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DIGITAL MODEL OF WALLS OF PADUA LOW RELIEF

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ABSTRACT:

Photogrammetry has been widely used in the recent years in a number of applications, e.g. cultural heritage, surveying buildings and infrastructures. Despite nowadays its use is quite common, most of the used photogrammetric softwares are commercial. This paper aims at comparing the use of a free Matlab tool that is being developed at the University of Padova mostly for educational purposes with that of a commercial (and widely used) software (Agisoft PhotoScan). Despite the above mentioned free Matlab tool is designed to work for airborne photogrammetric, in this work it is used in a slightly different case: the 3D reconstruction of a low relief of the walls of Padova, which is on the façade of the church Santa Maria del Giglio, Venice, Italy.

1. INTRODUCTION

Photogrammetry and laser scanning are widely spread techniques used in order to obtain digital models of real objects, buildings and infrastructures. In particular, the results of laser scanning are often seen as more reliable, whereas photogrammetric reconstruction is typically more flexible, allowing surveying in a larger range of conditions. Despite laser scanning has been considered the state of the art in surveying during the last decade, the introduction of automatic matching and data processing procedures in photogrammetry (mostly related to the development of algorithms for automatically solving the Structure from Motion problem, which has been originally faced mostly by the Computer Vision community in the last decade (Agarwal et al., 2010, Hartley, 1997, Ma et al., 2012) is recently making photogrammetric surveying quite popular.

In most of the past works the use of either photogrammetry or laser scanning has been considered (Remondino et al., 2005, Pirotti et al., 2013). Instead, a recent trend aims at the combined use of both of them: indeed, the combination of both such techniques can be of wide interest in order to take advantage from their respective advantages while reducing their limitations.

This work presents the comparison of photogrammetric reconstructions done with different softwares to obtain a reliable digital model of a low relief of the walls of Padua (Italy). Such row relief of Padua's walls is positioned on the façade of the Church Santa Maria del Giglio (Santa Maria Zobenigo, Venice, Italy, Fig. 1(a)). The overall size of the low relief's area is approximately 1 m^2, and photogrammetric survey has been performed by a distance comparable with the low relief size.

In several applications (e. g. when surveying objects in environments difficult to reach, and in certain digital heritage applications) there can be an interest in obtaining reliable digital models while minimizing the size and weight of the surveying instrumentation. Interestingly, in order to minimize such requirements, in the case study considered in this paper surveying has been performed by using small and portable instruments. To be more specific, the acquisition system in this case is related to the use of a standard consumer camera and a metric tape (in order to obtain a metric 3D model).

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Photogrammetric reconstruction has been obtained by using a standard camera, Canon G7X (Fig. 2), setting all acquisition parameters (e.g. zooming factor, focus distance) to constant values during the survey, i.e. they do not varied during all the acquisition procedure. It is worth to be noticed that most of the software currently available for photogrammetric reconstruction is intended for commercial purposes (its use is restricted by the need to pay for a licence). Instead, in this paper results obtained with commercial software (Agisoft Photoscan) are compared with those obtained with a free software currently under development at the University of Padua (Masiero and Vettore, 2016, Masiero et al., 2014). Camera self-calibration has been used in both the cases (Habib and Morgan, 2003, Remondino and Fraser, 2006, Heikkila and Silven, 1997).

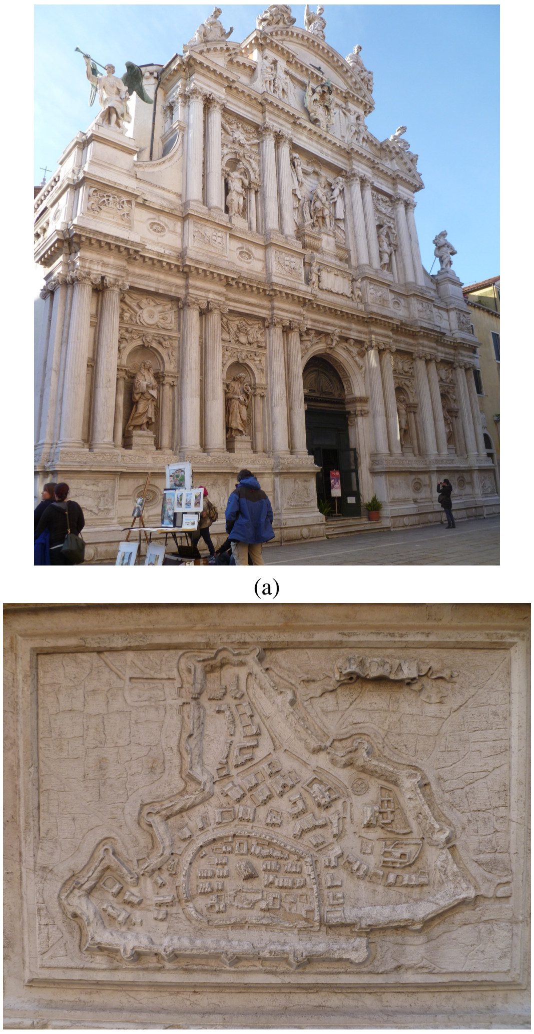
The obtained digital model has been used during the virtual museum exposition Museo Multimediale delle Mura in September 2016 in Padua (exposition and surveying have been funded by Fondazione Cassa di Risparmio di Padova e Rovigo, within the fellowship provided by Culturalmente 2015).

Future work of our research group foresees the development of an application for mobile devices (e.g. smartphones) allowing to simultaneously deal with indoor/outdoor navigation, by the integration of multiple positioning sensors such as inertial sensors, WiFi, UWB (Saeedi et al., 2014, Fissore et al., 2018, Masiero et al., 2015a), and photogrammetric/laser scanning acquisition of georeferenced data (Aicardi et al., 2016, Masiero et al., 2015b). Further work will aim to the integration of such method in a monitoring system (e.g. landislides, infrastructures (Guarnieri et al., 2015, Pirotti et al., 2015, Kersten et al., 2004))

It is worth to notice that the free Matlab tool under development at the University of Padova actually takes advantage also of certain built-in scripts in Matlab and other free libraries, i.e. (Vedaldi and Fulkerson, 2008, Fusiello, 2013, Xiao, 2014).

2. SITE DESCRIPTION

The "Chiesa di Santa Maria del Giglio" is a church in Venice, Italy. The church, whose name translates into St. Mary of the Lily referring to the flower classically depicted as being presented by the Angel Gabriel during the Annunciation), is more commonly known as Santa Maria Zobenigo after the Jubanico family



(a)

(b)

Figure 1. (a) Façade of Santa Maria del Giglio, Venice, Italy. (b) Low relied of the walls of Padova (Italy), on Santa Maria del Giglio façade.

Figure 2. Canon G7X camera.

who founded it in the 9th century. The edifice is situated on the Campo Santa Maria Zobenigo, west of the Piazza San Marco. It was rebuilt by Giuseppe Sardi for Admiral Antonio Barbaro between 1678 and 1681 and has one of the finest Venetian Baroque façades in all of Venice. The church is now part of the parish of San Mois.

The church façade (Fig. 1(a)), work of Giuseppe Sardi, is one of the most original and imaginative expressions of Baroque Venetian art and forms a majestic monument of the Barbaro family, representing portrait statues of the five brothers and illustrating maps of the various places in which Antonio Barbaro served the Venetian Republic including Candia, Zadar, Padua, Rome, Corfu and Split. Among the illustration maps placed on the church façade we are interested on the low relief of the walls of Padua (Italy), Fig. 1(b).

The Walls of Padua (Italian: cinta muraria di Padova) are a complex of defensive works around the Italian city of Padua, designed to defend it from hostile attack and It was built in 4 phases: Roman, 13th century, 14th century and 16th century. Actually the "16th century Walls", also known as the Mura rinascimentali or Mura Veneziane, are visible and almost entirely preserved, for a track of about 11 km. With 20 bastions and six gates.

The Mura Veneziane was erected after Padua, in 1509 during the War of the League of Cambrai, was temporarily occupied by the Maximilian of Austria imperial troops. The city was soon released, but the danger induced the Venice Senate to order the walls' complete overhaul. Begun in 1523 by Bartolomeo d'Alviano, Serenissima's general captain, the work was continued by Michele Sammicheli, and in 1544 could be considered completed. The defensive system complex, ordered on walls and formidable ramparts, excellent for the military architecture of the time, mades Padua, in the opinion of contemporaries, an impregnable city. "16th century Walls" survive to this day, almost entirely unbroken apart from sections demolished in the 1960s to build the new Ospedale Civile. Nearly all the walls' gates survive, including for instance: Porta Savonarola, Porta San Giovanni, Porta Ognissanti, Porta Liviana, Porta Santa Croce.

3. METHODOLOGY

Photogrammetric survey has been done by using a standard camera, Canon G7X. 117 photos of the low relief have been taken at an approximate distance of 1–2 m. Camera parameters (and focus distance) were constant during all the acquisition.

Reconstruction has been obtained by using both a commercial software (Agisoft PhotoScan) and a free tool (Matlab free tool under development at the University of Padova). It is worth to notice that the latter is being developed mainly for educational support for the students of photogrammetric courses at the University of Padova. Nevertheless, its use in this case study is considered in order to show a moderate ability to be useful also in real applications.

Self-calibration have been used in order to calibrate the camera (Fraser, 1997, Fraser and Stamatopoulos, 2014) Furthermore, metric tape measurements have been used in order to properly scale the obtained 3D model to obtain metric reconstructions.

4. RESULTING 3D MODELS

Fig. 3(a) and (b) show two frontal views of the 3D model obtained by using Agisoft PhotoScan. 3D model, obtained after some hours of computation, has 25 millions of points.

Certain details of the model reconstructed with Agisoft PhotoScan can also be seen in Fig. 4(a) and (b).

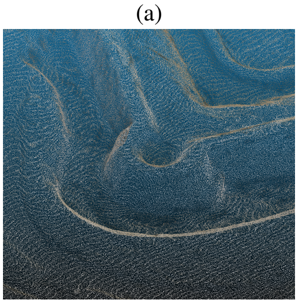
Furthermore, Fig. 5 shows a frontal view of the 3D model obtained by using the software under development at the University of Padova. The point cloud generated in this case is definitely smaller (400 thousands of 3D points): this is actually mostly due by the need of reducing the computational burden while using

(a)

(b)

Figure 3. (a) Frontal view of the 3D model of the low relief. (b) Rotated view of the reconstructed low relief.

(a)



(b)

Figure 4. (a) Zoomed view of the reconstructed low relief. (b) Close view of "della Gatta" bastion, walls of Padova, Italy.

Matlab to generate the point cloud. Nevertheless, it is worth to notice that, given the low relief size, the generated point cloud has a 30points/cm^2 density, approximately, which should probably be sufficient in most of the cases of interest. Moreover, the computational time for the generation of the point cloud in Matlab in this case was approximately 10 times shorter than those of Agisoft Photoscan (however PhotoScan generated a cloud with a much larger number of points).

Figure 5. Frontal view of the 3D model of the low relief obtained by using the software under development at the University of Padova.

Finally, Fig 6 shows the comparison (cloud to cloud distance computed with Cloud Compare) between the two point clouds generated with Agisoft PhotoScan and by our software. Values have been saturated to 0.02cm, approximately, whereas green and blue start at 0.011m and 0.0015m, approximately.

Average distance and standard deviation computed by the comparison of the two point clouds are 0.11 cm and 0.12 cm, respectively.

It is worth to notice that most of points are actually well estimated by the free Matlab tool. As expected, most of the differences with respect to PhotoScan reconstruction are along slopes in the 3D shape.

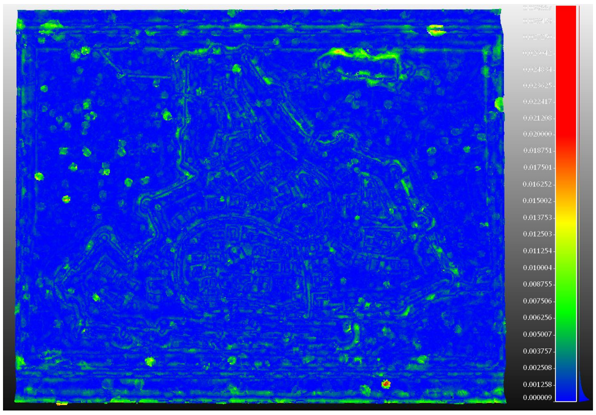


Figure 6. (a) Top view of "della Gatta" bastion, walls of Padova, Italy. Terrestrial laser scanner 3D reconstruction obtained with Leica ScanStation C10. (b) Inside view of the bastion.

5. CONCLUSIONS

This paper presented results obtained by using two different softwares (commercial and free, respectively) on photogrammetric 3D modeling of a the low relief of the walls of Padova, which is on the façade of Santa Maria del Giglio, Venice, Italy.

The relatively small average distance between the two point clouds (0.11 cm), shows that the software currently under development at the University of Padova shall be quite promising also for use in (probably not too complex) real applications.

6. ACKNOWLEDGMENTS

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