SURVEY AND 3D MODELLING OF CASTEL DEL MONTE

A. Capra, D. Costantino, G. Rossi, M. G. Angelini, M. Leserri
DIASS – Politecnico di Bari, V.le del Turismo 8, 74100 Taranto, ITALY
a.capra@poliba.it; d.costantino@poliba.it; grossi@poliba.it

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ABSTRACT

Castel del Monte, symbol and emblem of the buildings Federico II architecture, seems has been realized for wish of the same Federico II on 1240. In 1876 the castle has been acquired by the Italian State and numerous interventions of restauration have been take. From 1996 Castel del Monte has been inserted by the UNESCO in the worldwide patrimony of the humanity for his oneness and it's currently the monument more visited of Puglia.
Numerous and rather fanciful hypotheses have been argued around original destination; such as many have been the interpretations around the octagonal matrix of the castle and the number eight, recognizing in these elements magic, ancestral, esoteric, astronomic references; by according to some researchers, the castle would have even hosted the Saint Graal.
The originality of the site has induced a surveying more deepened through laser scanner technique, for the complexity of the structure, it was to plan a simulation of surveying steps.
The above mentioned phases have allowed one more expeditious activity of survey; particularly the laser scanners survey have allowed a 3D model that could allow to verify different hypotheses or to formulate new one.

1. HISTORICAL NOTES

1.1 Survey object

In Apulia, near to Bari, Castel del Monte stand over the Murge plateau and it is visible from many kilometers of distance. It is a Mediaeval castle that Federico II own wished to buiold up around 1240, as control system centre of the territory and symbol of the power of the Svevi imperial house of which it reproduces, in large-scale, the octagonal crown.
Aura mystery fed from absurd sideboards about the Frederic octagon contributes to make Castel del Monte one of the monuments most visited in South Italy, behind only Pompey. It is destination of lightweight numerologistes, mystery science lovers, ufologistes, archaeo-astronomers, all attempts to search imaginative esoteric, magical and/or ancestral references. These superinterpretations are generated from the difficulty to recognize the castle in the monument that, in truth, is lacking in the traditional elements of defence, but one trend to see in it the temple, the astrolabe, the astronomical clock, etc.

Figure 1. Castel del Monte

The castle is placed on an hollow base in correspondence of the inner courtyard, where a reservoir is placed. It is structured on two levels connected from three helicoidal stair systems, located in the angular towers. There are eight octagonal angular towers disposed to the corner of the octagon of the planimetric system. Eight trapezoidal rooms, covered from ribbed cross vault, compose both levels. In the centre there is an uncovered courtyard of octagonal shape too.
A complex system of pseudo-loophole characterizes the prospects lacking in whichever element of defence. Equally articulated is also the system of the accesses and running of rooms related to a logical not clear yet. After the recent restoration and the elimination of the false *torrino* of the stairs, the access to the terraces is made through the opening of a balancing horizontal platform.

1.2 Research frontier

In this context we are not interested to research frontier about the castle, but the state of surveying on this monument. Infact, the literature is very rich and there are many imaginative interpretation of local historians and mystery inquirers that have made an worrying number of contributions, whose list would demand numerous pages.

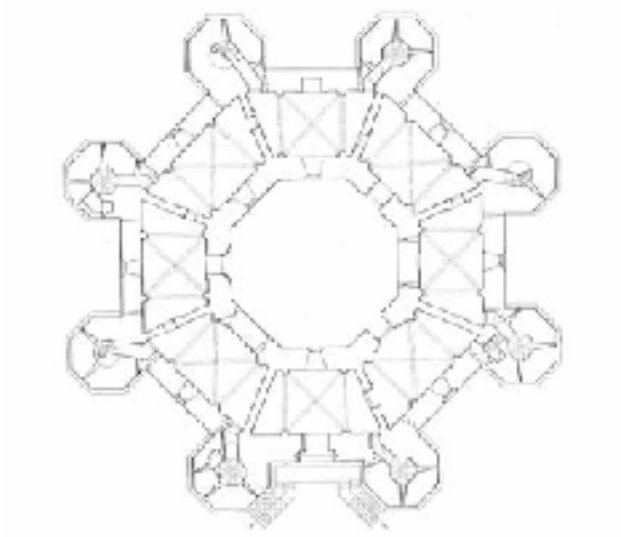

Figure 2. Castel del Monte plan from *Reale Accademia d'Italia*

There are surveys made by the in 1934, published from the State Bookcase in the Italian Monuments series and the superb job of *Wulf Schirmer*, result of a series of campaigns of surveying between 1990 and 1996, published in Mainz (Germany) in 2000.
The surveys made in the thirties by the *Reale Accademia d'Italia* have been lead with techniques of traditional architectonic survey. Instead, the job of *Schirmer* couples the topographical surveying with a photogrametric survey and restitution.
The surveying lead from *Schirmer* has highlighted a series of incoherences of the octagonal geometric matrix of the castle and it has recognized the presence of incorrect alignments. The dimension unhomogeneities of equal parts of the octagon and a series of uncertainties are probably due to the moment of the construction.

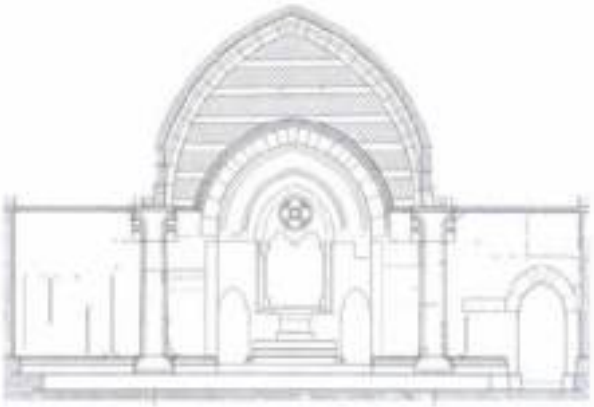

Figure 3. Photogrammetric restitution by Wulf Schirmer

The slowness of the photogrammetric restitution reduced the extension of Schirmer surveying, who made only a restitution of upper levels and the longitudinal section in correspondence of the entrance portal. The requirement of a survey derives from the absence of a complete documentation of the monument. A scientific support that could integrate and could complete the existing materials is needed and, with use of the most suitable techniques of surveying, provides a metric support of high reliability that constitutes the base of verification of imaginative interpretations that have been formulated about the size and the proportional relations of several parts of the castle.

Figure 4. Photograph of the Castle before the restoration

However, we ask ourselves if we surveyed a monument or a simulacrum, because the castle has been strongly compromise due to massive restoration. We refer to the earliest restorations after the purchase of the monument, because they have made widely use of operations of substitution as recognizable on the old photos that show a strongly degraded building with numerous erosion phenomena not more recognizable after the restorations.

2. SURVEYING PLANNING

In planning the survey we have considered which could be the best technique in order to model this monument. We pointed out the attention on the laser scanning surveying then we have organized the operations in such way to have the execution of the necessary measurements in smallest time and with the required precision.
The laser scanning surveying needed the integration of techniques of traditional measurements in order to georeference all the scanning images in only one local reference system.
The surveying operations required, primarily, the establishment of a topographical reference network for all elements insides and outside of the castle, reference network has been the support for the following measurements of detail elements.
Considering the required precision, close polygonals among them connect and related to the outside the inside and the two plans of the castle have been selected.
The preventive choice of the vertexes of the polygonal has been realized through the aid of a simplified castle model realized on the base of precedent surveys, as following shown in next figure.

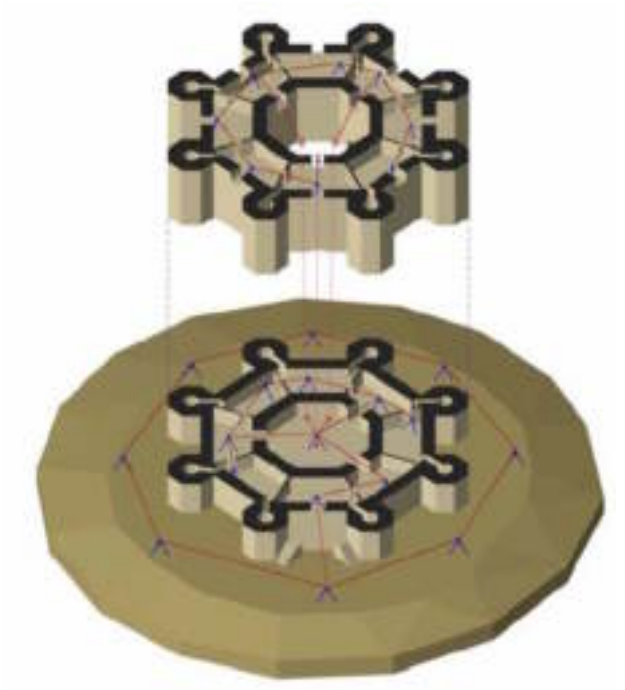

Figure 5. Planning of topographical reference network on simplified model

After different examination, stations were localized that were visible each other from the inside to the outside of the building through the existing openings, and they allowed the survey of relevant number of points necessaries for laser scanning surveying.
The laser stations and the number of necessaries scannings are also planned for covering the whole site.

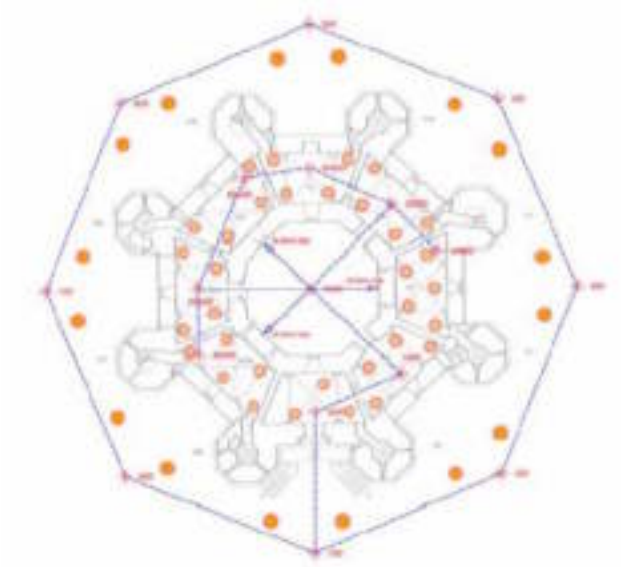

Figure 6. Plan of laser scanning surveying on simplified model

3. SURVEYING OPERATIONS

3.1 Topographical surveying

The measurements have been performed with a total station Leica TCRP 1201 Pin Point R300, instead the compensation has been make with 3D adjustment STARNET sw.
The outside and the inside surveying (plant ground, foreground and courtyard) required four days.
The polygonal is composed by 28 vertexes. Outside of the castle we have realized 8 stations nearly prepared in central position between the two towers of every side of the castle.
The station 100, origin of the reference system, has been oriented on station 900 (first room of the plant ground) in direction of entrance portal of the castle.

Figure 7. Total Station for the topographical surveying

At the ground floor 8 stations have been performed with one of these (station 2000) positioned to the centre of the inside courtyard, in such way that it could be successively connected s to some stations of the ground floor and the first floor level through the three portals and the three doors windows lean out in the courtyard.

Figure 8. Station 2000

At first floor level we have realized 11 stations.
The summary of the performed stations is shown in table 1.

	Stations	n° Stations
Outside	100-200-300-400-500-600-700-800	8
Rooms Plant Ground	900-1000-20000-30000-40000-50000-60000-70000	8
Courtyard	2000	1
Rooms Foreground	3000-4000-5000-6000-6500-7000-8000-9000-9500-10000-11000	11
	TOTAL	**28**

Table 1. Distribution of topographical stations

The natural points and the targets, as GCP for laser measurements, have been collimated and GCP description have been made (table 2).

	Collimated Natural Points	N°
Outside	143	143
Rooms Plant Ground	198 + 24 TARGET	222
Courtyard	36	36
Rooms Foreground	92 + 23 TARGET	115
	TOTAL	**516**

Table 2. Characteristics of Ground Control Point

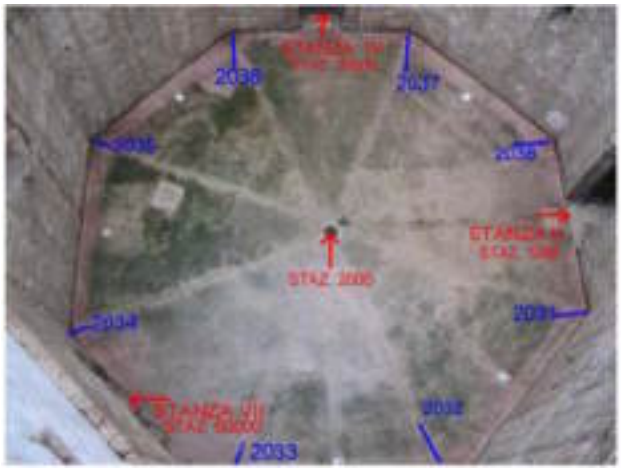

Figure 9. GCPs description

The elaboration of the data acquired has been performed compensating the polygonal and, subsequently, determining the coordinates of the coincided vertexes.

Adjusted Coordinates (Meters)						
Station	**N(Y)**	**E(X)**	**Elev(Z)**	**rms X**	**rms Y**	**rms Z**
100	0.000	0.000	0.000	0.0000	0.0000	0.0000
200	24.753	28.476	0.302	0.0088	0.0089	0.0023
300	50.395	38.033	0.363	0.0124	0.0101	0.0026
400	77.396	26.117	0.299	0.0131	0.0128	0.0028
500	86.107	-3.173	0.341	0.0124	0.0140	0.0029
600	72.515	-29.838	0.119	0.0124	0.0126	0.0029
700	46.290	-48.497	-0.140	0.0091	0.0090	0.0025
800	11.038	-32.560	0.192	0.0033	0.0085	0.0017
900	31.674	0.000	3.556	0.0052	0.0000	0.0011
1000	37.973	10.486	3.536	0.0062	0.0055	0.0011
2000	48.248	-1.250	3.509	0.0046	0.0088	0.0006
3000	55.862	5.521	13.145	0.0062	0.0000	0.0045
4000	61.427	8.402	12.980	0.0093	0.0037	0.0046
5000	64.988	-1.587	13.006	0.0029	0.0064	0.0006
6000	59.450	-13.130	13.110	0.0391	0.0112	0.0006
6500	55.171	-8.816	13.137	0.0066	0.0000	0.0121
7000	48.603	-18.104	13.053	0.0071	0.0000	0.0004
8000	35.784	-11.871	12.992	0.0080	0.0043	0.0006
9000	33.130	0.812	12.973	0.0101	0.0064	0.0007
9500	38.384	-0.622	13.126	0.0000	0.0118	0.0138
10000	38.259	11.647	12.991	0.0089	0.0035	0.0006
11000	48.993	15.416	12.976	0.0045	0.0097	0.0070
30000	60.019	9.839	3.590	0.0104	0.0110	0.0012
40000	63.762	-5.030	3.582	0.0054	0.0079	0.0011
50000	60.948	-11.684	3.593	0.0041	0.0100	0.0011
60000	46.953	-16.567	3.596	0.0089	0.0105	0.0010
20000	53.904	14.379	3.561	0.0052	0.0039	0.0003
70000	38.998	-15.184	3.626	0.0064	0.0011	0.0003

Table 3. Adjusted polygonal stations coordinates

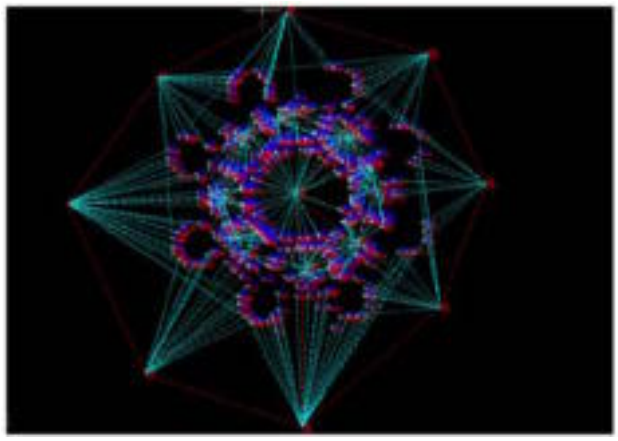

Figure 10. Plan of topographical surveying

3.2 Laser scanning surveying

The laser scanning surveying have been realized through the laser HDS 4500 distributed by the Leica Geosystems S.p.A., that is based on phase observation with maximum range of 52 m.

Figure 11. Phase of Laser scanning surveying from an outside station

For the castle we have been effected 92 scanning acquisitions (Table 4)

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	Stations	**n°Stations**
Outside		12
Plant Ground	room I	3
	room II	4
	room III	5
	room IV	4
	room V	3
	room VI	3
	room VII	3
	room VIII	4
Courtyard		3
Foreground	room I	5
	room II	5
	room III	5
	room IV	5
	room V	5
	room VI	5
	room VII	5
	room VIII	5
Acquisitions		8
	TOTAL	**92**

Table 4. Summary of laser scanning acquisitions

Obtained the position of the station and the targets, we started the laser acquisitions taking into account that from every station were visible contemporarily three targets and that a large zone of overlap was present of different scanning acquisitions. The selection of scanning parameters has been formulated on a grid size of 1 mm and the projection distance was about correspondent to the middle distance of the rooms.
The scannings processing has been performed with Cyclone 5.2 and JRC Reconstructor sw through a first process of alignment based on the recognition of the control points materialized from the reflecting targets and of the natural GCP. The data processing has been realized separately for every room of the ground floor, of the first level floor, for the courtyard, for the outside and finally for the coverage.

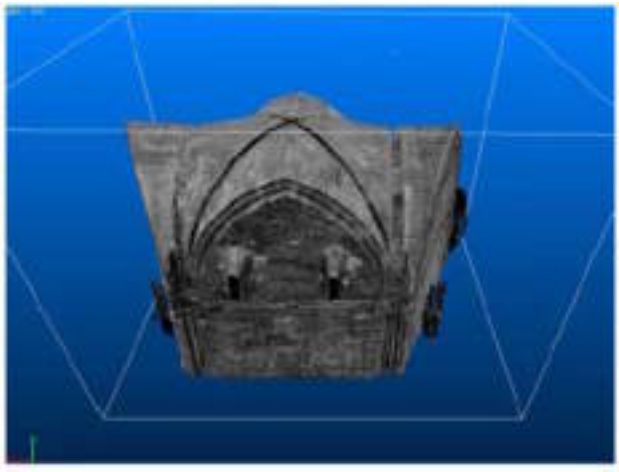

Figure 12. Room I of first level floor

The rms obtained for almost all of the tie points vary from 0,001 to 0,03 m.
Then we proceeded with the automatic matching that identifies the overlapping areas between the adjacent scanning acquisitions (overlapping zones defined by the user), on the base of opportune confidence values; the results have been optimized and rms reduced.

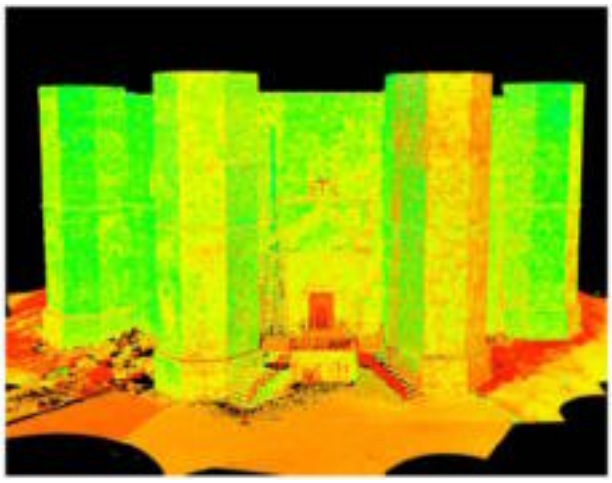

Figure 13. Cloud points view of the castle

On the model obtained has been reconstructed a surface constituted by triangular grid beginning from the cloud points. In the sw, the meshing , that transforms the set of 3D raw points in a continuous surface, has been performed on every single scanning using different layers and producing a more intuitive visually representation.

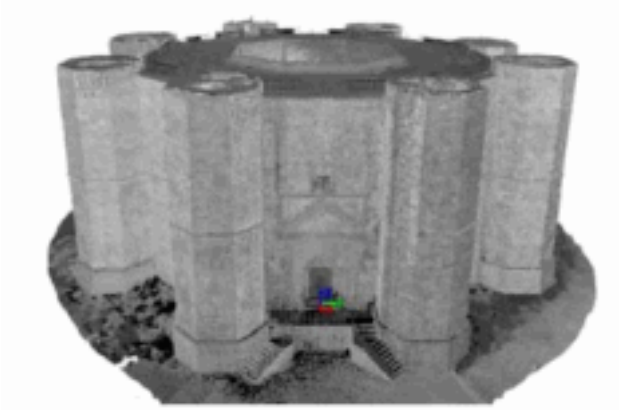

Figure 14. Mesh view of the castle

4. THE RECONSTRUCTED 3D MODEL

The elaboration of the model based on laser scanning or CAD elaboration, foresees, notoriously, a series of procedures different from the traditional 3D representation. The aspect that mostly identifies the model, is to be a intermediary tool toward other forms of representation, rather than an elaborate finished, autonomous and defined.
The use of the digital model is, besides, extremely effective if compared with the traditional formalities of space reading. It allows, in fact, the possibility to realize some virtual runs irremediably inside lost situations or simply crusted by over constructions and it constitutes a fundamental contribution to the description of the architecture and her evolution.

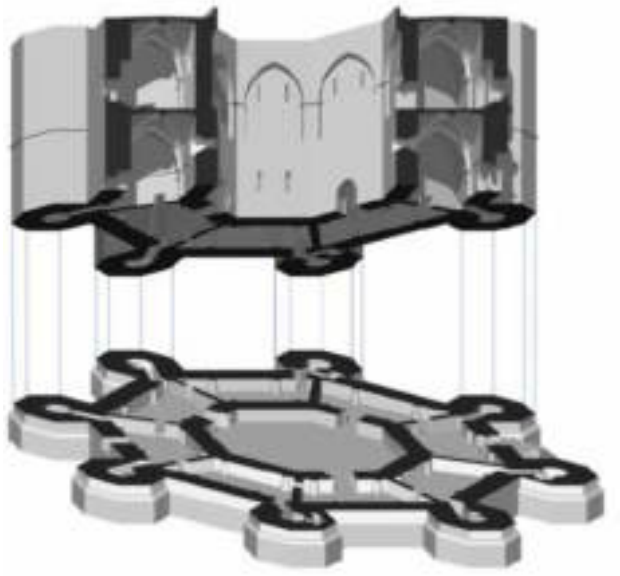

Figure 15. 3D Model

5. OUTLOOKS

The study and research on Castel del Monte has been effected within the financing “Law 598/94 art. 11 interventions for the Technological Transfer”. through the project realized in collaboration with the society Plans Consulting Net denominated S.r.l” VR-PLACONEL LAB - Development of systems VR for the fruition of the cultural heritage”.

Purpose of this project was the realization of a "virtual museum" characterized by following principal characteristics:
a) to allow the fruition of an architectural evidence of notable merit ; the generic consumer will be able, first and after the real visit, to sail virtually inside the Castle acquiring relative information through images, texts and voices interacting directly with the 3D model;
b) to allow a new way to file and to manage all the informations related to the cultural heritage composed by different evidences (monuments, paintings, finds, etc.), through the direct interrogation of the 3D model.
We would like to conclude the aforesaid surveying study with the integration of inevitable lacking parts. Some architectural elements, though they have a notable historical-cultural interest, had not been surveyed. Particularly we could mention the interior of the towers and the particulars bas-reliefs in them contained.
In the future we paln to complete, through classical topographic techniques and photogrammetry the whole structure surveying, as well as to make a restitution of the elements of frieze of great interest.

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