Studying the Archaeological Record from Photogrammetry

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Abstract
In this paper, there are presented a series of new and different applications, in archaeological investigation, specifically in the archaeological record, using Geographic Information Systems (GIS) and Photogrammetry.

The spatial situation, of the complete archaeological record, gives us more information, than materials and levels alone. At the same time, it allows one to relate different levels to each other, and even to compare archaeological materials across levels.

This whole procedure needs tools, that structure data entry, to give an output, corresponding to the objectives that we have set for ourselves. GIS carries out the functions of introduction, structuring, and the exit of data. This task has to be supplemented with a method, that allows one to capture the data required, without extensive effort. This is where Photogrammetry is introduced, as a group of methods and operations, that allow making topographical planes and maps, and supplementing the drawing of materials, starting from aerial and/or terrestrial pictures.

Introduction

Archaeological objectives are of a diverse nature, but methods of research and fieldwork rarely differ. Fieldwork can be subdivided into excavation and laboratory work, where objects are registered and classified, and results or conclusions, of the extracted information, are obtained.

One of the biggest problems in fieldwork is that archaeologists face the systematic destruction of the settlement, or archaeological site, and its context, in the process of excavation. This paradox, that archaeologists destroy what they study, as they study it, is unavoidable, due to the nature of excavation. Also, in practice, all investigation plans, especially excavation plans, are constrained by existing material and economic parameters. As a direct consequence, the surface, to be excavated, has to be limited to the time allowed for the work.For this reason, the results of fieldwork investigations can be dramatically altered, simply, due to the cicumstances outlined above.

History of the investigation

With the introduction of new technologies, we find different methods geard towards overcoming these problems. Already in 1975, the use of stereophotography was introduced in archaeological investigation, along with other techniques (Harp, E.; 1975). In recent years, numerous efforts and works have been made in the same direction, for example, analytic photorestitution (San Miguel, L. C.; 1991), and later, digital restitution, and concretely, digital, photogrammetry restitution. (Caballero, L., Arce, F. and Feijoo, S.; 1996)

The latter is a good example for understanding the importance of the restitution of the settlement surface, that has been excavated, as well as all of its archaeological levels. It resolves the relationship between Harris Matrix and Photogrammetry, but not the collection of data in the field. It seems a difficult task, given the steps to carry out. However, some excellent data and information, in general, are obtained, but we do not take profit because because of the problems in data structuration and administration.

In general, only concrete and punctual investigation problems are solved. The main problem, facing archaeologists, still remains: cost.

Proposal

The solution, on which I am working, the first results of which, are described in this paper, is to use GIS (Geographic Information Systems) allowing the appropriate administration of data, by integrating standard, archaeological data with aerial and terrestrial photogrammetry; that is to say, it integratates the capture, introduction and manipulation of data. All of these elements make, according to the investigator's necessities, a true, digital stereoplotter.

For this investigation, I have used a Geographic Information System, or GIS, called IberGIS, developed by the company ICI S.A. (Investigaciones Cibernéticas S.A.). This GIS has a stereoscopic, photogrammetry tool, that transforms it into a stereoscopic, digital stereoplotter.

In this paper, I will talk about this last tool, stereoscopic digital restore, because I consider it to be the most innovative element, that I present. It speeds up field work, saves steps in the manual recording of data, and reduces time, taking measures in the field . So, it is more secure and more profitable.

Components of the system

The necessary hardware, to use the IberGIS system, consists of a conventional Pentium computer, with monitor, trackball, and another (stereo) monitor, with filter and polarized glasses added to it. This filter and these polarized glasses are what allow the reproduction of objects in virtual reality and in relief, thanks to the phenomenon of stereoscopic vision. Therefore, the stereo monitor is used to work with images in 2 or 3 dimensions, and the other one, the normal one, is used to execute the applications of different modules of the system.

On this platform we install IberGIS, which is not a closed product, like those we usually encounter. It allows the user to tailor its measure, according to his needs. It is an open product, composed for up to 15 tools, or modules.

Development of the system: photogrammetric surveys

Now, I will explain the diverse steps, that are necessary to make photogrammetric surveys, with this system. It´s important to specify terrestrial photogrammetry, because aerial photogrammetry is more common and already well-known. This system has been utilized, in practice, in the following settlements:

ARCHAEOLOGICAL SITES	APPLICATIONS
Iron Age "Castro" in Peña Sámano (Cantabria, Spain)	Aerial Photogrammetry
Torralba y Ambrona (Soria, Spain)	Terrestrial Photogrammetry
The Miron Cave (Cantabria, Spain)	Terrestrial Photogrammetry

It is important to note, that this is not a general description of what you can do with a system, like IberGIS. It´s a description of one of its multiple tools or " clients ": photogrammetric restitution.

Aerial photogrammetry

Castro of Peña Sámano

Beginning with an aerial view of Castro of Peña Sámano (Cantabria, Spain), we wanted to make a topographical model. For it, negatives of aerial photos were digitized. After scanning the images, they went to the digital stereoplotter, and are stored in a database of raster images. Once there, it was possible to proceed with their manipulation.

The following step was orientation, or triangulation. The computer, geo-rreferenced pictures, individually, and then analysed consecutive pictures. This operation is known as relative orientation. Later they were given a series of points, common to both, or more, pictures, with their respective coordinates (x, y, z), so we could obtain absolute orientation. What was really achieved was that each pixel of the image had its corresponding coordinate in the real terrain, and vice versa, so that each coordinate on the ground had its corresponding pixel, in the image. It also allowed us to see images in 3D, on the stereo monitor, and to take measurements, to create DTMs (Digital Terrain Models) and to begin restitution.

The system was very flexible, because programme menus could be manipulated freely, adapting them to our needs.

Starting from the DTM, we could obtain contour lines, with the intervals needed, as well as other functions, like calculating profiles and perspectives.

The RESTORE command, besides calculating the profiles between two points, gave us a series of data (e.g., the coordinates of a starting point and a final point, in longitude, latitude, and height, as well as the total longitude of the profile). Another possibility was to calculate, and to make automatic drawings of profiles, starting from only one signal point.

DTM also enabled us to obtain perspectives, from any point of view, selected by the operator. In fact, these perspectives were done by a series of successive profiles, obtained automatically, at regular intervals, according to the required precision.

All types of graphics, commented on above, were done with punctual, lineal and superficial events, that were stored in a vectorial database. All associated information was stored in the Alphanumeric database. These two types of database, along with the raster database, all conformed to GIS Geographic database.

Terrestrial photogrammetry

The same theories apply in terrestrial photogrammetry as for aerial photogrammetry; the only difference is the material and equipment used. In aerial photogrammetry, the overlap between pictures of one flight should be 60%, and between pictures of different flights, 30%. The same thing happens in terrestrial photogrammetry; the difference is that reflex (35 mm) and digital cameras are used. These cameras are easy to use, and avoid any possible losses. Also, by connecting the digital camera to a laptop, the printing of a horizontal and vertical image, of the archaeological record, *in situ*, is possible, facilitating identification and numeration, of the materials for laboratory work. Another advantage of terrestrial photogrammetry is that it is not obligatory to make a vertical flight, over the archaeological surface, because the program calculates orientation angles of the camera; however, it is necessary to measure the distance between the camera and the surface, and the real measure of the picture, in order to obtain parameters, like focal distance and "flight " scale.

Torralba and Ambrona

This system was used in the Torralba and Ambrona sites (Soria, Spain), last summer (1997). In this case, we wanted, through photogrammetric work, to draw bone artifacts and the floor where they were located, obtaining their orientation and slope, at the same time. Some Terrain Points were marked on the surface, and we took a series of pictures. It was important that the points were well distributed, as this eliminated errors.

Next, the coordinates of the points were measured. The number of points was variable, depending on the quantity of pictures taken. In general, when we work with only one pair of photos, five points are enough, according to the precision desired.

On this site, a total station was employed, to carry out the topographical support, although its use was not indispensable. A level, metric tape, and a plumb line would have been sufficient.

The Mirón Cave

This method was also employed in The Mirón cave (Cantabria, Spain), where there were other difficulties, besides technique: humidity, limited space, and insufficient light posed problems.

A photogrammetric work was carried out on one of the levels which had many hearths. In fact, we wanted to reconstruct a hearth, down to the finest detail. The procedure was the same, as the one described in the case of Torralba and Ambrona. Also, it was important to obtain the exact position of the different materials, because we needed to be able to relate them, to those of other levels.

We took a series of photos, from aproximately the same position, for each level excavated. In this way, we obtained the stratigraphic sequence of the settlement. At a later point in the investigation, we were able to observe, in 3D, the excavated and destroyed level. We obtained geo-referenced information of the excavation surface, which allowed us to relate spatial or geographical, archaeological objects and structures, within of the stratigraphic sequence.

Also, we photographed and reconstructed the section, where the stratigraphic sequence was shown. So it was not necessary to draw, during excavation.

In this example, the power of the system is clear: we can discover spatial situations, and make automatic drawings of structures, sections, and other elements, captured in the digital image.

Conclusion

The steps involved in the construction of terrestrial, photogrammetric works, as described above, are: first, take a series of photos, with digital and/or reflex cameras. Specialized training is not needed. Second, establish the topographical support, using either a meter rule and plumb line, or a total station, or even using a bubble level or teodolit. Last, triangulate (relatively and absolutly) and carry out the restitution of archaeological objects.

The advantages, that the use of this system offers us, are: a reduction of the time spent taking measures, during excavation; and, a reduction in the number of steps necessary, for manual data entry in the laboratory consequently diminishing the potential for error. We are speaking about simplified photogrammetry, that offers photogrammetric works at low cost, but, with the appropriate precision, necessary for each moment and circumstance, without requirung any specialized training.

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