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# SIMPLE PHOTOGRAMMETRIC METHODS WITH ARPENTEUR 3-D PLOTTING AND ORTHOIMAGE GENERATION:

## THE I-MAGE PROCESS

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### ABSTRACT

This paper focuses on an original approach to architectural survey whereby the measuring step, driven by an architectural model, is left to the architect's or the archaeologist's initiative, with reduced participation by the photogrammetric expert. A new set of tools to this end is available in the Web-based tool ARPENTEUR (Architectural PhotogrammEtry Network Tool for EdUcation and Research).

Surveys are accomplished with the so-called I-MAGE process (Image processing and Measure Assisted by Geometrical primitive) which enables the user, for instance, to obtain 3-D measurements while digitising a single image with "no loss" of accuracy. I-MAGE is a new measuring method for digitising 3-D points, based on the coupling of image correlation and the expected shape of objects. Shapes are primitive surfaces or partial surfaces like planes, cylinders, cones and spheres. We have developed the I-MAGE process to assist the plotting phase: the homologous point is determined by the system using both the image orientation and the geometrical primitive computed on a set of 3D points already measured.

On the other hand, so far, accuracy has not always been the principal purpose of surveys in archaeology and architecture. Each photograph contains a tremendous amount of qualitative information which is not often used to its full potential. We suggest, therefore, the full use of all the information made available during the photogrammetric process, such as: camera orientation results, 3-D primitive surface computation, and rectification or projection of the images onto the primitives. The result is a scaled image containing all of the qualitative information. Accuracy is then a consequence of the hypothesis made when nearing the real surface with a primitive. We present as an example an orthoimage generation from a rubbed vault (estimated with a cylindrical primitive) at the *frigidarium* in the *Thermes de Cluny*, at the Museum of the Middle-Ages, Paris.

### 1. ARPENTEUR PROJECT DESCRIPTION



ARPENTEUR is a digital photogrammetry software package running on the Web jointly developed by MAP-gamsau (a laboratory of the French National Science Council) at the School of Architecture at MARSEILLES and the Photogrammetry and Geomatics Group of ENSAIS-STRASBOURG. The package is intended to be used as a Web-based tool since photogrammetric and modeling concepts are embedded in Web technology and Java™ programming language. Two kinds of servers are available:

- ✓ A HTTP server (Hyper Text Transfer Protocol) is used for the connection to computers equipped with ARPENTEUR. There are presently two possibilities: one in Strasbourg and one in Marseilles. A user can create a workspace to access his / her own data or example projects.
- ✓ An FTP server is used to upload or download data between the (remote) server and the local computer. Data or result files can be handled by this means.

Several example, configuration, or help files are also available on the ARPENTEUR Web page (<http://www.arpenteur.net>).

The goals of the project are as follows:

- ✓ As software for education and research, the Java™ programming language includes tools and technology that allows diverse workgroups of several developers or users, using diverse hardware platforms, to work together free of software installation costs;
- ✓ Due to the specialization of the two principal partners in Strasbourg and Marseilles, the modeling tools have been developed for close-range applications, mainly for the description of architectural information;
- ✓ ARPENTEUR is, above all, a photogrammetric tool and its aim is to provide not only different orientation solutions for photogrammetrists, but also simple tools for non-specialists using desktop computers.

These objectives integration in the same ensemble is based on technical and conceptual choices.

The first choice consists to use the digital images obtained thanks to digital cameras, now available on the market, and could have good enough characteristics on image quality. These digital images allow also to offer to the user treatment tools to automatize some jobs ordinarily human made. Also they allow treatment chain total integration from photographs to some final results as 3-D visualization in CAO-DAO 3D software.

One takes the opportunity of this integration to assist an other conceptual choice, based on the idea of a process driven by the knowledge related to the domain. In architecture as well as in archeology the goal is to allow the domain expert to use his knowledge to get his wished goal. The result may be plotted documents, files devoted to visualization, or a corpus of data base

For this purpose, the system supplies the Expert with a complete set of tools allowing him to formulate hypothesis related to his investigation field, hypothesis leading to a simplification of the measuring process. Among others, for instance, the creation of a corpus figuring the present objects in the investigation field

As a profit from these choice, ARPENTEUR looks like a tool developed for architectural an/or archeology professionals, with a reduced intervention from the expert photogrammetrists.

## 2. I-MAGE PROCESS

I-MAGE method (standing for Image processing and Measure Assisted by GEometrical primitive).

ARPENTEUR is a simple photogrammetric tool devoted to architectural report. In this way of thinking, we would like to offer a simple and efficient tool for archeologists and architects use, not needing an important photogrammetric knowledge or expertise.

Therefore, if the first orientation step must be done by the photogrammetrists, at less for photogrammetric model control and validation, the measuring step, made with the ARPENTEUR software, can be performed under the field expert responsibility, archeologist or architect.

We offer a set of software tools ( I-MAGE process ) conceived to guide the operator during the most delicate phase of photogrammetric report : determination of homologous points on photographs on exploitation.

In marketed software two different types of solution are offered : in simple software this phase is reduced to the minimum, the operator shows a point on a photograph thanks to the mouse pointer, then the homologous point on another photograph, this is the case, for instance in : Photomodeler, Rollei CDW, etc.... In heavier software, based on stereoscopy, sometimes bounded with correlation, homologous points determination is more accurate but remains limited to two photographs and needs the intervention of a photogrammetric restitution professional.

Our first answer to this problem is the setting of a self-correlated mechanism : the operator shows precisely a first point on a photograph, and in a approximate way a second one on the second image. The homologous point on the second image is determined thanks to the correlation in between the two images, a precision estimating tool is supplied to the user.

This method has the advantage to be systematic, regular and optimal in use, results are equivalents to those obtained by a professional operator. Therefore this method remains boring and impose to scan very carefully the two oriented photographs.

We offer a new process to liberate the user from these constraints.

The I-MAGE process has been designed as an help for measuring process : user can make a 3-D measurement using one single photograph, without altering result precision.

For objects based on geometric primitives (planes, cylinders, cone, or sphere shapes), we can combine image correlation and the geometry of the object for the calculation of 3-D points. This I-MAGE method is based on four steps, assuming that a geometric primitive has been measured from a set of 3-D points visible on two images (Figure 5).

In architecture, many architectural features can be approximated by geometric primitives. The parameters of so-called architectural features are part of the basic data required for the modeling process. Our idea has been to compute these different architectural features. The object is first reduced to geometric primitives such as plane, cylinder, cone, or sphere shapes.

Our first example is the survey of a Romanesque priory, Notre-Dame d'Aleyrac (Figure 1), in northern Provence (France) which employed Arpenteur and which was presented last year at the ISPRS congress ([Drap, Gaillard , Grussenmeyer , Hartmann-Virnich, 2000]). If we consider again the Aleyrac project, we can see that the monitoring of the survey by underlying geometrical models stemming from architectural knowledge is very appropriate. For objects defined as primitives, see Figure 1, where architectural features are labeled as planes, cylinders and spheres.

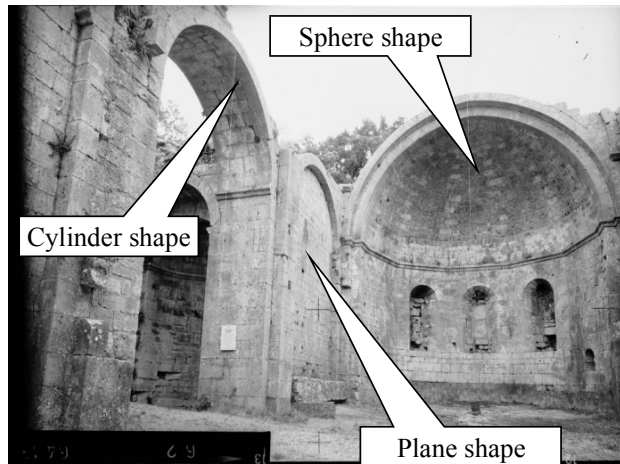


Figure 1. Wild P32 image of the Aleyrac site (France).

### 3. SIMPLE 3-D MEASUREMENT

#### 3.1 3-D Measurement Principles

The result of each primitive adjustment is used to simplify the measuring process. That is to say that for a computed primitive of an object, from one measurement in one image it is possible to compute and measure by correlation to its homologous in the other images.

We employ four steps (Figure 8) in our Semi-automated Primitive Measurement Method, considering that a geometric primitive has been measured from a set of 3-D points visible on two images :

- ✓ Point  $P$  can be computed from one image by intersection of an image ray ( $p_1, O_1$ ) and the geometric primitive (the cylinder in Figure 8 is defined by seven parameters in an earlier process from a set of 3-D points);
- ✓  $P$  is projected as  $p_2$  onto the second image;
- ✓ Point  $p_2$  is used as an approximate position to initiate the area based correlation process;
- ✓ Point  $p_3$  is the result of the correlation;  $p_1$  and its homologous  $p_3$  are used for the computation of the 3-D co-ordinates of  $P_1$ .

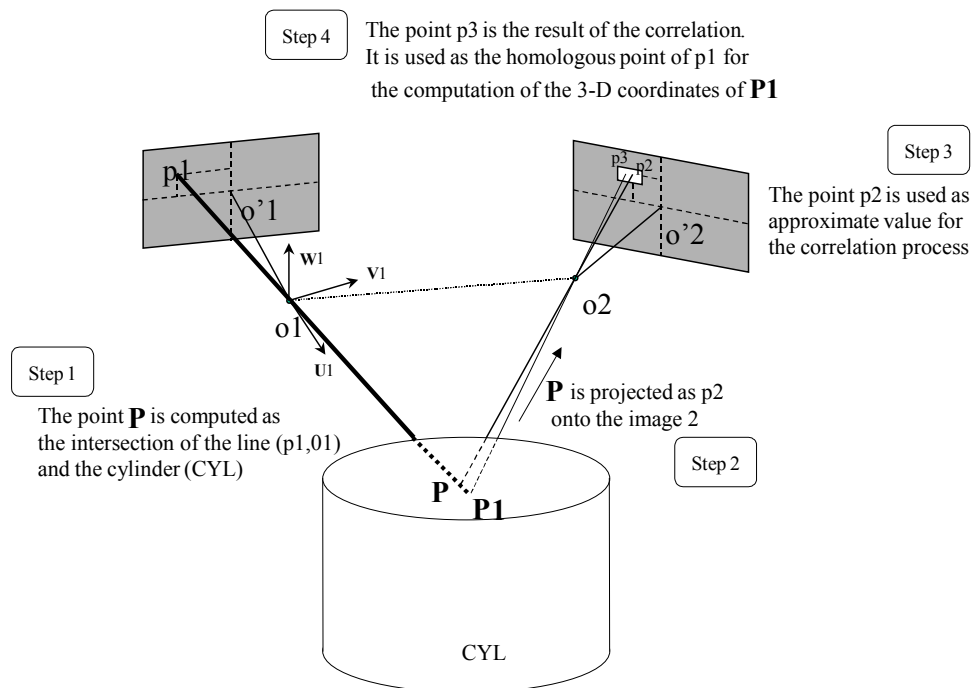


Figure 2. Steps of the Semi-automated Primitive Measurement Method in ARPENITEUR.



Figure 3. Aleyrac project : Semi-automated Primitive Measurement Method applied to a cylindrical shape.

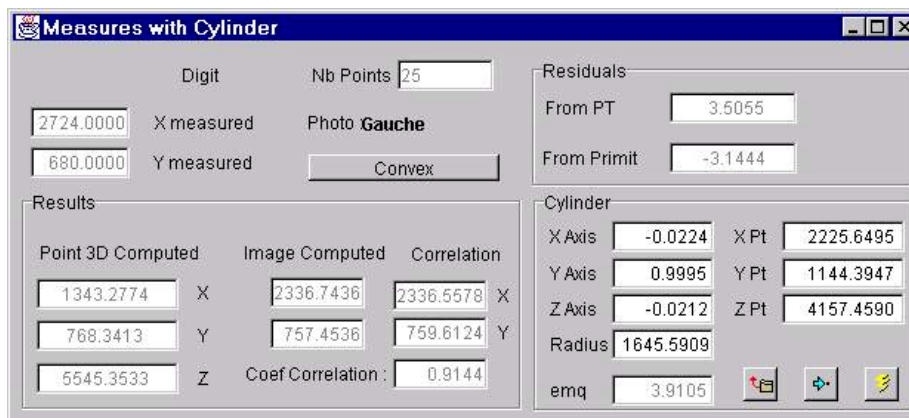


Figure 4. User interface of the processing module for the Semi-automated Primitive Measurement Method.

The final co-ordinates of P1 can be compared to P (computed in step 1 depending on the parameters of the primitive) and to the definition of the primitive. The example presented in Figures 9 and 10 is applied to a cylindrical shaped object:

- ✓ The cylinder is defined by its seven parameters from a set of 3-D points;
- ✓ digit: a digitised point is defined by its co-ordinates given in pixels (in one image, left or right one);
- ✓ Results: the 3-D point (step 1), the pixel co-ordinates of p2 in the other image (image computed) and p3 (correlation)

✓ Residuals: discrepancy distance between P1 and P on the one hand, P1 and the primitive on the other hand.

The I-MAGE process is available with several geometrical primitive : Plane, Cylinder and Sphere.

During the plotting phase generic modeling possibilities are available using, if desired, the I-MAGE process ; meaning that one can combine traditional plotting (one image after the other, with the possible help of correlation) and I-MAGE process that give you a 3-D with one photo digitized.

ARPENTEUR offers a set of modeling possibilities such as 3-D measurement of points, lines, line-strings, curves and polygons directly available in Bentley's Microstation DGN format, in addition to ASCII files.

Our Semi-automated Primitive Measurement Method is a useful tool for fast object-modeling. It is interactive, as the operator follows and analyses the results of adjustments directly on the images. For archaeologists, architects or civil engineers, the object-geometry parameters given by the process make the interpretation of the object-building available for several computer-assisted applications. More geometric primitives can be added during the process and it can be used for other types of projects; such as industrial applications:

### 3.2 Automatic 3D measurement

We see that the I-MAGE process is available during the plotting file and the operation can limit his observation on one photograph if he don't got out the calculated primitive, we have introduce this approach in the main real time loop of ARPENTEUR and each time you move the cursor the I-MAGE process is done and you get the right cursor position for the other photo and the 3D coordinate of the observed point. After an appropriate referential definition this is particular convenient to make facade observation for example.

Of course the system can be wrong in the case where the building is very irregular and the gap too much important related to the first calculated primitive. Important gaps in deepness lead to increasing image parallax, it is possible to correct this default increasing correlation matrix size ( configurable from ARPENTEUR menu ).

The result control can be numerical by computing the distance between the line of sight or graphical by the observation of the epipolar line on the other photo.

## 4. IMAGE RECTIFICATION

I-MAGE process, as described here over, uses photogrammetric calculation results ( according to used photograph orientation ) and optimization calculation results of a geometrical primitive which gives an approximation of studied scene element. Using the same information we developed an image parametric rectification module based on the primitive geometrical parameters. Therefore we use the same way for the plan rectification or cylinder development.

Rectification modules are so integrated to restitution modules, after orientation phases and the calculation of a geometrical primitive observable in the scene, the user can choose between a helped 3-D keyboarding or the rectification of an image portion where the primitive can be seen.

This experiment was performed in collaboration with the AGP company ( Art, Graphique et Patrimoine , Tremblay, France) and was the object of a study agreement between CNRS and the Company. The aim was the study of Thermes de Cluny frigidarium in "Musée National du Money-Age in Paris.

We proposed an original way for the cartography of the frigidarium barrel vaults. In this case, where an important photogrammetric and a topographic report were asked, we used a photographic equipment and the photogrammetric results to develop the barrel vaults, in independent cylinders. We supplied a set of scaled graphic documents showing the barrels developed.



Figure 5. Thermes de Cluny, Frigidarium.  
(Photograph from : <http://www.musee-moyenage.fr/>)

#### 4.1 The chosen technique.

Photographs rectification showing cylindrical surfaces on cylinders is seldom made but one can find some good examples in literature, either in photogrammetry [Hemmler, Wiedemann, 1997] or in computer vision [Puech, 1997].

We made the decision to generalize the approach integrating image development to I-MAGE process. This introduces two consequences :

- ✓ Method applies to any developable surfaces ( plan, cylinder, cone ).
- ✓ Process is integrated to ARPENTEUR restitution module and corresponds to a restitution choice ( depending of the wished precision, final document type planned..).

As they are integrated to the I-MAGE process, one takes as acquired camera orientation, and the existence of a visible geometrical primitive on photograph, calculated from a previous measured point set.

The method unfolds in different steps ( see fig. 6 ) :

- ✓ Studied cylinder primitive calculation and development,
- ✓ Resulting image size choice,
- ✓ For each pixel resulting image color determination
- ✓ Homologous point calculation  $P(\theta, r, d)$  of developed cylinder.
- ✓ Point P calculation in land referential ( on the cylinder )
- ✓ Point P projection on the photograph ( after determination of point position concavity or convexity )
- ✓ Point  $P(x_2, y_2)$  interpolation on neighbor point  $P(x_1, y_1)$  pixels.

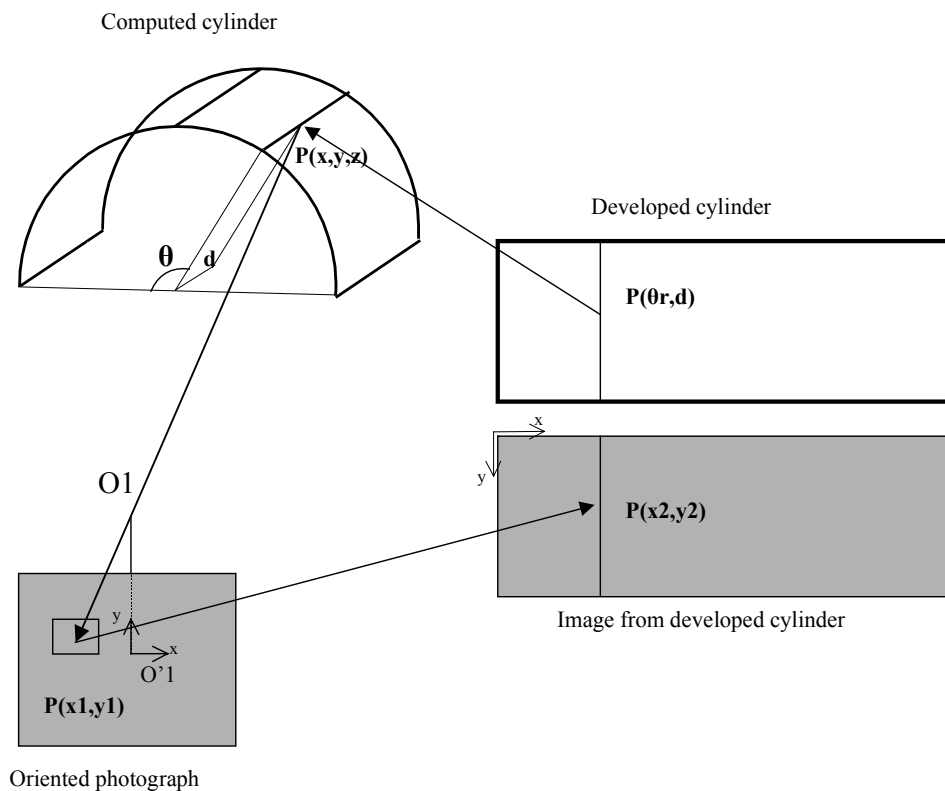


Figure 6. Cylinder rectification.

This approach has been integrated in ARPENTEUR restitution module with two possible primitives : plan and cylinder. Of course this approach is strongly dependant from both, primitive orientation and optimization calculations. These dependencies make ARPENTEUR, in a regular photogrammetric context, a strong and reliable method.

## 4.2 RESULTS

The shooting was made with semi-metrical equipment (Elcovision 24x36 et Rollei 6x6) by AGP company; the photographs topometrically adjusted. We introduce here after a result on the annexed small room Frigidarium.



Figure 7. Shooting with a semi-metric camera 24 x 36.

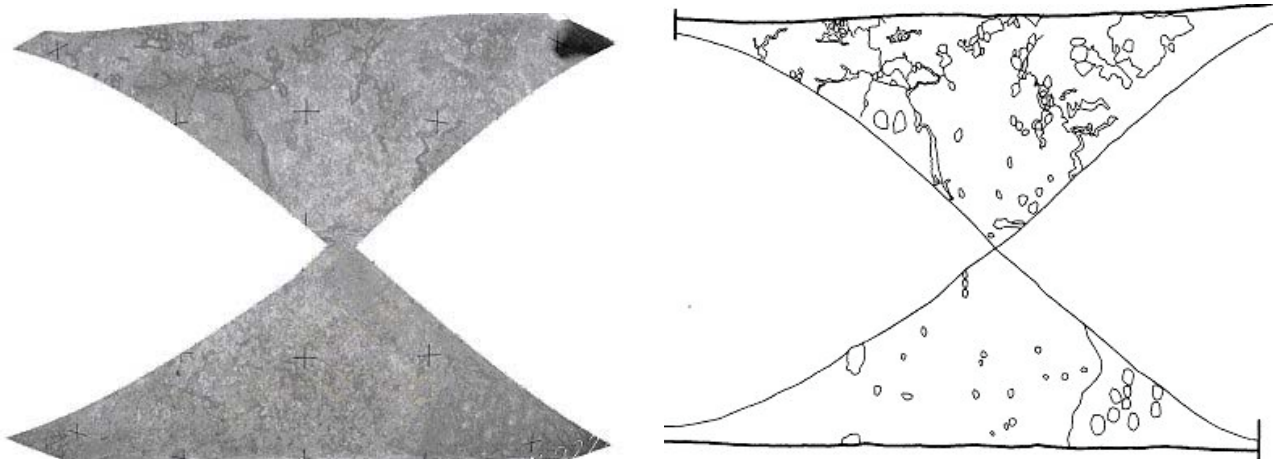


Figure 8. On the left North-South developed cylinder, on the right cartography of digitized plastering erosion made by AGP Company rectified photographs.

## 5. CONCLUSION

I-MAGE process is one of the ARPENTEUR recent evolutions and make a tool devoted to the Archeologists and to the Architects, thanks to an automatization of photogrammetric treatment to allow a non photogrammetrists person to make a correct plotting.



In the I-MAGE process, cylinder development integration, and more generally image rectification, offer to the operator another restitution way, which in the building archeology context has often a great interest. The produced document allies qualitative information driven by the photographic medium, metric information in two dimensions (sometimes in a unused space, as a developed cylinder ) and also last but not least secures the link with the tri-dimensional model and permits to re-locate all the measurements made on the land referential.

Developed for a quantification cartographic aim, this approach should on the other hand, open interesting way of future development in wall painted studies. In this perspective it remains to develop our research according two main axes :

- ✓ Projections on non- ruled surfaces ( which is the case for a sphere in the study of domes or cupolas ) where the choice of projection type shall be capital. [Karras et al., 1997].
- ✓ Mosaics generation from some corrected photographs [Puech, 1997]

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