3D Modeling by thermography for non-destructive analysis of archaeological heritage

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ABSTRACT. *Nowadays, the law define as "cultural heritage" a big amount of artifacts. It is immense and in continuous expansion.The need to know as much as possible about the goods and to maximize its duration while maintaining its integrity and its accessibility to the public, has led to the search for increasingly effective solutions to fulfill the purpose. Thermographic analyses are fundamental to determine the insulating and thermo-absorbing capacities of the constituent elements and the position of structural elements not otherwise identifiable to the naked eye. The operation of the Thermographic camera is based on the material's ability to absorb and release heat. The instrument generates maps in different colors that associate a corresponding color with a detected temperature.The present note describes the methodology for the realization of a thermical three-dimensional photogrammetric model, realized with infrared images applied to archaeological assets.The 3D modeling is based on the combined use of imaging techniques as digital photogrammetry and computer vision.*

RÉSUMÉ. *De nos jours, la loi définit une grande quantité d'objets artisannaux comme "patrimoine culturel". Cela est immense et en expansion continue.Le besoin de savoir autant que possible sur le bien et de maximiser sa durée en maintenant son intégrité et son accessibilité au public a conduit à rechercher des solutions de plus en plus efficaces pour atteindre cet objectif.Les analyses thermographiques sont fondamentales pour déterminer les capacités isolantes et thermo-absorbantes des éléments constitutifs et la position des éléments structurels non autrement identifiables à l'œil nu.Le fonctionnement de la caméra thermographique est basé sur la capacité des corps à absorber et à libérer de la chaleur. L'instrument génère des cartes de différentes couleurs qui associent une couleur correspondante à une température détectée. La présente note décrit la méthodologie pour la réalisation d'un modèle photogrammétrique tridimensionnel, réalisé à l'aide d'images infrarouges appliquées aux biens archéologiques.La modélisation 3D est basée sur l'utilisation combinée de techniques d'imagerie comme la photogrammétrie numérique et la vision par ordinateur.*

KEYWORDS: *archaeological heritage, 3d model, thermography.*

MOTS-CLÉS: *Patrimoine archéologique, modèle 3D, thermographie.*

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1. Introduction

Each artifact, contains in itself the history and the artistic interest, including information on its production, its use and its state of conservation. The task of art historians, archaeologists, restorers and others involved in the the field of cultural heritage study and preservation is to highlight all of its history. (Saio *et Al*., 2017)

The expert's eye, however, is not able to go beyond the surface, where however a not less important and substantial part of the information is hidden. Under and/or in the surface it is possible to highlight everything that is not visible to the naked eye.

The fundamental task for the application of physics in Cultural Heritage consists ultimately in unveiling this hidden story.

Non-destructive techniques are the complex of diagnostic investigations, examinations and surveys conducted using methods that do not alter the material, do not require the destruction or even the sampling. These are generally all indirect methods. They are based on the use of electromagnetic radiation throughout its energy spectrum.

Thermography is one of the main non-destructive analyzes.

The possible information that can be obtained may concerns: - the identification of buffered openings; - the identification of hidden architectural details; - the identification of buildings incorporated in posterior constructions; - the positioning of structural elements; - the mapping of thermal leaks; - the presence of humidity or detachment. (Bergero S. *et al*., 2018).

In this paper, we present an experimented procedure that allows the use of thermal sensors using digital cameras in the photogrammetric field in order to obtain a product from which the geometric and thermal information of the studied object can be extrapolated. The case study presented concerns the survey of one of the three works (called Trans-letter and made in bronze painted in black and white) created by the sculptor Rabarama (Figure 1), and placed on the seafront Italo Falcomatà of Reggio Calabria. Monitoring with integrated sensors is a completely new technique that has revolutionized the classic methodologies within a couple of years, as it allows us to obtaining information unimaginable so far.

Figure 1. Bronze sculpture - trans-letter (rabarama)

The objective of the survey was purely technical to evaluate the functionality of the system.

For the data processing phase and for the creation of three-dimensional models, a series of open source software and commercial programs are used to generate dense clouds of points and orthophoto with a metric value.

The creation of Digital Surface Model (DSM) is carried out throught the free software VisualSfM, a semi-automatic program that, starting from a system of photographic images, is able to provide dense, geo-referenced clouds.

The treatment of the three-dimensional model is performed with the help of an open source software called Cloud Compare.

2.The survey methods

2.1. Digital photogrammetry

In the last 10 years, the use of digital images to reconstruct a 3D model of an object has greatly increased. The main development concerns the automatism introduced in the image matching algorithms, both for the image orientation and for the DSM extraction (Gustafson, 1998).

Moreover, the actual availability of a higher computing power allows orienting huge series of photos with a free acquisition network and to model very complex objects.

With the advent of digital images, we have gone to the use of the latter, giving birth to a new branch of photogrammetry called precisely "digital photogrammetry".

In digital photogrammetry, the operator can use automatic collimation procedures and measurement of characteristic points, and as known and consolidated, throught Collinearity equations we can defines the straight correspondence between the object points and the image points.

A digital image can be considered as a continuous function g (x, y) where x, y are spatial variables.

The dependent variable expresses the radiometric content. The digital image is, therefore, a discrete function obtained by sampling the spatial variables and quantizing the corresponding grey values and consists of a matrix g (x, y) whose elements are called pixels.

$$g(x, y) = \begin{bmatrix} g(0,0) & g(0,0) & \cdots & g(0, C-1) \\ g(0,1) & g(1,1) & \cdots & g(1, C-1) \\ \vdots & \vdots & & \vdots \\ g(R-1,0) & g(R-1,1) & \cdots & g(R-1, C-1) \end{bmatrix} \quad (1)$$

Where:

- x=0,1,…,C-1 row index
- y=0,1,…,R-1 column index
- R= maximum number of rows
- C= maximum number of columns
- g(x,y)= grey values

Therefore, the digital image consists of areal elements of finite size (pixels) each of which is associated to a positive integer called Digital Number (DN).

The DN represents the radiometric value of the portion of an image contained within the pixel.

Each pixel can be seen as an element of a matrix, and therefore uniquely identified by two integers, which represent the position of the pixel within the matrix: the row and column index. The pixel is, therefore, the elementary and inseparable part of the image and has an a priori fixed position that cannot change over time (metric content of the image). (Pozzoli and Mussio, 2003).

The resolution of a digital image can be analyzed under two aspects, radiometric and geometric resolution. The first defines the number of tones that a single pixel is able to represent, while the second one is a function of the physical size of the pixel.

The radiometric resolution to the type of transformation that is applied to the intensity of the light signal, perceived by the sensor, is a whole numerical value called Digital Number. The DN is then memorized for each pixel providing the radiometric value of the portion of the image occupied.

The geometric resolution depends on the size of the image portion occupied by the single element constituting the sensor. Since a digital image is made up of a two-dimensional array having as many elements as the pixels of the image, then a high geometric resolution corresponds to a matrix with a high number of rows and columns and consequently a small pixel size.

The parameter that characterizes the pixel size is the geometric resolution indicated with Dots per Inch (DPI). The DPI is the number of pixels contained in one inch, or 24.5mm. (Costa *et al.*, 2016)

The resolution of the digital image can be evaluated taking into consideration the real surface area whose image, projected on the focal plane and then on the sensor, covers the surface of a pixel; this area is called Ground Sampling Distance (GSD).

$$\mathrm{GSD} = l * \frac{Z}{c} \tag{2}$$

Where:

- Z is the gripping distance,
- c is the focal length of the camera,
- l is the size of the pixel side,

- Zc is the scale factor mb

At the same distance of the object from the lens, the resolution of an image is as greater as smaller is the size of the pixel side of the sensor: greater is the number of pixels and better the image reproduces the reality.

2.2. Automatic image correlation

With the development of digital photogrammetry, automatic techniques have been developed for the identification of homologous points within digital image systems. The coordinates of the homologous points can easily be measured by being visible simultaneously on two or more frames (Remondino and Menna, 2008). These are fundamental to the realization of representative models of the object and for their orientation. The problem of identifying these points is called Image Matching and is mainly developed in 4 phases:

-selection of a portion of the image in one of the two images to be related;

-identification in the second image of correspondences;

-calculation of the three-dimensional position;

- evaluation of the quality of the matching procedure used.

2.2.1. Correlation AREA BASED

The Area Based correlation is based on algorithms that compare the radiometric value in grayscale among pixels belonging to different images. The images then initially undergo a transformation into grey levels and afterwards are subjected to correlation algorithms that evaluate the similarity of the radiometric values. A matrix called silhouette representing a portion of an image is identified. Subsequently, a Search window is used to search for matches.

2.2.2. Correlation Feature-based matching

Feature-Based Matching (FBM) is a type of algorithm that exploits the presence of significant points within an image and seeks correlation within others. Points of interest are identified by special operators called operators of interest.

These points of interest, however, are not specific points, but rather features, i.e. the groupings of pixels made in such a way that those portions of the image are unambiguous and have some peculiarity.

2.2.3. Structure for motion

The term Structure for Motion is a technique that, through the automatic collimation of homologous points present in a set of photos, allows the reconstruction of the real form of objects.

Initially, a series of elements (normally punctual) are selected on the individual images. These, with a certain degree of probability, can be traced on several frames through the use of mathematical operators of interest. (Fonstad *et al*., 2013).

Then it is possible to try to catalog, in the first attempt, the homologous correspondences through geometric and radiometric criteria.

The reconstructed geometry does not obviously coincide with the real one, but rather represents a projective level equivalent to the real one. To obtain a real reconstruction, it is sufficient to know the internal orientation parameters that can be known a priori or estimated directly.

Finally, it is possible to obtain an optimal model, through bundle adjustment in which information can be inserted (such as points of support, known inter-distances, etc.) in order to achieve a complete definition of the parameters orientation (motion) and reconstruction of the structure of the scene (structure).

The main phases are therefore two, a first process of extraction of the features for the correlation and subsequently the determination of homologous pairs.

The extraction of features consists in the identification of interesting elements of a punctual type that are easily identifiable and traceable in different frames through the use of mathematical operators of interest (detectors).

There are several types of operators with different characteristics that change the ability to extract homologous points from frame sets.

As greater the invariance degree, compared to geometrical transformations (translation, rotation) and radiometric transformations (scale, illumination) of an operator, as higher the extraction capacity will be.

The second phase concerns the determination of homologous pairs and it is a phase of considerable interest because the made couplings will be dragged to the end of the elaboration. For this reason, it is important to "bring along" the least possible error, to avoid obtaining unsatisfactory or unwanted products.

The matching phase is, therefore, a crucial phase which is more complex because it is not carried out through simple analytical procedures but can be subject to errors and may require particular attention depending on the specific case being analyzed.

2.3. Visual SFM

VisualSFM is a software that allows the three-dimensional reconstruction of dense clouds of points.

The software was created to operate on sets of images, resolving with impressive speed orientation problems and providing three-dimensional point clouds.

The process of reconstruction of the three-dimensional scene is divided into two phases:

- The extraction and matching of the features carried out through an implementation to the GPU calculation of the SIFT (Scale-invariant feature transform).

- Triangulation and bundle adjustment based on a multicore (parallelized) compensation algorithm between CPU and GPU thanks to the OpenGL and CUDA libraries.

In the phase of bundle-adjustment is important to underline that the internal parameters of the used chamber are not kept constant but evaluated differently for each individual socket and the distortion model is particularly simplified as it adopts a single parameter for radial distortion, for a total of 4 POI (Point of interest).

2.4. Agisoft Photoscan

Agisoft PhotoScan is a low-cost commercial software produced by Agisoft LLC in St. Petersburg. This software implements the digital photogrammetric technique, applying computer vision algorithms and the latest multi-view technologies, to generate 3D spatial data.

It allows creating 3D models from a photographic system through an automatic photogrammetric procedure using automatic correlation algorithms that are widely used in Structure from Motion photogrammetric software (SfM).

The Structure from Motion identifies the correlations with feature matching processes between the block of images, called chunk, which must be stable with respect to variations in lighting and point of view. On each of them, a descriptor is generated which is based on a reason defined around the point. An algorithm similar to the SIFT (Scale-Invariant Feature Transform) is used to determinate the correspondences between the digital images and then it will be possible to resolve the internal and external orientation parameters.

First, a crude algorithm found the camera shutter center coordinates and subsequently refined using the Bundle Adjustment. Rebuilding the point-dense cloud uses a multiple-view approach with merging depth maps.

Photoscan provides a filtering of the outliers that can be set on three levels (moderate, mild, aggressive) each to be fixed depending on the regularity of the surface, thus indicating the presence of a regularization factor.

The workflow is completely automatic both as regards the orientation of the images and for the generation and reconstruction of the model. This condition led to an optimization of the processing times ensuring good performance of the machine/software complex.

The phases of the elaboration were the following:

1. Alignphotos (photo alignment) consisting in identifying the binding points using operators of interest. The points chosen in the various photos must have characteristics in common in order to be adequately superimposed. For a good result the quality of the image must be high, you must have few areas of shade and adequate lighting;

2. Build Dense Cloud. Through this phase, a dense cloud is constructed using dense image matching algorithms. These are subdivided into algorithms that use a stereo pair to find matches (stereo matching) and those that identify them in multiple images (stereo multi-view);

3. Buildmesh, which consists in generating a polygonal model based on the newly created dense cloud. The mesh is a subdivision of a solid into smaller solids of a polyhedral shape;

4. Buildtexture instead allows obtaining the 3D representation of the work under investigation.

3. Termography

Thermography is one of the most non-destructive methods used in the diagnostics of pathologies of buildings and structures that, even if carried out in a workmanlike manner, are subject to degradation due to the aging of materials and the prolonged lack of maintenance (Grinzato *et al*., 2002).

The thermal and hyperspectral sensors allow studying the properties and characteristics of the soil and of the objects present on it by exploiting the solar radiation reflected in regions of the electromagnetic spectrum that are invisible to the human eye. This makes it possible to identify phenomena, characteristics and qualities that are much faster, and more precise as they avoid costly and lengthy on-site investigations.

Infrared thermography is a non-destructive diagnostic technique that exploits the physical principle according to which anything with a temperature higher than absolute zero, corresponding to -237.15°C, emits energy in the form of infrared radiation.

3.1. Thermal imaging camera

The thermal imaging camera is an instrument that detects the radiated energy and determines the superficial thermal distribution, generating images, thermograms, false-colour or black and white, where the nuance of color or grey scale are related to the distribution temperature of the objects examined, allowing to measure the absolute temperature value of each point (pixel) of the image. (Zaginaylo et al., 2017)

As greater is the geometric resolution of the image, i.e. the number of pixels contained, as greater will be the detail and the precision with which is possible to read the temperature since the radiometric cameras are able to measure it for each pixel detected (Bolognesi *et al*., 2014).

The camera used for the survey (figure 2) is the FLIR P620 thermal imaging camera that is equipped with an uncooled microbolometeter detector and produces thermal images with an IR resolution of 640x480 pixels, capable of detecting even the smallest details.

Another fundamental parameter is the thermal resolution which represents the minimum temperature difference that can be appreciated by the thermal imaging camera.

The thermal imager used for the survey is able to detect temperature differences of 0.06°C (30mK) (Barrile *et al*., 2015).

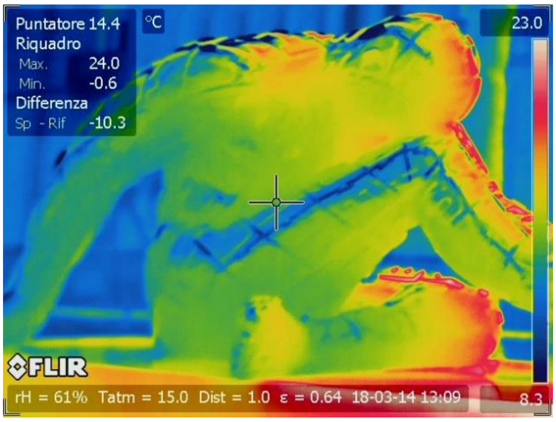

Figure 2. Bronze Sculpture - Trans-letter (Rabarama) acquisition with the thermal imaging camera

4. Case study

4.1. Description of the study area

The photogrammetric survey was carried out to monitor a bronze sculpture of Rabarama on the Lungomare of Reggio Calabria, and therefore constantly exposed to saltiness and to the weather, as well as to strong sun exposure. The objective of the survey is to identify any problem superficial and/or detachment.

The object of study was received through a series of acquisitions of digital and thermal images around it, made in a number congruous to the model generation.

4.2. Treatment of thermal data

For the problems related to thermal modelling, as known from the literature, we proceeded to use particular empirical methodologies both in the acquisition, processing and processing phase.

That said, the thermal images (figure 2) were initially acquired in a table format of Excel CSV (comma-separated values), which shows the matrix that describes the photo, in which for each pixel its radiometric temperature value is associated. The array is the same size as the frame resolution (640 x480).

Subsequenlty through the software ImageJ (open source software, programmed in JAVA, of digital image processing developed by the US National Institutes of Health), a tonalty of grey was associated to the radiometric value of each pixel in order to convert the above images greyscale (for higher temperatures the hue is whiter, while a lower black colour is associated with lower values).

The same software allows us to view, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. The supported formats are TIFF, JPG, GIF, BMP, DICOM, FITS and "text image".

ImageJ also offers the possibility to calculate the area and statistics on pixel values relative to the regions of interest selected by the user. You can also measure distances and angles, plot charts and histograms, and support the most common geometric transformations such as scaling, rotation, and zooming.

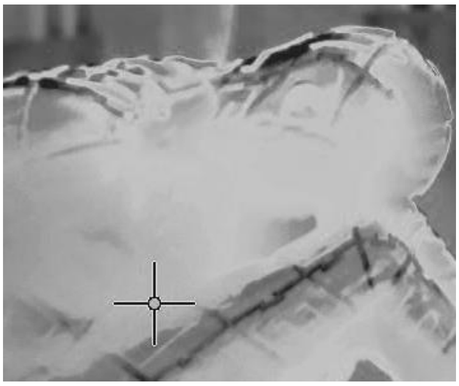

Figure 3. Grayscale image on ImageJ

Starting from a text image in CSV format, graphic representations were created in grayscale, representing the radiometric values assigned to the pixels of the matrix constituting the initial data (Figure 3).

4.2.1. Automatic photogrammetric return procedure of the thermal datum

SFM visual software allows the creation of a dense cloud of points that will subsequently be scaled and geo-referenced on the basis of the coordinates of the photogrammetric support points (Pollefeys *et al.*, 2001).

There are 4 phases for the realization of the dense cloud of points, identified by as many commands placed in the software toolbar:

- Add Images: add images to the workspace;

- Match the Images: start the search for features and the correspondence between pairs of images;

- Sparse Reconstruction: start sparse reconstruction;

- Dense Reconstruction: start dense reconstruction using CMVS / PMVS by Yasutaka Furukawa.

In the first phase, the photos to be inserted were selected, which the program has tried to get to the realization of a dense model.

The photos were made with the type of grip as normal as possible, with axes parallel to each other.

Subsequently, through the "Compute Missing Matches" command, the characteristics were extracted by looking for alleged correspondences (SIFT) on all the frame pairs (Figure 4) (Scovanner *et al.*, 2007; Lingua *et al.*, 2009).

```
    [Tools->Enable GPU->Set Maximum DIM]
Note some octaves may be automatically skip
SIFT: 0000, 3968x2976,  10079, 2.72sec
SIFT: 0001, 3968x2976,  10315, 0.51sec
SIFT: 0002, 3968x2976,  9899, 0.88sec
SIFT: 0003, 3968x2976,  10615, 0.42sec
SIFT: 0004, 3968x2976,  10283, 0.42sec
SIFT: 0005, 3968x2976,  10441, 0.71sec
SIFT: 0006, 3968x2976,  9312, 0.34sec
SIFT: 0007, 3968x2976,  9524, 0.35sec
SIFT: 0008, 3968x2976,  10001, 0.34sec
SIFT: 0009, 2976x3968,  7842, 0.50sec
SIFT: 0010, 2976x3968,  8509, 0.37sec
SIFT: 0011, 2976x3968,  6729, 0.29sec
SIFT: 0012, 2976x3968,  6243, 0.33sec
SIFT: 0013, 2976x3968,  5347, 0.26sec
SIFT: 0014, 2976x3968,  5004, 0.25sec
SIFT: 0015, 2976x3968,  5088, 0.48sec
SIFT: 0016, 2976x3968,  3747, 0.48sec
SIFT: 0017, 2976x3968,  3735, 0.40sec
SIFT: 0018, 2976x3968,  3393, 0.24sec
SIFT: 0019, 2976x3968,  3977, 0.25sec
SIFT: 0020, 2976x3968,  3906, 0.45sec
SIFT: 0021, 2976x3968,  4324, 0.65sec
```

Figure 4. File SIFT

So, a first scattered reconstruction of the point cloud was obtained, which is generated continuously (figure 5).

Afterwards, the triangulation and the Bundle Adjustment (PBA) was carried out in order to generate a cloud file in.ply format. From which the dense one could be created using the "Run Dense Reconstruction" command (Ahmadabadia *et al.*, 2013).

This procedure takes a set of images with the related parameters of the camera and reconstructs a three-dimensional structure of the object represented in the images.

Despite all the precautions and improvement processes, the point cloud obtained was not of quality.

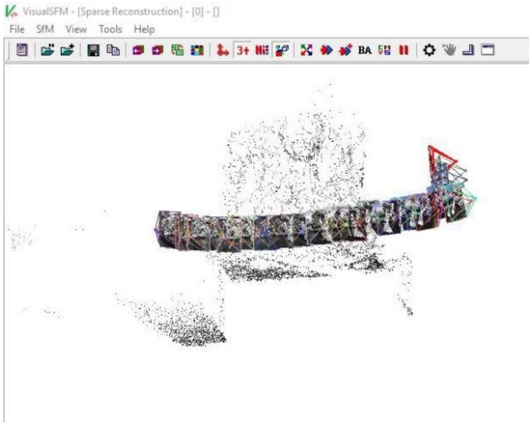

Figure 5. Spread reconstruction effected with triangulation

The result obtained after dense reconstruction is shown below in figure 6.

Figure 6. Dense cloud display of thermal imaging points

The georeferencing of the dense cloud is carried out by conforming rototranslation, with a 7-parameter scale variation, starting from the coordinates of the photogrammetric support points (measured with the Leica 1250 GPS receiver) chosen in coincidence with the four corners of the base of the sculpture, and inserted manually within the software used (Heipke, 1997).

The coordinates manually entered (User Coordinates) have been compared with those transformed (Transformed points), and the residual data was calculated from the difference between the two values emphasizing the no presence of systematism (Haala *et al*., 2010).

The dense cloud obtained, contains, even in its limited and incomplete nature, the three-dimensional metric information related to the thermal images transformed into grayscale only visually reported (depending on the highlighted gray tonality) (Pozzoli *et al*., 2004).

The objective was to create a three-dimensional model whose texture represents the thermal values corresponding to certain points of the model as it happens for the classic three-dimensional models in which the same information are assigned to the same dimension.

As you can see from fig. 5 and as expected, the product obtained following the realization of the dense cloud of points is not of great quality. The planimetric error was found to be very high, with peaks of 12 cm for the North and almost 20 cm for the East, and important residues were also obtained with regard to temperatures, with errors even more than 5' (Eltner and Schneider, 2015).

4.3. Processing of digital images with Agisoft photoscan

For the creation of the classic three-dimensional model, digital images were imported into Agisoft Photoscan, ensuring the overlap between the photos that would not lead to the creation of "noise" in the alignment of the frames.

The alignment phase compares the common points in the different photographs, rediscovering the spatial position of the camera when shooting each frame,; thus generating a cloud of homologous points necessary for the reconstruction of the photographed object (Barrile and Bilotta, 2017).

A great advantage of Photoscan compared to Visual SFM was found in this passage; in fact, in Photoscan it is implemented an algorithm that studies the epipolar geometry of the image. It follows that once a point has been identified in an image the epipolar plane is created passing through the center of projection of two images (containing the point) and the point. This intersected with the image where it has not yet been identified generates a line that limits the search for correspondence to the line itself.

Figure 7. Dense cloud of digital photo points in RGB

Once the alignment process was completed, a scattered cloud of points was created and the dense cloud was created through the process of densification. The product obtained, consist in a very dense point cloud. The outliers have been eliminated with the classic data processing procedures.

Once the densification has been completed, the interpolation process has been carried out to determine the mesh, i.e. a surface that allows a better visualization of the three-dimensional object (Figure 7) (Baltsavias *et al*., 2008).

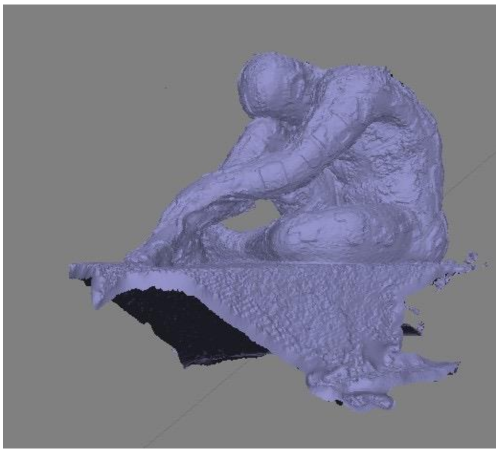

Figure 8. Mesh construction

The processing continues with the application of the Texture that describes the material qualities of the object and allows us to export the model according to oriented views (Figure 9) (Büyüksalih and Li, 2005).

Figure 9. Geometric 3D model

4.4. Processing with cloud compare

For the realization of the thermal-geometric model, we proceeded by joining the two clouds of points previously made.

The environment chosen for the processing and analysis of dense georeferenced clouds is CloudCompare. Open source software was used for the management of point clouds and triangular meshes.

The software is able to perform various operations with clouds including their union, resampling, colour management, management of scalar fields, etc.

Through the use of this software, starting from one of the dense clouds of points made previously, it was possible to resample, refine and merge the parts of real interest and then be able to realize the model.

The new point cloud obtained is shown in figure10.

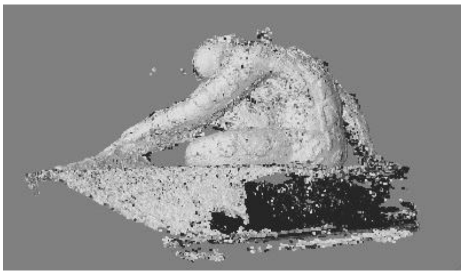

Figure 10. Union of dense clouds

The realization of the three-dimensional thermal model has been realized through the application of the texture of the point cloud obtained from thermal photos to the cloud obtained as a union between thermal cloud and geometric cloud (Remondino *et al*., 2008).

The result obtained is shown in Figure 11.

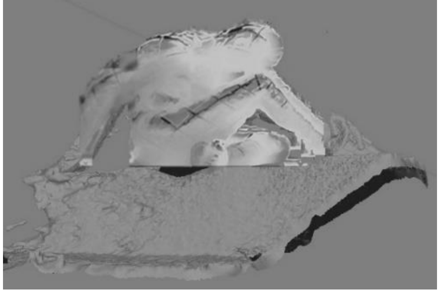

Figure 11. 3D thermic model

Of course, even if the model has excellent geometric characteristics, the adaptability of the texture to the new mesh generated by the two point-clouds has nevertheless been not very adaptable.

The model generated certainly allows us to have the advantage of being able to simultaneously see two types of data: geometric and thermal (Kalantari and Kassera, 2004).

It is however mandatory to observe that while from a geometric point of view the final model has an excellent geometric precision (errors in the order of 0.5 cm), on the other hand, from a thermal point of view there is an imperfect coincidence of the thermal value detected and shown and displayed on the model with the corresponding real and effective value as observed by the starting thermal images.

Certainly, such methodologies can be improved optimizing both the acquisition phase and the matching and modelling algorithms, opening up new frontiers in the field of non-destructive tests.

5. Conclusion

As already specified in the introduction, this elaborate treat of the photogrammetric relief flanked by the thermal one.

The objective was to experiment a process that allows using the thermal sensors side by side with digital cameras in the photogrammetric field in order to obtain a product from which the geometric and thermal information of the study object can be extrapolated.

The thermal images have a lower resolution than the classic RGB digital images and therefore at the same distance of grip provide less information of the framed object.

The geometric surface of the sculpture and the thermal model has been georeferenced using the same photogrammetric support points. This allowed inserting vector and raster products obtained from photogrammetric software, in a single reference system.

In this paper, an experimental procedure was described for the return of three-dimensional geometric and thermal elements through experimental methodologies that can certainly be improved and implemented in order to obtain a detailed 3d model both from a metric and thermal point of view. In this regard, the thermal values are not intentionally reported because the objective of the note is to propose an alternative way for the 3D visualization of thermal images through photogrammetric methods.

This technique for engineering studies could be very useful as it allows obtaining simultaneous metric and thermal information, allowing the georeferencing on a three-dimensional thermal model.

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