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INTEGRATED METHODOLOGIES FOR THE STUDY, ENHANCEMENT AND SHARING OF ARCHAEOLOGICAL HERITAGE: THE ARCHEOFANO PROJECT

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Abstract

The fear that knowledge regarding the archaeological remains of the historic centre of Fano could be lost led to an agreement between the authorities concerned, with the goal of providing the city with a modern archaeological map, to create a uniform data base to use as a starting point for a final analysis of the urban context of the ancient Fanum Fortunae. Starting with the bare bibliographic and archival material, supporting topographical investigations were carried out via total stations systems and GNSS of known archaeological sites, and laser scanner point clouds were subsequently taken from a few roughly known sample areas. Some areas were pinpointed, gravitating around the apparent forum area, and ground penetrating radar surveys were carried out in order to detect underground structures attributable to Roman era remains. All captured material was placed inside an Open Source GIS platform.

Keywords

Archaeology, Fano, Topography, TLS, GIS

1. *Project development*

The modern town of Fano occupies the site of the ancient *Iulia Fanestris* settlement, the outlet point to the Adriatic Sea and the turning point towards *Ariminum* on the ancient Roman road *Via Flaminia*.

The numerous pieces of archaeological evidence, in many cases incorporated into subsequent structures and not usable, have already been the subject of many, mostly isolated, studies[1] which have greatly stimulated knowledge of the city's archaeological heritage, but through which it was not possible, however, to reach a comprehensive understanding and certain understanding of the urban structure of the Roman city.

The lack of a unified system of arrangement and organisation of the city's archaeological heritage, the difficulties accessing various archaeological sites, and the lack of detailed studies on some of these sites, are certainly some of the main issues faced in interpreting the uncertainties of Roman town planning.

In an effort to respond to this situation and promote the archaeological progress of the investigation and enhance the existing known areas the research project "ArcheoFano" was launched in 2014, with a focus on ''Updating, redefining and consolidating the archaeological diagram of the city of Fano in the shared database" and drawn up by the Department of Civil Engineering, Construction and Architecture of the Marche Polytechnic University, the Vitruvian Studies Centre of Fano, the Archaeological Superintendency of the Marche, the Province of Pesaro and Urbino and the City of Fano.

The project is structured according to the different stages of research regarding the collection, data organisation and enhancement of the archaeological heritage. The various stages of the project focused on:

Survey of the archaeological fabric of the urban core of the city of Fano, enclosed within the

[1] The Fano archaeological studies are summed up in the following articles: Alfieri (1976-77); Bacchielli (1989); Baldelli (2002); Battistelli and Deli (1983); De Maria (2015); De Sanctis (1998); Luni (2000); Milesi (1992); Purcaro (1982); Sensi (1984-85); Sensi (1987); Taus (1999); Taus (2000).

Roman city walls and examination of all library and archive materials.

– Creation of an updated and georeferenced archaeological plan of the city, with the creation of various thematic layers, into which the graphic-planimetric data derived from the various stages of investigation and precision topographical survey were inserted.
– Digitisation in 3D of the difficult to access archaeological areas through TLS (Total Laser Scanning) platforms.
– Geophysical surveys of some open spaces free from buildings, probably occupied by the old city *forum*, using ground penetrating radar.
– Implementation of a relational database, designed to create a geodatabase in an open source GIS environment for the entire area of the historic centre, with the aim of tracking and filing historical data as well as current and future data.
– Implementation of city archaeological landscapes in augmented reality, and digital reproduction of the Archaeological Museum of Fano.

Achieving these goals was only possible through the interaction of different technologies and areas of expertise, using a specific methodological framework.

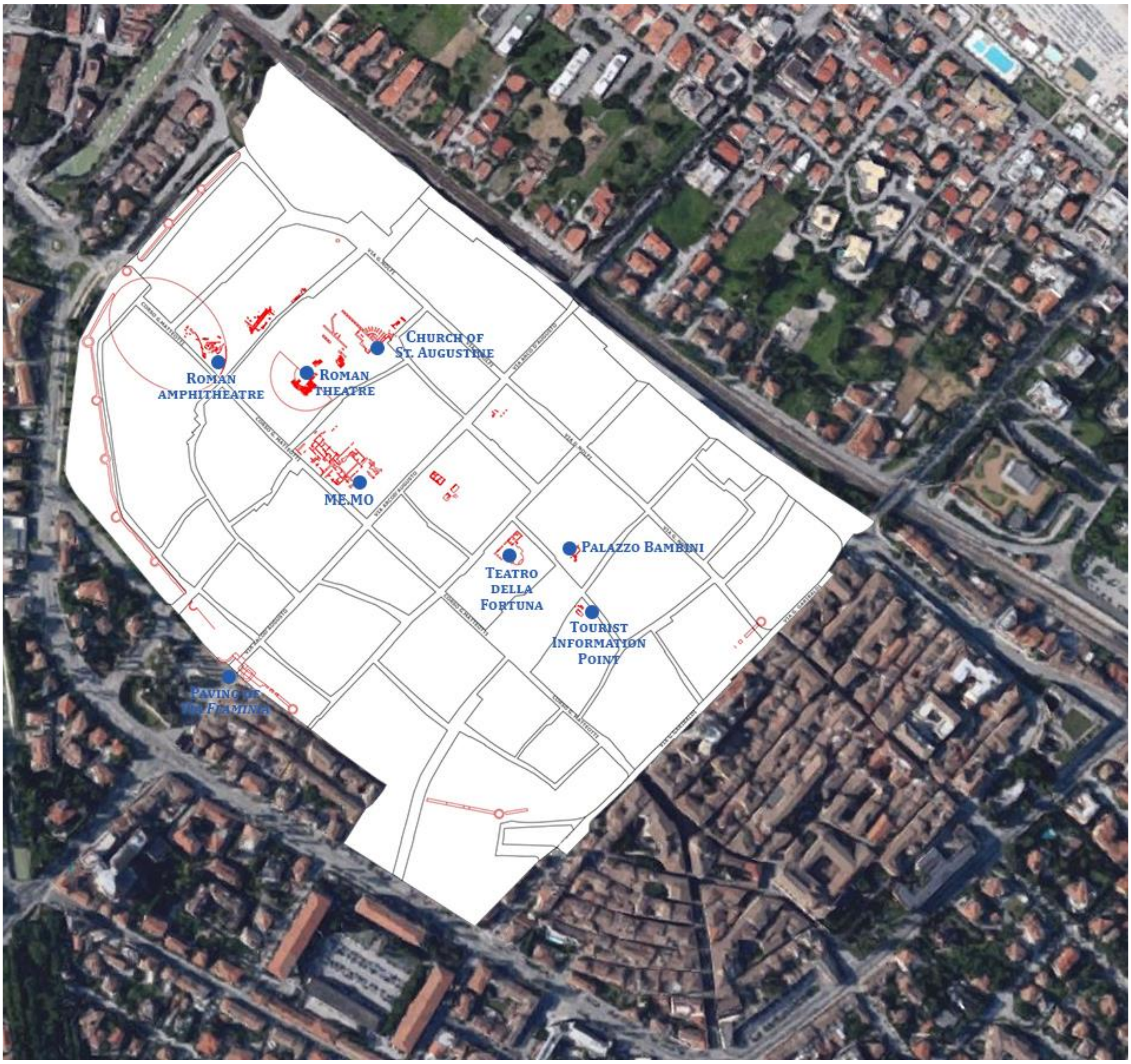

Fig. 1: Archaeological map of Fano with roman complexes highlighted.

2. *Precision topographical survey using GNSS, Total Station, TLS equipment*

Following the preliminary collection of archival and library materials related to the ancient *Fanum Fortunae*, a survey of the entire urban layout of the Roman city was carried out, with a primary objective of listing and georeferencing all functional levels found and preserved within the fabric of the modern city[2]. The overall dimensions of eleven floors, divided into eight distinct archaeological sites scattered throughout the urban network, have therefore been recorded (Fig. 1). These functional levels are identifiable in:

- Paving of *Via Flaminia* near the Porta d'Augusto located at the intersection of Via Arco d'Augusto and Via Martino da Fano.
- The floor of the *vomitorium* of the the Roman amphitheatre (Complesso di Santa Teresa, Corso G. Matteotti).
- The archaeological complex of the conference room of the MeMo - Montanari Multimedia Library. In this area parts of the bases of the columns of the porch were found to be preserved in the conference room, and parts of the *opus sectile* floor, likely related to the city *Augusteum* (Piazza Amiani).
- Orchestra floor of the Teatro Romano (Ex Filanda Bosone, Via de Amicis).
- Archaeological complex below the Church of St. Augustine. In this area fragments were found relating to to the base of a pillar of the side exedra of the probable temple *podium* and of a drain channel from the side of a minor axis road.
- Residential Building in the basement of the Tourist Information Point (Piazza XX Settembre, Via de Cuppis n. 2).
- Mosaic floor of a probable Residential building and the so-called "Fish Mosaic", both stored in the vaults of the Palazzo Bambini - offices of the Fano Savings Bank (Piazza XX Settembre).
- *Opus spicatum* flooring and a pair of mosaics located in the basement of the Teatro della Fortuna (Piazza XX Settembre).

The detection was performed by integrating topographic methods, GNSS (Global Navigation Satellite System) and TLS (Total Laser Scanning) (Fig. 2).

The overall reference system adopted was the National Datum Gauss-Boaga Roma 40 East zone and orthometric heights derived from the reconnection to the RDN-ETRF2000 IGM network (similar to WGS84).

From this system a local pseudo-coordinate Gauss-Boaga system was derived, devoid of the first digit, then with planimetric offset 2'360'000E and 4'856'000N, in order to allow proper processing of laser scan data.

The topographical support network was constituted of a series of topographical vertices detected with geodetic dual frequency GNSS and multi-constellation Topcon GMS-2 equipment.

All GNSS survey data was processed to obtain precision in the compensation for each point down to the centimeter. Reconnection to the national datum was run through the NetGeo GNSS network (IGM certified).

The latitudinal, longitudinal and ellipsoidal coordinates were obtained in ETRF2000, and converted to Roma40 Gauss-Boaga Fuso East coordinates and orthometric heights (above sea level) using the relevant Military Geographical Institute grids.

During all phases of the relief the GNSS RTK mode equipment was used preferentially, but where this was not possible, a survey was run with Topcon GPT-7005i total station, with support for the previously described GNSS network points and therefore detecting the targets for the geo-referencing and alignment of the laser scanner scans, the elevation points used for the reconstruction of archaeological levels dating back to Roman times and the topographic profiles of the GPR sections, which will be discussed later.

The topographical compensation in this case also allowed for greater precision down to centimetres.

In some cases, such as the underground areas inside some buildings where it would have been necessary to perform a large number of topographical stations, an acquisition laser scanner was used instead due to the considerable reduction in acquisition times. The equipment used consisted of a Faro Focus 3D 120 phase time Laser Scanner, with a range of 60 m and a speed of about one million points per second.

[2] The topographical surveying was performed by SI2G - GEOGRAPHICAL INTELLIGENT INFORMATION SYSTEM, Spin-off of the Marche Polytechnic University.

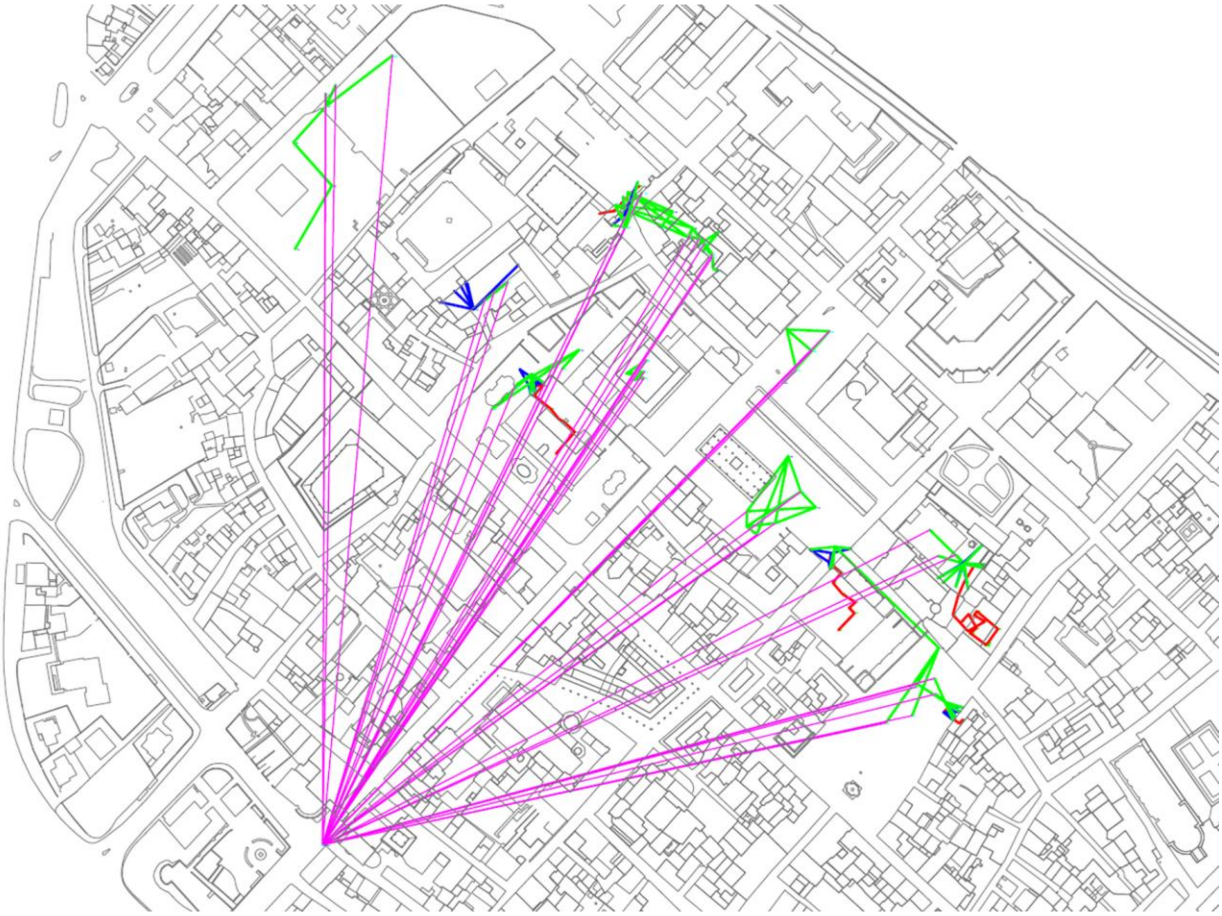

Fig. 2: Topographical support network. In magenta: baseline GNSS; in green: topographical polygonal; in red and blue: polygonal laser.

They are used with flat checkerboard and sphere targets. Each laser scan obtained has at least 3 targets in common with the others, in order to minimise alignment errors. The coordinates of the flat targets were acquired topographically allowing georeferencing of the entire laser scanner survey.

Following alignment and georeferencing of all the laser scanner scans using software, it is possible to detect alignment accuracies of 1-2 millimeters.

The exhaustive topographical surveying performed has therefore revealed, with high precision, for the first time in the history of the study of Fano archaeology, the absolute dimensions of the archaeological Roman intramural complex.

3. *Digitisation in 3D of the difficulty to access archaeological areas*

In conjunction with the surveying work, a three-dimensional survey of the intramural archaeological complexes which are difficult to access by the public and which presented the greatest shortage of graphic documentation was carried out[3]. The group of archaeological complexes examined concerns the Roman Theatre, the Residential complex in the basement of the Tourist Information Point, the probable residential complex in the basement of the Palazzo Bambini and the mosaic flooring preserved in the basement of the Teatro della Fortuna. The equipment used consisted of a time of flight Leica C10 Laser Scanner and a Nikon D90 camera. The phase of data acquisition was carried out during a day of capture for each of the detected archaeological sites (Tab. 1). The spatial relocation of the individual scanners was designed so as to ensure sufficient coverage of the entire archaeological complex.

[3] 3D capture and calculations were performed by members of the research team of the DISTORI Laboratory of the Department of Civil Engineering, Construction and Architecture of the Marche Polytechnic University.

Tab. 1: Register of the TLS data acquisition of the detected archaeological sites

Teatro — 2014.01.20

Station	ScanWord	Scan	Target Included in Scan	Name Target	Instrument Ht	Description of Area Scanned	Time	scan	image	Resolution Scan	Time Exp	Comments
ST001	001	001	B/W	t190, t192, t193, t188		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST002	002	001	B/W	t190, t192, t193		Target All 360°x270°	01:15:00	x	x	Medium	auto	
ST003	003	001	B/W	t190, t192, t193, t188		Target All 360°x270°	00:15:00	x	x	Medium	auto	

c/o Ufficio Turistico — 2014.01.20

Station	ScanWord	Scan	Target Included in Scan	Name Target	Instrument Ht	Description of Area Scanned	Time	scan	image	Resolution Scan	Time Exp	Comments
ST001	001	001	B/W	186, 200, 187, 180		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST002	002	001	B/W	184, 186, 177, 187, 180, 181		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST003	003	001	B/W	186, 177, 184, 187		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST004	004	001	B/W	181, 187, 177, 189		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST005	005	001	B/W	186, 189, 181, 177, 184		Target All 360°x270°	00:15:00	x	x	Medium	auto	

Carifano — 2014.03.06

Station	ScanWord	Scan	Target Included in Scan	Name Target	Instrument Ht	Description of Area Scanned	Time	scan	image	Resolution Scan	Time Exp	Comments
ST001	001	001	B/W	t111, t112, t115, t116, t124, t125, t123		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST002	002	001	B/W	t129, t112, t116, t118, 123, t124, t125, t126		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST003	003	001	B/W	t112, t116, t117, t121, t125, t126, t128		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST004	004	001	B/W	t111, t112, t113, t115, t116, t117, t121, t123, t124, t125, t128, t129		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST005	005	001	B/W	t111, t113, t115, t116, t117, t123, t125, t129, t130		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST006	006	001	B/W	t111, t113, t116, t125, t129, t114		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST007	007	001	B/W	t123, t125, t115, t114, t116		Target All 360°x270°	00:15:00	x	x	Medium	auto	

Teatro Romano — 2014.03.10

Station	ScanWord	Scan	Target Included in Scan	Name Target	Instrument Ht	Description of Area Scanned	Time	scan	image	Resolution Scan	Time Exp	Comments
ST001	001	001	leccalecca B/W paline	lec1, p1, p2, t197	1,648 m	Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST002	002	001	leccalecca B/W paline	lec1, p1, p2, t197, t217, t221, t213, t147, t146, t145, t214		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST003	003	001	leccalecca B/W paline	t197, t217, t221, t246, lec2		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST004	004	001	leccalecca B/W paline	t214, t217, t221, t146, lec2		Target All 360°x270°	00:36:00	x	x	High	auto	eliminare e sostituire con ST015
ST005	005	001	leccalecca B/W paline	t213, t145, t146, t147, t220, lec2		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST006	006	001	leccalecca B/W paline	t145, t196, t147, lec2, t146, t194, t155, t197		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST007	007	001	leccalecca B/W paline	t194, t155, t208, t145, lec, t205, t206		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST008	008	001	leccalecca B/W paline	t145, t146, t155, t200, t201, t202, t198		Target All 360°x270°	00:15:00	x	x	Medium	auto	
ST009	009	001	leccalecca B/W paline	t208, t205, t206, lec3, lec4 , lec5, p3, p4		Target All 360°x270°	00:36:00	x	x	High	auto	
		002				Target All 360°x270°	00:36:00	x	x	High	auto	da cancellare
ST010	010	001	leccalecca B/W paline	t216, lec3, lec4		Target All 360°x270°	00:36:00	x	x	High	auto	
ST011	011	001	leccalecca B/W paline	t216, lec3, lec4, lec5		Target All 360°x270°	00:36:00	x	x	High	auto	
ST012	012	001	leccalecca B/W paline	t211, lec3, p3, p4, t215		Target All 360°x270°	00:36:00	x	x	High	auto	
ST013	013	001	leccalecca B/W paline	t211, t212, t215, p3, p4		Target All 360°x270°	00:36:00	x	x	High	auto	
ST014	014	001	leccalecca B/W paline	t211, t212, lec3, p3, p4, lec4, lec5		Target All 360°x270°	00:36:00	x	x	High	auto	
ST015	015	001	leccalecca B/W paline	t146, t214, t217, t220, t221		Target All 360°x270°	00:36:00	x	x	High	auto	in sostituzione della st004

To allow alignment of point clouds, three different target types have been used: HDS Twin targets Pole (poles), Black/White Target (A4 sheet) and HDS Tilt & Turn targets (lollipop). The resolution grids used were 1 cm to 10 m (Medium Resolution) and 0.5 cm to 10 m (High Resolution). Simultaneously with the metric data the instrument used allowed for the acquisition of radiometric data via the integrated high-resolution photographic camera (260 shots with a single shutter resolution equal to 1920x1920 px), but sometimes not sufficiently suited, as in low light situations in covered areas. In these cases, it is necessary to takes photographs with a digital reflex camera, indispensable both for documentation and the texturing step.

Each scan was mapped from the spherical panorama made by the integrated camera, so that for every point in space there is a precise RGB value correspondence[4].

After the alignment phase of the different scans acquired, it is possible to detect an average maximum of 1 cm error, consistent with instrumental properties and the size of the minimum characteristics of the objects.

The subsequent joint development of point clouds obtained by laser scanner and topographic survey allowed for the realisation of various two-dimensional outputs: using appropriate reference planes, orthophotos and slices were generated for the vectorisation of standards developed (altimetric sections comparing the various archaeological sites detected, planimetric orthoimagery, and sections, Figs. 3-7).

Additionally, navigation interfaces have been carried out of all archaeological sites discovered, using the Leica TrueView System, allowing, through a web browser, for three-dimensional exploration of the monuments and direct precision measurements on the spherical panoramic collimated to the point clouds.

[4] The high intrinsic value of this stock model has already been proven in other work from the DISTORI group: Clini, Nespeca, and Bernetti (2013); Clini, Quattrini, Frontoni, and Nespeca (2015); Clini, Quattrini, Nespeca, De Carolis, and Ruggeri (2015). Even without further costly processing, in browsing the object in three dimensions you can extrapolate metric information and very important morphological and radiometric information, for analysis, knowledge and protection of the site.

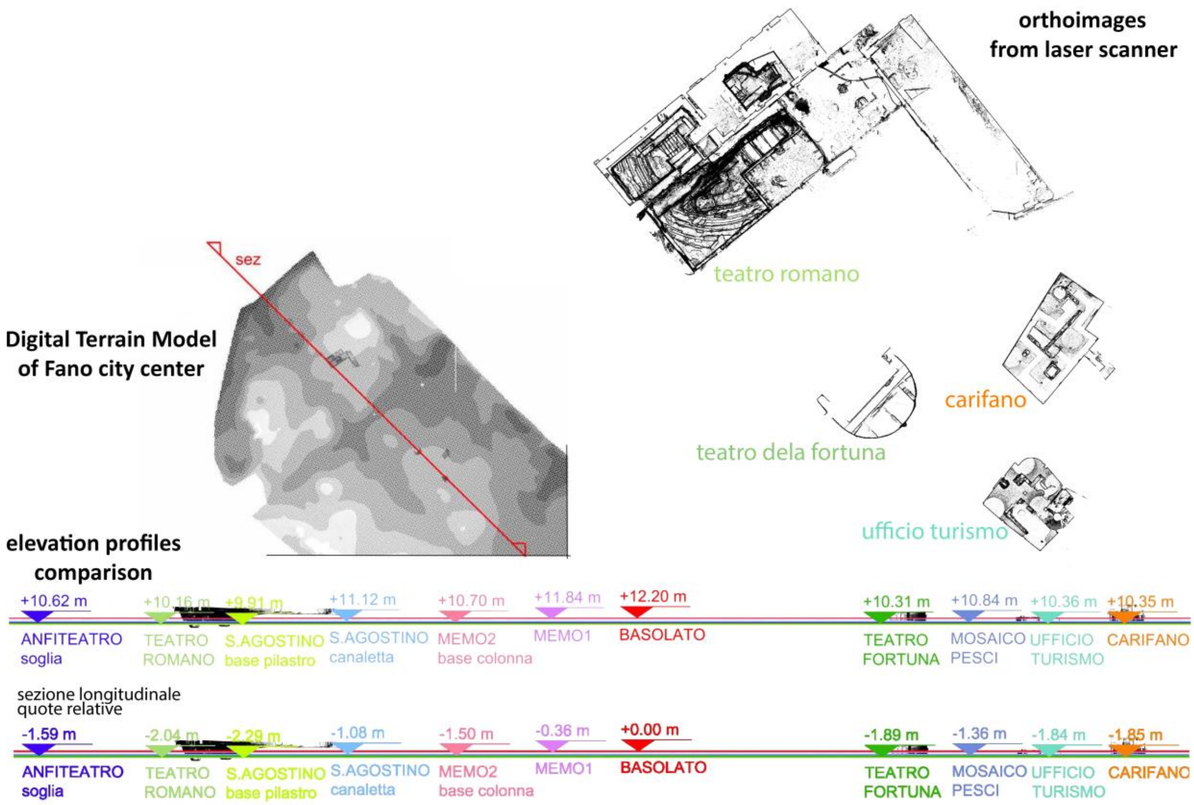

Fig. 3: DTM of Fano city center, orthoimages from laser scanner of the surveyd sites and elevation profiles comparison.

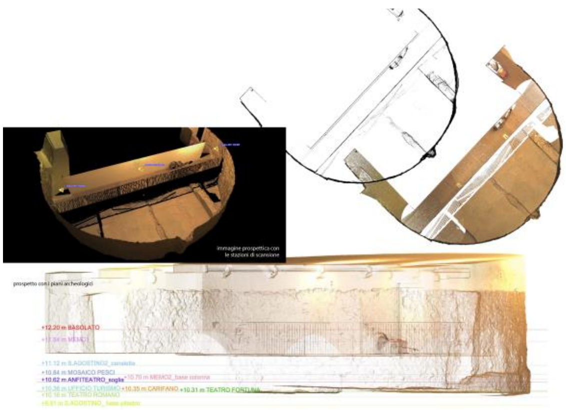

Fig. 4: Drawings from laser scanner point clouds of Fortuna Theatre mosaic floors.

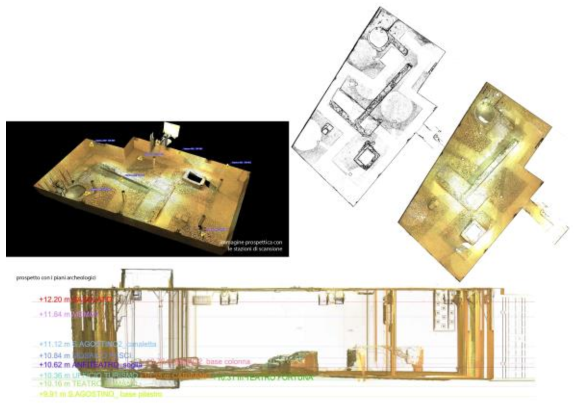

Fig. 5: Drawings from laser scanner point clouds of d*omus* under Palazzo Bambini.

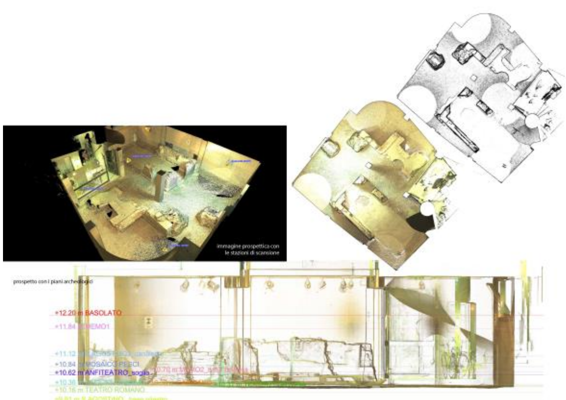

Fig. 6: Drawings from TLS of the *domus* under Tourist Office (Piazza XX Settembre).

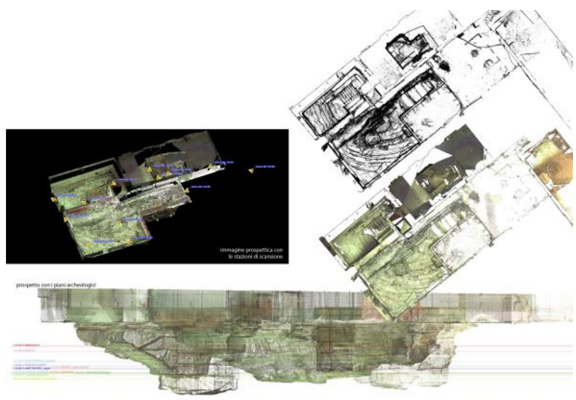

Fig. 7: Drawings of thel Roman Theatre resulting from laser scanner point cloud.

Fig. 8: Detail of the archaeological map of Fano. The higlighted areas are those interested by geophysical analysis: 1) Area Ex Convent of the Benedectines; 2) Block betweeen Via Nolfi and Via Vitruvius; 3) Piazza A. Costa; 4) Piazza Avveduti.

4. *Geophysical surveys with ground penetrating radar*

The geophysical prospecting campaign using GPR (GPR - Ground Penetrating Radar)[5] was planned in a manner to be performed in open spaces free of buildings (such as car parks, cloisters and gardens) in the area probably occupied by the ancient forum complex in the city of *Fanum Fortunae*, to detect information on the exact location of the forum and thus facilitate, in case of positive results, the planning of precise excavations in easily accessible areas. The investigations were focused in three distinct areas identified as the North Area and the Cloister of the former Convent of the Benedictines, Courtyard of the block between Via Nolfi and Via Vitruvius, Piazza Avveduti and Piazza Andrea Costa (Fig. 8). 128 profiles were recorded for a total of more than 2000 linear metres.

The equipment used consisted of a GSSI SIR-3000 GPR equipped with antennas at centre frequency of electromagnetic pulse of 500 MHz, 270 MHz and 200 MHz.

All radargrams produced were analysed; from these 14 considered to be particularly significant in relation to the anomalies, precise or extended,

[5] Operations and processing of the data obtained was carried out by GeoExploration srl (Forlì, FC).

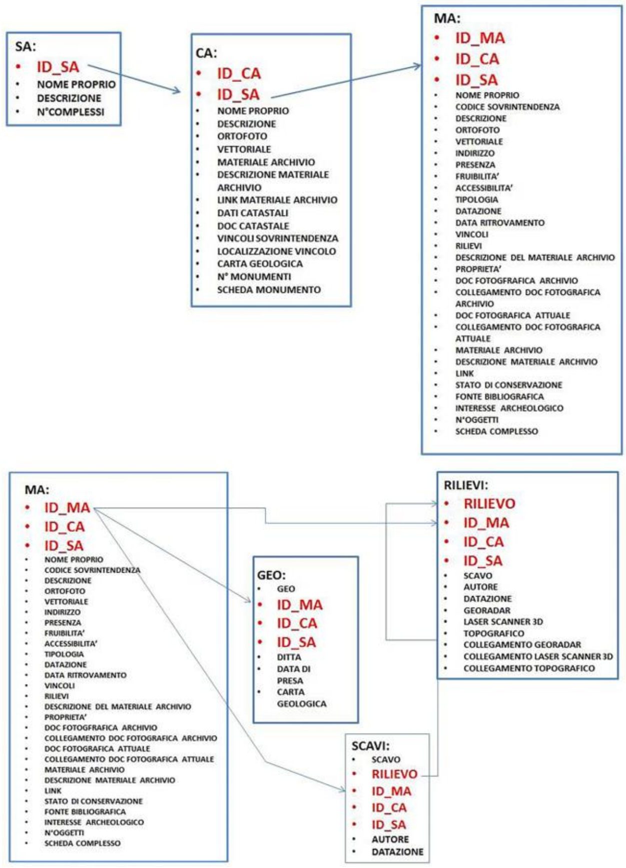

Fig. 9: Structure of the relational database. On the top the relations between the entities tables: Archaelogical Monuments (SA), Archaeological Complex (CA), Archaelogical Monuments (MA). At the bottom the relations between the tables MA, Rilievi, Scavi and Geo (Carta Geologica).

were selected, highlighted, and data derived from their intersection with the dimensions obtained from the topographic survey. Information obtained showed the presence of interesting anomalies, both linear and precise, characterised by similar dimensions to those of the functional Roman levels closest to the point of detection (for the area of the former Convent of the Benedictines dimensions of underground structures are similar to those of the archaeological complex of the MeMo, while the numerous masonry fragments collected from Piazza Avveduti and Piazza Andrea Costa relate to those of the Roman building complexes around Piazza XX Settembre).

However, the substance of these structures detected during the geophysical analysis cannot be defined with certainty nor, of course, a time span in which to frame them.

5. *Creating a geodatabase in an open source GIS environment*

In parallel to the steps described so far, in order to allow for systematic organisation of the information collected, the construction of a relational database model was also initiated, aimed at creating a geodatabase in a QuantumGIS open source environment[6].

The organisation of a base of georeferenced data, adapted to metrically describe (in 2D and 3D) and document the archeological findings of the Roman age of the city of Fano, has, as previously mentioned, different purposes, both to support historical/archaeological analysis and conservation/monitoring for the protection of the monuments and as a useful tool for sharing the heritage.

As regards the physical implementation of the relational database, reference was made to the commercial Microsoft Access software, while for the implementation of the geo-database the open-source software QuantumGIS was used.

Following the arrangement of the data, it was necessary to focus on the process of organising data in a conceptual model able to support the project's designated purposes: for this reason it was decided to weigh up and interact with the technical items and framework generally defined in the MA-CA (Archaeological Monument/Complex) profiles, adopted for the Cataloguing of Cultural Heritage by the Central Institute for Cataloguing and Documentation (ICCD). In the first instance fundamental entities that define the subject of the Roman Fano study area were identified in order to better interpret the information hierarchy and address the problems of database organisation. Using the basic city mapping and Detailed Plan three entities were defined, linked together on 3 levels: Archaeological Site (AS - identified with the part of the historic centre of the city of Fano during the Roman era, with the function of the general territorial container of all the information catalogued), Archaeological Complex (AC - well defined areas of the Detailed Plan within which archaeological sites of note have been recorded and catalogued. Generally every individual AC relates to the modern urban blocks) and Archaeological Monument (AM -single body of the building with specific architectural features and a

[6] Pierdicca, Malinverni, Tassetti, Mancini, Bozzi, Clini, and Nespeca (2015).

single function: it is the object or set of objects that distinctly belong to a particular Archaeological Complex. Each Archaeological Monument corresponds to a real archaeological presence, with their own specific features). This identification system for complexes and monuments is the basis for the construction of the Archaeological Charter and the geodatabase. The subdivision of the investigated area has allowed for a current *corpus* of 63 Archaeological Complexes and 48 Archaeological Monuments.

Following the definition of the structure of the relational database, its physical creation began. Data was organised in tables; each row (record) identifies an entity, the columns (fields) identify the attributes that belong to it. Each table, while related to a precise entity, also has logical links with the other tables (Fig. 9). These connections are formed by means of connections between tables: the AS table is connected to the related AC table via ID_SA, with a one-to-many relationship. In turn, the AC table is linked to the related AM table via ID_CA, with, again, a one-to-many relationship (Tab. 2).

After the creation of the relational database, the next stage of work involved the construction of the geodatabase in a GIS environment; this allowed for the creation of a collection of spatial data of various kinds, both vector and raster (such as municipal mapping, orthophotos, DTM - Digital Terrain Model - and vector files that describe the topographic surveys, laser scanners and ground-penetrating radar, all related to database entities created in Access environment).

The shape and spatial location of the objects within the GIS is described by a set of shape files. Archaeological Sites and Archaeological Complexes are represented by a polygon, while the monuments are represented by dots (Fig. 10).

So that all the geodatabase data could be connected, proper georeferencing procedure was required, for which the topographic survey represented the fundamental basis for all data, providing the cartographic support.

The organisation of the information in layers has allowed for the creation of a series of calculations and spatial analyses, which allow for the overlay of information by synthesis and theme.

6. *New methods of sharing archaeological heritage*

As regards the implementation of new systems of

Tab. 2: Data sheet of Archaeological Monuments (MA) of the relational database in a QuantumGIS open source environment.

Tabella degli attributi - MA :: Totale degli elementi: 51, filtrati: 51, selezionati: 0

	ID_MA	ID_CA	ID_SA	NOME PROPRIO	ICE SOVRINTENDE	DESCRIZIONE	ORTOFOTO	VETTORIALE	INDIRIZZO	
7	MA_06_01	CA_06	SA_01	Ex Porta Giulia	NULL	NULL	NULL	NULL	NULL	N
8	MA_06_02	CA_06	SA_01	Tratto Via Mura A...	NULL	NULL	NULL	NULL	NULL	N
9	MA_06_03	CA_06	SA_01	Porta della Mandria	NULL	NULL	NULL	NULL	NULL	N
10	MA_07_01	CA_07	SA_01	Mosaico Ex Filan...	NULL	NULL	NULL	NULL	NULL	N
11	MA_07_02	CA_07	SA_01	Resti NI Palazzo ...	NULL	NULL	NULL	NULL	NULL	N
12	MA_08_01	CA_08	SA_01	Teatro Romano	Assente	Quanto č oggi vis...	Ortofoto MA_12....	Vettoriale MA_08...	Via Edmondo De ...	Ce
13	MA_08_02	CA_08	SA_01	Resti tardo-antic...	Assente	Nel corso di saggi...	NULL	NULL	Via Edmondo De ...	Ce
14	MA_08_03	CA_08	SA_01	Tombe tardo-anti...	Assente	Durante la camp...	NULL	NULL	Via Edmondo De ...	Ce
15	MA_08_04	CA_08	SA_01	Resti murari cd. ...	Assente	I resti venuti alla ...	NULL	NULL	Via Vitruvio	Ce
16	MA_08_05	CA_08	SA_01	Resti lato Via Nolfi	Assente	Si tratta di strutt...	NULL	NULL	Via Vitruvio	Ce
17	MA_08_06	CA_08	SA_01	Resti murari Filan...	Assente	I saggi di scavo r...	NULL	NULL	Via Edmondo De ...	Ce
18	MA_12_01	CA_12	SA_01	Edificio pubblico ...	Assente	In alcune campa...	Ortofoto MA_12....	Vettoriale MA_12...	Piazza Amiani	Ce
19	MA_15_01	CA_15	SA_01	Torrione sinistro ...	NULL	NULL	NULL	NULL	NULL	N
20	MA_16_01	CA_16	SA_01	Resti murari NI Pi...	NULL	NULL	NULL	NULL	NULL	N
21	MA_17_01	CA_17	SA_01	Resti di colonne	NULL	NULL	NULL	NULL	NULL	N
22	MA_17_02	CA_17	SA_01	Resti murari NI E...	NULL	NULL	NULL	NULL	NULL	N
23	MA_18_01	CA_18	SA_01	Resti NI Piazza	NULL	NULL	NULL	NULL	NULL	N
24	MA_21_01	CA_21	SA_01	Resti murari Duomo	NULL	NULL	NULL	NULL	NULL	N
25	MA_21_02	CA_21	SA_01	Mosaico del Cav...	NULL	NULL	NULL	NULL	NULL	N
26	MA_21_03	CA_21	SA_01	Mosaico della Pa...	NULL	NULL	NULL	NULL	NULL	N
27	MA_22_01	CA_22	SA_01	Tratto Mura inter...	NULL	NULL	NULL	NULL	NULL	N
28	MA_24_01	CA_24	SA_01	Mosaico dei pesci...	NULL	NULL	NULL	NULL	NULL	N
29	MA_24_02	CA_24	SA_01	Resti murari Pala...	NULL	NULL	NULL	NULL	NULL	N
30	MA_25_01	CA_25	SA_01	Resti murari e du...	NULL	NULL	NULL	NULL	NULL	N

Mostra tutti gli elementi

sharing Fano's archaeological heritage, the DICEA is in charge of the development of two strands of research, still in an evolutionary stage, relating to the creation of a series of augmented reality applications (of which, at present, the most developed is related to the reconstruction of the Roman theatre, based on data obtained from the metrically correct point clouds obtained by the laser scanner survey) and the creation of a virtual visit to the archaeological museum of Fano, for which navigable spherical panoramas of the rooms of the museum have been combined with surface models of a selection of the exposed archaeological remains obtained using Structure from Motion photogrammetry (Fig. 11).

7. *Conclusions*

The ArcheoFano Project allowed for the first time a structured systematisation of all the archaeological data relating to the urban center of Fano, with particular reference to the central areas investigated. The geoferencing of all present and new data has allowed for the construction of a metrically defined urban model that lends itself as a basic tool for the development of new studies, reviews and advancement of knowledge about the individual sites and the general urban model.

Archaeological plans produced allow for a full and defined state of the art knowledge of the archaeological context of the urban site of the city of Fano. A scientific method of data integration and return has also been identified and established, achieving complete results for the investigated areas,but also establishes as a container that will be able to implement detailed studies of all other areas of the historic centre not currently included in the surveys.

The laser models returned are morphometric databases on which evaluations, measurements and detailed inspections can be performed, available to scholars not engaged in direct operations in the archaeological sites (including some inaccessible sites).

In particular, the work has shed light on the dimensions of the Roman city, defining new structures and layouts for the Roman theatre of Fano - creating the conditions for its proper and scientific three-dimensional reconstruction -, relating all archaeological sites detected by laser method to each other and identifying areas of interest in which to propose carrying out excavations.

The ground penetrating radar surveys made and verified in light of the topographical surveys

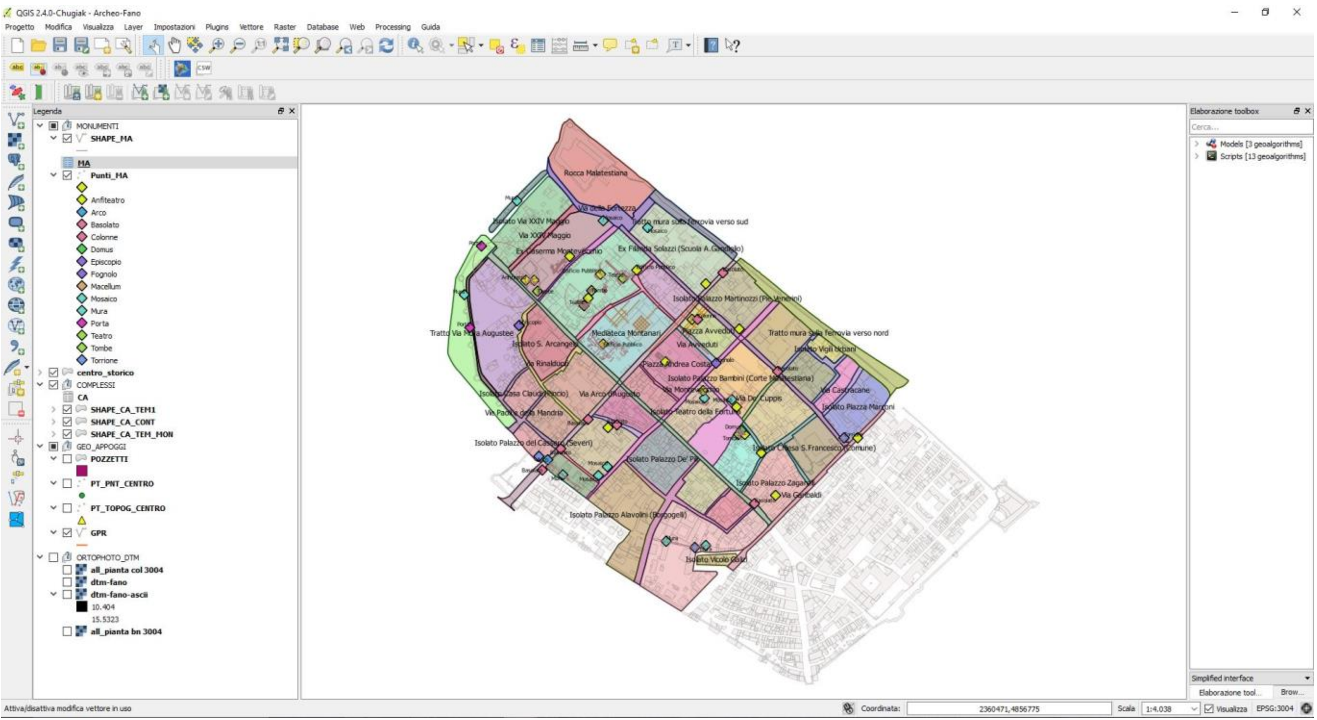

Fig. 10: Archaeological map of *Fanum Fortunae* in geodatabase QGIS. Coloured polygons correspond to the Archaeological Complexes (CA). Inside them the Archaeological Monuments (MA) are higlighted by dots.

have shown no significant presences related to wall remains in the cloister of the Benedictines and the block between Via Nolfi and Via Vitruvius.

Traces of walls have been instead found in both Piazza Andrea Costa and Piazza Avveduti. In particular those of Piazza Avveduti are in the vicinity of known Roman structures of similar depths.

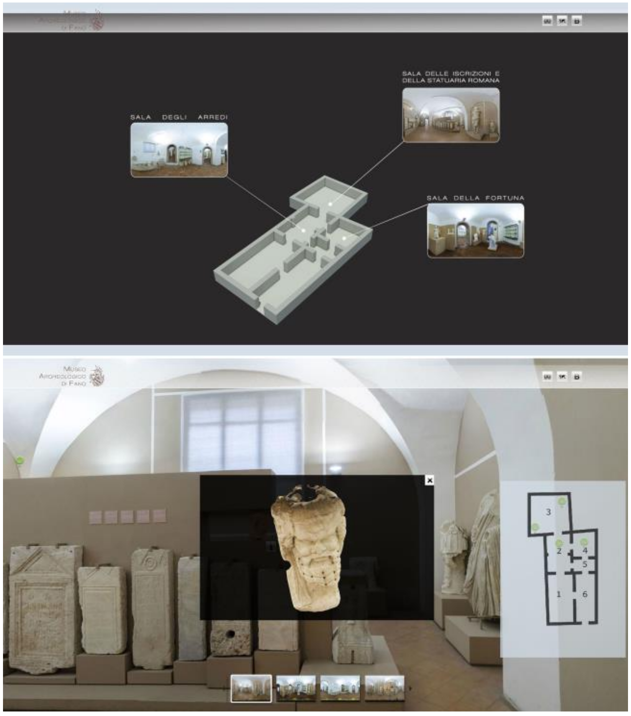

Fig. 11: Archaeological Fano Museum virtual Tour. On the top the navigable spherical panoramas of the rooms; at the bottom the 3D model of a h*erma*, obtained using Structure from Motion photogrammetry.

However, given the intensive constriction in the area over the centuries, such structures cannot be traced back to Roman times with certainty. In this case excavations could confirm or deny the most credible hypothesis that the walls do belong to Roman ruins. The structures found in Piazza Andrea Costa relate to areas which, at least from the historical maps available, were not built up over the centuries, and therefore the possibility seems more consistent that they belong to the relevant structures of the Roman period, of which there are already traces on the opposite side of the square.

Among the conclusions of the work, the structure of the specially created Archaeological GIS is also noteworthy, used for storing and linking all types of data acquired, and for easily navigating through the interrogation paths and data visualisation, making it a valuable tool for the scholar and the area manager (Superintendent, Local administrations).

REFERENCES

Alfieri, N. (1976-77). Per la topografia storica di *Fanum Fortunae* (Fano). *Rivista storica dell'Antichità*, VI-VII, 147-171.

Bacchielli, L. (1988). La porta di Augusto a Fano nella cultura antiquaria locale. In *Proceedings of conference L'antichità classica nelle Marche (Atti e memorie della Deputazione di Storia Patria delle Marche, 93)* (pp. 43-63). Ancona, IT.

Baldelli, G. (2002). Per una nuova carta archeologica di *Fanum Fortunae*. Primi dati su teatro e anfiteatro. *Quaderni Accademia. Fanestre*, I, 31-48.

Battistelli, F., & Deli, A. (1983). *Immagine di Fano Romana*, Fano, IT.

Clini, P., Nespeca, R., & Bernetti, A. (2013). All-in-one laser scanning methods for surveying, representing and sharing information on archaeology. Via Flaminia and the Furlo tunnel complex. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (Proceedings of XXIVInternational CIPA Symposium - Strasbourg, France, 2-7 September 2013)*, Volume XL-5/W2, 202-216.

Clini, P., Quattrini, R., Frontoni, E., & Nespeca, R. (2015). A New Cloud Library for Integrated Surveys: The Ancient Via Flaminia and the Nextone Project (Chapter 20). In S. Brusaporci (Ed.), *Handbook of research on emerging digital tools for architectural surveying, modeling and representation* (pp. 579-606). Hershey, PA, USA: IGI Global.

Clini, P., Quattrini, R., Nespeca, R., De Carolis, G., & Ruggeri, L. (2015). Disegnare la città insegnando a rilevare, tecnologie integrate per un rilievo urbano 3D. Drawings of city as teaching method. Integrated techniques for urban 3D models. In A. Marotta, G. Novello (Eds.), *Drawing & City. Culture, Art, Science, Information* (pp. 523-530). Roma, IT: Gangemi.

De Maria, S. (Ed.) (2015). *L'Augusteum di Fanum Fortunae. Un edificio del culto imperiale nella Fano d'età romana*, Milano, IT: Silvana Editoriale.

De Sanctis, L. (1998). *Quando Fano era romana*, Fano, IT.

Luni, M. (2000). *Studi su Fanum Fortunae*, Urbino, IT: Quattroventi.

Milesi, F. (Ed.) (1992). *Fano romana*, Fano, IT.

Pierdicca, R., Malinverni, E.S., Tassetti, A.N., Mancini, A., Bozzi, C.A., Clini, P., & Nespeca, R. (2015). Development of a GIS environment for archaeological multipurpose applications: the Fano historic centre. In *HERITAGE and TECHNOLOGY, Mind Knowledge Experience* (pp. 588-597). Aversa-Capri, IT: La Scuola di Pitagora Editrice.

Purcaro, V. (1982). Osservazioni sulla "porta augustea di Fano". *Atti della Accademia Nazionale dei Lincei. Rendiconti*, XXXVII (5-6), 141-162.

Sensi, L. (1984-85). L'area archeologia di Sant'Agostino a Fano. *Atti della Pontificia accademia romana di archeologia. Rendiconti*, LVII, 3-36.

Sensi, L. (1987). Lo scavo archeologico del 1910 in piazza A. Costa. *Nuovi Studi Fanesi*, II, 23-37.

Taus, P. (1999). *Nuove ipotesi sulla basilica di Vitruvio nella Colonia Iulia Fanestris*. Ancona, IT.

Taus, P. (2000). *Il foro di Fanum Fortunae*. Ancona, IT.