Oblique aerial photography in a GIS environment for geo-archaeological research – A case study: The Potenza Valley survey

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ABSTRACT: In January 2000, Ghent University started the Potenza Valley Survey, a geo-archaeological project. One of the research methods employed is aerial photography. This method has already proved to be an extremely valuable tool in archaeological survey, in particular simple oblique photography from a small aircraft, as photographs can easily be made in the most appropriate season, weather and light conditions. A major drawback of this method is the complex geometric distortions that are encountered, preventing the photos to be automatically incorporated in an archaeological GIS. “AirPhoto 2.20” is used to rectify the images, as it is low-cost software that is specifically developed for the rectification of photographs made with handheld uncalibrated cameras. Nevertheless, different transformation procedures have to be followed as the terrain is very varied. Afterwards, the input in a GIS enables a better interpretation as well as on-screen digitizing of the archaeological and geomorphological features.

1 THE POTENZA VALLEY SURVEY

During his reign, Rome's first emperor Augustus (27 B.C.-A.D. 14) divided Italy into eleven different regions. More than a century and eight emperors later -in A.D. 77- Gaius Plinius Secundus (also called Plinius Maior or Pliny the Elder) wrote his Naturalis Historia. In addition to the knowledge of that time concerning ethnography, anthropology, human physiology, zoology, botany and mineralogy, Pliny the Elder’s Natural History also contains information about geography. Glancing through the third volume -in which Pliny deals among other things with the eleven Italian regions- one might read ‘Quinta regio Piceni est, quondam uberrimae multituidinis...’ (Plinius Secundus, Naturalis Historia III.13) -’The fifth region is that of Picenum, which formerly was very densely populated...’ (Rackham 1942: 81). It is the first sentence used by the author to describe the fifth region, denominated as Picenum. Nowadays, the northern half of the former Picenum forms the southern part of the Marches: one of the contemporary Italian regions. The northern half of the Marches was part of Augustus’ sixth region: Umbria (Fig. 1).

In January 2000, Ghent University (Belgium) initiated a geo-archaeological research project called the 'Potenza Valley Survey' (PVS) in what was once the fifth and sixth region of Roman Italy. This interdisciplinary project was set up by the Departments of Archaeology and Geography. Under the direction of Prof. Frank Vermeulen, the major aim of the PVS was -and still is, as the project will last until at least 2006- to measure the evolution of social complexity within the valley of one of the Marches’ major rivers.

Although Pliny describes a densely populated land, this project wants to discover how populous the region was, what the different types of settlements were and how the settlement patterns changed, in time as well as in space. Therefore, the project got the subtitle ‘From Acculturation to Social Complexity in Antiquity: A Regional Geo-Archeolog-
2 HISTORY OF AERIAL SURVEY

Photography can almost celebrate its second centennial, since Joseph Nicéphore Nièpce (1765-1833) invented this “drawing with light” in the 1820s. Aerial photography in archaeology covers approximately one half of that time span. Although the tradition of spying balloons in the nineteenth century - especially in the American Civil War (1861-1865) - it was not until the end of the First World War that archaeologically interesting pictures were made (Crawford 1954, 206). Someone who needs to be mentioned here is O.G.S. Crawford. This Englishman is considered as the inventor of scientific aerial archaeology as his work in the 1920s and beyond was the basis for the future development of the subject.

The major advances achieved and the different projects initiated in the Interbellum were interrupted by the Second World War. Nevertheless, this period witnessed an outbreak of technical developments. That many archaeologists were trained as air photo interpreters, was another result of the war.

However, it was not until the late 1950s that academic research took place: thousands of new archaeological sites were discovered. Accordingly, a growing number of governments began to understand the need to protect the historic environment. The lifting of the Iron Curtain probably was the last major development, resulting in a lot of countries being able to enjoy the benefits of aerial reconnaissance. (Bewley 2002: 11-4 & Wilson 2000: 16-22)

3 PRINCIPLES OF AERIAL ARCHAEOLOGY

In aerial archaeology, two methods can be employed: vertical and oblique photography. Vertical aerial photography is achieved by taking a series of overlapping images at regular intervals with a calibrated camera mounted onto an airplane and pointing directly down to the earth. This technique also allows the aerial images to be viewed stereoscopically. However, archaeologists mostly use hand-held cameras and simply take oblique photographs at an angle from a low flying aircraft. As a consequence, this results in distortion of features caused by perspective, but is extremely flexible and cost-efficient.

Archaeological remains can be seen from the air in a number of ways. Besides large material remains (e.g. castles, churches, bridges, ...) and partly-eroded remains of structures (earthen banks, ditches, low walls, mounds, ...), most of the features that can be viewed from above are the remains of buried archaeological sites. While the first type of features is directly visible (Fig. 3-1), the second type -often referred to as earthworks- is noticed through shadow marks. In the right conditions, mostly with the sun low in the sky, these archaeological features can re-

The Potenza -called Flosis in Roman times- flows over its ca. 80 km long course from the Apennines through a wide and fertile Apennine foothill landscape before it ultimately runs into the generally flat Adriatic coastline zone. Already important in Prehistory, the Potenza river valley became one of the most commercial routes of the Central Italian Protohistory and even in later periods the valley remained an important corridor for political, economical and cultural contacts between the Thyrrenian and the Adriatic coast. In Roman times, several cities developed in or near the valley floor (Potentia, Helvia Recina, Trea, Septempeda & Prolaqueum cf. Fig. 2) and even a southern branch of the Roman Via Flaminia passed through it. In the subsequent period, the area remained of importance as it formed the contact zone between Longobards and Byzantines. These are only a few of the reasons why a geoarchaeological survey was launched in this particular area.

The research project consists of four important cornerstones: field survey, geomorphological survey, historical survey and aerial survey. Systematic prospection of the ploughed fields, always carried out in the month of September, is the method used in the field survey. In search for archaeological evidence, intensive linewalking was chosen as prospection method. Therefore, an interval of 10 to 15 meters between different walkers is aimed for. Scholars of the Department of Geography conduct the geomorphological project part by making as many field observations as possible. Additionally, some augering is also performed to reconstruct the evolution of the coastline and tackle the problem of alluviation and colluviation. To study known archaeological sites of all periods into detail, an intensive historical survey is implemented as well. Moreover, some research of toponymical and historical written information is on-going. Finally, there is the aerial survey, where the remainder of this article will focus on.
veal themselves by the pattern of sunlight and shadow (Fig. 3-2). To obtain best results, the linear earthworks should be at right angles towards the sunrays. The more parallel they are, the weaker the shadows will be.

Soil- and cropmarks will disclose the buried or levelled remains. Cropmarks are patterns of differential growth in vegetation, caused by subsoil variations. Trenches or pits for instance will often be filled with organic material or new soil, having a greater moisture retention and more nutrients than the surrounding matrix. In periods of drought, these humous soils hold the available water longer, allowing the plants to grow longer and fuller. The adjacent plants will be less tall or ripen quicker, leading to patterns -differences in height and/or colour- that can be seen from above (= positive marks) (Fig. 3-3). The reverse is caused by archaeological features like stone walls or floors. They have less water retention and nutrients than the undisturbed subsoil, which will correspond to weaker and shorter plants (= negative marks). Although a lot of crops can display good marks, the best cropmarks can be noticed in cereals (wheat and barley in particular). It is also noteworthy that, due to the possible height differences in the crops, shadowmarks can occur as well.

Soilmarks are mostly caused by ploughing, as it brings the archaeological subsoil to the surface. Because the deposits often differ from the non-archaeological soil, the result is a pattern caused by the colour differences (Fig. 3-4). These can be two-fold: darker or lighter than the undisturbed soil. Like already mentioned, the refilling of a deepening is mostly more humourus, making it darker-coloured than the surrounding ploughed soil. Because these past features also have a better water storage, the refillment appears darker than the surrounding soil. This can be visible, even without the terrain being ploughed. When dealing with walls, the opposite happens, leading to bright traces. However, when talking about archaeological remains, one certainly might not forget the artefacts (=man-made objects). Archaeological materials give rise to soilmarks likewise, as concentrations of dark pottery or red tiles can be seen easily from the air against a natural background.

Two infrequent kinds of marks are snow- and watermarks. The former are created by dissimilarities in the temperature of the subsoil. Walls and trenches are always colder or warmer than the adjacent ground, causing the snow to melt accordingly faster or slower. Earthworks can create snowmarks too, as snow of the sunlit areas will melt the quickest. It is typical of these marks that they can be detected just during a few hours’ time span. Watermarks can be viewed in periods when and areas where there is plenty of water, filling the lowest parts of the landscape.

4 AERIAL PHOTOGRAPHY IN THE PVS

4.1 Photographing

“Be at the right place at the right time” is valid for the noticing of all marks. Therefore, the flying needs to be very intensive. As a consequence, several flights at different seasons are made annually, so the photographs can accumulate in order to build up a reliable picture. Additionally, the aerial survey in the PVS is also very extensive, with flights over the whole valley, although a specific interest for the three sample zones remains. Using a small Cessna, the pilot flies on an observation altitude of 1000 feet (ca. 300 m). Frank Vermeulen takes oblique photographs at an altitude of approximately 300-500 feet (ca. 90-150m), therefore using a Canon 35mm SLR camera, mostly filled with Fujichrome slide film -100 ISO.

4.2 Inventory

From the beginning of the project, it was the aim to incorporate all gathered survey data into a Geographic Information System. Until now, it still is the easiest way to manage and analyze such quantities of-almost- all geographically linked data.

Once the photographs are taken, a whole process needs to be applied before they can enter the PVS-GIS. First of all, every slide gets a unique number which is written onto the slide mount. Afterwards, all slides are inventoried in the PVS-database -one database that contains all project data. Besides the slide number, a whole series of items can be filled in (Where and when is it taken? Which kind of marks can be seen? Is it important for certain periods?). Because we also take on-ground photographs, another table was created. Here, more detailed metadata specifically concerning the aerial photographs can be added: the type of film, the camera and lens used, the shutterspeed etc.

Thirdly, the best and most unveiling images are digitized onto Kodak Digital Science Photo CDs. Although we have them on these CD-ROMs, these...
images are also saved on the central PC, which allows us to link them directly to the database. Furthermore, it offers the possibility to perform some image enhancement, creating an optimized image that can be used and re-used for different applications, without having to redo the adaptations again (which would be the case when only using the CD-ROM).

Besides their illustrative function, the main purpose of these aerial images is -of course- to reveal new archaeological sites or confront the already known or discovered features with the aerial evidence. Secondly, geomorphological marks of interest -like paleofluvial gullies- are looked for as well. Therefore, one needs to map as accurate as possible the marks that can be distinguished on the digitized slides.

4.3 Rectification

As the oblique airphotos have been made with a handheld, uncalibrated reflex camera, only a semi-quantitative result is attainable. Therefore, there is no use in obtaining a high accuracy photogrammetry package. These days, at least two low-cost programs are available that allow transformation of scanned images: Irwin Scollar’s AirPhoto and John Haigh’s AERIAL. Because Airphoto has a greater functionality, the PVS team purchased Scollar’s specialized software.

AirPhoto 2.20 truly is a useful tool for archaeologists. It makes, without spending a large amount of money, (pseudo-) ortophotos from extreme oblique images. (Scollar 2002: 167). Although not a photogrammetric plotting program, it is a true ortophoto program working from a Digital Elevation Model, even though the DEM is not required. Furthermore, it offers three interpolation methods, a calculation of the mismatch between the source and the target image (control of the goodness-of-fit of the rectification!), has a lot of image processing techniques and supports different GIS-formats.

Offering different transformations (with and without height information) is very useful when one is working in different topographic regions, as is the case in the PVS. For flat terrain, a simple projective transformation can be applied. This transformation doesn’t require ground heights, only four corresponding points (=control points) in the source/photograph and the target/topographic map (Fig. 4). The accuracy of the transformation can be improved by adding more control points.

![Figure 4. The projective transformation.](image-url)
For hilly terrain, the Fischler-Bolles image rectification is used. This option only requires three corresponding control points. Furthermore, some camera parameters need to be filled in as well. The focal length of the lens, the film frame width and height and the principal point. The latter is accurately determined by photogrammetric calibrated cameras, but working with a normal reflex camera, it is estimated as the geometric center of the image. Finally, at least five heights not too far from the control points are needed to apply the transformation. As we have digital topographic maps (scale 1:10 000) of the whole valley, a DEM\(^6\) can be calculated (Fig. 5).

4.4 Mapping and interpretation in a GIS context

After the desired images are rectified, they are used in ESRI’s “ArcView 3.2” GIS software. Here, all the orthophotographs are displayed in their right geographical location. This enables a comparison of the features as well as the corrected raster images to serve as the basis for a vector layer which will hold the on-screen interpretation. To make the features become more distinct, some image processing might be advisable (the most common routines are also available in AirPhoto 2.20 cf. Fig. 5). The possibility GIS offers to add other digital information, as hydrological, geological and field survey data, can help to interpret the marks and increases the process’ reliability. As the target map is on a scale of 1:10 000, this mapping method is adequate for the production of 1:10 000 (and smaller) archaeological maps (Fig. 6).

5 FIELD CAMPAIGN 2004

In the fourth September campaign, total station height measurements will be implemented in this research. By taking height measurements, it is hoped that even the most difficult photographs -where the terrain is very differentiated and the topographical contour lines are not sufficient- might be rectified. Moreover, these new data will also enable us to make detailed maps on a larger scale.

The second innovation will be the use of a digital camera (type: Canon Eos 1 Ds). One can already imagine the consequences: no film and processing expenses, no extra costs in digitizing images, the freedom to take as many pictures as wanted without having to worry about the number of pictures that is affordable, always the right camera parameters (as focal length, shutterspeed and diaphragm are saved automatically), instant display of the image, the possibility to shoot on different types of “film” just by adjusting a setting, etc. Aerial archaeology may be one of the oldest prospection methods, this invention will certainly have its consequences.

6 PROSPECTS

As the flights are going on, new features (archaeological as well as geomorphological) are regularly discovered. Therefore, rectification and interpretation is a constantly continuing process. However, when the material processing has finished, these results will be compared with the data from the field survey. On the one hand, the images will give a better idea of the ‘real’ proportions of sites (like the Roman city of Potentia in Figure 6), on the other hand the sherds and pieces of marble and glass can tell something about the intra-site spatial organisation and temporal delineation of the features.

Besides, this highly significant data can -and will- be combined with the geomorphological and historical information in the three survey zones, just to make the whole settlement process easier to understand and the interpretations more reliable. In this way, the capabilities and advantages GIS offers will be completely expressed in the PVS-project.

7 CONCLUSION

Oblique aerial photography is already an old technique and therefore a well established archaeological prospection method. In the Potenza Valley Survey, this technique has once more proven to give a lot of additional information that otherwise might be overlooked. As the photographs are made without a calibrated camera, it is possible to utilize specifically designed low-cost software, which allows archaeologist (and others) to rectify these data, without having to be a photogrammetric specialist. One of these software packages is called Airphoto. It offers a lot of useful functions and is capable of rectifying images, with or without using height information. As a consequence, it enables working in a topographically varied research area, as long as there are height measurements available for the most differentiated terrain. Once transformed, the importation in a GIS allows the combination with other survey data layers, making the on-screen digitizing and interpretation of the images a more reliable procedure and the analysis of all data layers a more fruitful process.
Figure 5. The Fishler-Bolles image rectification and an example of some image processing.
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REFERENCES


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1 For a detailed overview of the main goals, the reader is kindly asked to consult Vermeulen 2002a.

2 More information about the aerial survey and the work performed until now can be consulted in the following articles: Vermeulen 2002b, Vermeulen & Boullart 2001 and Vermeulen, Monsieur & Boullart 2002.

3 Mr. Jacques Semey, a Belgian pilot-photographer, participates partly in this stage of the aerial survey.

4 One central PC was purchased and configured to contain all possible data in an orderly and easily accessible way. In consequence, this PC also functions as the centre of most GIS-analyses. (Hardware specifications: 2.4 Ghz processor; 512 MB RAM; 75 GB hard disk; 1.44 MB floppy drive, CD-R/RW 48x/16x/48x and several printers. Software specifications: ArcView3.2 as GIS-software, Minitab 13 to perform statistical analyses, AirPhoto 2.20 to rectify images and Photoshop 7.0 to edit images. All programs are working on a Windows XP OS.)

5 It is also worth to underline that, besides this central PC, every member of the PVS-team has his own PC, sometimes with some important peripheral instruments as a CalComp 9500 digitizer tablet, an A3-scanner (EPSON 1640 XL) and a slide scanner. (Canoscan 2700F).

6 The aerial evidence encompasses also vertical images (mostly from the R.A.F.). They are inventoried, rectified and interpreted as well. However, this is not discussed here into detail, because it is not the purpose of this particular article.

7 To create a DEM, it matters which interpolation is run. Therefore, different interpolations with different parameters were calculated. The one which gave the most accurate results -tested by comparing some geodetic points to the computed result- was saved. For more information concerning this topic, the reader is kindly asked to consult: Verhoeven 2002 & Verhoeven 2003.