An interactive Tunisian virtual museum through affine reconstruction of gigantic mosaics and antic 3-D models

ELGHOUL,S
CRISTAL Laboratory,
Pole Grift
Campus University
Manouba 2010, Tunisia
sinda.elghoul@ensi-uma.tn

SAIDANI,M
CRISTAL Laboratory,
Pole Grift
Campus University
Manouba 2010, Tunisia
maweheb.saidani@gmail.com

GHORBEL,F
CRISTAL Laboratory,
Pole Grift
Campus University
Manouba 2010, Tunisia
faouzi.ghorbel@ensi.rnu.tn

Abstract

Museums are no longer static depositories for objects, as they used to be for the past two centuries. Online and interactive access has created new opportunities for museums and cultural institutions to reach out and discover new audiences for promotion of cultural achievements. The virtual tours and the panorama reconstructions become among the most popular solutions for virtual consultation of historical monuments. A Tunisian virtual museum application aims to make its relative monuments more accessible to experts such as archaeologist or art historians, and even to the large public. In this research, we intend to present an invariant based approaches for the reconstruction of both mosaic panorama and 3D models. We propose a framework to create a Tunisian virtual museum and we focused on an interactive application related to Bardo museum. We apply affine invariance in a finite set of viewpoints to compute shape descriptors with completeness and stability properties. Such affine invariants serve to refine 3D model generated by classic shape-from-silhouette algorithm and to assist the creation of panorama image mosaics from uncalibrated images.

Keywords

3D, virtual museum, virtual reality, multi-view reconstruction, stitching mosaics.

1 INTRODUCTION

The cultural and historical heritage is consisted of goods that have been created by the previous generations. These objects, because of their symbolic meanings have special value for the current generations and they affect the forming of their identities. UNESCO creates in 1956 ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property)[DeCaro2014] offers a real enhancement for conservation of monuments, archeological sites and excavations. Nowadays, virtual museums propose various possibilities to keep that heritage through digitization, analyzing, converting to electronic form and organizing this material. In literature, a virtual museum can be defined as:
a collection of digitally recorded images, sound files, text documents and other data of historical, scientific, or cultural interest that are accessed through electronic media [Malraux1965]

The goal of the virtual museum is not to replace the real museum. Only by cooperation of the ones who work on preserving and presenting the cultural heritage (historians, archeologists, museum curators etc.) can results to cultural creation that can be achieved. Furthermore, we insist that the term of virtual museum can take various forms depending on the application scenario and end-user. It can be a 3D reconstruction of the physical museum or even a completely imaginary environment. In the other hand, with the help of new technologies, V-museums collections [Swartout2010], in place of material ones, present some interesting features: money and space savings, easier management potential, digital analysis or modeling [Pearce1993], etc.

In Tunisia, over 23 sites are registered in UNESCCO as world heritage; however, much of the information produced by archaeological research over the past century exists in technical, sometimes limited distribution reports scattered in offices across the country. Moreover, several museums are spread out on the Tunisian territory: it contains many type of objects related to different historical periods: romain, punic, bysantic etc.

Therefore, the creation of Tunisian virtual museum is today an expected choice to preserve cultural heritage and to help visitors to obtain efficiently any information about the Tunisian archeology without having to visit physically museums. The remainder of this paper will be organized as follows. The section 2 is about state of art of virtual museums, in section 3 we give our methodology for realization of Tunisian virtual museum prototype including panorama images and 3D reconstruction of models, next in section 4 we provide experimental results and finally we conclude with a summary and discussion.

2 VIRTUAL MUSEUM: STATE OF ARTS

In 1947, Andre Malraux introduced the first virtual museum, where he proposed the concept of an imaginary museum [Malraux1965] without walls, with its information surrounding the objects, might be made accessible across the world. From this date, this definition knows a different side of points. Its about three categories that are developed like an extension of physical museums [Hu2016] : 1) the first one is the brochure museum which contains basic information such as resume history, opening hours and sometimes a calendar of events etc. the second one is known as the content museum which is almost a web site containing some information about the museum. The third one is called the learning museum propose many points of access for its visitors, depending on their different age, background, and knowledge [Hu2016]. The main goal is to motivate the virtual visitor to discover more about a particular subject and come back to establish a personal relation with the online collection. Today, museums are committed to the construction of V-Museums as an important international window for exposing different heritages and cultures worldwide [Styliani2009]. In the interest of convergence between the world of culture and new technologies, the most cultural institutions aim to spread and share the treasures of cultural heritage in a virtual way. Archaeological sites, sculptures, masterpieces, monuments, etc. are digitized in high definition to be exhibited via websites or cultural applications allowing users all over the world to discover history and art [Addison2000].Many studies tell that most of the people that try a virtual tour or assist to a virtual exhibition are interested to see physically monuments and archaeological sites. Moreover, some virtual exhibitions offer access to places and museum areas that are usually inaccessible to the public, so users can discover details that are imperceptible to the naked eye. Creating a virtual museum need the collaboration of various methods and technologies like 3D modeling, 360 panoramic photos, digitization in gigapixel format (Google), 3D videos, augmented reality, etc [Styliani2009].
Many monuments have their virtual tour: Giza 3D is a great web application that provides a free 3D tours and permits online visitors to virtually discover Egypt pyramids. This work is a result of the partnership between the Museum of Fine Arts in Boston, Harvard University, and Dassault System. The project used QuickTime Virtual Reality technology. Its contain 1,300 panoramic views inside the program that make users have 360-degree views inside and outside the tombs [der2013]. Beylerbeyi Palace virtual tours was done in the years 2007 and 2008. Panorama shootings were taken by a Nikon D80 digital camera, 10.5 mm fisheye lens, panoramic tripod head, and a tripod. This Turkish Palace contains 672+ pictures [gur2013]. These digital technologies can offer historians and the general public to discover the history and cultural heritage of a site like Versailles 3D offered by Google art project [perriault1997].To visit a famous monument in Paris without being carried away by the crowd and without having to privatize a part to feel sovereign the time of a moment the virtual visit allows to see with extreme precision the paintings and other historical beauties that it would be difficult to observe this by going to a palace [riedinger2015], it uses the street view technology of Google and offers the discovery of the gardens, the King's and Queen's large apartments and the Hall of Mirrors.

3 METHODOLOGY

Here, we propose a framework to create a Tunisian virtual museum. Figure 1, present the global architecture with different steps. In this paper we will focus on creating panorama images for mosaics and 3D reconstruction of objects.

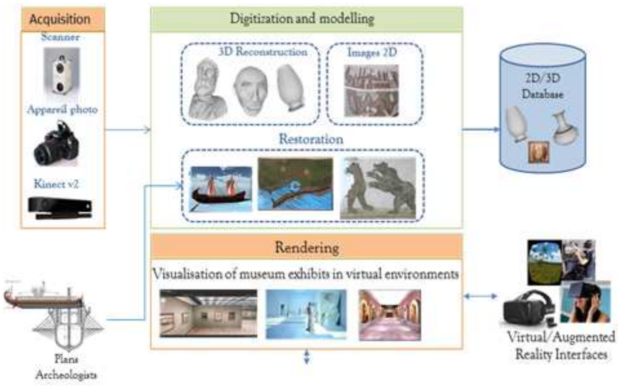

Figure 1: The global architecture of the Tunisian virtual museum.

3.1 Affine acquisition

The acquisition is a key step in virtual museum application. It consists of acquiring high-resolution images for sites and models. In practice, we used CANON

EOS 5D camera (see table 1 for the characteristics) for the different acquisition. So to perform numerical calculations, an algebraic representation is required. thats camera models has been proposed: The most general one is perspective one. Geometric entities: points, lines and planes are represented using homogenous coordinates. In this representation, a point in three-dimensional space is represented by four coordinates which are defined up to a scale factor.

Camera	Canon EOS 5D MarkII
Size of sensor	21 megapixels
Sensitivity	ISO100
Focal Length	24mm
Opening of diaphragm	for f/18 to f/22

Table 1: Technical characteristics of camera

When the distance between object and a camera is much greater than the depth variation affine approximation can be used in stead of respective model. Affine camera, was introduced by [mundy1992], which is widely adopted to simplicity the estimation of the geometry of the acquisition system. weak-perspective or a first order perspective approximation of full An affine camera is a camera whose projection matrix is an affine transformation has the following form:

$$P \sim \begin{pmatrix} P_{2*3} & P_2 \\ 0_3^T & 1 \end{pmatrix} \quad (1)$$

P is an affine matrix projection of a camera whose projection matrix is assumed to affine transformation.

$$P \sim \begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ 0 & 0 & 0 & P_{34} \end{pmatrix} \quad (2)$$

The last row of the projection matrix is of the form [0, 0, 0, 1] and the matrix have only eight degree of freedom.

The affine camera matrix can be decomposed in: 1. A 3D affine transformation between world and camera coordinate system 2. Parallel projection to onto the image plane 3. A 2D affine transformation

3.2 Affine Mosaic panorama

Bardo Museum contain the second largest collection of ancient mosaics in the world. Some of these large mosaics completely cover the walls of his rooms that have very high ceilings in the order of 10 to 16 meters while the widths of these rooms are both similar. Also, the mosaics are exposed in a museum with laying conditions of the low recoil of the camera compared to the extent of the scene. This state of affairs is made in most cases unable to acquire a mosaic entirely with a single capture. Our goal is to develops an interactive system which integrates high-resolution panoramas and a high color quality of the entire collection of ancient mosaics of the Roman and Byzantine.The Key idea is to take a lot of pictures from multi point of vue and assembled them to find a composite image with a much larger field of view relatively to the size of the acquisition system. Therefore, these acquisitions of piecewise of images obtained in varying positions by cameras undergo a strong apparent deformation. These deformations are known in literature by an affine transformation of the image plane. Also, the variabilities of the illuminates in the same mosaic represent a strong constraint for the construction of panorama[van1992].

In this case of a museum the major defiance are: 1. transformations type like perspective distortions: The deformations transforming the rectangular edge in a kind of trapezium having a large base of reports on a small base increasingly important. 2. Highly variable chrominances gradually and unevenly changing the bottom to the top of the mosaic left and to the right of the camera The image stitching technique can be classified into two approaches: the first one is the direct techniques that compare the intensities of all pixels of the images with each other, while the second based feature techniques are designed to determine a matching between the images with different descriptors extracted from the processed images. Figure 2. These transformations belong to a Lie group noted SA (2, R)) [adel2014].

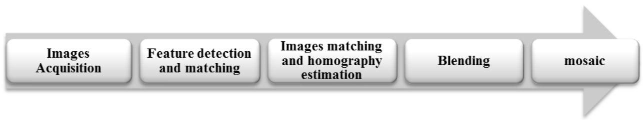

Figure 2: The proposed stitching pipeline.

Iwasawa decomposition lets say that an element of this, the group can be seen as a movement of the plane followed by stretching[ying2011].

Thus this type of transformations can be considered as a first approximation prospects even if these processes show the case where the scene is located sufficiently far from the camera. In this case, the affine invariant is the best solution.

This is why we propose to study different extractors of keys points that are invariant to the displacements of the plan and those with invariance under affinities[yu2011] such as SIFT(Scale-invariant feature transform) [lowe2004] , MSER (Maximally stable extremal regions) [matas2004] ,color-SIFT (CSIFT) [abdel2006] ,Harris-affine , Hessian-affine [mikolajczyk2004] and Affine-SIFT (ASIFT) [Morel2009] . The descriptors Affine Scale Invariant Feature Transformation (ASIFT) which are known by their invariance with respect to affine transformations are obtained according to pro-

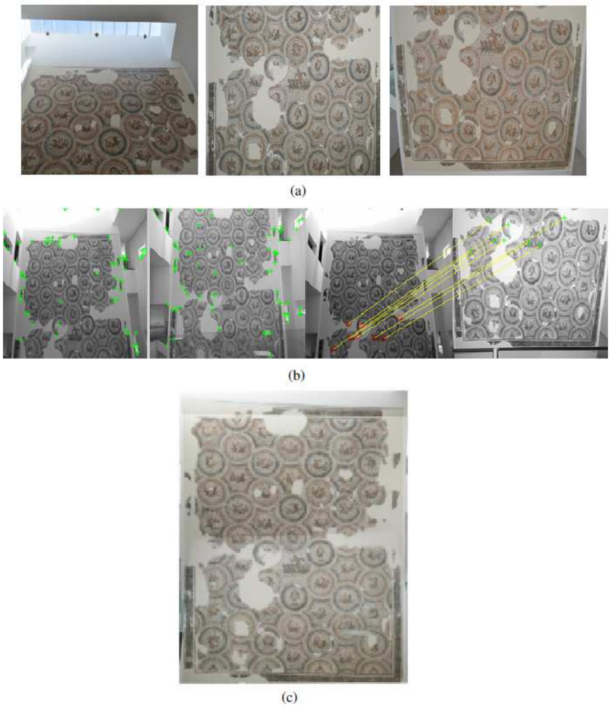

Figure 3: (a) Different acquisitions of the same large mosaic in three shot. (b) ASIFT keys points detection and matching. (c) reconstruction of the mosaic by the proposed stitching algorithm.

cedures similar to those of SIFT [yu2011],[juan2009] , [wu2013] .

They also provide a set of points of interest around which invariant attributes relative affinities are defined. In part of matching, we follow the usual approach, using a k-nearest neighbor algorithm (KNN) to link the keys points and RANSAC (random sample consensus) presented by Martin A. Fischler et al. in [9] to eliminate mismatches, in different variations descriptors.

3.3 Affine 3D reconstruction

Our goal is to reconstruct 3D objects from a sequence of geometrically calibrated images. For this aim, we dispose of several types of information contained in images. Among all the information available, silhouettes are the most useful for shape retrieval.

The reconstruction algorithm, here presented, consists of two phases. In the first phase it computes visual hull of the object using classical carving method [lazebnik2007],[laurentini1994] utilizing camera calibration parameters [esteban2004]. The second phase refines this coarse model using a geometric approach based on aligning contours of real silhouettes and re-projected visual hull silhouettes using affine invariant matching [saidani2012]. Such matching is based on estimating affine transformation between real and re-projected contours. Let O_1 and $O_1^{'}$ be two closed curves that define the same silhouette. O1 and $O_1^{'}$ are said to be related by an affine transformation if and only if:

$$h(l) = \alpha A f(l + l_0) + B \tag{3}$$

Where B is a translation vector, A is linear transformation, l_0 is a shift value, α is a scale factor, f and h are their respective re-parametrization by affine arc length. Such re-parametrization is affine invariant [ghorbel1998]. In Fourier space we get:

$$U_K(h) = \alpha e^{2i\pi k l_0} A U_K(f) + B\delta_k \tag{4}$$

Where $U_K(f)$ and $U_K(h)$ are respectively the Fourier coefficients of f and h. So we could estimate the affine motion between a pair of contours by estimating affine motion parameters: the affine matrix A, the shift value l_0, and the scale factor α. For more details we refer to [saidani2012].

For the proposed refinement algorithm (algorithm 1), we propose to compute a signed distance to the visual hull. For a P_M point, we determine the minimal negative Euclidean distance d(VH,P_M) between real position of P_M in silhouettes and the projection of this point on new silhouettes.

$$d(VH, P_M) = mind(S_i, P_i P_M) \tag{5}$$

Where P_i denotes the projection matrix of the camera i and S_i is the i^{th} image silhouette. Negative distance implies that the contour projection is outside silhouette, so we propose to iteratively perform surface reconstruction by re-carving visual hull according to the affine contour alignment until this distance become positive. For more details concerning results of 3D reconstruction the reader can be referred to [saidani2016].

4 TOWARD A TUNISIAN VIRTUAL MUSEUM: EXPERIMENTAL RESULTS

The goal of this virtual museum is to connect Tunisian archaeological sites and objects of the whole country in order to emphasize its importance as well as to point out the need for preserving the heritage and to open the possibility for future international cooperation between Tunisia and Mediterranean countries.

For this demonstration, we choose to reconstruct Bardo museum. The Bardo is one of the most important museums of the Mediterranean basin. It traces the history of Tunisia over several millennia and through many civilizations through a wide variety of archaeological pieces. It contains the largest collection of Roman mosaics in the world and other antiquities of interest from

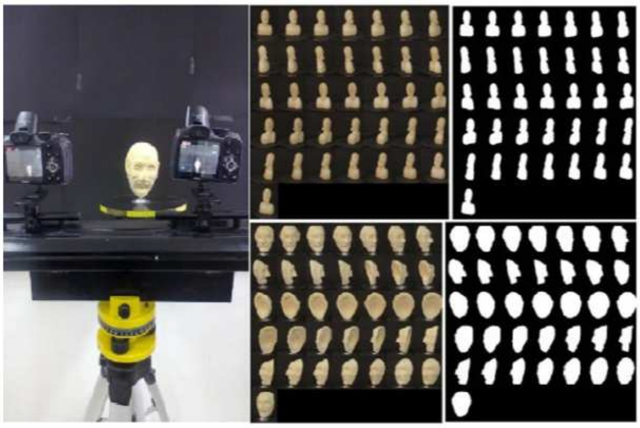

Figure 4: Real acquired sequence of archeological objects: 36 calibrated frames of "hannibal" and "punic mask" and their correspondent silhouette sequence.

Algorithm 1 Visual hull refinement based affine invariance

Require: projection matrix P_i, original contours sequences C_i and reprojected contours sequence $C_i^{'}, i \in [1..36]$ compute N the affine normalization on contour C_i and $C_i^{'}$

for all C_i **do**

repeat

Compute (α, l_0, A) the affine transformation parameters between C_i and $C_i^{'}$

Compute $D = mind(C_i, C_i^{'})$

Increase VH resolution ocTree algorithm.

Project Ray $l = P_i * N$

Compute the 2D interaction interval $I = l \bigcap C_i$

Re-cave visual hull: $VH^{'} = VH \bigcap P_i^{-1} \bigcap I$

until $(D \geq 0)$

end for

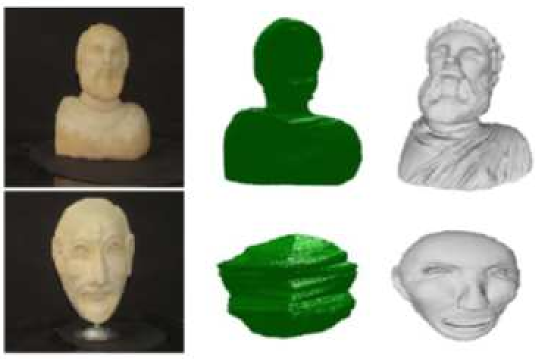

Figure 5: 3D reconstruction of a real archeological object.(from left to right) image extracted from the acquired sequence, the corresponding visual hull and the 3D model.

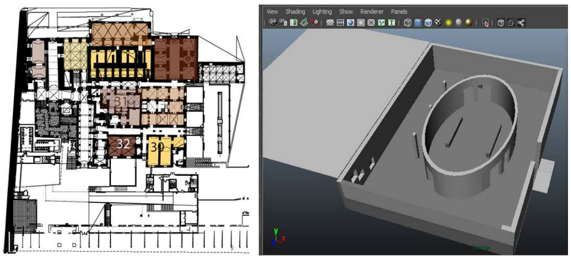

Figure 6: A 2d plan of Bardo museum and its 3D reconstruction of the Bardo.

Ancient Greece, Carthage, Tunisia, and the Islamic period.

The first step in our pipeline is 3D modeling of the Bardo museum environment from initial 2D plans. The results are shown in figure 6.

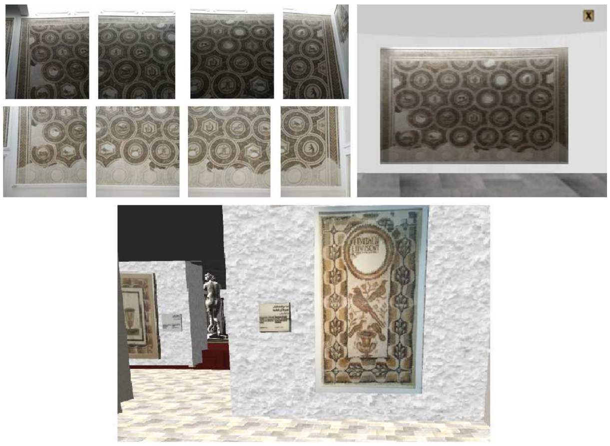

Figure 7: Panoramic image of huge mosaic in virtual environment of Bardo Museum.

Next step of our work consists on integrating panorama images of mosaics and 3D reconstruction of objects results in an interactive application of virtual tour in Bardo museum. Objects are placed in the same way that we retrieve on real visit (figure 7, figure 8). but we provide detailed and up close images of museum artefacts and text descriptions, sometimes with even more information than in the museum itself (figure 9).

5 CONCLUSION

Museums audiences, often regarded as passive participants, now look for interaction and seek to participate in new ways and to have greater access to stored objects. Tunisian virtual museum aims to offer new opportunities for museums and cultural institutions to reach out and discover new audiences and for promotion of cultural achievements in Tunisia. In this paper, we have presented two keys of this framework: panorama mosaics and 3D reconstruction and their integration in a

Figure 8: 3D objects in virtual environment of Bardo Museum.

Figure 9: Historical description of objects in virtual tours.

virtual tour for the Bardo museum. We inderline that the Tunisian virtual museum is a development platform with a possibility of constant input of new data and content, the mapping of new sites and expansion of the database.

6 REFERENCES

[DeCaro2014] De Caro, Stefano . International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM)(Conservation and Preservation). Encyclopedia of Global Archaeology,Springer, pp.3937–3940, 2014.

[Pearce1993] Pearce, Susan M and Pearce, Susan M and für Museumsstudien, Professorin. Museums, objects, and collections: A cultural study,Smithsonian Institution Press Washington, DC pp.453-469,1993.

[Swartout2010] Swartout, William and Traum, David and Artstein, Ron and Noren, Dan and Debevec, Paul and Bronnenkant, Kerry and Williams, Josh and Leuski, Anton and Narayanan, Shrikanth and Piepol, Diane and others.Ada and Grace: Toward realistic and engaging virtual museum guides.International Conference on Intelligent Virtual Agents.International Conference on Intelligent Virtual Agents.pp 286–300.2010

[Morel2009] ASIFT: A new framework for fully affine invariant image comparison.Morel, Jean-Michel and Yu, Guoshen.SIAM Journal on Imaging Sciences.Vol 2 pp.438–469.2009

[Malraux1965] Malraux, Andre.Le musee imaginaire ,Gallimard Paris.1965.

[Hu2016] Hu, Qingwu and Yu, Dengbo and Wang, Shaohua and Fu, Caiwu and Ai, Mingyao and Wang, Wende. Hybrid three-dimensional representation based on panoramic images and three-dimensional models for a virtual museum: Data collection, model, and visualization,Information Visualization.2016

[Styliani2009] Styliani, Sylaiou and Fotis, Liarokapis and Kostas, Kotsakis and Petros, Patias,Journal of cultural Heritage vol 10.pp520–528,2009.

[Addison2000] Addison, Alonzo C, Emerging trends in virtual heritage.IEEE multimedia vol 7.pp 22–25.2000

[der2013] Der Manuelian, Peter, Giza 3D: Digital archaeology and scholarly access to the Giza Pyramids: The Giza Project at Harvard University.Digital Heritage International Congress (DigitalHeritage), vol 2.pp 727–734,2013

[gur2013] Gur, Faik,Sculpting the nation in early republican Turkey,Historical Research vol86. pp 342–372.2013.

[perriault1997] PERRIAULT, I, Beatrix Saule: visite en 3D du chateau de Versailles.Archimag,pp 23–35.1997.

[riedinger2015] Riedinger, Christophe and Jordan, Michel and Tabia, Hedi.Restitution 3D de monuments historiques a partir de plans anciens. 2015.

[van1992] Van Gool, Luc J and Brill, Michael H and Barrett, Eamon B and Moons, Theo and Pauwels, Eric.Semi-differential invariants for nonplanar curves.Geometric invariance in computer vision pp 293–309.1992.

[adel2014] Adel, Ebtsam and Elmogy, Mohammed and Elbakry, Hazem,Image stitching based on feature extraction techniques: a survey,International Journal of Computer Applications (0975-8887).2014.

[ying2011] Ying, Shihui and Peng, Yaxin and Wen, Zhijie.Iwasawa decomposition: a new approach to 2D affine registration problem.Pattern Analysis and Applications vol 14.pp127–137.2011.

[abdel2006] Abdel-Hakim, Alaa E and Farag, Aly A. CSIFT: A SIFT descriptor with color invariant characteristics.2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06) vol 2.pp 1978–1983.

[lowe2004] Lowe, David G.Distinctive image features from scale-invariant keypoints vol 2.pp 91–110.2004.

[matas2004] Matas, Jiri and Chum, Ondrej and Urban, Martin and Pajdla, Tomás,Robust wide-baseline stereo from maximally stable extremal regions.Image and vision computing vol 22.pp 761–767 2004.

[mikolajczyk2004] Mikolajczyk, Krystian and Schmid, Cordelia, Scale & affine invariant interest point detectors,International journal of computer vision vol 60 . pp 63–86 .2004.

[yu2011] Yu, Guoshen and Morel, Jean-Michel,Asift: An algorithm for fully affine invariant comparison,Image Processing On Line,2011.

[wu2013] Wu, Jian and Cui, Zhiming and Sheng, Victor S and Zhao, Pengpeng and Su, Dongliang and Gong, Shengrong. A Comparative Study of SIFT and its Variants.Measurement Science Review vol 13.pp 122–131,2013.

[juan2009] Juan, Luo and Gwun, Oubong,A comparison of sift, pca-sift and surf,International Journal of Image Processing (IJIP) vol 3,2009.

[lazebnik2007] Lazebnik, Svetlana and Furukawa, Yasutaka and Ponce, Jean.Projective visual hulls,International Journal of Computer Vision vol 74 ,pp 137–165,2007.

[laurentini1994] Laurentini, Aldo,The visual hull concept for silhouette-based image understanding,IEEE Transactions on pattern analysis and machine intelligence, vol 16,pp 150–162, 1994

[esteban2004] Esteban, Carlos Hernández and Schmitt, Francis,Silhouette and stereo fusion for 3D object modeling,Computer Vision and Image Understanding vol 96,pp 367–392, 2004.

[saidani2012] Saidani, Maweheb and Ghorbel, Faouzi,Affine invariant descriptors for 3D reconstruction of small archaeological objects,CompIMAGE 2011 pp383–386,2012

[ghorbel1998] Ghorbel, Faouzi, Towards a unitary formulation for invariant image description: application to image coding,Annales des telecommunications vol 53. pp 242–260, 1998.

[mundy1992] Mundy, Joseph L and Zisserman, Andrew, Appendix-projective geometry for machine vision,Citeseer 1992.

[saidani2016] Maweheb, S., Malek, S., and Faouzi, G. (2016). Geometric invariance in digital imaging for the preservation of cultural heritage in Tunisia. Digital Applications in Archaeology and Cultural Heritage, 3(4), 99-107.2016.