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Teaching and Researching with the GIS: an archaeological story

Paolo Carafa[a]
[a] Dipartimento di Scienze dell'Antichità, Sapienza University of Rome, Rome, Italy
Email: paolo.carafa@uniroma1.it

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Abstract

The aim of the paper is to present the gradual evolution of standard operating procedures applied both in research and teaching since 1992 by the Chair of Archaeology and History of Greek and Roman art, University of Rome "La Sapienza". IT tools and GIS applications, in particolar, we developed during this fifteen year to manage large quantities of records and data-sets from wide area stratigraphical excavations and archaeological surveys are also briefly presented.

Keywords: Archaeology, Landscapes, Architecture, Research, Teaching

1. Introduction

Since 1992, the Chair of Archaeology and History of Greek and Roman art, University of Rome "La Sapienza", directed by Andrea Carandini (1992-2009) and Paolo Carafa (2009-to date), has promoted or has been involved in systematical large scale analyses. Wide area stratigraphical excavations as well as archaeological surveys devoted to the reconstruction of ancient urban and rural landscapes, have been carried out in selected cities and areas of ancient Italy, including major archaeological centers such as Rome, Pompeii. and the Etruscan city of Veii. Applying "traditional" archaeological methods and strategies of investigation, we had nonetheless to face a twofold challenge: to recover, collect and analyze large amounts of very detailed, rapidly increasing data-sets on the one hand, integrate the fragmented framework emerging from field collected evidence aiming at wider historical interpretation/reconstruction and cultural evaluation of archaeological and cultural heritage under investigation on the other. In 1998, thanks to more substantial funding opportunities provided by the Ministry of Education University and Research, we could turn to IT tools. GIS applications, in particular, seemed to us the only way of preserving high quality standards for graphical geographical and spatial representations and analyses. Over the last fifteen years, the use of Information Systems has gradually become our standard operating procedure in field and lab research and the core of our teaching programs for undergraduates and graduates students, fellows in the School of Archaeology and PhD candidates.

The aim of this paper is to briefly present the GIS applications we developed during this fifteen year, "archaeologically" oriented experience.

2. Phase 1: intra-site analyses, volumetric analyses and 3D models (1998-2000)

Since 1985, under the scientific direction of A. Carandini, research on the northern edges of the Palatino, in Pompeii Insulae VIII, 2 and VII, 9-11 and in the central monumental area of Veii has been carried out. In 1998 we started planning the creation of a computer assisted System able to manage the whole archaeological data-set and to perform automated information recording and elaboration. The first task of our project was to create archives updated day by day with the information collected in the field, in order to extract diachronic thematic maps (phase maps) from them. The computer assisted systems existing then allowed the management and the storing of data with the possibility of limited queries only. Therefore, since our final goal was to quickly develop a stratigraphic sequence to be analyzed phase by phase, we decided to use a GIS as the engine of our final System, as it could reflect our scientific fieldwork procedure. This would have made the reconstruction of phase-to-phase image sets for historical interpretation easier.

As our final aim was to develop a methodological and strategic pattern for the study and the analysis of an archaeological deposit, we worked out different operative steps, which gave us some kind of feedback, a continuous information improvement resulting in various layers. The final result will be the output of the information, characterized by a retroactive cognitive value, useful for the screening and for an deeper analytical study of the monumental complex.

Firstly, because of the huge amount of data and their typological diversity, we carried out an accurate analysis on previously collected data, both written (Stratigraphical Unit Sheets – SUS) and geo-topographic records (plans, sections, etc.). Secondly, we tried to define a SUS standard from the different data-sets, creating a thesaurus of appropriate terms for every class of data, in order to provide the user with a previously assessed data-entry. This was in order to avoid lexical problems and data redundancy. The same kind of analysis was performed almost along the same line on graphic documentation, examining the general and detailed plans and then digitizing them.

The main function of our GIS should have been the reconstruction of the relationships existing between archaeological finds and spatial distribution of data. In order to be as accurate as possible in using very detailed and precise (even in geographical terms) information, we decided to use a vector based GIS.

Therefore from the first phase of the research project, the computing application requires the definition of an operative path for the normalization of different information through different layers and for the final goals (topographic base reconstruction, overlapping of SU in one file, linking of collected data code to the spatial information through an id). Starting from these premises, we established the following different steps of the research path:

a) codifying of data and creation of the database;

b) elaboration of the vocabulary and algorithms for the control of data-entry;

c) digitizing of cadastral and photogrammetric maps and SU plans making up different layers for each SU;

d) geo-referring of digital cartography and attribution of an id code to the single SU graphic representation;

e) implementation of cartographic and database data in the GIS vector engine;

f) realization of a graphical user-friendly interface to simplify the display of data.

The work flow was broken down into different phases. The first one – planning the archives – took a long time for the analysis and the evaluation of problems concerning the data codification. Keeping in mind that the information will be managed by several users (students and researchers), we chose a relational architecture, rather than an archive linked together by a primary key.

The first archive contains general information about SU reflecting the Ministry SUS standards. The second one is used to record the graphical documentation. The last one is about materials and finds. In order to simplify the data input phase, we created a hierarchical and modular data-entry System that leads the user through the choice between alternative values, using user friendly interfaces developed by us and managed with hidden algorithms. The next step was the digitizing of various maps and overlays (essential for the correct positioning of the finds and the complete visualization of existing graphical data) which allowed us to test our GIS based System.

From this moment on, we were able to work out outputs of phase plans directly from the collages of different digitized and geo-referred US plans (“overlays”). As we needed to create several layers for each US, we were obliged to establish precise rules for the digitizing of each single 1:20 map. Then we proceeded to the geo-coding of the relational database (with 1:1 and l:n relations), thus establishing different joins and links between databases and associated graphical entities, in order to allow simple and crossed sql queries.

At this point thanks to the implemented relational system, the user could easily produce thematic maps and layouts using the sql query functions, also saving the themes obtained in a new view of the same project.

Our final task was to create a System capable of managing information and data from new excavation projects (Pompeii just at the beginning by that time) as well as data of already excavated contexts (Veii and the Palatine Hill on-going for a longer time).

Considering the specificity of archaeological records, we decided to structure the project in a modular way, each module being at the same time different but complementary to the others. The making and the management of the database and the planning of the final GIS based system are the main elements of the system.

a) Archives and Data-Entry.

The software chosen for the data-entry was based on a typical relational database, ensuring an exchangeable format for the output data. We therefore chose Microsoft Access, a standard used all over the world for the management and recording of data and archives; in order to control the data input phase, we used Visual Basic rel. 6.0, a software with its own source code. Thus we created user-friendly on-screen layouts and we helped the user in the choice of alternative values, selected, implemented and checked by hidden scripts.

The core of the database system is the su table, where the SU number is the primary key. The making of combo boxes containing different vocabularies, available for ali the tables, allow us to reduce mistakes during the input operations and to speed up the work.

b) Plans and maps. Digitized data.

This step presents a few problems in some cases, especially for the lack of control points necessary for the geo-referring. Therefore we created polygons/blocks identifying each SU with its own number as id key.

The use of cad for the recording of graphical documentation in an archaeological excavation makes it possible to reach five main goals:

- saving time, avoiding long manual drawing operations;
- quick control of the excavation;
- outputs and plotting of thematic maps;
- realization of vector bases for GIS use;
- preliminary operations for the 3D model.

We used AutoCad rel. 14 for the digitizing of maps, sections, overlays, especially because its output formal (.dwg) is readable and editable by almost all the GIS packages.

The use of IT for the management of archaeological excavations is fundamental at least during the recording and the preliminary analyses of the collected data. A correct arrangement of the recorded data could provide the archaeologist with a lot of advantages, increasing the analytical possibilities and the control capacity of the information. Therefore the planning of the computer assisted system to be used on an archaeological site is very important. Having claimed that a single system for the management of all the different archaeological research projects does not exist, there are nonetheless some common approaches and problems. Above all, the complexities of physical relationships between objects and contexts in an excavation are extremely important. These relationships must be evident to the final users. However, the archaeologists always try to consider the data as more or less distinctive groups, not correlated to each other, such as SUS, finds preliminary recording sheets, objects, photos, drawings and so forth. Thus we could imagine having different containers available in a tabular form, where the labels refer to the information recorded in the container. Such containers or data tables could be numerous and the data must be classified in order to manage the complexity of the archaeological record as a whole. For example, the information recorded as walls will be different from the information related to floors even if they do have some common data, such as excavation date, fieldwork director, etc.

For the final GIS engine we chose a desktop mapping software instead of creating the System ourselves. Considering the power/cosi ratio of the GIS software on sale today and also considering the economic and physical efforts that the making of such a System will require, we preferred one of the most widespread GIS software: esri ArcView rel. 3.1 with some optional extensions.

Once the System was ready to operate and the data-bases full of information, we decided to move a little forward and create a GIS based 3D model of the stratigraphic sequence. The selected data-set was collected in one single room (Room VII) of a Pompeian house: the Casa della Pescatrice.

The main aim of this new experiment was to test a new standard of documentation, consisting not only of a graphic documentation but also of a research tool.

As we decided that our GIS would consider even the neglected aspects of elevation, we put great care in the recording of SU. Never until now had the traditional documentation of an archaeological excavation recorded all three dimensions of space. The few elevations marked on the excavation plans and sections are in fact never satisfactory, because they can not represent the entire profile of the entire SU surface. On the other hand, the SU volumetric data had become in the past years more and more important. Following this idea, we elaborated what we considered a qualified strategy for fieldwork data acquisition. For data recording, we used an electronic total station (ETS) and a digital photo camera. We wanted the documentation strategy to include the survey of control points, borderlines and internal surface points and the photos of each SU. The post-processing phase is based on two data formats: the .dxf files coming out from the ETS and the .tiff digital images. At this stage, our problem was to optimize the survey proceedings and timings; with this idea in mind, a long and complex recording methodology would have been totally useless.

Giving the SU volumetric value as the space between its surface and the surfaces of the SUs covered by it, our methodology (i.e. recording the complete three dimensions of a SU) is limited to the survey of the surface of each SU. Any SU has been surveyed with an average of 100 points per square meter. When the SU surface was rugged, we registered up to 400 points per square meter.

The innovative aspect of this methodology is the way we have recorded the shape of the US as a solid volume. As a matter of fact, the bottom of a given SU is the part of the underlying US/USs covered by its own projection. It means that the surface of a SU (which we will call upper surface from now on) touches the underlying SU surfaces (SU bottom from now on) in a portion of space limited to its extension.

At this stage we realized that the ortho-rectification of the digital images of SU was necessary. Once the images have been ortho-rectified thanks to the four control points surveyed by the ets, the photo was geo-referred and linked to the topographic data of SU, following the same co-ordinate System.

We decided to use an Arc View extension, 3D Analyst, to build the tin of the upper surface and of the bottom surface of each SU. As those tin overlapped on the borderline, we could see the SU as a single solid. On the upper surface tin we overlaid as texture the geo-referred and ortho-rectified photo. In this way we obtained a jpeg photo, including the values of the elevations and two different tin that allow us to calculate the volumetric values.

The volumetric count was made by calculating the space between an upper surface and a bottom surface, using the "cut fill" function of Arc View.

We must underline also that importing the ortho-rectified and geo-referred photos and points onto a cad we could also produce a "traditional" plan of any recorded SU, avoiding the usual metrical errors occurring in hand-drawing (Carafa and Carandini, 2000; Carafa et al., 2002).

3. Phase 2: large scale analyses and predictive models (2002-2005)

Landscape archaeology has been a core interest activity in the frame of our research activities. In 1993 a vast survey program in the Roman *Suburbium* started, with the aim of reconstructing the changing landscape and analyzing settlement and land exploitation patterns in the area surrounding the ancient city of Rome from the Iron Age (9th century b.c.e) to the Middle Ages (6th century c.e.). GIS was "the" tool to be used to manage this kind of field research (Capanna and Carafa, 2009).

One of the most debated items in the recent discussion about archaeological field survey is the relation between so called "archaeological visibility" and the methodology of collecting and interpreting data. In particular, how the degree of visibility – that is how easy it is to see surface scatters of artifacts due to land use – influences the possibility of identifying ancient sites and the related settlement topographical distribution. As is now well know, the more we see the more we find and this means that the recorded site distribution in any survey has not to be considered as a face value but just what land use conditions let us see/find. To avoid such a difficulty, mathematical algorithms have been selected to reconstruct a precise as possible average distribution of sites per square kilometer.

We assumed seven degrees of visibility/land use: 1) highest: ploughed fields; 2) good: ploughed fields with plants beginning to grow; 3) medium: fields with growing or grown plants; 4) low: un-ploughed fields or clear woodlands; 5) lowest: dense woodlands; 6) *nihil*: urbanized area; 7) no evidence: inaccessible areas or areas for which it is impossible to recover the visibility degree at the time of previous survey/surveys. Any degree has been turned into a mark/value (1 to 7) to be considered by the algorithm.

The correction has been elaborated according to the two following different formulas, in order to eventually compare different values:

a) $k = d / (i * v)$

where "d" is for the average distribution of archaeological sites per square kilometer, "I" is for the area investigated by one researcher per day, "v" is for the visibility score and "k" is the "corrected" number of sites to be assumed distributed in the areas classified by the visibility score inserted in the formula (Terrenato and Ammerman, 1996);

b) *corrected number of sites = recorded sites* * (x / *visibility score*) (van Leusen, 2002).

Moreover, using the ArcView ESRI software, we also developed a mathematical procedure to predict the possible density of sites in uninvestigated areas or in areas with a visibility score from low to *nihil* (Figures 1-5).

4. Phase 3: AIS, The archaeological Information System (2005 - …)

Managing excavations and rural landscapes we realized something unexpected was within reach: linking in one Information System not just archaeological records but any kind of document preserving information about objects, places, buildings, events connected to any ancient time and/or place.

Since the publication of Forma Urbis by Rodolfo Lanciani (1893-1901), no archaeological map of Rome has been made that contains the discoveries made since the beginning of the 20th century up to the present day. Instead, in 1990 the Carta dell'Agro Romano was produced, a basic tool for the management of the surrounding area of Rome, but now a supplement and a new edition with more appropriate symbolic depiction of sites, cartographically and archaeologically speaking, is needed.

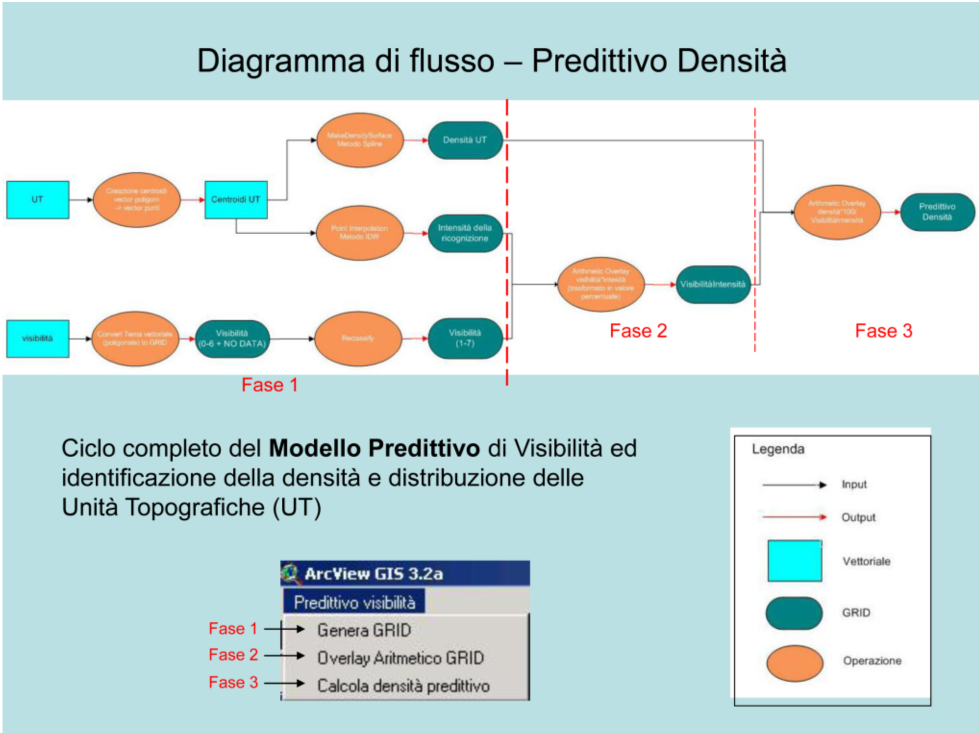

Figure 1. Predictive Model. Flux diagram.
Author: Nicoletta Capanna, *ES Progetti e Sistemi*, Rome.

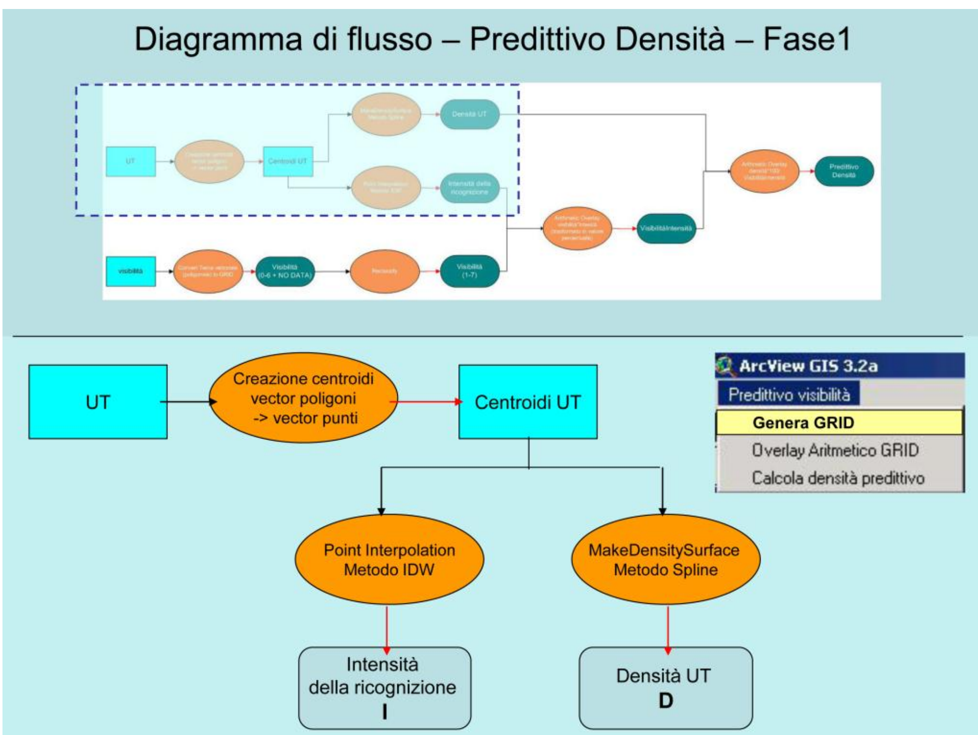

Figure 2. Predictive Model. Flux diagram. Phase 1a. Managing archaeological records.
Author: Nicoletta Capanna, *ES Progetti e Sistemi*, Rome.

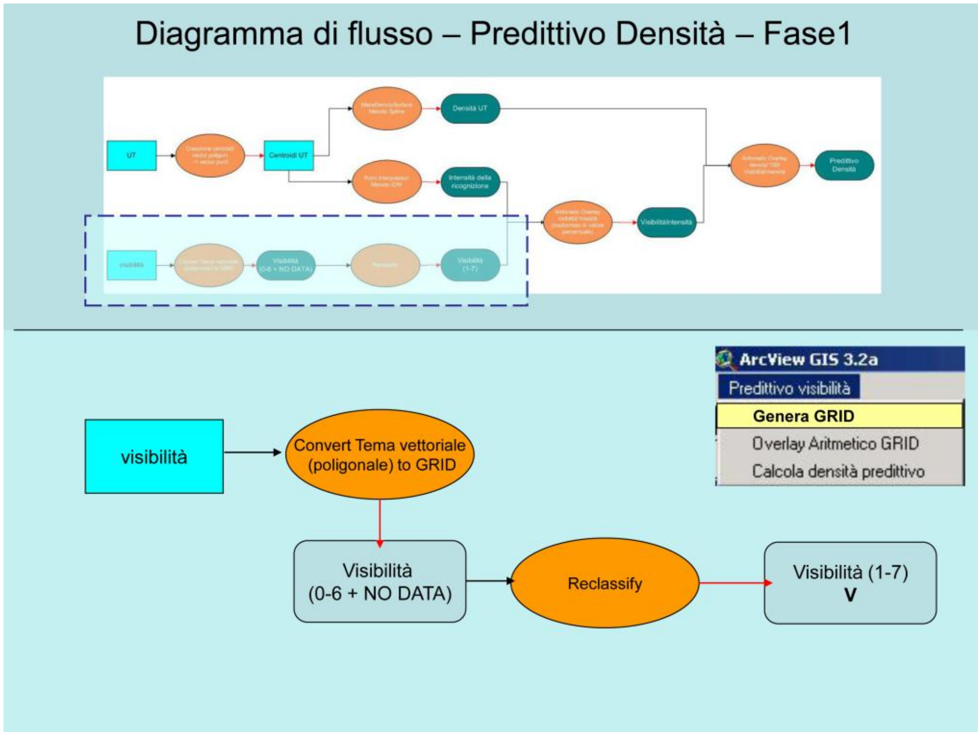

Figure 3. Predictive Model. Flux diagram. Phase 1b. Assessing visibility score.
Author: Nicoletta Capanna, *ES Progetti e Sistemi*, Rome.

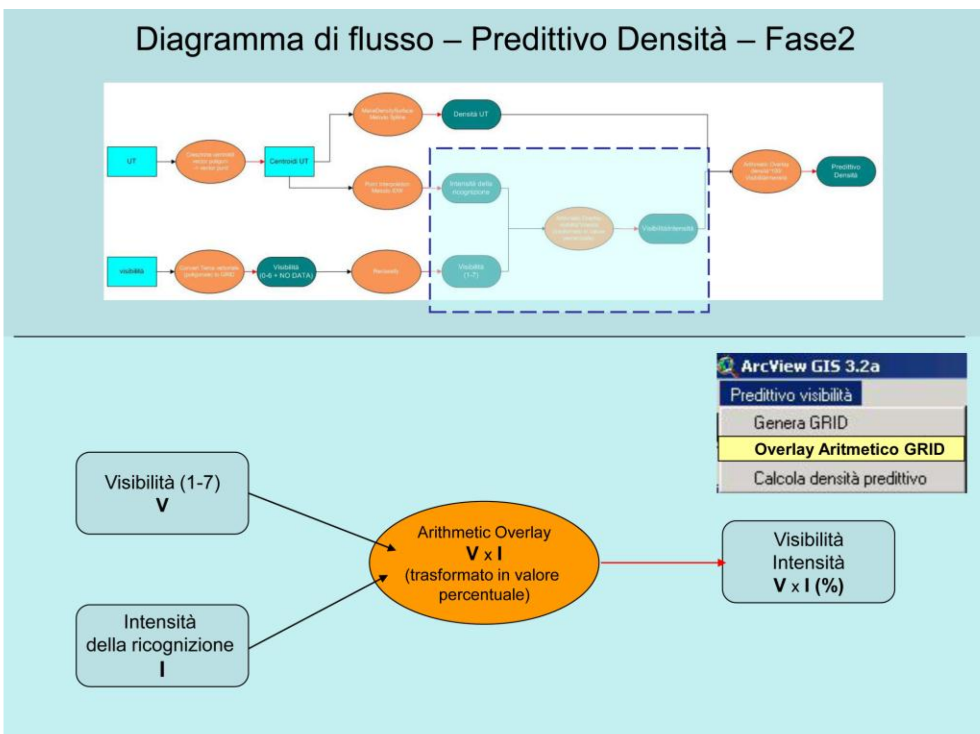

Figure 4. Predictive Model. Flux diagram. Phase 2.
Author: Nicoletta Capanna, *ES Progetti e Sistemi*, Rome.

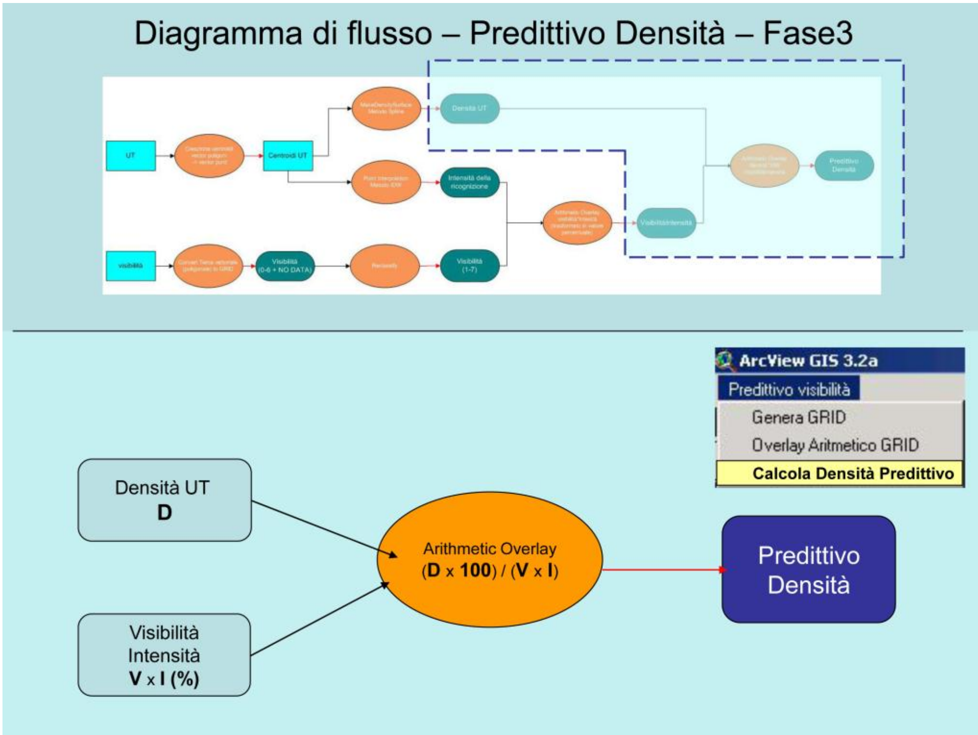

Figure 5. Predictive Model. Flux diagram. Phase 3.
Author: Nicoletta Capanna, *ES Progetti e Sistemi*, Rome.

A recent and useful aid in the planning of works in urban areas, although still in the experimental phase, is the Carta per la Qualità, introduced by the new Piano Regolatore Generale di Roma. In fact, the Carta aims to register and quantify the stratigraphic potential of the city. Regarding museums, there is a lack of museums of the city and surrounding area in Rome, except for a few rare exceptions, such as the Museo Civico di Modena and the Museo della *crypta Balbi* at Rome.

GIS could be turned into a much more powerful tool, oriented not just to geographical analyses but also to lost architectures and landscape reconstructions, that is to the creation of scientific images and narratives of great historical and cultural interest: an Archaeological Information System.

The AIS – Archaeological Information System – is a tool (protected by a patent since 2006) which, through the use of a new model of specialist information management (which combines the latest computer technology with innovative methods of scientific collection and analysis of data), makes it possible to analyze and reconstruct the ancient landscape through the integration and comparison of any type of material, archaeological, historical and cultural "document".

All the classified "documents", in all investigation contexts, contribute to the identification and/or characterization of one or more of the components of the ancient landscape (individual buildings, monuments, blocks, neighborhoods, infrastructure etc.)

Since these latter represent a determined or determinable geographical area, it was decided to assign absolute geographical coordinates to all the elements to be classified transferring and linking them to a current map in a vector format. This format, in fact, makes it possible to break down the graphic object into significant levels in order to obtain thematic plants based on the cognitive needs of the system's user.

The main target of research which created the AIS was to implement interventions aiming at:

- protection and knowledge of the archaeological and cultural heritage –

visible and invisible – in the national and international field;

- knowledge and management of the territory and of the heritage of the cultural property;
- development and enhancement of cultural heritage;
- development of the economy related to this particular field and to the cultural management;
- advanced training.

The first application of this system – thanks to public funding for a total of approximately 1 million euro – was made on the city of Rome, creating a reference model for future projects or developments.

An instrument which helps in the study and understanding, relating, enhancing and safeguarding of the ancient city of Rome – and what is left of it today – from just before its birth (in the mid-ninth century B.C. circa), to its final de-structuring (in the mid-sixth century A.D. circa), through the reconstruction of the landscapes that have come down through the ages, is now available.

It has not been only a question of updating the available knowledge or, more simply, the archaeological map of Rome. It was necessary to create new images that would give back the physical aspect of the urban landscape and that would bring it to life again. We are not just content with analyzing the many elements still visible of the ancient city. The connections which have been broken through time have been rejoined, between objects and architectures, visible and non-visible buildings to acknowledge the elements that compose the urban landscape.

The landscape – urban or rural – is like a number of boxes put one into the other, that form more and more extended and complex agglomerates, beginning from the smallest element: the building. It is an element that can be analyzed by applying methods typical of archeological stratigraphy to rebuild history. Many buildings form a “monumental complex”. Many complexes form a “block”. Many blocks form a “district”. All the districts form a city.

To make all this comprehensible, a deep innovation in analyses and data collecting methodology was necessary: there must not be any distinction among things, texts, ancient or modern images and monuments; between beautiful and ugly or worthy or not worthy objects. It all contributes to giving back a part of the information necessary to rebuild the context.

This System has been developed with a GIS software, devised on the Intergraph GeoMedia software. The cartographic basis is the one used by the local administration to draw the City Plan of Rome. All the ancient structures and the five classes of objects mostly linked to architecture have been filed, classified and put into the databases connected to the System: paintings and stuccos, floors, architecture decorations, sculptures and inscriptions. All the graphic information is in vector format (more than 100,000 “graphic objects” have been included), geo-referenced and non symbolic.

The “ancient” documents also include: the slabs of Forma Urbis Marmorea (the enormous marble city map that the Emperor Septimius Severus wanted to exhibit at the beginning of the III century A.D.; the literary sources reportable to buildings and/or pinpointed places in Rome, and ancient iconographic sources (portrayal on coins, relief etc.). The information put into the system is integrated by modern iconography and historical cartography: the first zenithal map of Rome was drawn by G.B. Nolli in the XVIII century and was published in 1748 (obtained by kind permission of the CROMA Centre, Roma Tre University), the archaeological map of R. Lanciani and currently in acquisition of the Rome urban cadastre of 1828. And lastly, geological and hydrographical data have been geo-referenced in the area within the Aurelian Walls.

The on-line accessibility was made possible of the databases and images acquired and/or produced during the earlier research and the proposed project (plan reconstructions and phase depictions, three-dimensional reconstructions, historical images etc.) through a website called “Imago Urbis”. Due to the system upgrade the web site is presently not on-line and the exact forms of access to the renewed site and to the associated databases still has to be defined

The system can be examined in chronological phases or in typologies. So the research can be aggregate in significant contexts and, on the basis of all the available information, the urban landscapes and the architectures can be reconstructed. In this way, step by step and where the research allows it, the ancient city comes back to life, with its landscapes and the relations among the architectures, not only reconstructed but also re-contextualized.

Therefore the System has expressed all its scientific capability, but the communication can be enhanced with the intervention of specialists, who we have asked to illustrate some of our reconstructions.

The reconstructions – graphic and virtual – preserve the correctness of the analyzed archaeological data to create them, and they lose the coldness and the reading difficulty of the first draft of the information. They are beautiful and comprehensible. The Information System, behind all this, remains the symbol of quality and reliability of the popular elaboration that it sets out to produce, whether it be narrative or iconographic. In this way the research does not only represent a worthwhile instrument for the safeguard of memory and the knowledge of the past, but also for a communication to a wider and non-specialist public (Carandini and Carafa, 2012).

All this turned to be a key element also for the educational sphere. Students and graduates have now a IT dedicated tool to manage archaeological record in a contextual perspective thanks to the inter-connection of archaeological historical and any other kind of evidence and thanks to the connections of any data-set to any time and any place. Secondly we, involved in teaching and education, can now explain in a very clear way how evidence can be managed to produce hypotheses and reconstruction. The patterns of our epistemology are supported – and somehow tested – by the AIS/GIS procedures, even in class activities.

5. Conclusions

Special attention must be dedicated to IT, often used by archaeologists working on computer assisted applications.

When we turned to Information Systems, the usual questions from archaeologists were: “What is an excavation GIS for?” or “How will it be made? Which benefits could I get from it? Can it be used for analytical queries and for the making of historical and interpretative models?” or simply “Will it work?”.

Keeping such a situation in mind, our main aim was to create a team able to manage a computer and to use it for its own needs.

Our final System is not the ultimate one but, nonetheless, it is functional and useful for the management of our research and teaching activities.

More still has to be done. The completion of the activities described above constitutes the introduction to a series of actions and products.

The further development of the Information System could form the basis of scientific archaeological, and more general, publications (such as, for example, district guides of Rome).

The Archaeological Information System could represent an essential tool for the creation of a Centre of Excellence for University teaching, advanced training, heritage management, for the planning of any kind of works in urban and/or rural areas, and for the professional development of archaeologists and tourism operators.

From this viewpoint, one can foresee dynamic integrations of the Archaeological Information System with the documentation and instruments used by the bodies in charge of higher education and urban and rural areas management (cadastral units, references to administrative files or acts, constraints etc.).

To sum up: archaeology is a perfect experimental area for digital technology. There are several applications possible, which could help us to communicate Antiquity as a fascinating complexity.

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