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Efficiency and quality raising in preventive archaeology: work in progress of the project ARCHEO 3.0

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Abstract. Preventive archaeology aims at assessing the archaeological interest of a given area, as well as discovering, interpreting, documenting, and protecting archaeological remains that might otherwise be destroyed by land development works. On request of private stakeholders or institutional bodies, archaeologists intervene on a given construction yard (of infrastructure or urbanisation works) in order to investigate the possible archaeological significance of zones subjected to excavation works. In many cases archaeological assays are carried out, which are associated with thorough stratigraphic documentations and definition of the final preservation conditions. The latter can involve suitable re-burying or musealization of some of the archaeological remains recovered. During these activities, the construction works are slowed down or completely interrupted up until the conclusion of the mentioned archaeological research, which can generate possible delays with respect to the planned time schedule and increase of the costs. Improvements are needed in order to minimise the duration of the archaeological assessment and, simultaneously, to guarantee quality standards even higher than tose stated by the competent superintendences. Within this framework, the project ARCHEO 3.0 "Integration of Key Enabling Technologies for rising the efficiency and quality of preventive archaeological excavations" (co-funded by Tuscany Region, POR-CReO 2014-2020) aims at speeding up the archaeological excavation and at improving its documentation. It foresees the development of a set of characterisation tools, their integration and validation in archaeological yards. Thanks to ICT solution such a multidisciplinary integration will be made possible by a dedicated web-based platform that will allow to manage 2D and 3D photogrammetry along with the data provided by electromagnetic, and acoustic sensors. The project aim at promoting a substantial step ahead of the preventive archaeology in order to overcome the traditional empiric approach. In this respect, data exchange and the ICT solutions for direct collection of information on archaeological evidences represent the major challenge. Here, we preliminarily focus on the general features of management protocols of the archaeometrical data, as well as on their suitable integration within the operative phases of the archaeological excavation.

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1. Introduction

The topic of preventive archaeology has been discussed for decades both from the theoretical and methodological point of view and from the more strictly operative aspects. For a long time, in fact, archaeologists directly involved in the field have posed the problem of reconciling the needs of protection with the operational ones that involve excavation work in the construction sector, mining and in large infrastructural works. At the European level, experiences of preventive archaeology have taken place mainly in the countries of central and northern Europe starting from the second post-war period (excavations connected with the construction of the London underground). Also in Italy the first experiments in this sense took place with the intervention of English archaeologists followed, in the eighties of the XX century, by more systematic prevention activities throughout Italy, with interventions supported by both private and public clients. An opportunity to verify and consolidate the operational practices already tested on more limited territorial areas has been the construction of the high-speed railway lines, which have seen numerous preventive investigations, systematic and extensive excavation interventions from Lombardy to Campania, interventions still ongoing in some areas. Therefore, now it is common practice, by the Superintendences for archaeological heritage, to coordinate excavation interventions aimed at the construction of public and private works. At present these kinds of archaeological excavations are the overwhelming majority of those conducted in Italy. However, these excavations, after the scientific recovery of all the stratigraphic and structural data, necessarily require the removal of the archaeological context or modifications of the projects in order to allow the total or partial conservation of the remains found on site. In some cases, however quite rare, it was necessary to completely abandon the planned construction due to the discovery of archaeological assets of such importance that did not even allow scientific disassembly and relocation operations. The law 25 June 2005, n. 109 provides a legitimization for the interventions imposed by the same needs for the protection of archaeological heritage (established by the Code of Cultural Heritage and Landscape as reported in the Legislative Decree 22 January 2004, n. 42) and helps regulating a common behavior practice followed by all the archaeological Superintendences. Also in the new public procurement code (Legislative Decree 18 April 2016, n. 50) updated with the amendments introduced by the Corrective Decree (Legislative Decree 19 April 2017, n. 56, published in the Official Gazette 5 May 2017, n. 103), the article 25 of the legislative decree 18 April 2016, n. 50 establishes the need for prior verification of the archaeological interest carried out according to the usual practice [1-2].

2. Protocols and procedures in use for the preventive archaeology

Paragraph 13 of Article 25 establishes the need to adopt *".... guidelines aimed at ensuring speed, efficiency and effectiveness of the procedure referred to in this article. The same decree identifies simplified procedures… that guarantee the protection of the archaeological heritage, taking into account the public interest in the realization of the work. "*

This concept is explained in the indications reported in the Reference Practice UNI / PdR 16: 2016 "Guidelines for exploratory survey, archaeological assistance during construction and stratigraphic archaeological excavation"

The preliminary verification procedure of the archaeological interest requires that the contracting companies must transmit, before approval, to the territorially competent Superintendent copy of the preliminary project of the intervention including preliminary archaeological and geological investigations. This is a preliminary phase that involves four different types of operations, without involving excavation activities:

a) the collection of archive and bibliographic data, i.e. historical "knowledge;

b) surface surveys on the areas affected by the works: this is the so-called survey, which provides for the systematic collection of the findings brought to light seasonally during the ploughing or in sections exposed in the natural or artificial land exposures;

c) the "geomorphological interpretation of the territory" in relation to their settlement potential throughout the past ages;

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d) the photointerpretation (provided exclusively for "network" works), i.e. the study of anomalies identified by reading aerial photographs available or realisable for the purpose.

The results of these operations must be "collected, processed and validated". In case of archaeological evidences in the areas affected by the works, supposed on the basis of the transmitted documentation and "further information available", the Superintendent may request a further investigation phase:

Phase 1) integrating of the preliminary planning:
1.1 - execution of cores;
1.2 - geophysical and geochemical prospecting;
1.3 - archaeological tests;
Phase 2) integrating of the final and executive planning:
2.1 - execution of surveys and excavations, even in extension.

The procedure ends with the drafting of the definitive archaeological report, approved by the territorially competent Superintendent. The report, satisfying the requirements established by the legislation, contains an analytical description of the investigations performed, qualifies the archaeological interest of the area, according to the following levels of archaeological significance of the site, and dictates the following requirements:

a) contexts in which the stratigraphic excavation directly satisfies the need of control and protection from archaeological point of view of the excavation area;
b) non-monumental contexts with a low level of conservation for which re-interventions or disassembly-reassembly and musealization are possible;
c) complexes of particular relevance, extension and historical-archaeological value that can be fully protected according to the Code of Cultural Heritage and Landscape.

The efforts of the project ARCHEO 3.0 are devoted to increase the speed and quality of these operations, overcoming the difficulty of storing of metadata and their management. In particular, it is focused on the Phase 2 of the planned procedure i.e. when excavation is required.

3. Materials and methods

The targets of the project ARCHEO 3.0 that we will discuss in this paper concern the following topics: development and techniques for a speditive approach for exploratory surveys; semi-automatic reconstruction of the SU (Stratigraphic Unit) during the excavation operations; management of the metadata collected during the excavation and their immediately processing. All these aspects are finalized to improve the speed and quality of the preventive archaeology yard.

3.1 Speditive approach for exploratory surveys

The purpose of exploratory surveys is to evaluate the presence of remains and archaeological evidences and their consistency. They are usually carried out by means of a forced section excavation with mechanical means provided with a smooth bucket. In presence of archaeological evidences, the excavation is stopped and the next operations are carried out in the framework of real archaeological yard, in according to stratigraphic criteria. The documentation drawn up during the operational phase in the yard must always include:

- description of the stratigraphy units found for each step of the excavation, the so-called stratigraphy diagram (Harris's matrix, or *matrix*);
- graphic documentation of the temporal succession of the excavation and sequence of deposition of archaeological evidences;
- list of the drawings, photos, videos, etc.;

The target of this topic has been achieved by using 3D technologies and digital instrumentations that allow improving the quality and speed of the survey in a compatible way with yard activities. In particular, the techniques of Structure from Motion [3] bring to new perspectives in the field of architectural and archaeological relief [4-5] and documentation; furthermore, Computer Vision algorithms are ready to be also managed by non-technical users.

3.2 Identification of the SU

The stratigraphic archaeological excavation is an activity that involves the removal of portion of terrain to bring out archaeological evidences like ruins of building or monuments, tombs and archaeological finds, and archaeological remains in general. The aim of this activity is the understanding of the relationship between remains and their ground layer, through a correct reading of the sequence of the ground layers it is possible to date the sequence of the events that interested the excavation. The stratigraphic archaeological excavation is carried out on the basis of the identified ground layers, distinguished according to *their different consistency, their composition and their colour*. The 3D modelling makes possible to realize a metrical restitution of each stratigraphic unit, giving priority to the correctness of its perimeter limits, relief and quotas after a properly graphic elaboration. To one specific area on the 3D model, or on the rectified photography (2D), can be referred the results obtained by different equipment and visual observation. Each stratigraphic archaeological excavation must include the following operations: identification of the stratigraphic units; manual cleaning of the stratigraphic units for suitable definition and graphic and photographic documentation; numbering and description; photographic documentation; graphic documentation.

These operations are achieved for each step of the excavation until to the archaeological deposit has been completely removed.

3.3 Management of metadata acquired on the yard

The exact and objective descriptive, graphic and photographic documentation of a stratigraphic archaeological excavation is a necessary condition for a correct recording of data and information, for possible future reviews of the investigated contexts and for the approach to restoration.

The proposed approach is based on the use of GIS to organize and analyze the acquired documentation (images, videos, results from analytic analysis or physical investigation, etc.) is developed by the following steps:

1. The topographic relief that gives the reference system on the official cartography and it is the reference for a right positioning of the archaeological targets inside the archaeological area;
2. The expeditious 3D relief of targets – objects or selected areas inside the excavation yard – that are positioned in the topographic relief (geo-referenced). The 3D model allows the extraction of digitalized sections of the area of interest improving the quality documentation;
3. The targets within the archaeological site are geo-referenced. Each target can be referred to the location of the archaeological find or to ruins, and it is possible associate every information (description, images, results of analysis, etc.) to it.

In such way, the proposed approach aims to increase the speed and quality of the information collected during the excavation phases. Then, a post GIS database linked to a QGIS project collects the aforementioned data through an internet server provided with REST services. Both services, Server API and Client API, use RESTfull data interchange protocol, such as in a classic client-server application in this way an easy and robust data transfer method is implemented.

The metadata analysis and management is made easier by procedures and protocols defined in the project and by a web-based platform properly designed, that allows to subsequent analysis and re-elaboration of data and metadata to drawing up the executive project. The drafting of the executive project will must comply with the following requirements: general report of the excavation; list of stratigraphic units; SU record cards; photographic documentation; graphic drawings including the positioning of the excavation area; list of boxes containing the findings and their description.

4. Improvements in the preventive archaeology yard

The ARCHEO 3.0 project aims to develop a series of innovative technologies to improve the surface and sub-surface investigation of the excavated area starting for the relief.

The proposed improvement on the relief procedure is based on the use of SfM technique applied on the frames acquired by a video recording of the excavation area. The SfM is a range imaging technique that allow us to reconstruct a 3D models starting from points extrapolated from 2D images. The 2D imaging can be automatically extracted from the video recording.

The video has been registered by GoPro Hero 3 camera equipped with stabilized rod. The camera was set with 1920x1080 pixels, and 50 fps as acquisition speed. The relief of the excavation area was just achieved in 11 min. To compare the performance with the standard procedure the same area was covered using a Nikon COOLPIX S3000 (setup: 4kx3k, f/3.2, ISO 200) the time used was 4 times longer. The modeling procedure consists of recovering 3D camera position related to pictures and 3D positions of the content of the images, this is obtained by identifying similar content between N views and solving 3D geometry problems. The test area for the speditive relief was the yard in the square of the Unità d'Italia, in Firenze (Fig. 1a). This is an emergency excavation carried out for the laying of the main sewage system in relation to the works for the construction of the tramway line in Florence. At the present, doesn't provide any musealization. At a depth of about 2 meters from the paved floor of the square, several remains have been found, maybe part of a farm linked to the exploitation of the fertile Florentine plain (Fig. 1b). These remains can be attributed at the end of the Republican age (end of the 1st century BC), when the Florentine plain was centuriated and divided among the veterans of the civil war. At the current state of knowledge, it isn't possible to establish with precision the chronology of the rustic settlement, of which we have found some levels of roof collapsed - made with tiles - and some masonry structures in *opus coementicium*, pebbles and limestone.

(a)

(b)

Fig.1 - (a) Details of the excavation area of square of the Unità d' Italia in Firenze; (b) details of the remains found at 2 m depth respect to the paved floor

3D digital models were created using Agisoft PhotoScan. This software performs photogrammetric processing of digital images and generates 3D spatial data. Refinements, editing, cleaning and texturing operations on the obtained models were performed by MeshLab [6], an open source software for processing and editing 3D triangular meshes. 258 frames were extracted for the images alignment/matching that were achieved by the Scale Invariant Feature Transform (SIFT) algorithm through the identification of features in single images (grayscale converted). SfM estimates the relative camera position from the matched anchor points computed at the previous step and the sparse point cloud is built at the same time. In this way a sparse point cloud is obtained to roughly represent the scene. Approximately only 15 minutes has been sufficient to obtain the sparse point cloud by a notebook (equipped with Intel® Core™ i7-6700HQ @ 2.60GHz and RAM 16 GB).
The reconstruction of the 3D polygonal mesh was performed by using the PhotoScan software, in such way the geometry (mesh) is generated and the texture is applied using the photos initially acquired (Fig. 2). The realized model has been edited with MeshLab by performing a decimation of meshes, erase of detached components, close mesh holes, and other filtering operations. This process has been necessary to reduce the number of triangles that make up the 3D mesh so the 3D model is less "heavy" and easy to use on portable devices. This approach improves the management of the data acquired in the yard during all work stages by their direct insertion in a postGIS database that reduces the loss of information and allows changes as consequence of new archaeological evidence. Digital elaboration and procedures for the recognition of features useful for an automatic recognition and identification of SU are also aims of the project. A procedure for the automatic edge detection of the SU will be presented by I Cacciari et al. in this congress [7].

Fig. 2 - The textured model, rectified photography extracted from the 3D model

The mobile IT infrastructure aim is to integrates hardware and software devices to be able to acquire and store information in order to support the operational staff (archaeologist, technician and scientist) during their work, starting from the activity on site.

The platform is designed for an access through a tablet or other device capable of WiFi connection to the local server and to the central server in the headquarters. The infrastructure will allow to compile and store the documentation required directly online, sending the acquired information in real time to the specific server.

The principle scheme of the IT infrastructure is shown in Fig. 3.

The activity for the achievement of the IT infrastructure has been splitted into the following sub-activities:

1. Supply and appropriate configuration of the server that will host the database, the portion of the application that exposes the Application Programming Interface in order to interact with the database and a package of applications for a correct interface among the devices (server, mobile device, measurements systems, cameras, video cameras etc.).
2. Creation of a software structure in order to allow a safe interaction between the external world (applications that reside on device and server-side) and the database, with exposure of Application Programming Interfaces (APIs) with read/write access to the database;
3. Implementation of an executable app on the device (client-side application) that allows to the archaeologist, or end-user, to perform the cataloging and documentation of the finds directly on-site, and their processing.
4. Design of an on net software infrastructure to provide support to the dedicated app, and which allows the management and processing of data also through a PC.

The physical server was set up with Linux installation, allowing to integrates open-source software and advanced technology without license costs, Therefore, a Linux server was installed with Ubuntu distribution in the desktop 16.04.2 LTS (xenial), whose choice is motivated by two factors of fundamental importance:

- Desktop version so that the desktop version of a set of software can be run directly on the server, among which we include the geographic information system QGIS, Web GIS: QGIS and QGIS - Server.
- Ubuntu LTS because it is the long term support (up to 5 years) version of the Canonical desktop distribution.

This server runs the Apache 2.4.18 web server and the Tomcat application server, both open-source products, as well as having installed a series of desktop software for the project implementation. In particular, among the installed packages we include:
DBMS: PostgreSQL + PostGIS 9.5; PHP 7.0.15; Python 2.7.12; Java JDK 1.8; Jax-RS library for Java; Eclipse Oxygen; GIS: QGIS 2.18; WebGIS (MapServer); QGIS Server (2.18); QGIS Web client server; "pyArchInit" plugin for QGIS; Plugins for QGIS openLayers; Plugin for QGIS QGIS2Threejs.

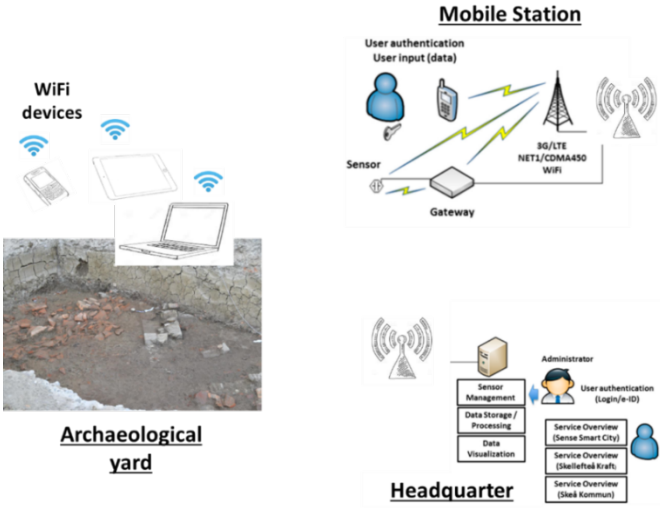

Fig. 3 - The IT infrastructure of the ARCHEO 3.0 project

For the second step, the software components are related to the interfacing on TCP / IP protocol, which allows to use the services also remotely with any device with Internet connection.

These products constitute the first-party software layer interposing between the database and the web app. These can be divided into two different APIs (API Server and API Client) both based on a data exchange protocol of the RESTFull type. The choice of standard restfull protocols both server-side and client-side is due to a simple access to data supply, typical of client-server applications.

In detail, with regard to the development of the Server API, it was decided to implement the latter in Java, using the Jersey library, with which it is possible to benefit from a set of tools able to create a REST infrastructure in a transparent way for the developer. For the realization of the WEB services, it was decided to implement, starting from the previously illustrated database, a three-level architecture as follows:

• Pojo: Objects that "map" (encapsulate) the tables present in the database, so that we can interact with these respecting the principle of encapsulation.

• Manager: Repository objects for entities mapped via Pojo, there are defined a number of methods that allow to perform queries in the database. Some of these operations, such as those identified by the acronym CRUD (Create, Read, Update and Delete) are common to all entities, while others will be specialized according to the entity considered (e.g. to recover a point of interest from a stratigraphic unit or vice versa). Among these operations we therefore include:

o GetById: Retrieve a record of a specific table in the database by mapping it as a Pojo object through its id;

o GetAll: Recovers all records of a given table by mapping them as a list of Pojo objects;

o GetAllPaginated: Same operation as the GetAll, but with the addition of the pagination for the results obtained;

o GetByFilter: Allows to select a certain number of records, mapping them as a list of Pojo objects, according to a given filter;

o DeleteById: Allows to remove the specified record via id;

o DeleteAll: Allows to remove all the records in the table;

o Insert: Insert a record in the database;

o Update: Performs the update of the selected record in the database;

Data exchange is expected both in XML format and in JSON format, the latter preferable for the conciseness in data representation. Therefore, based on the call made, the data will be directly displayed in either format. The OpenAPI tool to define the previously repoted services is shown in Fig. 4.

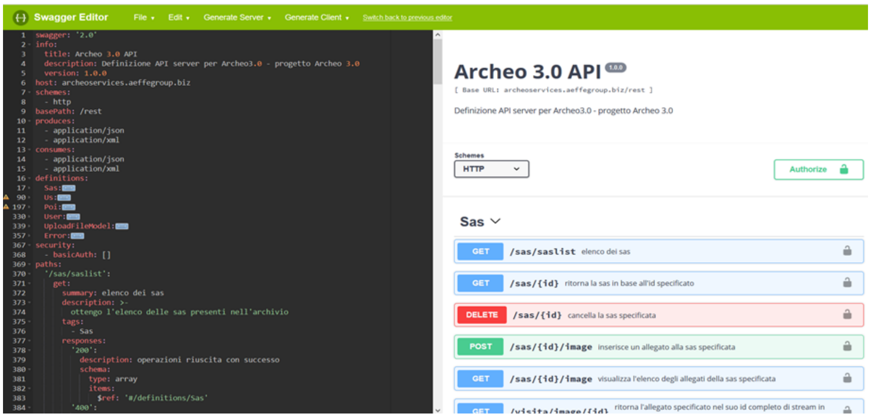

Fig. 4 - The IT infrastructure of the ARCHEO 3.0 project

Thanks to this tool, the documentation of the services and a skeleton have been realized on which it was then possible to continue with the development both for the server and client, since this tool allows server side and client side generation of the bees in almost all programming languages suitable for this purpose. In addition, OpenAPI, combined with the use of soapUI, has made it possible to directly test the services developed. In fact, by importing the documentation produced on soapUI, the unit tests are automatically generated.

6. Conclusion

In the case of preventive archaeology excavation often few time for survey and for the acquisition of information is allowed, therefore it is important to improve the rate of image and information to better define and understand the archaeological meaning of the site under investigation.

The acquisition through video of the excavation area has been proposed to reduce the time to achieved the 3D model, and to extract rectified photos, thanks to the implementation of SfM technique. The correct methodology for video capturing and the amount of frames to be extracted, is being studied in order to develop an effective pipe line of work.

And, the mobile IT infrastructure was realized to integrates hardware and software devices for acquiring and storing information in order to support the operational staff (archaeologist, technician and scientist) during their work starting from the activity on site.

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