Journal of Archaeological Science 40 (2013) 4450–4456

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Performance evaluation of a multi-image 3D reconstruction software on a low-feature artefact

Anestis Koutsoudis [a,*], Blaž Vidmar [b], Fotis Arnaoutoglou [a,1]

[a] Institute for Language and Speech Processing, Multimedia Department, Research Centre 'Athena', PO Box 159, Xanthi 67100, Greece
[b] University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana 1000, Slovenia

ARTICLE INFO

Article history:
Received 12 April 2013
Received in revised form
3 July 2013
Accepted 7 July 2013

Keywords:
3D laser scanning
Image-based 3D reconstruction
Structure-from-Motion
Dense multi-view 3D reconstruction
Data comparison
Surface deviation
Featureless object

ABSTRACT

Nowadays, multi-image 3D reconstruction is an active research field and a number of commercial and free software tools have been already made available to the public. These provide methods for the 3D reconstruction of real world objects by matching feature points and retrieving depth information from a set of unordered digital images. This is achieved by exploiting computer vision algorithms such as *Structure-From-Motion* (SFM) and *Dense Multi-View 3D Reconstruction* (DMVR). In this work, we evaluate the performance of a low-cost commercial SFM–DMVR software by digitising a Cycladic woman figurine. Although the surface properties of the specific artefact are considered *3D laser scanner friendly*, its almost featureless white-grey surface composes a challenging digitisation candidate for image based methodologies as no strong feature points are available. We quantify the quality of the 3D data produced by the SFM–DMVR software in relation to the data produced by a high accuracy 3D laser scanner in terms of surface deviation and topological errors. We question the applicability and efficiency of two digitisation pipelines (SFM–DMVR and laser scanner) in relation to hardware requirements, background knowledge and man-hours. This is achieved by producing a complete 3D digital replica of the Cycladic artefact by following both pipelines.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Although 3D digitisation is commonly addressed today in the archaeological domain, research efforts are still focused on establishing affordable and efficient pipelines for the production of artefact's digital 3D replicas. Based on the requirements specifications and the financial plan of a digitisation project, various methodologies can be applied. All of them involve the use of both hardware and software. The use and quality of the produced 3D data in terms of geometrical and colour information are only some of the key factors that lead a project team to select an appropriate digitisation methodology. Image-based 3D digitisation methodologies offer the option of reconstructing an object by a set of unordered images that depict it from different viewpoints. As their hardware requirements are narrowed down to a digital camera and a computer system, they compose an attractive 3D digitisation approach.

In this paper, we evaluate the performance of a low-cost commercial software (PhotoScan by Agisoft LLC) that implements *Structure-From-Motion* (SFM) and *Dense Multi-View 3D Reconstruction* (DMVR) algorithms. We question the performance of the software as an all-in-one solution for the generation of digital 3D replicas of artefacts. We have selected a Cycladic female figurine that is considered a challenging artefact for image-based methods. Its nearly featureless white-grey surface composes an unfriendly object due to the fact that image based 3D reconstruction approaches attempt to identify corresponding feature points between images. In fact, the quality of the data produced by image-based methods is greatly affected by the surface feature richness (e.g. strong feature points, texture with frequent colour alternations). Furthermore, we digitise the same artefact using a high accuracy 3D laser scanner. We adopted these data as our ground truth and evaluate the quality of the 3D data produced by the image-based method.

The rest of this paper is organised as follows. In Section 2, we briefly mention a number of SFM–DMVR software solutions that are currently available along with references to related works that also attempt to provide suggestions of the method's applicability. In Section 3, we give a short outline of the artefact and we continue by describing the data collection and 3D data processing phases. In

* Corresponding author. Tel.: +30 2541 0 78787.
E-mail addresses: akoutsou@ipet.athena-innovation.gr (A. Koutsoudis), blazvidmar@student.uni-lj.si (B. Vidmar), fotarny@ipet.athena-innovation.gr (F. Arnaoutoglou).
[1] Tel.: +30 2541 0 78787.

0305-4403/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2013.07.007

Section 4, we present the 3D data comparison and evaluation results. We conclude in Section 5 by outlining important findings.

2. Related work

Over the last years numerous image-based 3D reconstruction solutions have been made available. Some of them are based on combining *Structure-From-Motion* (SFM) with a *Dense Multi-View 3D Reconstruction* (DMVR) algorithm. It is a relatively new approach and it is purely based on the continuous increase of the average computer's processing power. The SFM algorithm reconstructs a sparse point cloud of a stationary scene or an object that was captured from an arbitrary number of unordered images from different viewpoints. The automated and markerless orientation of images is considered as a large development in the photogrammetry community (Remondino et al., 2012). SFM mainly (Dellaert, 2000) uses the corresponding features that are visible in different images that depict areas from different viewpoints, in order to calculate the intrinsic and extrinsic parameters of the digital camera (also known as self-calibration method). As no targets are used, the success of SFM depends on the properties of the imaged surface details. One of the most common feature point detectors is SIFT (Scale Invariant Feature Transform) and SURF (Speeded Up Robust Features) that allows the identification of correspondences between images taken from different positions, scales and illuminations (Lowe, 2000; Bay et al., 2008). As SFM matches all images together the epipolar geometry is reconstructed (Brutto and Meli, 2012). Many systems involve the *bundle adjustment* method in order to improve the accuracy of calculating the camera trajectory, to minimize the projection error and also to prevent the error-built up of the camera tracking (Engels et al., 2006). The bundle adjustment is formulated as a non-linear least squares problem (Remondino et al., 2012). Wu et al. have developed an improved version of bundle adjustment that uses hardware parallelism (Wu, 2011; Wu et al., 2011). Snavely et al. proposed a method that allows the exploration of images that have been organised in 3D space by using Bundler, an open source SFM system (Snavely et al., 2006; Snavely, 2008). Bundler is also used in PhotoSynth, a Web-based SFM system offered by Microsoft (Web 1). Generally, the results produced by SFM in terms of point cloud density are for most 3D reconstruction cases insufficient. They can be considered adequate for manual based low-polygon mesh 3D reconstructions where the developer will manually select key vertices on the point cloud in order to create geometrically simple surfaces. On the other hand, in order to produce a dense and detailed point cloud or polygon mesh SFM is coupled with DMVR algorithms. DMVR attempts to determine the correspondence information for each pixel in the images. To achieve this there are different methods available organised into local and global. While local methods are sensitive to areas of low features (locally ambiguous areas), global methods attempt to minimise an energy function and although they require more computational power they do provide a more robust solution (Ahmadabadian et al., 2013).

The EU funded project 3D-Coform developed ARC3D, a Web-based SFM–DMVR service that allows the automated 3D reconstruction of a scene by asking the user to upload a number of images. Similar Web-based solutions are 123D Catch by Autodesk (Web 2), My3DScanner (Web 3) and Cubify Capture (Web 4). In addition, SFM–DMVR algorithms are offered as standalone applications. Pix4D developed the Pix4UAV software that is able to create 3D digital elevation models from image collections captured by unmanned aerial vehicles (Web 5). Apero and MicMac are also open source tools used for the calculation of digital elevation models from aerial and satellite images (Web 6).

Eos Systems have enhanced their photogrammetric software to provide dense point 3D reconstructions by positioning photogrammetric targets around an object (Web 7). Moreover, Agisoft LCC created PhotoScan (Web 8). The software provides a SFM–DMVR solution that is able to automatically align unordered image datasets and reconstruct the content of the dataset in 3D by merging the independent dense depthmaps of all images.

As the application of the SFM–DMVR method ranges from museum artefacts to monuments and architecturals, several researchers have attempted to evaluate the quality of the produced data and the applicability of the method. Some works are focused on creating digital elevation models of aerial photographs (Neitzel et al., 2011; Opitz et al., 2012) while others have demonstrated the use of image-based 3D reconstruction as a cost-effective method for the recording an archaeological excavation and its progress (Reu et al., 2012) (Doneus et al., 2011). Furthermore, research has been made on comparing the results produced by different SFM–DMVR systems on different objects derived from the cultural heritage domain (Nguyen et al., 2012) (Kersten and Lindstaedt, 2012). Koutsoudis et al. digitised a monument using different methodologies (range scanning, SFM–DMVR based on aerial and terrestrial imaging, total station and empirical measurements) and compared the quality of the 3D data produced by each method (Koutsoudis et al., 2012).

In this work, we evaluate the performance of a commercial low cost SFM–DMVR standalone application by using a non-friendly for image-based methods artefact. At the same time, the selected artefact is considered suitable for 3D laser scanners due to its bright colour (laser beam high visibility) and low reflectivity (low laser beam scattering). Such an imbalanced comparison allows us to quantify the performance on a challenging case while being able to use the laser scanner data as a ground truth. Moreover, we attempt to broaden the application domain defined by the previous related works and provide additional information for objectively identifying the range of projects that SFM–DMVR can be applied by relying on the data quality and the practical use the produced data.

3. 3D digitisation of the artefact

In this Section, we provide some historic information about the artefact and we describe the data collection procedures that have been followed and the equipment being used.

3.1. A Cycladic female figurine

For the evaluation of the SFM–DMVR software we selected an accurate replica of a Cycladic female figurine that was produced by the Hellenic Archaeological Receipt Fund. Cycladic figurines are particular objects in terms of style and shape (Fig. 1). The one being used has a height of 16 cm and it is a replica of an artefact produced at some point between 2800 and 2300 BC in the island of Sifnos (Cyclades). The standing female figurines have been interpreted as representations of the deceased, substitute concubines, servants, ancestors or even substitutes for human sacrifices. Other scholars attempt to explain them as symbols of a mother-goddess, associated with fertility and rebirth, conductors of souls, apotropaic images, divine nurses or even worshipers. Nevertheless, there is a general consensus that the nudity of the figurines and the emphatic rendering of the breast and the pubic triangle refer to fertility. This is also reinforced by some examples with swollen abdomen, indicating pregnancy, as well as figurines with creases on the belly, believed to symbolise post-partum wrinkles (Renfrew, 1984; Doumas, 2000).

Download English Version:

https://daneshyari.com/en/article/7443959

Download Persian Version:

https://daneshyari.com/article/7443959

Daneshyari.com