USABILITY AND POTENTIAL USE OF THE HIGH RESOLUTION DIGITAL CAMERA IN THE DETERMINATION OF 3D DIGITAL MODEL

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CIPA 2003 XIX International Symposium
"New perspectives to save cultural heritage"
Antalya – Turkey, 30 September – 4 October 2003

KEY WORDS: Cultural heritage, Photogrammetry , Calibration, Modelling, Orthophoto

ABSTRACT:

The research describes the study realized by the Department of Hydraulic, Environmental, Street Infrastructures and Survey Engineering - Survey Division of Polytechnic of Milan, in order to examine the potential use of the high resolution digital camera in the determination of 3D digital model. The aim of this work was to develop an method to estimate and compared the parameters of inner orientation and geometric distortions, i.e. radial, tangential. The method has been implemented in such a way to allow a calibration camera and compared the result whit the builder metric calibration certificate. The digital metric camera used in this work is the Rolleiflex 6008 integral with fixed mounted digital back Sensor and chip with 4080 x 4076 pixel (36.72 x 36.684mm).
In the second step it has been built up the application and experimental phase: particularly, the realization of a 3D digital orthophoto at scale 1:1 of the mosaic surface of the S. Marcus Basilica in Venice; the DSM obtained for auto-correlation with software of digital photogrammetry is compared with the levelling control point.

1. INTRODUCTION

1.1. Method to estimate the inner orientation

In order to extract from theses digital images careful 3D information today is possible whit the high resolution camera. The camera calibration typical issue in photogrammetry applications where the dimensional measurement are required.
The aim of this work was to develop an method to estimate and compared the parameters of inner orientation and geometric distortions (i.e. radial) and compared the result whit the builder metric calibration certificate: the digital metric camera used is the Rolleiflex 6008 integral with fixed mounted digital back Sensor (Phase One) with 4080 x 4076 pixel (36.72 x 36.684mm).
The main aspect of camera calibration is the estimate of the internal parameters and the correction of geometrical lens distortions.
In order to solve this calibration, the research adopting a three-steps method:

1. the first step define the initial value of calibration and external orientation of an image without lens distortions;
2. with the initial parameter we improve the estimate of all camera parameters (internal orientation and only radial distortions;
3. Use the estimate value in step 2 for T.A. block adjustment.

This approach can be useful when the builder metric calibration certificate is not present or when is required a comparison.

1.2. The method of calibration

Lens distortion is the aberration most relevant to photogrammetry. While other aberrations mainly affect image quality, lens distortion directly affects the metric accuracy of the image and must be corrected in photogrammetry .
Radial distortion is the radial displacement of an imaged point from its theoretically correct position or, equivalently, a change in the angle between a ray and the optical axis.
In order to define the distortion the parameters of the internal orientation of the camera it is rerun by means to self-calibration, in which the distorsion and camera parameters are included as part of the bundle adjustment solution.

The digital camera used in this research is Rollei DB44metric with optical lens 40mm. The camera allow the following point:

- saving of images Loss-free or RAW-format, up to 48 bit colour depth, 32 MB per image;
- lenses, interchangeable metric lenses PQ (fastest shutter speed:1/500 sec) between 40mm and 350 m, interchangeable metric lenses PQS (fastest shutter speed: 1/500 sec) between 50 mm and 500 mm.
- metric calibration for each lens;
- pixel in X (4.080), pixel in Y 4.076 and pixel size 9µm.

The calibration certificate for the camera used in this work supply:

- C_k -41.195 mm;
- X_h 0.374 mm and Y_h 0.057 mm
- A_1 -3.548E-005 and A_2 2.457E-008 as parameter for the radial distortion;
- R_0 15.0 mm

Figure 1. The Rolleiflex DB44-Metric

The procedures of the Rollei define the curve of distortion by equation

$$\Delta_r = A_1 \cdot R \cdot \left(R^2 - R_o{}^2\right) + A_2 \cdot R \cdot \left(R^4 - R_o^4\right) \qquad (1)$$

and in this case, R varied between zero and 26mm. The radial distortion curve is represented in Figure 2.

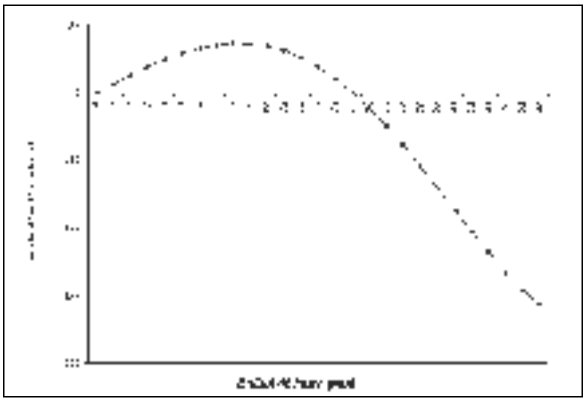

Figure 2. Curve radial distortion

It's self-evident as to the value of 26 millimeters of radial distance, the radial distortion assumes the value of 156μm same at 17pixel.
The used camera represented a prototype developed from the Rollei and therefore comparative calibration has been rerun to one.
The implemented analytical model in the self-calibration algorithm depends on the equations of collinearity complete of the relative part to the radial distortion.

$$f_{(x)} = x - x_o + c \cdot \left[\frac{r_{11} \cdot (X - X_o) + r_{12} \cdot (Y - Y_o) + r_{13} \cdot (Z - Z_o)}{r_{31} \cdot (X - X_o) + r_{32} \cdot (Y - Y_o) + r_{33} \cdot (Z - Z_o)}\right] + \\ -(x - x_o) \cdot \left[K_1 \cdot r^2 + K_2 \cdot r^4\right] = 0 \qquad (2)$$

$$f_{(y)} = y - y_o + c \cdot \left[\frac{r_{21} \cdot (X - X_o) + r_{22} \cdot (Y - Y_o) + r_{23} \cdot (Z - Z_o)}{r_{31} \cdot (X - X_o) + r_{32} \cdot (Y - Y_o) + r_{33} \cdot (Z - Z_o)}\right] + \\ -(y - y_o) \cdot \left[K_1 \cdot r^2 + K_2 \cdot r^4\right] = 0$$

where $$r^2 = (x - x_o)^2 + (y - y_o)^2 \qquad (3)$$

1.3. Test and result of method

For the determination of the parameters a polygon has been come true test in which they have been executed several photographies to several distances of taken, correspondents to several scales of photogram.

Figure 3. The Polygon Test where they are visible the target topographical finds by means of total station Leica TCRM1103

In order to evaluate the overall accuracy of our method, we have performed a calibration test using a target white 60 black squares on white background, each had a lateral dimension of 40mm. The vertices oh these squares were employed as control point.

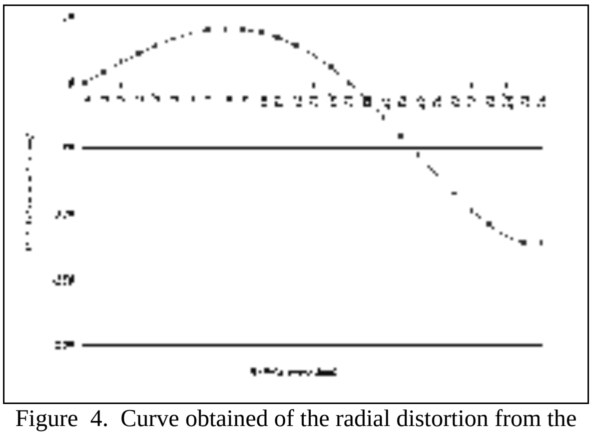

Figure 4. Curve obtained of the radial distortion from the process of self-calibration

The result experiences them of the phase test has supplied the following values of calibration:

- C_k 41.295 mm;
- X_h 0.458 mm and Y_h 0.035 mm
- K_1 -4.2007E-005 and K_2 3.5085E-008 as parameter for the radial distortion;

Radial Distance	D **Rollei and Self Calibration**	**Value** D
(mm)	**(micron)**	**(pixel)**
0	0	0
2	2	0
4	3	0
6	4	0
8	4	0
10	4	0
12	3	0
14	1	0
16	1	0
18	1	0
20	0	0
22	5	1
24	16	2
26	35	4

Table 5. The different value of radial distortion

It turns out demonstrate to you as between the curve of distortion supplied from the constructor for the used prototype of camera and that calculated a posteriori, substantial superimposition is one.

2. APPLICATION EXPERIENCE

2.1 3D digital orthophoto at scale 1:1 of the mosaic surface of the S. Marcus Basilica in Venice

The problems lie in the conservative restoration done on the floor which require a 3D reproduction to a 1:1 scale, in order to identify and replace damaged parts, as well as to install them while maintaining the characteristic altimetric irregularities, typical of the floor. It is clear that a strictly "plane" floor would not reflect the historic value to which we are accustomed .

Here then, we have a modellation using a 3D orthophoto and an automatic extraction with altimetric profiles for constructing templates to a 1:1 scale of the mosaic floor (measuring about 2000 m2). The object of application of the techniques proposed which must measure up to the economic and scientific aspects.

In the practical application it is proceeded in order is made successive that they have carried to the construction of following catalogues of data:

- the archives of the photographic images realized with the camera Rollei DB44metric with characteristic following, height 2.2m, covering to floor of 2m longitudinal, covering 60% and cross-sectional covering 10%;
- the archives of the GCP to use in the phase of support of the Aerial Triangolation;
- the archives of the points of level used like control element;
- the archives of scansions Laser in order to test a comparison between speed of execution of the measure and utilizzabiltà of the data;
- generation of DTM by means of process of photogrammetric auto-correlation comparison between the DTM produced by means of laser scanner and model for auto-correlation
- verification and comparison with the sections type;
- creation of the 3D digital orthophoto of the pavement .

As far as the first point the center of the basilica has been found completely and a meaningful champion of some photograms is itself chosen (13) in order to carry out the sampling.

Figure 6. S. Marcus Basilica in Venice

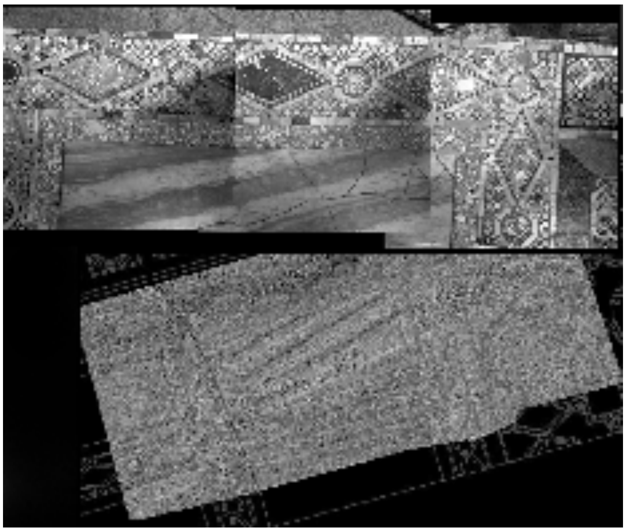

Figure 7. Particular of the zone interested from the research, with the model laser of the pavement and one crawled of photo

For the generation of a model 3D of the mosaics it has been used the laser scanner Mensi GS100, whose technical characteristics are:

- range 2 – 100m
- scanning speed up to 5000 points per second
- standard deviation 6mm
- angular resolution 0.0018°
- spot size 3mm at 50m

From cloud of points therefore finds has been created one surface GRID with step 2mm.

For the phase of Aerial Triangolation of (2 strips with a total of 13 photos) has been used the software APEX.

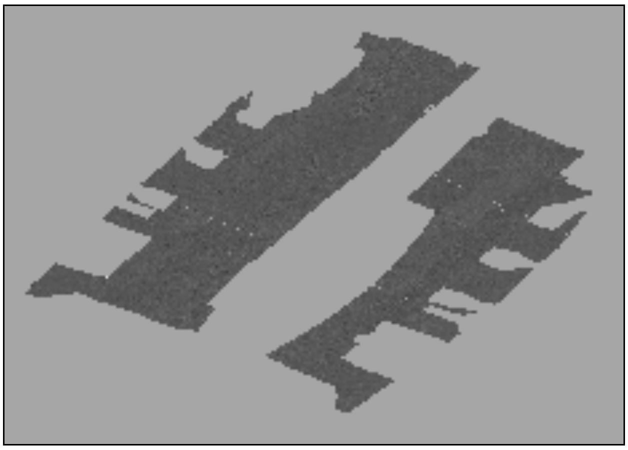

Figure 7. DTM laser with Mensi GS100

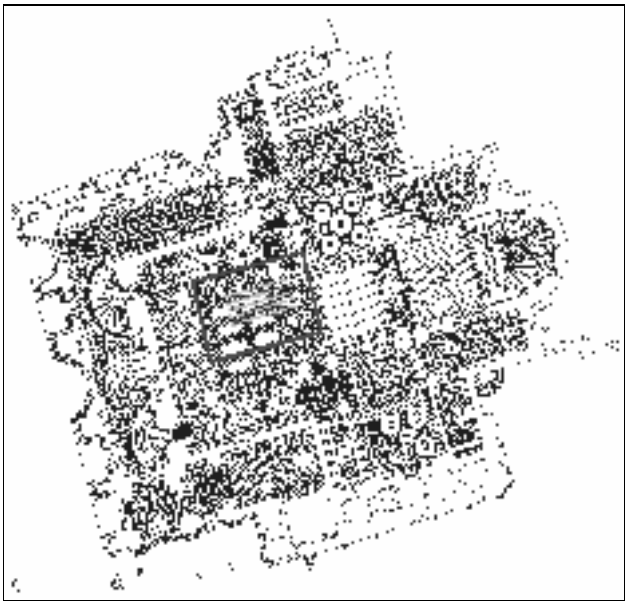

Figure 8. Mosaic of pavement

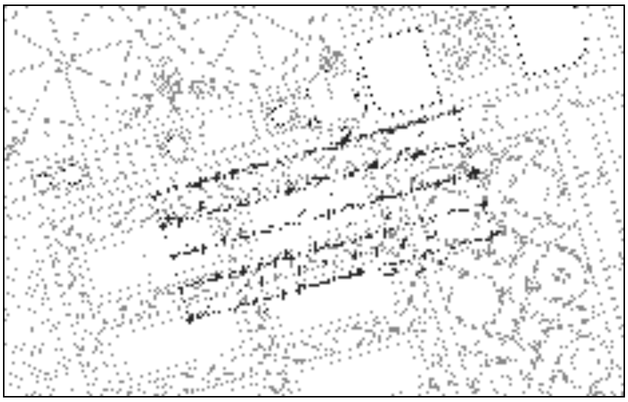

Figure 9. Level points

An extract is enclosed in the Figura 11, on the precisions obtained in the phase of TA and a medium value on all points observes and calculates.

In the Figura 11 the GCP are visible use in the phase of guideline and the calculated coordinated Tie Point with the relative ones to the end of the process

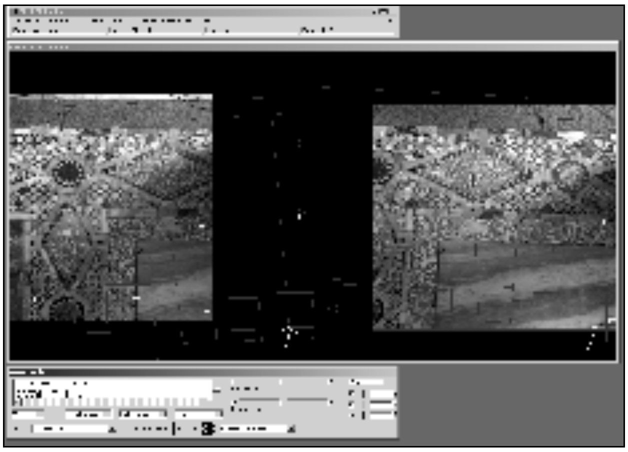

Figure 10. Apex software has been used for the phase of Aerial Triangolation

2_099	Camera X M,Ft	1893189,06	1,3
	Camera Y M,Ft	4718859,24	1,4
	Camera Z M,Ft	3877,53	0,5
	Omega Deg	-2:33:39,086	0,0
	Phi Deg	+0:07:11,748	0,0
	Kappa Deg	+16:58:04,054	0,0
2_100	Camera X M,Ft	1894026,13	1,2
	Camera Y M,Ft	4719026,3	1,3
	Camera Z M,Ft	3811,96	0,5
	Omega Deg	-1:37:46,777	0,0
	Phi Deg	-0:37:03,630	0,0
	Kappa Deg	+17:12:38,474	0,0
2_101	Camera X M,Ft	1894857,59	1,2
	Camera Y M,Ft	4719236,58	1,3
	Camera Z M,Ft	3842,76	0,5
	Omega Deg	-0:57:32,391	0,0
	Phi Deg	-0:05:08,289	0,0
	Kappa Deg	+17:25:58,733	0,0
2_102	Camera X M,Ft	1895850,24	1,6
	Camera Y M,Ft	4719492,39	1,6
	Camera Z M,Ft	3856,08	0,5
	Omega Deg	-0:48:39,183	0,0
	Phi Deg	+0:13:56,578	0,0
	Kappa Deg	+17:45:57,366	0,0
2_103	Camera X M,Ft	1896644,43	2,0
	Camera Y M,Ft	4719734,53	1,8
	Camera Z M,Ft	3837,36	0,7
	Omega Deg	-0:17:56,178	0,0
	Phi Deg	+0:03:16,986	0,0
	Kappa Deg	+17:28:08,032	0,0
101	x (Tie)	1891148,909	0,6
	y	4720833,918	0,5
	z	1398,527	1,4
102	x (Tie)	1891435,858	0,4
	y	4719971,333	0,4
	z	1344,788	1,2
103	x (Tie)	1891684,345	0,3
	y	4719218,403	0,3
	z	1367,112	0,7
104	x (Tie)	1892162,751	0,4
	y	4721124,382	0,4
	z	1397,825	0,9

Figure 11. Extract report AT, the last column is sigma coordinate (mm)

	Max s **(mm)**	**Max** s (mm)	**Min** s **(mm)**
GCP	0.49	0,95	0,23
TP	0,54	1,56	0,22

Table 12. Summary of value of σ coordinates.

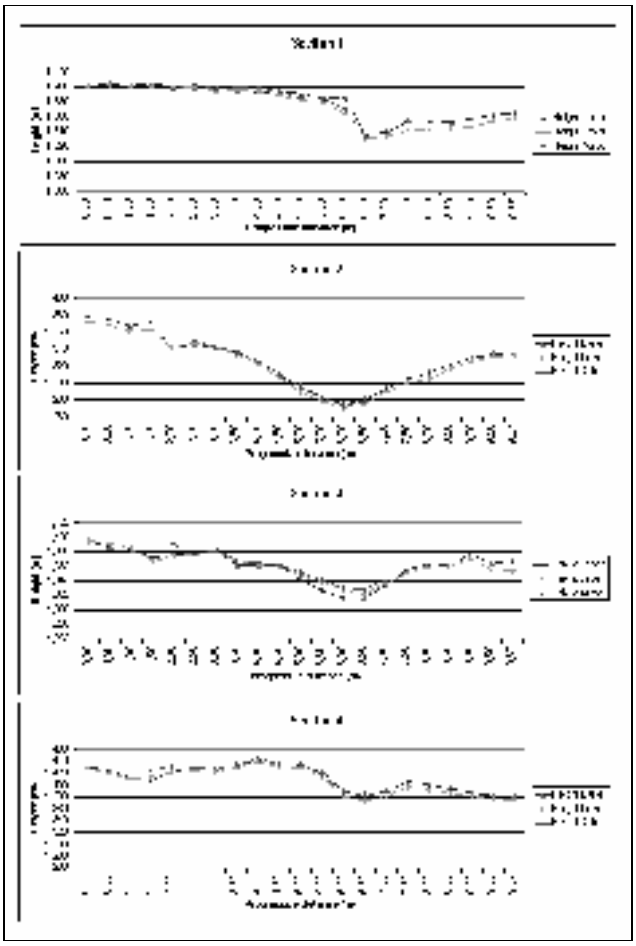

Figure 13. Comparison between heights Laser, heights Autocorrelation and level points.

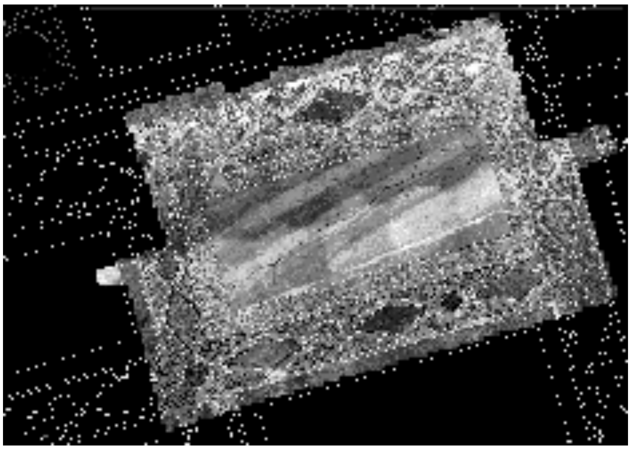

Figure 14. Superimposition digital orthophoto and vectorial restitution.

Calculated the external orientation of the photograms it is proceeded to the determination of a DTM given back by means of automatic correlation, defining a step of 20mm. The obtained DTM therefore is used in order to carry out a control on the level points determines to you a priori, obtaining of the precisions that they assume on the four sections of reference medium values in difference of 3mm.

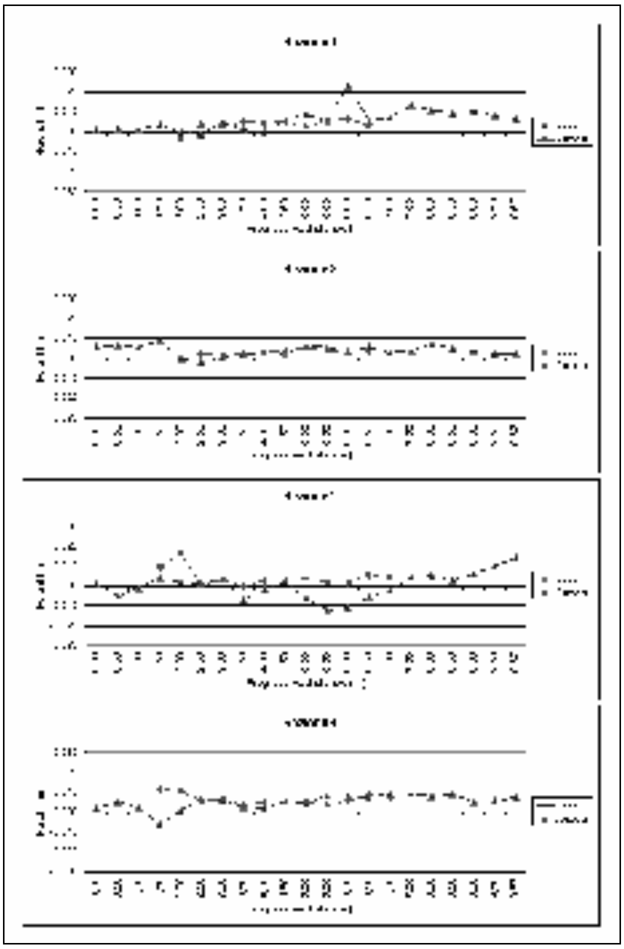

Figure 15. Variations heights respect the livel points.

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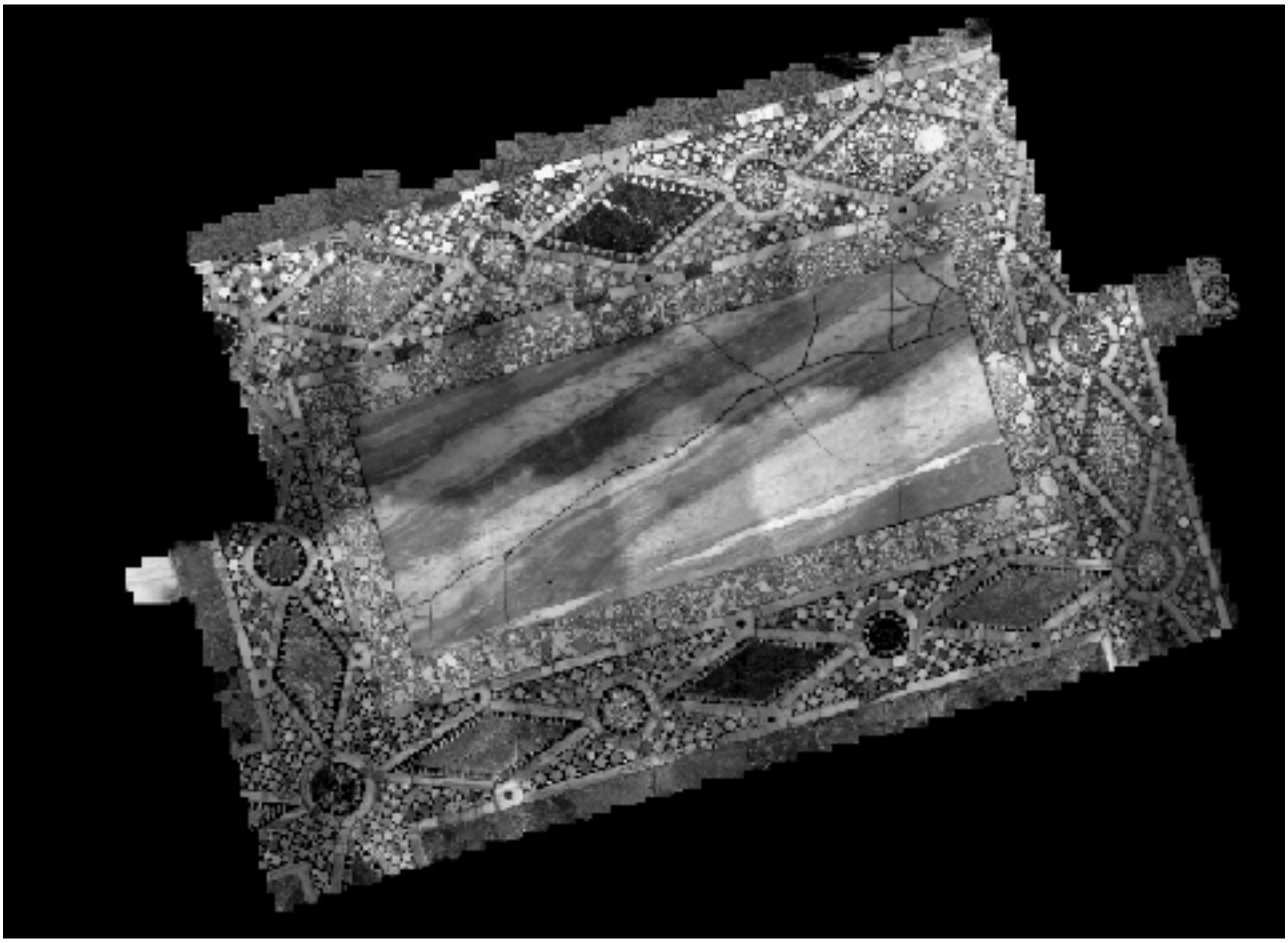

Figure 16. Digital orthophoto to high resolution (1 pixel = 0.5mm), 2D view.

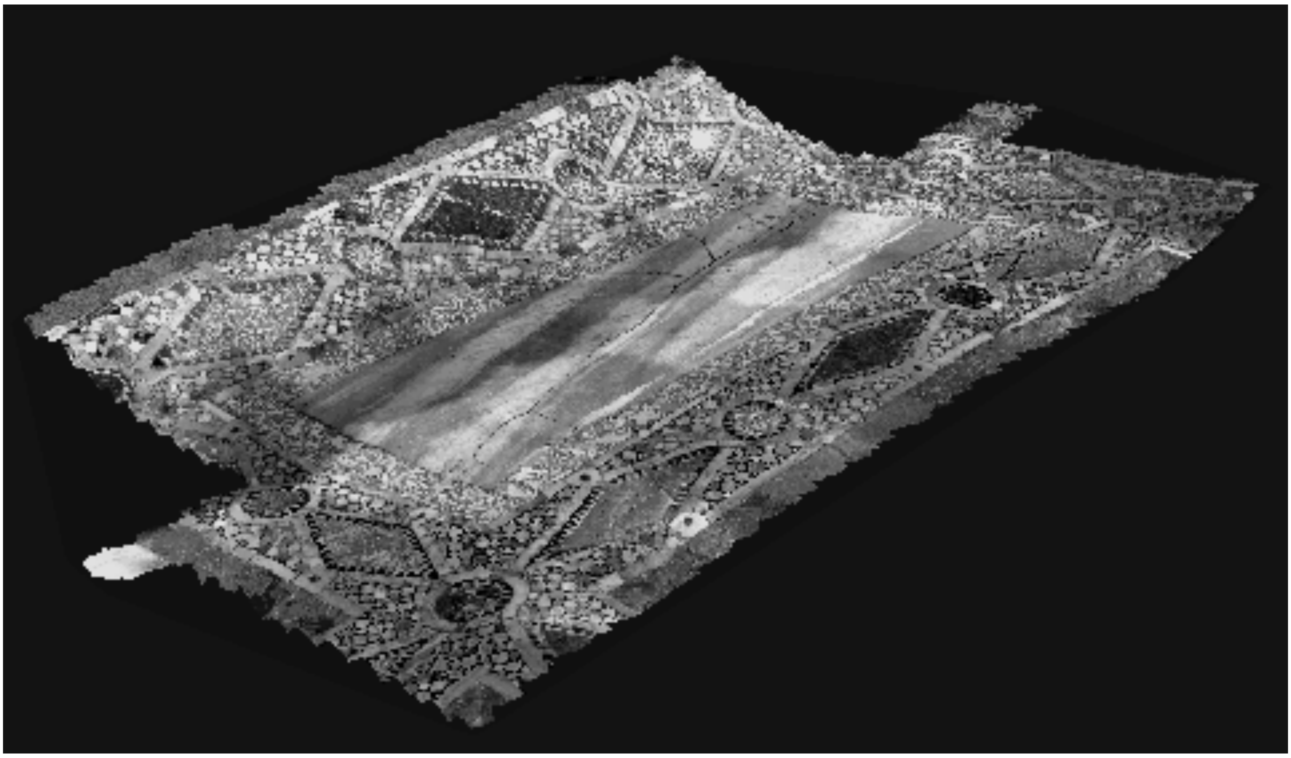

Figure 17. 3D view of Digital orthophoto