Perceived Quality as Assessment Tool for the Test Case Amore e Psiche Domus in Ostia Antica

LAURA POMPEI, OLIVIERO ELETTI, LUCA GUGLIERMETTI, FRANCO GUGLIERMETTI, LUCIANO RICCIARDI, ALESSIA D'ANGELO, BARBARA DE LIETO VOLLARO, Sapienza, University of Rome, Italy

Recent years have seen the development of many new ways for cultural heritage visualization; with the growing use of "Information and Communications Technology" (ICT) many 3D reconstructions, virtual tours and "Augmented Reality/Virtual Reality" (AR/VR) application has been developed to enrich the contents of museums, archeological sites and historical places. However, today only few cultural assets have an accurate 3D model with a detailed informative content. In fact, the costs due to the creation of virtual content are still high and they can be addressed only for the most iconic or important monuments. Inside this frame the project RECIPE (REsilience in art CIties: Planning for Emergencies) founded by ESA/ESTEC[1] use a crowdsourcing approach, involving tourists and interested people, to acquire cheaply the photos necessary to create photogrammetric models. Such a models to be correctly used inside different level of recording and monitoring tasks, require developing procedure to evaluate their quality. This work discusses, with reference to a study case, only how to validate models by proposing a methodology based on dimensional and color error calculation together with structural indices, such as SSIM and PIQE. Besides to avoid influence generate by different cameras, focus and positioning in photos taken by tourists, the used photo data base has been produced with a professional device following the state of art rules in SfM. At least, it is also discussed the possibility to implement the 3D models in a virtual reality environment to increase their diffusion on new multimedia and interactive plat-forms.

Key words:
Quality assessment, photogrammetry, structural similarity.

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INTRODUCTION

During the last century, with the growing of Computer Technologies, many new technological applications have been developed for the digital visualization of cultural heritage. One of the main goals of the digitization process is to support preservation and conservation issues. Visiting and maintaining archaeological site difficult to access is a complex problem especially if it is placed in dangerous areas such as places affected by earthquakes or conflicts. In Italy, the "Central Institute for Cataloguing and Documentation"[2] was found in 1975 precisely to discuss and cope with this awareness. The Institute published in 2004 the Code of Cultural Heritage and Landscape[3] that defined how to establish, increase and update the national documentations of cultural heritage. Also the "Carta del Rilievo" (relief charter), the main Italian document about preservation of cultural assets, discuss the various aspects involved, including: accuracy of the surveys, dimensional and geometrical characteristics of the monuments, the context and the sustainability for restoration, the criteria of cost-benefit analysis before interventions. This topic is still under

Authors addresses: Laura Pompei, Oliviero Eletti, Luca Gugliermetti, Franco Gugliermetti, Alessia D'Angelo, Barbara De Lieto Vollaro ,Department of Astronautical, Electrical and Energy Engineering DIAEE, Sapienza University of Rome, via Eudossiana 18, 00184, Rome, Italy; email:laura.pompei@uniroma1.it,eletti.oliviero@gmail.com,luca.gugliermetti@uniroma1.it,franco.gugliermetti@uniroma1.it,alessia.dangelo@uniroma1.it, barbara.delietovollaro@uniroma1.it.; Luciano Ricciardi, freelancer; email: luciano642@hotmail.com.

[1] ARTES 20 Demonstration Project, 1-AO6124
[2] http://www.icr.beniculturali.it/
[3] http://www.iccd.beniculturali.it/

discussion in Europe, where the “National Digitization Plan” (PND) is currently being implemented at national level, in line with the EU directive (2011/711/EU). Inside this framework, the development in the geomatic field has allowed to improve the accuracy of the relief methods, and consequently the digital representation, with the use of photogrammetric and laser scanner techniques. However, these technologies are very expensive, and their economic impact can be reduced using a crowdsourcing approach in which large group of people can contribute to generation, implementation, management and analysis of data to produce open source materials. Perhaps one of its greatest advantages, besides the distribution of repetitive tasks to a large amount of people, is that the participation in crowdsourcing gains a sense of ownership that motivates further participation and affects positively the outcome of projects.

Most crowdsourcing projects regarding cultural heritage have the aim to create a dedicated online platform, where users can share the photos they taken of monuments. Those platforms work as complex photographical database that can be used for different purposes. A famous example is about the ancient city of “Palmyra”, an archaeological area destroyed during the Syrian civil war in 2013. The site’s photos were collected through an important media awareness campaign, which involved a wide audience of users. The project, known as “NEWPALMYRA”[4] was encouraged by the UNESCO Convention of Krakow in 2017. A recent evolution of the project is “PALMYRAVERSE” a platform which involves the interaction between 3D models in a VR and AR environment. Another example of crowdsourcing project is “PROJECTMOSUL”[5] which has now changed its name to REKREI. By accessing the website, the user can view a global map of the destroyed archeological site and can decide to upload new photos. Moreover, some crowdsourcing project are related to the digitalization of the cultural heritage stored in museums and archives. For example, project MICROPASTS [Bonacchi et al. 2014] was born from the collaboration between the Institute of Archeology of the University College of London and the British Museum; it was originally focused on the findings of the Bronze Age unearthed in Great Britain. The volunteers, educated by professionals, have been involved not only in the phase of digitalization and georeferencing of the artifacts, but also in the photo-masking procedures. The project has catalyzed the interest among users, especially the younger ones, for 3D models obtained with data coming from crowdsourcing. Another example is the ACCORD project, founded by the UK Arts and Humanities research council's community and digital design at the Glasgow School of Art Archeology Scotland, University of Manchester [Jeffrey et al. 2014]; it engages existing community groups in the process of designing and producing 3D records and models of heritage places, many of which they have ongoing relationships with, by the availability of photogrammetric consumer level techniques. The use of crowdsourcing approaches is also encouraged in Italy by authorities through regulations as L.D 91/2013 "Valore Cultura", L.D. 83/2014 "Art Bonus" and L.D. 94/20149.

The present work is part of the project RECIPE (REsilience in art CIties: Planning for Emergencies) founded by ESA/ ESTEC (ARTES 20 Demonstration Project, 1-AO6124). RECIPE main objective is to provide low cost updated 3D models of cultural assets, using, as source of information, photos taken by commercial portable devices, provided by collaborative tourists through a crowdsourcing model. Moreover, RECIPE will make available selected photos assessing the status of the building or artifacts of interest along time, in a sort of real time monitoring, and will implement virtual reality. RECIPE is based on existing “Structure for Motion” (SfM) software for the 3D modelling integrated with two satellite assets: EGNSS services, for the characterization of the point from where the photos have been taken and EO services to capture the real proportion of the building without the need of costly and lengthy survey of the site. This goal is possible by means of a specifically developed smartphone application which attract people giving away the photogrammetry models they have made and some discounts to tickets of museums and archeological sites in exchange to the participation to the project. The elaboration of 3D models to be usable in monitoring and recording taskrequire to reach an appropriate Level of Accuracy (LoA) by a proper use of SfM technologies and to be comply to the main guidelines, as those developed by AHDS, Guides to Good Practice for CAD and Virtual Reality (2002), the by Virtual Archeology Special Interest Group (VASIG) [Grande and Lopez-Menchero 2016] and by the Cultural Virtual Reality Organization. (CVRO) [Frischer et al. 2000].

This paper only focused on the method to assess the quality of 3D model, that will be used to valuate RECIPE results; inside this frame, to avoid influence generate by different cameras, focus and positioning in photos taken by tourists, the data base photos are collected with a professional device following the state of art rules in SfM. At least, it is also discussed the possibility to implement the 3D models in a virtual reality environment to increase their diffusion on new multimedia and interactive platforms.

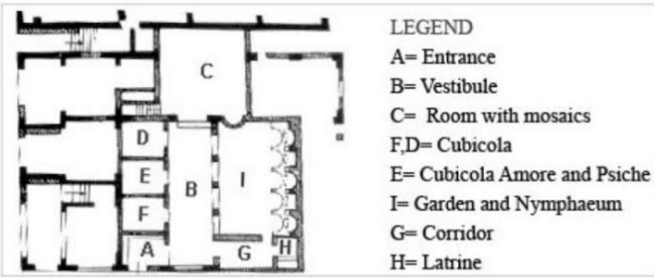
[4] https://www.newpalmyra.org/
[5] https://projectmosul.org/

The proposed approach involves the use of some structural and non-structural indices typical of the computer vision and medical field, in particular the Mean Absolute Percentage Error (MAPE), the "Perception based Image Quality Evaluator" (PIQE), the "Structural Similarity" (SSIM), the "Signal to Noise Ratio" (SNR), the "Peak Signal to Noise Ratio" (PSNR) and "Mean-Squared Error" (MSR) have been chosen for the assessment. Structural indices suppose that the human visual system is highly adapted for extracting structural information from the scene, and therefore a measure of structural similarity can provide a good approximation to perceived image quality [Wang et al. 2003].

CASE STUDY

The "Domus of Amore and Psiche" sited in the archaeological park of ancient Ostia was chosen as case study for its wideness and historical importance. The site is the biggest archaeological site in Europe and it is in the southwest of Rome, about 8 km from the coast (Fig. 1. a). The site is famous worldwide for its ancient buildings and mosaics. The name "Ostia" comes from the latin word "oris" [/ˈoː.ris/] which means "mouth" because it was placed at the mouth of the river Tiber. The "Domus of Amore and Psiche" (Fig. 1. b) is an ancient domus that was built in the second quarter of fourth century. The old owner probably was a Hercules's priest who built a temple in the south of the house. The building has the typical structure of roman domus: the entrance, south oriented, is the vestibule which is connected to three *cubicula*/bedrooms and to another room sited in the north of the house; this room is famous for its opus sectile on the floor. Following the entrance, there is a tiny garden, separated by a marble colonnade which is placed along the east-side of the vestibule. A nymphaeum (Fig. 1. c) is located behind the garden and consists in two rows of five semi-circular niches decorated with columns in the upper part. Finally, a small latrine was placed in a corridor connected to the vestibula. The domus takes its name from the statue of "Amore and Psiche", discovered in the bedroom (Fig.1. d).

a



b

c

d

Fig. 1. a) Aerial view of Ostia Antica, b) Amore e Psiche Domus plan, c) Nymphaeum, d) Cubicula with Amore and Psiche statue

METHODOLOGICAL APPROACH

Nowadays, many researches supplied guidelines for SfM applications in order to provide reliable results to assess 3D models quality for cultural heritage purposes. One of the most relevant work is “The Photogrammetric Applications for Cultural Heritage” [Bedford 2017; Koutsoudis et al. 2014], which discusses all aspects of photogrammetric processing in depth. Other important works, providing the latest developments in the field are [Stylianidis and Remondino 2016; Patias 2006; Fonstad et al. 2012]. Considering the guidelines and good practices, the photogrammetry campaign has been conducted in order to obtain the best possible results in terms of “Level of Accuracy” (LoA). All the followed steps involved in the process are described in detail in the next paragraphs

Measurement campaign

The measurement campaign was carried on the 23rd of June 2018, under a cloudless sky condition from 10 am to 15 pm, in order to have as far as possible a uniform illuminance condition. To reduce the sun effect on photos they were taken in this time span, when the sun reaches its zenith, reducing the shadow projected by the ruins which could lead to reduce 3D texture quality. For the campaign a NIKON D810 full-frame equipped with a GPS receiver MARREX MX-G20 MKII and with a photographic lens of focal length of 17 mm was used. During the field campaign a photographic database of 780 horizontal “Tagged Image File Format” (TIFF) photos has been collected with a resolution of 7360 x 4912 pixels. The TIFF format has been chosen for its suitability due to its lossless quality. All photos were taken with parallel-axis technique and with large overlapping areas (70 %-80 %) in order to capture the same scene at least in three different images. More photos have been taken for important details, such as columns and mosaic floors. Moreover, during the photographical campaign a relief has been made; the building shapes and dimensions has been measured by an EDM (Electronic Distance Measurement) device (Leica DISTO S910, error of 0.010 % at maximum distance range of 300 m). The relief data were used to aid the reconstruction process with the help of 68 markers that have been placed in the site to properly dimension the model. The distance between the markers has been taken placing the EDM device on a tripod in the centre of every room and measuring the distances between every visible marker. This method is important to understand the error made by the reconstruction process: each marker, in fact, highlight a specific point in both the real building and the reconstructed model. From this analysis 35 of the scale bars has been obtained from the 61 points and has been used as dimensional input for the photogrammetric program; not all the markers where used during the reconstruction process leaving 30 points to validate the results, comparing the measured value with the distance in the 3D model. This is important to do not affect the results with the input data: if all the markers were used as input the measured error would be modified due to the scale bars constraints.

SfM software

Agisoft PhotoScan Professional 1.4.1 has been chosen as reference software in this study[6]. As general statement, the quality of the photos used in photogrammetry is related to the final quality of the reconstruction; blur, shadows, changing of lights, foreign objects and bad exposition must be avoided as much as possible. As quick check on the image quality the “input quality imagine index”, created by Agisoft PhotoScan, has been used. It provides a value based on the sharpness level of the pictures in a range from 0 to 1; the photos with a quality value less than 0.5 units has been excluded from the photogrammetric processing. In this case, 771 imagines of the photographical database satisfied this quality threshold. Fig. 2 show the final reconstruction output obtained at very high settings. The obtained model is made of more than $15x10^9$ triangles and 40 textures of 8128 x 8128 pixels each.

[6] Agisoft PhotoScan Professional 1.4.1 Manual, DOI: https://www.agisoft.com/pdf/photoscan-pro_1_4_en.pdf

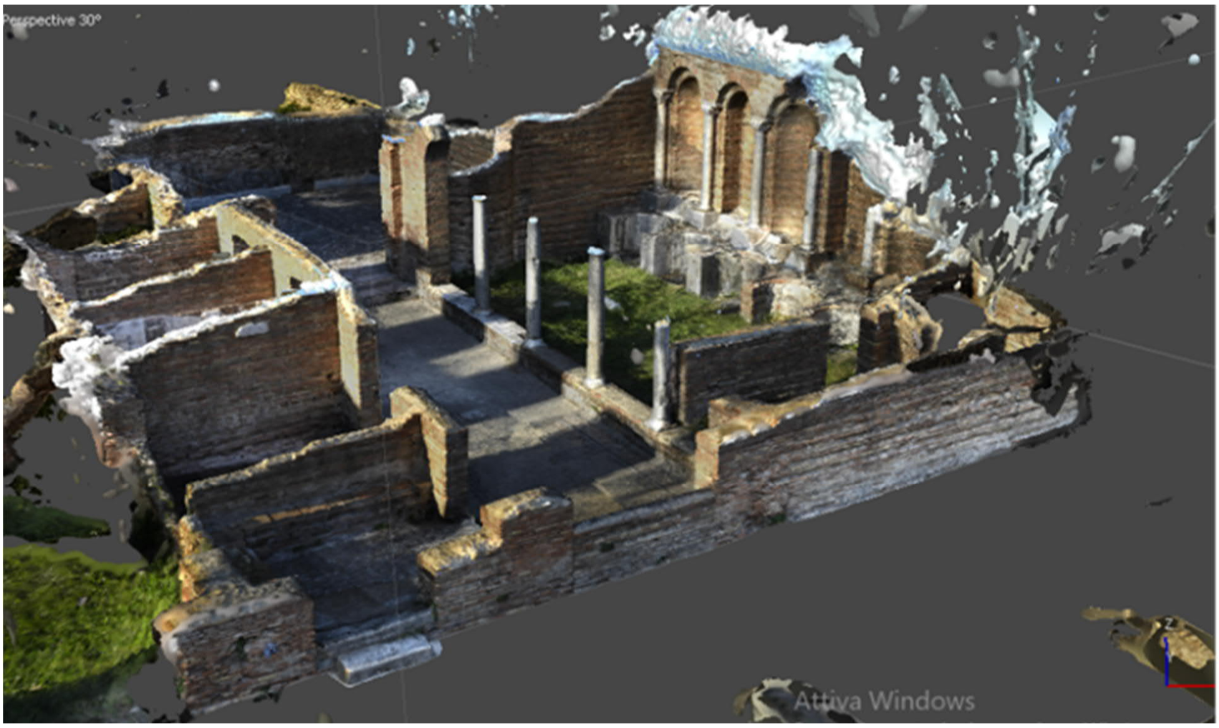


Fig. 2. Final reconstructed model

Dimensional errors and perceptual quality

To validate the model quality, it is proposed a “three-dimensional methodology” which takes in account dimensions, colours and perceived structure. The methodology involves not only the absolute pixel colour value coming from a singular pixel analysis, but it considers also the inter-relation between pixel in order to analyse the “true” representation of an object and the clearance and discernibility of its details. This methodology is useful where dark areas and hidden details could degrade the quality of the representation. Hence, for this study, the following indices have been calculated: “Mean Absolute Percentage Error” (MAPE), “Perception based Image Quality Evaluator” (PIQE), “Structural Similarity” (SSIM), “Signal to Noise Ratio” (SNR), “Peak Signal to Noise Ratio” (PSNR), and “Mean-Squared Error” (MSR). Their mathematical formulation and the recommended thresholds for SSIM and PIQE are discussed. The recommended values for SNR, MAPE and PSNR are not reported because these metrics are more useful for comparison purposes between different reconstruction of the same model; moreover, they do not consider the perceived quality but only the difference between the original photo and the virtual model. The colorimetric analysis, based on “International Commission on Illumination” (CIE) [Sharma 2003] recommendation CIE76 [Upton 2016], CIE94 CIEDE2000 [Lindbloom 2016], and the Euclidean distance in sRGB [Hughes 1998] space, was already performed by the authors [D’Angelo et al. 2018]. Regarding the dimensional error the best approach is to use a regression calculation, which involves the measurement of distance between every couple of markers on site and on the 3D model. Some authors as [Fritsch and Klein 2017] recommend the “Iterative Closest Point Algorithm” (ICP) but this method requires a deep knowledge of dense point cloud of the model that is not always easy to elaborate. An alternative method is to use a distortion matrix: considering a grid of points on the object surface, identified by shapes or edges, is possible to calculate the distances between the points in the reconstructed and real object [Pedersini et al. 2000; Arias 2005; Wang 2004]. A vector analysis, based on the MAPE parameter, has been performed to validate the geometrical accuracy between the real building and the reconstructed model. The formulation is reported below:

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{(A_t - F_t)}{A_t}\right| \quad (1)$$

Where At is the real measured value and Ft is the distance in the virtual model.

The structural analysis compares the shapes and colours information contained in two images. In order to compare a 3D model with the photos taken during the relief the used methodology can be reassumed as following: the camera position calculated by photogrammetric software, which is the point where the photos are supposed to be taken, has been used to render an image of the virtual model. Then, the original photos and render where scaled to the same resolution (N x M pixels, varying with every couple of images; It is not necessary to get high resolution due to the importance of the shapes not of the number of pixels) and converted both in RGB space before applying the calculations. Since the used indices are full reference metrics, the calculation must be made with uncompressed format such as Tagged Image File Format.

The fist metric considered is the Signal-to-Noise Ratio, it is a widely diffused index used in science and engineering to compare a signal to the level of background noise. It is expressed in Decibel as shown in the formula (2).

$$SNR_{dB} = 10\, log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \quad (2)$$

The Mean-Squared Error measures the average squared difference between the real values and what is estimated. Given a noise-free M×N pixel monochrome image I and its noisy approximation K, MSE is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (3)$$

Peak Signal-to-Noise Ratio is another diffused metric which is formulated as SNR but it evidences the maximum difference between a signal and the environmental noise. It can be defined trough the MSE (4):

$$PSNR_{dB} = 10 log_{10}\left(\frac{MAX_I^2}{MSE}\right) \quad (4)$$

Where MAX_I^2 is the maximum possible pixel absolute value, it is expressed in dB as for SNR. For the photogrammetry purpose the signal is the RGB value of the original photo and the noise is the colour difference between the original photo and the render of the virtual model.

The structural similarity is a model for predicting the perceived quality of a digital content; it is perception-based metric and considers the image degradation as a perceived change in structural information. It is based on the idea that the pixels have strong inter-dependencies when they are spatially close. The index is usually used for measuring the similarity between two images, one compressed and one not, but in this work, it is proposed as evaluation metrics for 3D model quality assessment. The model was developed in the University of Texas at Austin and at New York University [Venkatanath 2015]. To calculate SSIM the model, some render of the virtual model has been be sectioned into samples and compared with the section on a reference photo. As stated before, the render position was calculated by the software as the shot position. The SSIM index mathematic can be reassumed in following equation:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (5)$$

Where x and y are the two sample images (real and virtual) of the same size in pixels; μ is the average value between pixels of x and y; σ is the variance of x and y as stated by subscripts; σxy is the covariance, and C1 and C2 are two variables used to stabilize the denominator:

$$C_1 = (k_1 L)^2, C_2 = (k_2 L)^2 \quad (6)$$

Where K1 = 0.01, K2 = 0.03. L is the dynamic range of the pixel values calculated as below:

$$L = (2^{bits\ per\ pixel} - 1)$$

The index is symmetrical hence x and y can be changed in order. The three components, of which the index is made, can be calculated separately:

1. Luminance (l):

$$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu_x^2 + \mu_y^2 + c_1} \quad (7)$$

2. Contrast (c):

$$c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x^2 + \sigma_y^2 + c_2} \quad (8)$$

3. Structure (s):

$$s(x,y) = \frac{\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3} \quad (9)$$

Where C3 = C2/2 and:

$$SSIM\ (x,y) = \left[l(x,y)^{\alpha} * c(x,y)^{\beta} * s(x,y)^{\gamma}\right] \quad (10)$$

The three constants α, β and γ are weights that can be reduced to 1 to obtain the form showed in equation (2). SSIM can be applied both in luminance space (Grey scale) or in RGB space; in the present work all indices have been analysed only in RGB space. A SSIM value of 1 indicates a perfect match between images and a SSIM ≥0.65 indicates the recommended matching between images [Venkatanath 2015].

The last metric used for the validation purposes is the Perception based Image Quality Evaluator. It calculates the no-reference quality score for an image through a block-wise distortion estimation and through a Gaussian noise analysis. The evaluator generates a spatial quality mask that indicates the high spatially active blocks, noticeable artefacts blocks, and the noise blocks in the image. It is also possible to visualize the spatial quality masks by overlaying them on the image. The evaluator is useful to assess if the output image has a good quality and every part is clearly discernible. A quality scale for the images is given in the Table 1: a low score value indicates a high perceptual quality and high score value indicates a low perceptual quality [Sheikh 2013].

Table 1: PIQE quality scale

Quality Scale	Score Range
Excellent	0-20
Good	21-35
Fair	36-50
Poor	51-80
Bad	81-100

RESULTS AND DISCUSSION

The results of the study show a good agreement between the 3D model and the photos, for clarity purposes they were divided into two categories: dimensional errors (Table 2) and perceived quality (Table 3). In the dimensional error table, the column “Max.” indicates the maximum relative error between the scale bars in the whole database, the column “Metric” indicates maximum error on a segment, the column “MAPE” indicates the error calculated with (1) and the standard deviation is calculated on MAPE values.

Table 2: Dimensional errors

Errors model scaling			
Max.	**Metric**	**MAPE**	**Standard deviation (σ)**
3.04 %	2.32 mm/m	0.049 %	0.0212
Validation scale bars			
Max.	**Metric**	**MAPE**	**Standard deviation (σ)**
8.6 %	3.76 mm/m	0.051 %	0.0156

Concerning the perceived quality results, Table 3 presents the average results of all the metrics mentioned in the previous paragraph.

Table 3: Imagine quality results

SSIM	PIQE	MSE	SNR	PSNR
0.65	24.84	1031.50	10.70 dB	19.30 dB

The most clear and significant images analysed with the SSIM and PIQE metrics are in Figures 3, 4, 5, 6, 7, and 8 where it is possible to see the differences between the reference and reconstructed image in terms of perception. The three images were chosen to show high, medium and low SSIM and PIQUE results.

a *b* *c*

Fig. 3. SSIM = 0.746, a) Reference Imagine, b) Modelled imagine, c) SSIM index map

a *b* *c* *d*

Fig. 4. PIQE = 24.16, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

a b c

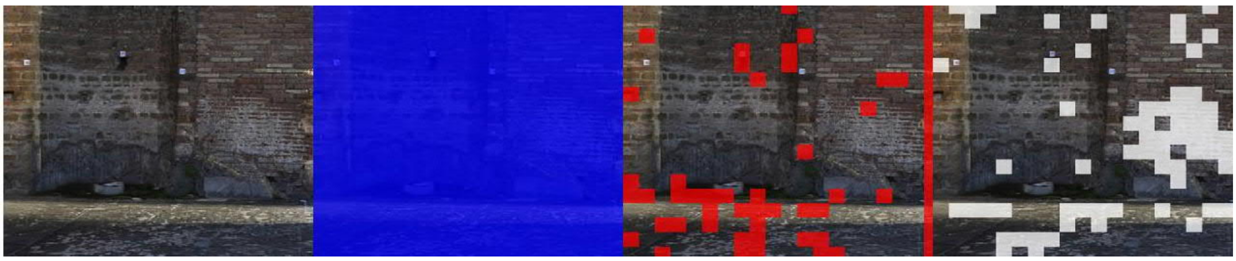
Fig. 5. SSIM = 0.548, a) Reference Imagine, b) Modelled imagine, c) SSIM index map

a b c d

Fig. 6. PIQE = 27.05, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

a b c

Fig. 7. SSIM = 0.819, a) Reference Imagine, b) Modelled imagine, c) SSIM index map



a b c d

Fig. 8. PIQE = 20.97, a) Distorted Imagine, b) Activity mask, c) Noticeable artefact mask, d) Noise mask

The “SSIM index map” visible in the Figures shows through a Grey scale the difference in terms of pixel luminance intensity between two imagines. The map is made by two layers, the luminance masking and contrast masking. The luminance masking is the phenomenon whereby the image distortion tends to be less visible in bright regions, while the contrast masking is the phenomenon whereby distortions become less visible where there is significant activity or "texture" in the image. Naturally, the SSIM measures also the presence of noise.

PIQE activity Mask is composed of high spatially active blocks in the input image (e.g. Fig. 8. b). These blocks are the regions with more spatial variability caused by factors such as artefacts and noise. The Artefacts Mask is composed of blocks in activity Mask that contain blocking artefacts or distortions, as showed with the red squares, and the noise Mask is composed of the blocks in the activity Mask that contain Gaussian noise, as showed with the white squares.

IMPLEMENTATION IN VR REALITY

This paragraph discusses about the methodology followed by the authors to implement the photogrammetry models in a virtual environment. As first step it was considered witch software use; it is common to use a real-time development platform for games as developing environment to create a virtual reality program. They offer a complete, mature and versatile development platform, rich of support and documentation. For this study has been chosen Unity, which is a free to use software for study or learning purposes. The procedure followed to create the virtual environment can be reassumed by following:

1. export and clean the model, create texture maps
2. import into Unity and create a virtual environment
3. optimize basing on the application

The export file type chosen is the object with the texture, provided by the photogrammetry software. The following cleaning process, has been performed with the use of an open source software called “Meshlab”; the process is important to remove all the artefacts including isles (piece of meshes that are not part of the real model), high-density edge poles, self-intersecting nodes, zero-area faces, feature points outside any primitive, overlaps, to fill holes and to control the vectors normal to surfaces. On Meshlab it was possible to perform all the tasks using the algorithms included in the software. Moreover, the model has been simplified as much as required by the application, controlling the quality of the result step by step. After this step it is possible to operate on a better 3D model, clean and faster to render. As a part of this step the Normal, Albedo and Occlusion maps have been made. These maps are important to increase the perception of the light and depths. The second step has been to import the model into Unity creating a virtual environment, filled with sounds, information, and animations. The aim was to create immersive environment able to give the impression to be on the site. In fact, the experience can be enriched with informative layers, to add historical/cultural information, teleportation beams, to move through the environment, and sound effects to maximize the immersive perception of the VR environment. These features have been coded into scripts (C# or Javascript, the two main programming languages supported by Unity) and game objects loaded into the Unity environment. However, some content is freely available online and needs only to be costumed on the specific project. The third and last step has been the optimization. It was composed by many sub-steps to avoid motion sickness and to grant the global performance during the virtual experience. To address such challenge may there are some constraints: first, the real time rendering must be fast, a rendering frequency of more than 90 fps is recommended, and delay must be lesser than 11 ms[7]. Moreover, where huge environments are present and where is necessary to move by teleportation beams, a fade effects had been added during the teleportation process to avoid motion sickness. Direct movement using controllers has been avoided because it is a common cause of discomfort and during simulations [Krueger 2011]. Moreover, before the developing of this study a questionnaire on colour and space perception in virtual environment has been delivered to stakeholders to grant the quality of the virtual environment and to check the acceptance of this new media. The statistic sample was not wide enough to consider this test as “significant”, but it placed the basis of this work, permitting to focus on the main aspects discussed. During the test a group of 30 people has been invited to evaluate, on a scale from 1 to 10, a virtual simulation answering to 30 questions about dimensions, colours and general perception of some elements specifically chosen. The results have been showed that objects that presented albedo, normal and occlusion map was seen more realistic then others with only albedo map. At the same time, the lighting has been found realistic and close to the real one. At least, testers have been found uncomfortable and dangerous the presence of wires connected “Head-Mounted Display” (HMD).

CONCLUSIONS

The results show how the considered 3D model is geometrically and perceptively similar to the original in term of geometry and perceptive accuracy. Dividing the results in two topics it is possible to get the following conclusion:

[7] https://help.irisvr.com/hc/en-us/articles/215884547

1. Geometry: The mean difference between model estimated dimensions and real measurements is lesser then 1% which is barely noticeable, the maximum error is 0,016 mm and is present at the distance of 8.56 m in the mosaics room, which is the widest room in the building.
2. Perceptive: The model shows a good perceptive quality compared to the real photos (SSIM = 0.65) and all the images are clear and well detailed (PIQE = 24.84).

Indexes are useful for the validation process in order to compare results with an optimal target. The last goal of this research is the application of the developed validation methodology both to support the next phase of the RECIPE projects, involving crowdsourcing resources, and to increase the knowledge of suitable model “prerequisite” for virtual reality representation. The second part of this study concerns the path to integrate a photogrammetry model into a virtual reality environment. Therefore, authors exposed a useful methodology to create a virtual environment.

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