

THE ARCHAEOLOGICAL INFORMATION SYSTEM OF THE UNDERGROUND OF ROME: A CHALLENGING PROPOSAL FOR THE NEXT FUTURE

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ABSTRACT

The paper describes the fundamentals of a project devoted to design and implement the first *Archaeological Information System of the Underground of Rome* (Italian acronym: S.I.T.A.S. ROMAe) in cooperation with the State Archeological Superintendence of Rome.

The project contemplates in fact to design a GIS suited to archive, manage and make available on-line (Web-GIS) all the documents concerning the archaeological sites (open or buried) and to establish guidelines to update the GIS archive with new archaeological data collected during future excavations, that must be followed by all archeologists and Companies involved in excavation activities.

1. INTRODUCTION

The archaeological sites and the underground of Rome and its suburbs (Agro Romano) are managed by the Government Department for Archeology in Rome (State Archeological Superintendence of Rome-SASR); this is an office dependent on the Ministry of Heritage and Cultural Activities which should be devoted both to safeguard the archeological heritage and to develop scientific researches about.

In fact, a major concern of the SASR is just the management of the routine and emergency excavations (about 40000 per year) for underground services and infrastructures (water, electricity gas, phone and data lines) and new building sites.

In most cases, the attendance of a (private) archeologist is requested by SASR whose cost is sustained by the Companies managing excavations. The archeologist task is just to continuously control the excavation progress, to stop or modify it if some object of archeological interest is found and, in the end, to document the absence/presence of archeological finds. In the same time, SASR officials have the role to give the official permission to start each excavation, to inspect from time to time the excavation activities, to give the appropriate indications in case of archeological finds and finally to collect all the documents prepared by the (private) archeologist.

In this last respect, it has to be stressed that the documentation collected by SASR is and not homogeneous, because a standardized procedures both for acquiring information during the excavation and to submit them to SASR does not exist, and it is available on paper only.

The lack of standardization and online information dramatically prevents both the SASR officials and all the other interested people and Companies from fast consultations, useful both for scientific investigations and for excavations planning. This situation is common also to other documents related to historical archeological studies (mainly maps), which are kept by SASR in the same manner.

This fact is relevant when the excavations are closed again; in fact the knowledge of the trend and alignment of structures is possible only when data are enough precise and correctly georeferenced.

Accounting for this situation, the idea of a global project arose, that integrates new but no quite expensive technologies both to acquire and to archive and manage all the information related to new excavations and to manage them together those attaining to past investigations according to a standardized protocol.

The paper shows the fundamentals of the project and discusses the results of some experiments designed in cooperation with

SASR just to test the feasibility of the standardized protocol as regards the field information acquisition and to implement a first section of the GIS concerning the archeological ties regarding private buildings and areas in the territory of Rome's municipality.

2. PROJECT

The global project is constituted by two subprojects, the first one (S.I.T.A.S. Romae) mainly attaining new excavations, the second (In.Forma) related to the management of ancient maps.

2.1 S.I.T.A.S. ROMAe

S.I.T.A.S. Romae (*Sistema Informativo Territoriale Archeologico del Sottosuolo per la città di Roma – Archaeological Information System of the Underground of Rome*) is a subproject which integrates different technologies (terrestrial and GPS surveys, close range photogrammetry, GIS) to acquire, process and organize data derived from excavations.

At the same time, proposes a standard procedure, which all professionals and all Companies working in this field must conform.

S.I.T.A.S. project develops through the implementation of a GIS devoted to archive and manage all the data collected in surveying and georeferencing of archaeological evidences in the territory under SASR jurisdiction according to a standardized procedure.

Surveying and georeferencing should be based on mixed terrestrial and GPS techniques, eventually integrated by close range photogrammetric images; the official new Rome numeric map, scale 1:2000, should be the GIS cartographic reference.

2.2 In.Forma

In.Forma (*“Indagando sulla forma di Roma”*) is a second subproject complementing S.I.T.A.S. Romae; it concerns georeferencing of ancient maps (geometrically correct), mainly based on GPS surveys, by standard GIS routines. These maps are often related to now buried archeological sites, whose consistency and correct enough position might be a posteriori reconstructed without any new excavation.

2.3 Project objectives and advantages

The goal of the project (S.I.T.A.S. and In.Forma) is to

standardize procedures for (Figure 1):

- surveying and georeferencing archeological finds during excavations usually carried out by public services Companies
- production, management and updating of a spatial database of the excavations and of the archeological sites and monuments
- realization of a database of the present archeological ties regarding private buildings and areas in the territory of Rome's municipality
- georeferencing of ancient maps (metrically correct) (Baiocchi, 2001; Baiocchi, 2002c)

Several remarkable advantages may be supplied by the development of the two subprojects, both for the SASR and for all the other interested people and Companies:

- archiving in a standard digital format all informations related to surveys of the archeological evidences, useful for fast consulting for scientific and technical investigations
- increased efficiency for supervising and documenting the archeological excavations and progressive reduction of the costs that SASR has to sustain for
- dynamic grouping of the streets within Rome municipality in two classes: "positive" and "negative" streets, with and without already discovered archeological finds in the underground respectively, useful for future excavations planning and for excavation official permissions release
- enhanced spatial analysis of the archeological finds distribution

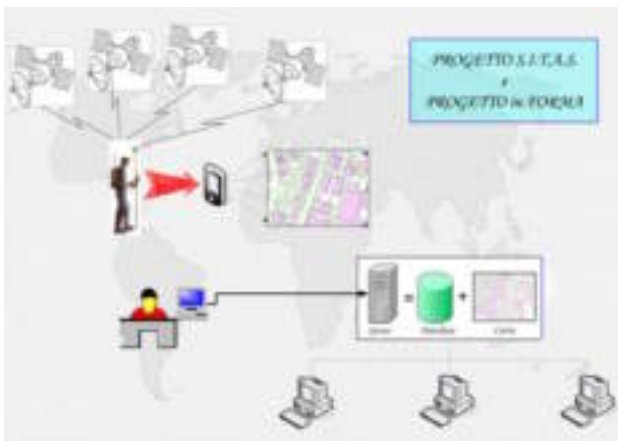


Figure 1. Functional scheme of S.I.T.A.S. and In.Forma projects

3. PRELIMINARY EXPERIMENTS

After presentation of the project to SASR, we were asked to perform some preliminary experiments in order to test the feasibility of the standardized protocol. Three of them, carried out between December 2004 and February 2005, concerned field information acquisition and historical maps georeferencing:

1. use of GPS in an urban environment, in presence of remarkable obstructions, to survey two archeological sites and georeference their ancient maps (Baiocchi et al., 2001; Baiocchi et al., 2002) with RTK technique assisted by the GPS permanent network of the Lazio Region, managed by the Area di Geodesia e Geomatica-Università di Roma "La Sapienza"
2. use of a new total station fully integrated with a double frequency GPS (Smart Station[®] by Leica) to survey a very large monument near Rome (20 km apart) in an extra urban region; in this case the RTK technique assisted by the GPS

3. permanent network of the Lazio Region was employed too
3. use of close range photogrammetry techniques applied to non-metric digital camera images to survey a Roman cippus of little dimension, comparable to those of the most part of archeological finds expected in routine excavations

Moreover it was produced a prototypical database of archeological ties regarding private and public buildings and areas in the territory of Rome's municipality, both according to the norms included in the quite recent "Codice dei Beni Culturali e del Paesaggio" (2004) and to the previous laws.

3.1 GPS-RTK survey in urban environment

Aim of experimentation was to evaluate the GPS-RTK survey performances in an urban environment.

In fact GPS (eventually assisted by total station) allows to determine with adequate accuracy (which may range from several cm to few tenths of meter) suitable points needed to compute the dimensions and volumes (depth w.r.t. the present ground level too) of excavations and eventual archeological finds (Figure 2).

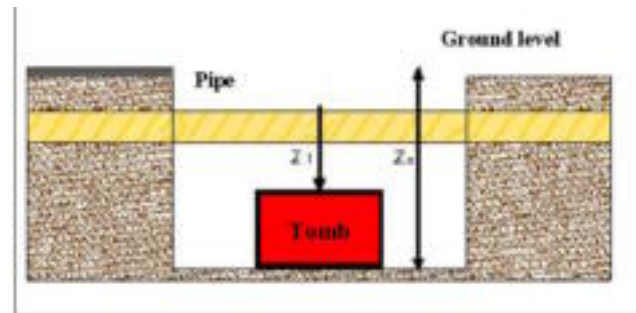


Figure 2. Positioning an archeological find and neighbouring underground services lines in open excavation

So two archeological structures have been surveyed and georeferenced; they both are located in the urban area represented in the section 37410G of the official map of Rome, scale 1:2000 (horizontal tolerance 0.6 m), produced by Cartesia S.p.a.

The first structure, called "Santuario Siriaco", lies near Gianicolo hill in a closed archeological area; 6 points approximately located at the vertices of Santuario Siriaco have been surveyed; a XIX century map of the ancient structure thanks to GPS survey was georeferenced, showing the correct position of the whole now buried or ruined structure (Figure 3).

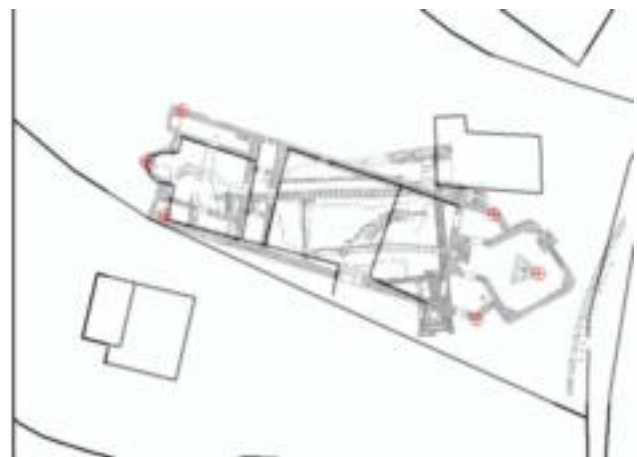


Figure 3. The survey of Santuario Siriaco (in evidence: the

points surveyed by GPS and the XIX century map).

The second structure lies inside a former public transportation bus depot near Mura Portuensi. This structure is composed by Roman deposits, partly buried, situated at about 5-6 m underground; 14 points were surveyed; an on foot kinematic survey was also executed around the area of the excavation. A map of the overall structure derived from a recent, large scale but not georeferenced survey was correctly positioned thanks to GPS survey (Figure 4).

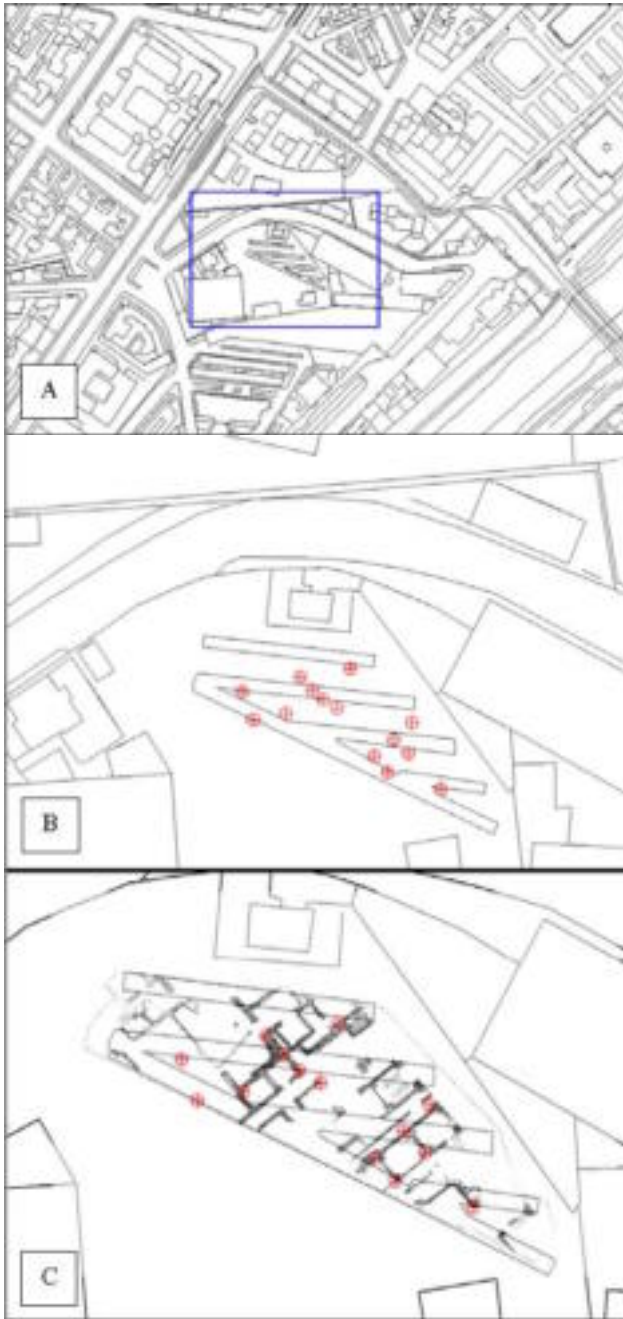


Figure 4. A - Portion of the map of the Roman deposits; B - Excavation trenches and GPS points; C - Map from SASR archives correctly georeferenced

As mentioned, both surveys was carried out with RTK technique, receiving differential corrections from the (RTCM) in real time from the GPS permanent network of the Lazio

Region, managed by the Area di Geodesia e Geomatica-Università di Roma “La Sapienza”. Each point position was estimated in a 2 minutes survey, allowing a 3D accuracy around 0.1 m, which fits perfectly with the overall archeological requirements.

In order to connect GPS surveys and georeferenced maps to the official map of Rome, presently available in the GAUSS-BOAGA cartographic reference system only with orthometric heights, some coordinate conversions were performed:

- ellipsoidal heights were transformed into orthometric ones applying the geoid undulations according to ITALGEO95 public model (<http://www.iges.polimi.it>) tied on 4 leveling benchmarks in the Rome area
- horizontal coordinates of all GPS points were changed into the GAUSS-BOAGA system employing the original software Trasformer (Baiocchi, 2002a; Baiocchi, 2002b; Baiocchi, 2004) developed at the Area di Geodesia e Geomatica-Università di Roma “La Sapienza”, allowing an error transformation below 0.3 m, acceptable w.r.t. the the Area di Geodesia e Geomatica-Università di Roma “La Sapienza” map tolerance.

3.2 GPS-RTK survey in extra urban environment

An archeological structure has been surveyed and positioned through the use of a new total station fully integrated with a double frequency GPS (Smart Station[®] by Leica). The structure is constituted by the rests of a Roman villa in the municipality of Monte Porzio Catone (Rome province). The positioning of 4 points has been carried out by RTK procedure with 3D accuracy around 5 cm; a complete and detailed survey, useful for future photogrammetric integrations too, was performed in about 5 hours setting up the total station on these points, allowing the georeferencing of the whole structure.

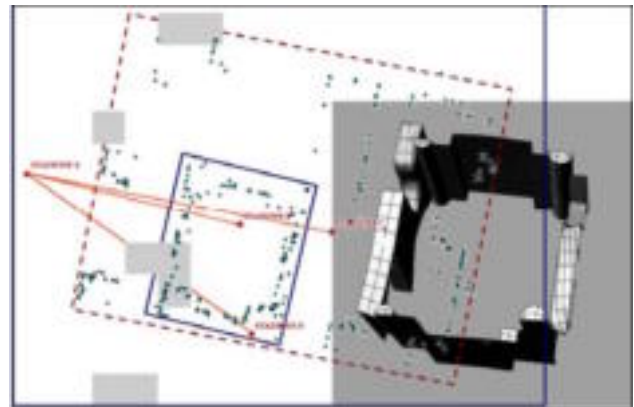


Figure 5. Surveyed rests of the Roman villa in the municipality Monte Porzio Catone (Rome province)

3.3 Photogrammetry for high precision surveys

The use of close range photogrammetry in the archeologic field is certainly not new, but fresh it is the goal to standardize a procedure to take, process and archive digital images by non-metric low cost cameras and low cost software, which may be used not only by few expert but also by a large part of the people interested in archeological excavation.

The main intent is just to substitute the traditional procedure of direct survey, in order not always able to guarantee and to lower the stop time of the excavation yards and to guarantee an uniform accuracy, which may became almost independent from the surveyor skill.

It has to be noted that laser-scanner is not considered here because of its relevant cost and its high accuracy which is not usually required to document eventual archeological finds in routine excavations.

The experimentation has been executed on a cippus which lies in the public gardens of Monte Oppio, just above the world famous Domus Aurea, near the Engineering Faculty of the University "La Sapienza"; dimension of this cippus are comparable to those of the most part of archeological finds expected in routine excavations.

The purposes of the experimentation were:

- to test the quality of a low-cost photogrammetric procedure applied to an object of archaeological value
- to test a simple procedure for the calibration of non-metric cameras, based on the facilities of the well known Photomodeler 4.0 software (Eos System), used also for the whole photogrammetric procedure



Figure 6. The cippus near Engineering Faculty of the University "La Sapienza"

We compared three low cost commercial cameras (Casio Exilim EX Z40; Nikon D100; Sony Cyber Shot DSC p200; Panasonic Lumix DMC-FX7) during the preliminary calibration and the Casio Exilim Ex Z40 (350 €) resulted the best one, so that it was used for the subsequent photogrammetric survey. 8 stations were set up and an image pair was shot from each station (one above, the other below). Mainly, two different kinds of processing have been carried out: the first by adjusting the whole 16 images block of using 16 GCP, materialized on the cippus with special targets surveyed by total station; the second without GCP, performing an intrinsic block adjustment just using corresponding points suitably observed on different images.

In order to check the accuracy of the photogrammetric surveys, 49 natural points were determined too by total station and their relative positions were compared to those derived in the two kinds of processing.

The results confirm an accuracy at millimeter level, suited for the most part (may be for all) of the archeological applications.

3.4 Database for archaeological ties in Rome municipality

The purpose of the database is the documentation of all the archeological ties regarding private and public buildings and areas in the territory of Rome's municipality, both according to the norms included in the quite recent "Codice dei Beni Culturali e del Paesaggio" (2004) and to the previous laws. Database was designed and a prototype was implemented by

Microsoft Access 2000; all the information regarding the about 300 ties will be collected and organized in order to enable a simple update in real time.

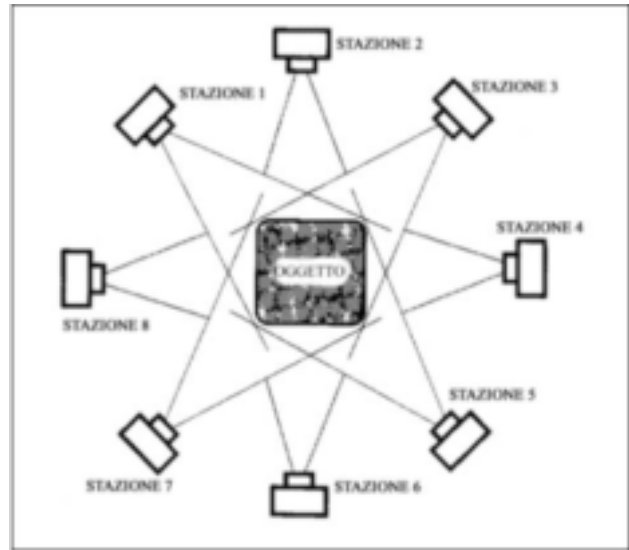


Figure 7. Horizontal set up of the photogrammetric survey

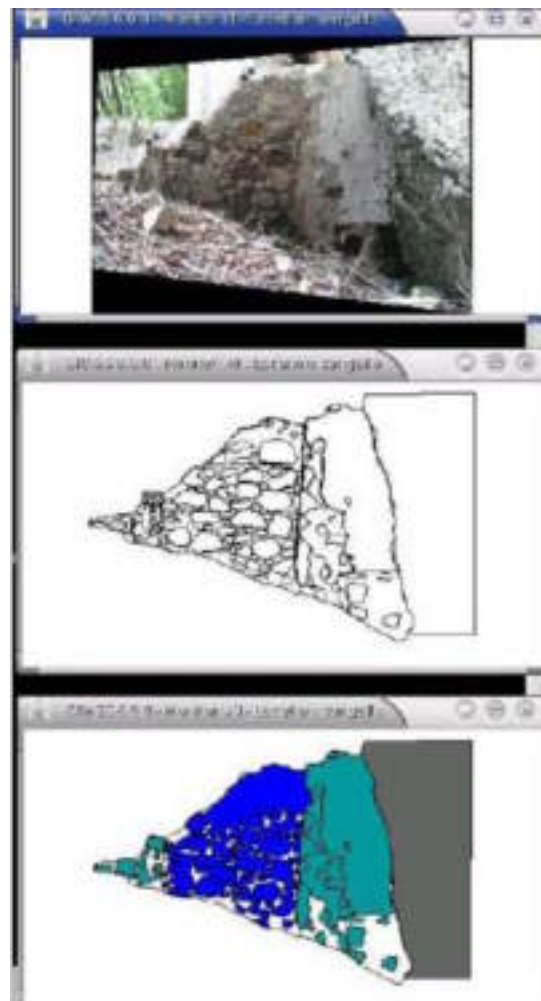


Figure 8. Sequence performed by the open-source Grass software regarding the rectification and digitization of a detail of S. Gallo hermitage, near Cagnò (TN) (Images taken from the presentation "L'utilizzo di Grass in archeologia: ricerca sul

territorio, documentazione di scavo, rilievo architettonico"-
<http://w3.uniroma1.it/geodgeom/homeGrass2005.html>)

Survey type	RMS Average value (pixel)	Maximum residual value (pixel)
With GCP	1.35	4.21
Without GCP	1.44	4.57
Pixel magnitude: 0.5 mm		

Table1. Photogrammetric survey results

In this way, SASR will be able to provide on computer support (CDRom) or online, a complete and updated documentation, allowing an easy and fast consulting by SASR officials and public or private people or Companies.

The structure of the database is simple and intuitive, with few fields to fill with the purpose to speed up its management and update. We foresaw an external directory containing only the raster map for each tie (taken from the SASR archives) to easily find its location and a series of external directories supplying all the ancillary information about each Ministerial Decree, instituting an archaeological tie. The directories are therefore connected to the database.

So, the SASR officials will be able to manage all the documents connected to the various Ministerial Decrees (technical reports, administrative correspondence, precedent laws). The documents in the directories will be indexed and ordered according to standard codes.

The advantages supplied by this database are several:

- possibility to get queries about ties and supplementary documents in the external directories
- possibility to connect the archaeological ties database to other communal, provincial, regional and national database
- possibility to easily supply the whole documentation related to the administrative management of the archeological ties both to the SASR officials and to public or private people or Companies in short time
- possibility to update and complement the database with other tie types (landscape, monumental...)

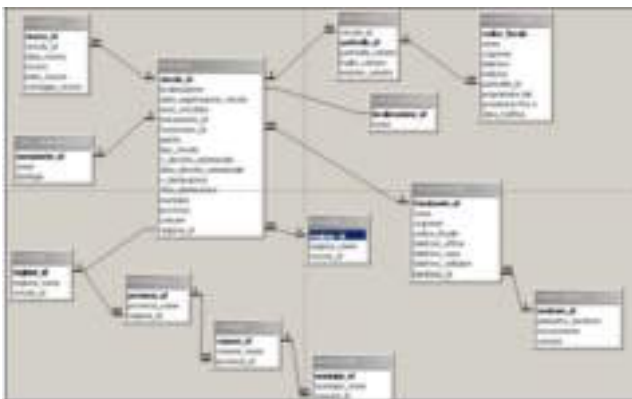


Figure 9. Database kernel (implementation by Microsoft Access 2000)

3.4.1 Tie alphanumeric code

A special mention deserves the possibility to introduce an alphanumeric code connected to ties database for the unambiguous definition of the elements related to each tie. Code should be realized by a standard bar code that returns, for every tie, the information of remarkable interest for the SASR.

The creation of an alphanumeric code for the archaeological ties would allow SASR to achieve a leading position in the definition of a standard that classifies all the present archaeological ties within the national territory.

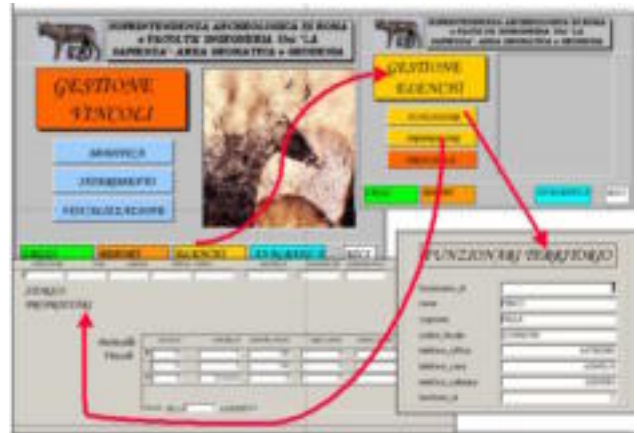


Figure 10. Archeological ties database

4. CHRONOLOGY

S.I.T.A.S. project should developed according to the following two phases.

In the first one, a stand-alone GIS will be created, in which to realize the spatial databases and to insert the maps; in this last respect, the cartographic database could be integrated by historical maps. The structure of GIS will be articulated in few principal layers (3 to 5), in order to simplify the access of the SASR employees and officials, the data immission and the realization of structured queries according to the needs.

In the second phase the GIS should be transformed in a Web-GIS, in order to make available online all the collected and structured information.

So, from the technical point of view, it will be possible the semi-automatic update of the database through the contribution of each archeologist working on the field by supplying all the data (qualitative and geometric) related to the excavation, through a standardized form available online.

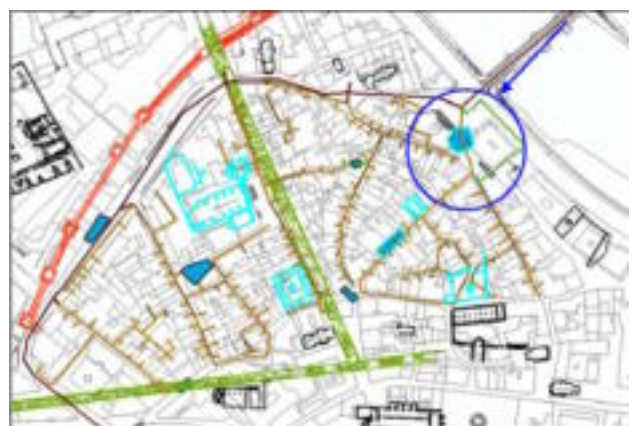


Figure 10. A possible future situation according to the implemented prototypical database: the choice of the best path for new underground lines is based on a GIS performed cross-analysis attaining both the existing lines and the archaeological finds.

5. CONCLUSIONS AND PROSPECTS

S.I.T.A.S. and In.Forma constitute a synergic project representing a remarkable application of the new geomatics techniques to the urban archaeology. They should allow for efficient (fast and low cost) and standardized archeological data collection, archiving, management and interpretation and may play a relevant role for a better heritage preservation and urban planning in so complex a reality as Rome is for archeology.

An possible and expected by-product of the project is to force archeologists to learn new geomatic techniques which surely may improve and standardize the quality of the data they collect, manage and analyze.

Further investigations and experiments are certainly required in order to completely develop the whole project; in this respect the already started cooperation with SASR officials is crucial.

Two main research paths have to be followed in the next future: low cost GPS receivers suited for DGPS surveys must be tested in order to assess the achievable accuracy in urban environment; open-source GIS and Web-GIS must be concerned in order to lower the designed system cost and to allow more easy customizations, according to recent indications of the Ministry for Innovation regarding the e-government.

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