]); a) AR visualization; b) Web application and the iconostasis orthophoto digital projection on a wall

Web application. Web application for the detailed iconostasis presentation is developed with the main idea to allow users to interact with the 3D model of the iconostasis in the virtual environment which provides additional options, such as more detailed visualization of the individual icons with accompanying information on the title of the work, the period of origin and the key characteristics that describe it as an art piece. In this case, the detailed representation of the first and the second iconostasis floors, with the obtained *GSD* of 0,90mm is presented as the digital projection of the orthophoto on the wall (figure 5b). The application provides options for click and zoom on one of the eight icons painted by Đura Jakšić, in order to visualize it in detail with additional text information on it.

MUSEUM MULTIMEDIA PRESENTATION OF THE ICONOSTASIS

This research presented an outcome of the collaboration between the university team and the Gallery of Matica Srpska in Novi Sad, realized throughout the museum multimedia presentation of the iconostasis. The painter Đura Jakšić and his artistic creation have brought together two national museum institutions - the Gallery of Matica Srpska and the National Museum in Belgrade - which have jointly realized the exhibition *Đura Jakšić. Between Myth and Reality* dedicated to the artist whose literary and visual artworks marked the Serbian art and culture of the 19th century.

Through three thematic wholes - portrait, religious and historical painting - the exhibition presents the visual art opus of Đura Jakšić. In addition to the paintings from the museum collections and from the Serbian Orthodox Church, his painting work in the Church of St. Procopius the Great Martyr is also available for viewing thanks to the implementation of modern technology (see figure 5).

CONCLUSION AND FUTURE WORK

This research presents the part of the wider study of the church heritage digitization and visualization, with the focus on the iconostasis. The paper explains the process of creating the multimedia presentation

of the iconostasis, as the unique element of the Christians Orthodox church heritage. The multimedia presentation of the iconostasis is shown as part of the museum paintings exhibition. The iconostases are ornamentally shaped and decorated elements situated in the altar area of churches, on which religious paintings are represented. Since the visualization of the iconostasis is possible only in situ, the multimedia presentation provides the user with the possibility to visualize and interact with the church heritage outside the physical church interior.

According to the detailed analysis on the iconostasis structure and dimensions, as well as its characteristic position inside the church, we designed a methodological approach, based on specific church interior conditions, which depends on the desired level of detail of the representation. The proposed methodology for the 3D digitization and visualization an iconostasis has been tested on the particular case study and can be further applied to a number of other iconostases, with manipulation of only a few key parameters of the surveying process. Considering that the initial results are very encouraging, further testing and improving the methodology on other iconostases is of particular interest in future developing the proposed techniques for the church heritage digitization.

ACKNOWLEDGMENTS

We would like to thank the Serbian Orthodox Church of St. Procopius the Great Martyr and the Cultural center *Đura Jakšić*, in Srpska Crnja for the approval for the iconostasis surveying.

The first author is financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, within the Project No. ON174009.

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