

# **Prospecting for archaeological features with Ikonos satellite images. A case study around Falerii Novi (VT)**

## **Introduction**

Aerial photographs and satellite images provide complementary information for the study of archaeological landscapes. The usefulness of aerial photographs in landscape studies, site surveys, and spatial analysis of individual sites is well established. Until the commercialization of very high resolution (VHR) satellites (Ikonos 1999; Quickbird 2001), satellite imagery was available at a resolution so coarse that its use was mostly limited to environmental studies. Lower costs and wider availability have led to the increasing feasibility of the purchase of VHR satellite images for archaeological investigations.

The Ikonos satellite provides images at a resolution of 4m multispectral and 1m panchromatic. Studies have shown that images at these resolutions are effective for identifying archaeological features in agrarian or partially built-up landscapes (Campana 2003; Lasaponara and Masini 2005). The VHR satellite images and air photographs were used to characterize the area surrounding Falerii Novi, a Roman town in central Italy. Special emphasis was given to the determination of the correct processing techniques for the best use of the satellite images in combination with the air photographs.

## **The area around Falerii Novi**

Falerii Novi is located in the region of Viterbo in central Italy (Fig. 1). The town has been previously studied as part of the Tiber River Valley Project by the British School at Rome. The town dates from the Republican period; the traditional date given is that of 241 BC.

The geology of the area around Falerii Novi consists of a series of layers of tufa eroded by streams which have effectively created a series of plateaus divided by gorges referred to as *fosse*. Most uncultivated land is covered by dense low scrub. The land is cultivated except immediately along the *fosse* where heavy tree growth dominates. Archaeological features are almost invisible along the *fosse* where the tree growth obscures any remains and are difficult to detect on the ground in areas where scrub dominates, making site prospecting difficult.

The remains of the town of Falerii Novi consist of an almost complete circuit of standing town walls, which are clearly visible in the satellite images and air photographs, and a large number of buried structures as discussed in Keay and Millett's geophysical survey (Keay *et al.* 2000). In the surrounding area a network of small roads and outlying buildings was identified in the satellite images and air photographs, most of which were previously unknown. A number of features representing small buildings were detected in the immediate vicinity of the town.



Fig. 1 – Falerii Novi seen from the air (5CM-703 5019).

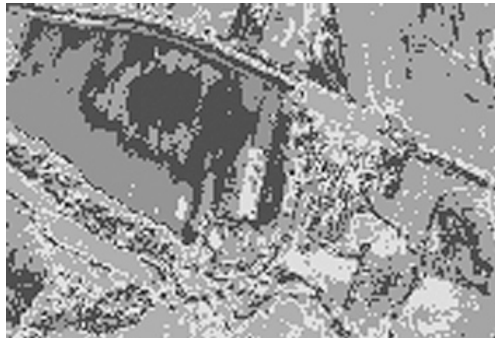


Fig. 2 – Secondary classification of the images highlighted this circular anomaly in a fallow field and a number of adjacent linear features.

Further from the town small clusters of rectangular structures appear to represent farmsteads. These buildings are often detected in the vicinity of linear features which are interpreted as part of the local road network or field boundaries. The overall picture produced by the satellite image survey is one of sparse rural occupation without an organized, i.e. centuriated, field system. Further interpretation will require detailed fieldwork.

## Analysis methods

WWII era air photographs were digitized and orthorectified for the area covered by the satellite images. These photographs were then visually inspected to identify features of archaeological interest and provided a basis for comparison with the features detected by the satellite images.

The possibility of automated feature extraction from satellite images remains some years in the future; however, the continued development of classification techniques and filtering algorithms continues to improve our ability to interpret

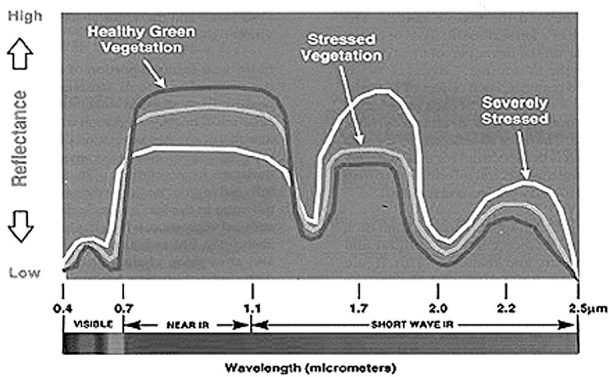


Fig. 3 – Vegetation stress is particularly visible in the NIR channel of Ikonos images (after Short 2004).

the images and extract information for archaeological purposes. The classification system was organised based on the ground-truth data for a sample of the total area until a specified high level of accuracy was reached. The semi-automated classification of large sections of landscape based on training expedited the process of potential feature identification. This initial level of classification was used to automatically exclude built-up areas from inspection and to identify areas unlikely to produce archaeological features, i.e. orchards of densely planted nut trees. A secondary level of classification was performed within each land-use category in order to separate those pixels which reflect in the main part the distribution for that land use category from the outliers which represent areas of variation of natural or anthropogenic origin (Fig. 2).

For example, a large circular anomaly is clearly visible in this field after secondary classification. A number of linear marks are also visible. This circular anomaly was not obvious in the original classification because the subtle variation in reflectance was swamped out by the algorithm used for the original classification. By highlighting internal variation within each class the secondary classification serves as a contrast-enhancing filter, bringing out anomalies of small amplitude caused by vegetation stress, water retention, etc. before they would be visible in air photographs (Fig. 3).

Edge detection algorithms and visual inspection were then used to identify features of a possibly anthropogenic origin. Due to the complexity of the images and the reasonably small size of the dataset, visual inspection was emphasized over edge detection algorithms. Comparison with WWII era aerial photographs was also undertaken to check the accuracy of the classification scheme.

## Results and difficulties

The study of the satellite images produced over 100 linear marks of interest, many of which did not appear in the air photographs. The main roads in the area, the Via Amerina and the Via Ciminia were clearly visible for most of their respective



Fig. 4 – A section of the Via Amerina (running top to bottom center) and a connecting road.



Fig. 5 – Marks visible in air photo are drawn on in black lines. White arrows indicate the corresponding mark in the satellite image.

courses and known sites such as the Castellaccio, north of Falerii Novi, were easily spotted. The local road network and a series of outlying buildings are visible in the immediate vicinity of the town (Fig. 4).

A sparser network of roads and buildings is apparent at a greater distance. The single channel bands consistently produced anomalies of a potentially archaeological nature. However, the higher resolution panchromatic image was needed to confirm the spatial characteristics of many of the smaller features. The presence of plowed out material in the soil near buried structures resulted in a blurring effect in many cases, where it was evident that an anomaly was present but its linear nature was not apparent in the 4m resolution images. Fusion of the panchromatic and single channel images produced more interpretable results.

Significant shadows due to the late hour in which the data was collected also contributed to the problem of blurring observed in the single channel images. While the variation in elevation was sometimes a clue to the presence of archaeological features, the equivalent of shadow marks in air photo interpretation, the spatial

characteristics of the features were masked to some extent. The fusion of the pan-chromatic and single channel data again led to improved results.

The WWII era air photographs consistently produced features that did not appear in the satellite data and *vice versa*. A variety of factors may account for this discrepancy. Changes in land-use, the time of year, and variations in weather are all potential suspects. The effect of the change in land use was directly addressed by the comparison.

## Tracking heavily damaged features

Satellite images, when combined with WWII era air photographs, provide insight into the effect of deep plowing and mechanized agriculture on unexcavated sites in the field and the appearance of surface material. Larger sites and those with deep walls, earthworks or ditches tend to survive the effects of deep plowing and continue to exhibit linear marks. These sites will develop a 'blur' area where plowed out material has been scattered across the nearby surface, but would still be recognizable in air photos and satellite images (Fig. 5).

Enough material remains in the ground in approximately the original spatial configuration that linear marks persist. However, smaller sites or those closer to the surface may be plowed out entirely after repeated exposure to deep plowing.

The overlaying of the digitized air photos and satellite images allowed a direct comparison of the landscape at the two temporal points. A number of features appearing as linear marks in the WWII era air photos appear in satellite images as irregularly shaped areas of a distinctly different reflectance value from the background spectrum. It was concluded that these anomalies in the satellite images were the plowed out material from the sites which had remained on the surface. These sites are still visible on the surface, although significantly less recognizable than those with characteristic linear marks. These features will generally not be identified by edge detection algorithms, but rather create a 'patchy' appearance.

## Conclusions

The study of VHR satellite images was successful in the detection of a number of new sites in the area around Falerii Novi, confirming its practicality as a prospecting tool. The ability to track damage and the erosion of unexcavated archaeological features through satellite images is useful to the conservationist. Comparison with historic air photographs gives a longer timeframe than can be obtained using only satellite images and is of considerable use in spanning the period in which mechanized agriculture was introduced in many parts of the Classical world. The process of the classification, analysis, and interpretation of satellite images requires careful thought in order to detect subtle anomalies. Improvement in classification and digital analysis methods is necessary for the continued development of the use of satellite images in archaeological studies.

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# **Moving without destination. A theoretical, GIS-based determination of routes (optimal accumulation model of movement from a given origin)**

## **Introduction**

In many archaeological contexts, the analysis of movement is a very difficult task, since the identification of direct material evidence of ancient routes is not always possible. The use of GIS tools has introduced new approaches, and a good number of experiences are already available (for example, Harris 2000). In this short text we will present a methodological proposal to analyse the possible influence of routes and paths in the location of archaeological settlements, from the basis of cost maps.

The general aim here is to explore to what extent communication (understood as actual nearness, as accessibility) is an ultimate criterion for locational decisions. Our aim is not simply to explore direct relations between archaeological settlements in terms of cost, but to analyse the proximity between archaeological sites and optimal areas to conduct movement<sup>1</sup> (in terms of cost).

## **Methodology**

Our proposal consists of representing the accessibility to the territory from a given departure point but without any particular destination, from a determination of optimal routes to guide movement. That is to say: given a starting point in an area, such as a settlement, to determine in which directions and through which points movement would be easiest. The proposal tries to complement both the determination of “natural pathways” (determined after friction surfaces, Bellavia 2002) and the calculation of “optimal pathways”, with a determined origin and destination.

The main problem with the calculation of natural pathways is their tendency to different forms of environmental determinism, as long as neither an origin nor destination are defined, understood as socially conditioned geographical positions. In the case of the optimal routes between two points, quite the contrary happens: the optimal routes are conditioned by both the origin and destination points, that are assumed *a priori* to be necessarily connected.

<sup>1</sup> This work has been developed as part of the research projects “Autopista ao Pasado: Investigación e Protección do Patrimonio Arqueolóxico nun Proxecto de Obra Pública (ACEGA D+I)”, PGIDIT04CCP606003PR Plan Galego de I+D 2002-2005 and “Da Protohistoria á Romanización: interacción cultural e dinámica do territorio no Norte da Provincia de Pontevedra” PGIDIT05PXIA23601PR Plan Galego de I+D 2002-2005.

What we are proposing here is not an alternative to those procedures, but an additional one aimed at estimating the setting of optimal routes from a number of given origins (typically, settlement sites), independently taken and disregarding neither specific destinations nor the position of the remaining points. This means that, given a set of settlement sites in an area, we should be able to analyse the relation between their locations and the optimal routes leading from each one of them, in order to explore to what extent those routes are channelling movement to specific points or directions or to what degree they connect sites. We must make it clear that we will not deal with questions concerning the calculation of cost surfaces, a question which has been widely discussed up to now (for instance, Van Leusen forthcoming) and certainly will be in the future. That is not one of the goals of this text, and our proposal will start with cost surfaces previously determined for every settlement, since the criteria employed to do it is now irrelevant.

The proposed methodology can be applied through different GIS systems. What is needed is only the ability to calculate cost maps and flow accumulation models. We have employed ArcGIS 9, so some technical specifications included will be referred to this software.

A flow direction model (Flow direction command-line in ArcGIS) represents the theoretical direction of the accumulation, and is usually employed to determine hydrological models after an aspect map previously calculated from a DEM. However, we will use it in a different way here. To calculate flow direction we will use, as the input surface, a cost map instead of an aspect. In this way, we will drive the cells with a higher cost value towards those with a lower one. For example (Fig. 1), after determining the cost map for a position (archaeological site) on the top of a steep sloped ridge, lowest value cells will be those on the top of the ridge, where slope values are lower<sup>2</sup>.

After the cost map we can calculate the flow direction for every cell, so that cells with higher cost values are oriented towards those with lower values. This way, the cells at the slopes (higher cost values) will flow to the cells on the top of the ridge (lower cost values); in their turn, cells on the ridge watershed will flow to the point of origin, since distance is always a primary cost factor (the lower the distance, the lower the cost).

## **The MADO model**

Once set, we will use the flow direction model to calculate what we have designated MADO (Spanish acronym for Modelo de Acumulación del Desplazamiento Óptimo desde un origen, “Optimal accumulation model of movement from a given origin”). The procedure consists simply in the use of an algorithm to calculate accumulation areas (such as Flow Accumulation in ArcGIS), typically used to determine hydrological models; we will use the previously calculated flow direction map as the input image. To follow the example, MADO will have higher values on the top of the ridge than at the slopes, and cell values will also increase as we approach the origin site along the top of the ridge.

<sup>2</sup> Assuming, in this concrete example, that topography is the only friction factor.



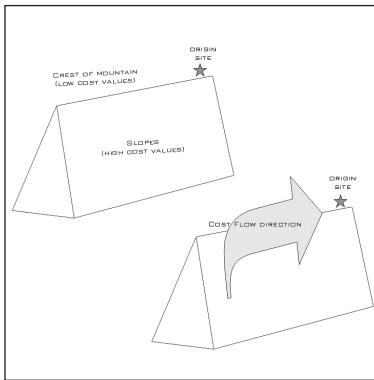


Fig. 1 – Flow direction for a single settlement (star) calculated from a cost surface.

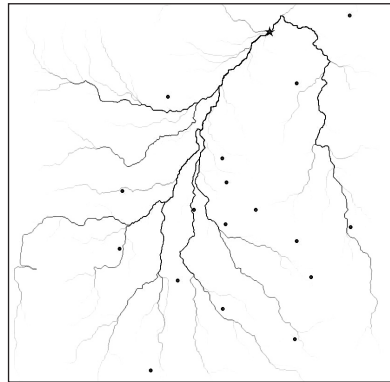


Fig. 2 – MADO. Flow accumulation calculated from a flow direction (the star represents the origin site).

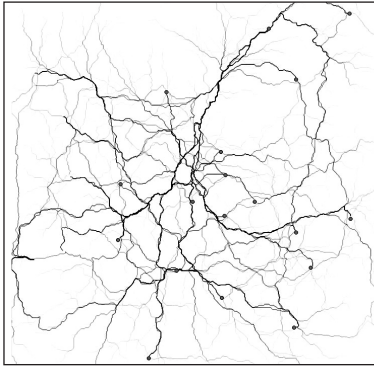


Fig. 3 – Sum of MADO calculated from every single settlement (dots) in the map.

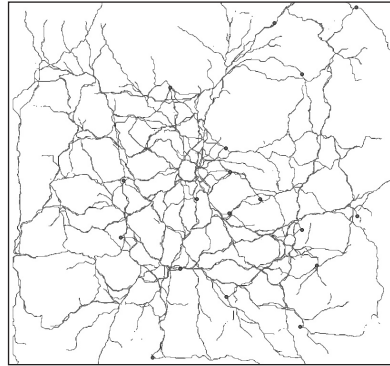


Fig. 4 – Boolean reclassification of Fig. 3.

MADO can be briefly defined as the representation of an accumulation model of lowest cost movement calculated from a given origin and without specific destination points (Figs. 2-4). Once calculated, the resulting image can be reclassified in order to remove low values (non relevant points) and to extract a new image where the highest value cells will indicate areas of potential routes. Despite the apparent complexity, MADO can be useful for different questions. Since destination points are not taken into account for the calculation, and given a suite of settlement sites in an area, this can be a good way to analyze the arrangement of optimal routes starting from every individual site and exploring to what extent these routes are linking settlements into a pathway network. It can also be useful to compare the reliance of “optimal pathways” between two previously defined points.

An interesting experiment is to calculate MADO for every individual site in a given series, to obtain a full range of values that represent the best or worse capability for movement of every position. Since that calculation is based on a flow

algorithm, the result will always be a sort of trend, track map. If we determine isochronal lines from every site, we will be able to establish their vicinity to those “flow tracks” in terms not of linear distance but of actual accessibility. This could be compared to the results of a typical analysis of optimal routes calculated from a previous setting of both an origin and a destination points.

Although MADO clearly has applications for analysing accessibility, it also poses some problems. As we move away (in terms of cost) from the starting point, absolute cell values decrease, since they are not only depending on friction. That makes it difficult to set a general-purpose translation of MADO values into a hierarchy of optimal routes. This problem does not have a straight forward solution, although we can suggest two possibilities. The first one is very simple: to sum up all the MADO for a given series of settlements of a same area. In that way, cells closer to every starting point (settlement) will retain higher values, but values will tend to get balanced between all sites.

The second possibility consists of performing a Boolean classification of a MADO, in order to remove (set to 0) all low values, while considering as valid (set to 1) high values, in order to get a non-hierarchical route network. The problem here is how to define a threshold to set out low and high values. Since MADO values depend to a great extent on the number of cells of the DEM, it is not possible to set a general reference value, as it will always depend on a combination of the extent of the area and the resolution of the DEM. However, it will always be possible to find significant relations between MADO values and actual route networks (either present or historical), so an approach is possible to the relation between the “value” of movement and its materialization (providing that our interest is to explore the processes of formation of tracks).

## Conclusions

In any case, it is quite wrong to present the problem in terms of setting significant reference values from a qualitative (absolute, general) point of view. That is why we will focus on the determination of a threshold between low and high values from a specific (and simple) statistical analysis of every single MADO. A MADO image will consist of a huge range of values, with a very uneven distribution, the majority being in the low part. Having that in mind, the first statistical indicator can be the use of the mean value as a reference threshold. In that way, we will get a network which is still complex but manageable. A further refinement will come from the use of the standard deviation, which will complement the representativeness of the mean.

Once calculated the single MADO for a number of points (settlements) in an area, and reclassified into Boolean images, we will be able to sum all up and to get a hierarchical map of routes for the area. Higher values will represent those points where more routes converge, and subsequently could be interpreted as highly probable locations for tracks or paths with regard to the points used as nodes for calculation.

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# **Integrated application of laser scanning techniques and close range photogrammetry. The case study of the ancient water supply system of Petra**

## **Introduction**

This research project is funded by the Italian Ministry of Education, University and Research and the Ministry of Foreign Affairs and has developed as a joint project between the University of Urbino, Istituto di Geodinamica e Sedimentologia and Centro Studi Archeologici “CESAR”, the Department of Medieval Archaeology (University of Florence), the CNRS, UMR 694-MAP of Marseille and the CNR, ITABC of Rome. The aim of the work is the development of an integrated system of automated topography applied to the remains of the Crusader castle of Al Habis at the western boundary of the archaeological area of Petra (Zayadine 1985).

The monumental site of Petra is located on the left rim of the Rift Valley, in central-southern Jordan (Raikes 1985). The only visible part of the architectural remains consists of tombs and temples dated to the Nabataean period and sculptures within the rock walls (Franchi *et al.* 2004).

Past investigations have emphasized the key role played by rainwater flowing down the facades of the monuments and causing their advanced deterioration. This risk had been considered by the Nabataean builders of these monuments, who succeeded in mitigating its effects by setting up an efficient network of drains and rainwater collection cisterns upslope from the monumental structures. Moreover, these complex hydraulic engineering projects also ensured an adequate water supply for the local population. Today, this drainage system is no longer operational, as it has been blocked by both the accumulation of debris and collapses caused by landslides and earthquakes.

One of the main objectives of the survey is to provide a precise documentation of the *status quo* of the surveyed objects (monuments, buildings, archaeological objects and sites) in order to preserve and protect them, to study and restore the monuments and to present them to the public. Complex objects which are not planar or have ornaments and decoration require high-density and high-resolution spatial data.

Laser scanning techniques and close range photogrammetry can offer two complementary sets of instruments and technologies able to respond to the specific requirements of architectural and archaeological survey.

## **Surveying methods**

In the last two years the team worked at the Al Habis Castle site, chosen not only because its characteristics make it a significant model system upon which to test the method but also due to its relatively small size.



Fig. 1 – The first water channel used to test the software.

### *Topography*

As mentioned above, the most important water collection channels run around the Al Habis site along a curve positioned at a level coinciding with that of the third plateau (Fig. 1). These channels were carved into the rocky slopes, and are still visible today even from the foot of the hill. It was therefore possible to quickly survey their course with the total station equipment and map their position on the 3-D model of the castle.

Given the inaccessible nature of the site, which made it impossible to use Global Positioning Systems (GPS), a Total Station Trimble 5600 was employed in order to rapidly acquire a cinematic view of the points and the measurements for the 3-D model reconstruction of the castle.

This automatic equipment was used with a laser pointer, acquiring points at distances every five meters horizontally and two meters vertically. In this way it was possible to record the route followed along the rock surface with a certain regularity and in a relatively short period of time.

### *Photogrammetry*

The site is not easily accessible, due to the morphology of the terrain and to the collapse of some of the structures of the castle. It was not always possible to use traditional and time-consuming procedures or to apply traditional topographical instruments.

This is one of the main reasons for using digital photogrammetry. The 3D reconstructions of the geometric shape of each single section of the channels were obtained by photogrammetry. The photographs were taken with a Nikon D100 digital camera, without a tripod, and for the most inaccessible places we used an extensible telescopic arm with remote shooting system.

Commercial software (PhotoModeler<sup>1</sup> 5.2) was used for *bundle adjustment*, while the ARPENTEUR and ROMA software were used for automatic or semiautomatic measurements of the surface of the object (Drap, Grussenmeyer, Gaillard 2001).

The ARPENTEUR<sup>2</sup> (Architectural Photogrammetry Network Tool for Education and Research) is a set of software tools developed by the MAP research Group, a French National Research Council (CNRS) laboratory. ARPENTEUR is developed in Java using the library JAI (Java Advanced Imaging) and X3D/VRML for 3D visualization.

The software is based upon a process guided directly by the available knowledge regarding a specific class of objects. In this way, experts can use their knowledge to facilitate the measuring process, thanks also to a series of tools provided by the software. The ARPENTEUR system can be used by professional architects and archaeologists with only minimal assistance from a specialist in photogrammetry.

### *Automatic generation of 3D measures*

Whereas in aerial photogrammetry automatic generation of DSM (Digital Surface Model) has been increasingly mastered, it still remains a research topic in a close range of photogrammetry because of the greater complexity of the scenes. A significant result can be obtained provided that a pre-existing network of 3D-measures is to be densified. With the aim of measuring new points automatically, two multi-image approaches have been explored: area-based and feature-based matching.

ROMA, 3-D Automatic Measurement Principles:

ROMA, **R**epresentation of **O**riented **M**odel for **A**rpenteur, is the first tool built on the I-MAGE method (standing for Image processing and Measure Assisted by GEometrical primitive) developed as part of the ARPENTEUR Project (Drap *et al.* 2003). Roma allows automatic measurement using a set of oriented photographs and a mesh visible on these photographs.

ROMA uses a simplified geometrical model, i.e. a surface mesh, image correlation and oriented photographs to determine 3D points visible on photographs and included in the mesh.

We use four steps in this Semi-automated Primitive Measurement Method, considering that a mesh has been measured and computed from a set of 3-D points visible on at least two images (Fig. 2):

<sup>1</sup> <http://www.photomodeler.com/>.

<sup>2</sup> <http://www.arpenreur.net/>.

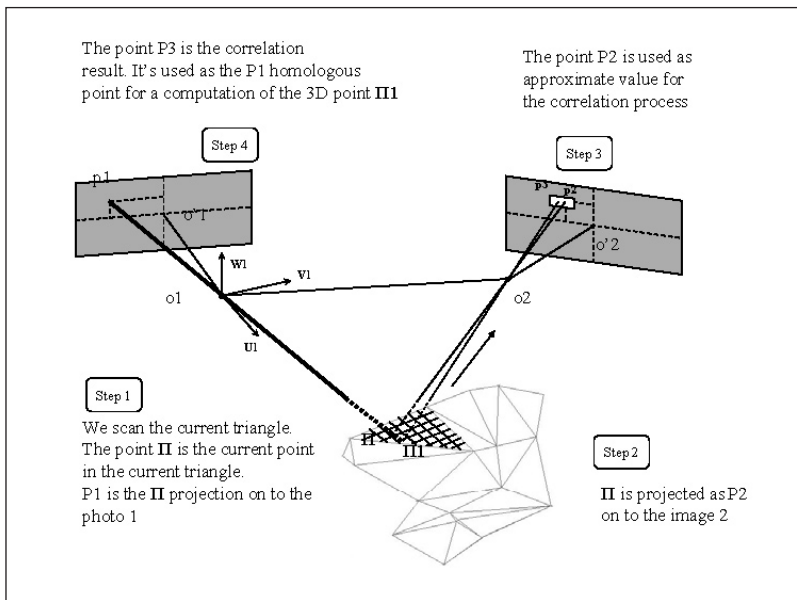


Fig. 2 – Principles of ROMA.

- For each triangle of the mesh we scan triangle and get point II. Each point II is projected as p1 on to the photograph 1;
- II is projected as p2 onto the second image;
- Point p2 is used as an approximate position to initiate the area based correlation process with p1;
- Point p3 is the result of the correlation; p1 and its homologous p3 are used for the computation of the 3-D co-ordinates of III.

This first implemented algorithm automatically generates regular 3D-points through area-based matching. Initially a set of points was measured by the user. This collection of points is triangulated and the regular scanning of the 3D-surface of each triangle provides theoretical 3D-points which are projected on a reference image. The semi-automated Primitive Measurement process called I-MAGE supplies measured 3D-points thanks to automatic correlation with other images (Drap *et al.* 2004). As a geometric-construction-based method, it gives a regular grid but the correlation process tends to fail when it works on low-textured image zones.

Other simple algorithms:

The second algorithm uses the featured parts of images. Firstly, points of interest are extracted by Harris' improved algorithm (Harris, Stephens 1988) considered as the most efficient according to Schmid *et al.* 2000. Then the homologous points of the reference image interest points are searched for among other images. But

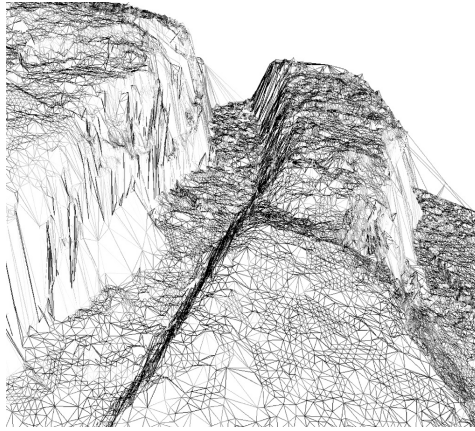


Fig. 3 – 3D view of the generated surface.

the correlation process is limited by two geometric conditions. Out of continuity constraint, when a point belongs to the projection of a triangle from the initial network, this homologous point must be in the projection of the same triangle in the other image. Moreover, each homologous point is checked by exchanging reference and search matrix.

To improve the number of matched points, an iterative method that applies this principle has been implemented. Indeed, corner detector can classify the points according to their degree of interest. Usually only the best points are kept. It would not make sense to take the larger part of the points because it would increase the number of wrong matches. However, we observed that if a point is repeated, its degree of interest has approximately the same rank in the other image. Then the algorithm can match feature points progressively by rank.

Combined algorithms:

Even though the feature-based matching is more robust than the area-based matching, it depends entirely on the repeatability of the detector. Another idea is to combine the two principles to avoid this drawback. For each triangle of the network of measurements, chosen by the user, a reference image is determined and the feature points are calculated in this area. Then, assuming that those points lie on the 3D-triangle, their homologous points are found by correlation in the other images through the I-MAGE process.

Although this method provides many successful matches, the repartition of the points can be inhomogeneous on some scenes if interest points are clustered. The solution used here is a mixed method using this algorithm iteratively.

## Conclusion and future work

The result of this operation is an extremely detailed and measurable 3-D model of the channels that can be used both for classification and study purposes as well as



for virtual tests and simulations of the flow of the waters. The creation of this detailed model made it possible to extract information on sections along the course of a channel and revealed the degree of deterioration of the side walls of the water channel (Fig. 3).

This castle has been studied by the team of Prof. Vannini, University of Florence, Italy as part of the project of the Italian mission in Jordan. The work presented in this paper will be the first step and the basis for a GIS (Geographic Information System) on the Al Habis castle where the topographic and photogrammetric survey will be used to manage all the archaeological data produced by archaeologists on this castle. This interdisciplinary approach gives new interest to the project and will produce an innovative Information System ranging from archaeological study to restoration.

Future work will involve immersive visualization and interaction of the 3D models in collaboration with the team of Dr Paul Chapman from the University of Hull, UK. Through the use of state of the art stereo display devices provided by the HIVE (Hull Immersive Visualization Environment), our aim is to gain greater insight into the data and also to provide the general public with a previously unachievable view of the archaeological site.

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## **The LandLab Project. Multimedia Laboratory for research, education and communication regarding archaeological landscapes**

LandLab is the name of a research project promoted by the University of Lecce, designed to improve our knowledge (and make it available to as many people as possible by means of Information and Communication Technology) of the cultural and archaeological heritage of two sample regions of southern Italy: Puglia and Sicily.

The project was co-financed by the European Union under the aegis of the National Operational Programme 2000-2006 entitled “Scientific research, technological development, higher education”; the participants include the University of Lecce (Department of Cultural Heritage, Department of Innovation Engineering, SIBA-University Library Services) in collaboration with the CNR-IBAM (Institute of Archaeological and Monumental Heritage of the Italian National Research Council), the NRC (Canadian National Research Centre) and the “Antonino Salinas” Regional Archaeological Museum in Palermo, under the scientific leadership of Prof. Francesco D’Andria.

The LandLab develops the methods and the technologies available in the field of Information and Communication Technology for the transfer of data, information management systems and multimedia communication in the reconstruction of ancient landscapes and cultural systems.

The aim of the scientific research developed in the LandLab is the reconstruction of ancient landscapes. The sample sites were selected from a number of pre-Roman settlements in the Salento that exemplify the urban landscapes of the 6<sup>th</sup> century BC (**Cavallino**), the religious landscapes (**Oria**, **Vaste**) and the rural landscapes of the Hellenistic age (**Acquarica di Lecce**). The Greek city of **Selinunte** (Sicily) was chosen as an exemplary site for the monuments of the Archaic period. The project gathered a quantity of data with the objective of reconstructing one of the most significant monuments in the city, Temple C, and the extraordinary figurative sculpted elements that decorated the metopes of the temple, currently kept in the Museum of Palermo.

The research group of the Department of Innovation Engineering, coordinated by Prof. Franco Tommasi, has been working in the field of computer networks, developing a satellite network system for optimising the possibilities of transferring data to areas not covered by the Internet.

The group has also created a multimedia repository able to hold a large amount of data. The multimedia database and satellite network are the focal points of a system whose terminals in the territory are a series of information points with

multimedia totems located in sites strategically linked to the project. These totems are designed to publicise the results of the project, especially concerning the communication products aimed at the wider public.

Communication is one of the key words of the LandLab project. While the project was in its preparation phase, various levels of cultural heritage user (i.e. target groups) were identified, for whom a differentiated set of products would be required. Broadly, a distinction was made between scientific users (researchers and university students), users with a medium-to-high level of education (associated with cultural tourism) and school users (children and high school students).

For the highest level of user, there are applications that use the Internet for presenting the results of the scientific research. As part of the project, two web applications have been implemented by the Laboratory of Archaeological Computing of the Dept. of Cultural Heritage (coordinated by Francesco D'Andria and Grazia Semeraro): the Web GIS of the pre-Roman settlements of the Salento and WO-DOS, the on-line version of the ODOS excavation data management system.

The settlements' Web GIS emerged from the experience gained from 1995 onwards in the School of Specialization in Archaeology at the University of Lecce. A systematic census of the evidence of settlements, as recorded in the literature, was carried out, with the objective of using the data as part of a GIS, providing the basis for the study of settlement dynamics in the indigenous societies of southern Italy. The interest generated by this work led to the preparation of a traditional programme of publications that subsequently became the on-line publication project – the Web GIS – implemented thanks to the LandLab.

The settlements' Web GIS gathers the published data and the archaeological evidence for all the settlements, over a period that starts with the pre-Roman phase. This tool makes available to scholars all the knowledge currently available in the literature, including material which is hard to access because it is published in journals or monographs with a limited, mainly local, range. Moreover the database include the ancient literary sources (research group coordinated by Mario Lombardo, Dept. of Cultural Heritage).

The database records of the settlements are characterised by a highly formalized structure, designed to facilitate understanding of the role of the individual centres within the overall settlement system. For each site there is an assessment of the dimensions, in accordance with real or estimated values: this makes it possible, in cases where the true value is not known, to give an indication based on a hypothesis, useful for providing an idea of the role of the settlement within the settlement system. The data relating to the presence of religious structures, of residential and public buildings, necropolises and workshops are similarly recorded in standardized form, so that each element can form the basis of a theme within the GIS. Each site is located in a territorial compartment characterized by a degree of homogeneity in terms of its geo-morphological, pedological and other features. The environmental and altimetric characteristics are described in the various themes of the GIS, together with the archaeological themes.

The application simultaneously manages the territorial and alphanumeric data. It allows users to search the cartography, at the same time extrapolating the information contained in the alphanumeric data archive. It is also possible to consult



Fig. 1 – Three-dimensional reconstruction of Temple C in Selinunte.

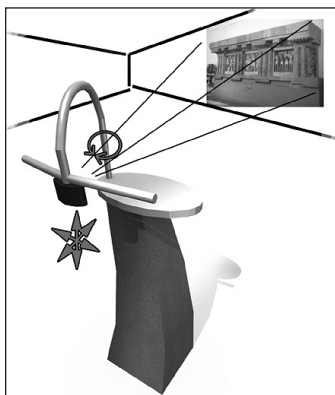


Fig. 2 – Combined viewing of the metopes and the entire Temple.

the territorial data from the site records and the landscape units. The main GIS functions are present, with the only limit being the technology currently available for on-line implementation. The search and advanced search functions, covering bibliographical and literary sources allow for a broad use of the data held in the database.

The second Web application concerns the on-line use of the WODOS excavation GIS. The ODOS system was first implemented in 1991 in the Laboratory of Archaeological computing and its purpose is the management of excavation data. Both the alphanumerical database and the graphic archives, already fully integrated in the off-line version, are based on highly complex models, as complex as the stratigraphic excavations that they are required to deal with. With this application, publication on the web is – at the moment – limited to the research groups working on the project itself. Thanks to the web it is also possible to access the server containing the data from a distance (e.g. from the excavation sites), thus avoiding the problems that arise from delayed uploading of new data from multiple terminals.

The multimedia communication aspect includes the applications of easier and more immediate comprehension designed for the basic levels of user. These include video-clips and short documentaries that provide the public with general information on what the job of an archaeologist actually entails and also on the main historical developments affecting the sites under study. For children there are on-line games based on the idea of the jigsaw puzzle, which must be completed from fragments of pots and objects discovered in the archaeological excavations.

The applications can also be used by means of multimedia and interactive totems (Davide Borra, Torino), which provide for various approaches to the content: the general public may limit themselves to watching a film, which they can follow up by using a specially prepared screen to access other pages to find out more. As part of the project, a number of “auto-stereoscopic” totems have been created that provide a three-dimensional view, without the need for special glasses. The

applications created for stereoscopic viewing are based on the three-dimensional reconstruction of the ancient settlements and provide a highly detailed reproduction of the objects and monuments. It is thus possible to enter a 6<sup>th</sup> century BC house in the settlement of Cavallino, near Lecce, and see objects from daily life, including furniture, pots, and weapons. These have been accurately reproduced in an environment that seeks to provide a picture which is authentic down to the last detail, including the colours, achieved by means of a thorough analysis of the remains discovered during the archaeological excavations.

Of great interest is the three-dimensional reconstruction of Temple C in Selinunte, one of the most important monuments of Greek architecture. Knowledge of this extraordinary monument has been based up until now on partial drawings and studies dating back nearly a hundred years. The LandLab project has made it possible first of all to make an analytical drawing of both the layout and the architectural elements conserved in the storerooms of the Palermo Museum. The three-dimensional reconstruction (Fig. 1), performed in the laboratories of CNR-IBAM (Francesco Gabellone), combined with the analytical study of the monument (Clemente Marconi, Columbia University, NY), has enabled us to make new and interesting observations, providing the scientific community with further knowledge of this important monument. The figurative elements (pediment, metopes) kept in the Museum of Palermo have been re-contextualized, finding their place in the new image of the building. Finally, a specially designed totem, the periscope (Fig. 2), enables users to combine the viewing of the figurative metopes with that of the entire monument.

The figurative metopes of Temple C have also been the focus of work by the “Coordinamento SIBA” (University Library Services) of the University of Lecce, headed by Virginia Valzano, on the acquisition and digital processing of images and three-dimensional models. By means of a series of laser scans, in collaboration with the NRC of Canada (J.A. Beraldin), accurate three-dimensional models have been created of these important exemplars of Archaic Greek sculpture.

For all these reasons the project is unique in the geographical context in question here, in that it represents the first thematic laboratory for research into the ancient landscape completely based on Information and Communication Technology.

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## **Forthcoming conferences**

### **CASA 2006**

#### **Computer Animation and Social Agents 2006 Conference**

Geneva, CH. 5-7 July 2006

For information visit: <http://casa2006.miralab.unige.ch/>

### **EVA London 2006**

#### **Culture x Technology across Europe & Internationally**

London, UK. 24-28 July 2006

For information visit: [http://www.eva-conferences.com/eva\\_london/2006/](http://www.eva-conferences.com/eva_london/2006/)

### **EVA Vienna 2006**

#### **Digital Cultural Heritage – Essential for Tourism**

Vienna, AT. 27-30 August 2006

For information visit: <http://www.eva-vienna.at/>

### **DRHA Conference 2006**

#### **Digital Resources in the Humanities and Arts**

Dartington, UK. 3-6 September 2006

For more information visit: <http://www.dartington.ac.uk/drha06/index.asp>

### **UISPP XVth Congress**

Lisbon, PT. 4-9 September 2006

For information visit: <http://www.uispp.ipt.pt/>

C04 – Technology and Methodology for Archaeological Practice. Practical applications for the past reconstruction (Alexandra Figueiredo, [alexfiga@ipt.pt](mailto:alexfiga@ipt.pt)/ Hans Kamermans, [H.Kamermans@arch.leidenuniv.nl](mailto:H.Kamermans@arch.leidenuniv.nl))

C05 – Re-construction, simulation, reconstitution. How real is our real, how fake is our past? (Gonçalo Velho, [gonvelho@ipt.pt](mailto:gonvelho@ipt.pt)/ François Djindjian, [francois.djindjian@wanadoo.fr](mailto:francois.djindjian@wanadoo.fr))

### **CIDOC Annual Meeting 2006**

Gothenburg, SE. 10-14 September 2006

For information visit: <http://cidoc06.se/>

### **11th workshop on Archaeology and Computers Cultural Heritage and New Technologies**

Vienna, AT. 18-20 October 2006

For information visit: <http://www.stadtarchaeologie.at/>

For the pre-conference forum visit: <http://www.stadtarchaeologie.at/forum/>

## **VSM 2006**

### **12th International Conference on Virtual Systems & Multimedia**

Xi'an, CN. 18-20 October 2006

For information visit: <http://www.vsmm.org/2006/>

### **CIPA, VAST, EG, Euro-Med Joint Conference**

#### **The e-volution of Information Technology in Cultural Heritage.**

#### **Where Hi-Tech Touches the Past: Risks and Challenges**

#### **for the 21<sup>st</sup> Century**

Nicosia, CY. 30 October-4 November 2006

For information visit: <http://www.vast2006.org/>

### **Sofia 2006 Globalization, Digitization, Access,**

### **and Preservation of Cultural Heritage**

Sofia, BG. 8-10 November 2006

For information visit: <http://slim.emporia.edu/globenet/Sofia2006/Index.htm>

### **34th Museum Computer Network Conference**

#### **Access to Assets: Return on Investment**

Pasadena, California, USA. 8-11 November 2006

For information visit: <http://www.mcn.edu/mcn2006/>

### **Remote Sensing Archaeology – 2nd International Conference**

Roma, IT. 4-7 December 2006

For information visit: <http://www.space2place.org/>

## **New books**

*GIS and Archaeological Site Location Modeling*. Edited by M.W. Mehrer and K.L. Wescott, London, Taylor & Francis/CRC Press 2006.

*Geographical Information Systems in Archaeology*. Edited by J. Conolly and M. Lake, Cambridge Manuals in Archaeology, Cambridge 2006, Cambridge University Press.

*Smart Environments and their Applications to Cultural Heritage. Proceedings of a workshop held in conjunction with UBIComp'05 (Tokyo–Japan, 11th September, 2005)*. Edited by N. Ryan, T. Salmon Cinotti, G. Raffa. EPOCH Publication ([http://www.epoch-net.org/index.php?option=com\\_content&task=view&id=156&Itemid=244](http://www.epoch-net.org/index.php?option=com_content&task=view&id=156&Itemid=244)).

*Trainings Offerings and Needs in Europe on ICT Applications to Cultural Heritage. Report on an EPOCH Survey on the state of Higher Education in European Countries in the field of Applications of Information and Communication Technologies to Cultural Heritage*. Edited by F. Niccolucci. EPOCH Publication ([http://www.epoch-net.org/index.php?option=com\\_content&task=view&id=167&Itemid=258](http://www.epoch-net.org/index.php?option=com_content&task=view&id=167&Itemid=258)).