ARPENTEUR:A WEB-BASED PHOTOGRAMMETRY TOOL FORARCHITECTURAL MODELING

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ARPENTEUR:
A WEB-BASED PHOTOGRAMMETRY TOOL FOR ARCHITECTURAL MODELING

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ABSTRACT

ARPENTEUR (as Architectural PhotogrammEtry Network Tool for EdUcation and Research) is a web application for digital photogrammetry mainly dedicated to architecture. ARPENTEUR has been developed since 1998 by two French research teams: the "Photogrammetry and Geomatics" group of ENSAIS-LERGEC's laboratory (Strasbourg, France) and the MAP-gamsau CNRS laboratory located in the school of Architecture of Marseille (France).
The software package is a Web based tool since photogrammetric concepts are embedded in Web technology and Java programming language. The aim of this project is to propose a photogrammetric software package and 3D modeling methods available on the Internet as applets through a simple browser (http ://www.arpenteur.net).
The use of Java and the WEB platform is full of advantages. Distributing software on any platform, at any place connected to Internet is of course very promising. The updating is done directly on the server and the user always works with the latest release installed on the server. Three years ago the first prototype of ARPENTEUR was based on the Java Development Kit (J.D.K. 1.1) at the time only available for some browsers. Nowadays, we are working with the J.D.K. 1.3 plug-in enriched by Java Advancing Imaging (J.A.I.) library.
Our photogrammetry package includes different solutions for the orientation of the digital images. Different kinds of cameras (with fiducial marks, réseau cameras, non metric and digital cameras) can be used. The réseau crosses are measured automatically in the interior orientation. An area based correlation process allows semi-automatic measurements on the images. Various examples from different projects mainly based on small and medium format images are accessible via the world wide web on our servers located in Marseille and Strasbourg (France). Users can set-up their own projects by transferring their images, camera and control information on the ARPENTEUR servers from any place in the world connected on the Internet.
The concept of running photogrammetric software on the Internet by a simple browser is extended by a new approach of architectural photogrammetry 3D modeling. The architectural survey is monitored by underlying geometrical models stemming from architectural knowledge. Image correlation, geometrical functions and photogrammetry data are combined to optimize the modeling process. The resulted 3D models can be visualized either on the internet-oriented VRML plug-ins, or inside the Microstation™ software package.

Keywords: architectural photogrammetry, digital photogrammetry, object modeling, Java, WEB technology

1. INTRODUCTION

Due to the development of digital cameras, close range photogrammetry is more and more used for accurate documentation and 3D modeling of objects. Several applications mostly running on windows based platforms are proposed on the market (Grussenmeyer & Al Khalil, 2000). But for each update and depending on the computers's operating system, another installation is required. For software packages available as applets or applications on the Internet by simple browsers, the user always works on the server with the latest release available. We present in this paper our web based tool called ARPENTEUR (as ARchitectural PhotogrammEtry Network Tool for EdUcation and Research). This project has been initiated in 1998 by two French Research groups located in Marseille and Strasbourg. It aims to develop a digital photogrammetric workstation on the Web and 3D modeling tools dedicated to architectural survey. The programming language chosen for the ARPENTEUR software is Java™. Any computer with a Java Virtual Machine can run the same compiled Java code. The Java program (applet or application) is automatically downloaded from the Web (at http ://www.arpenteur.net) and runs within a Web browser on the user's desktop.

2. CHRONOLOGY OF ARPENTEUR

Three years ago, the first prototype of ARPENTEUR presented at the ISPRS Commission V Symposium in Hakodate (Drap & Grussenmeyer, 1998) was based on the Java Development Kit (J.D.K. 1.1) at that time only available for some browsers.

The release presented at the ISPRS Congress and CATCON contest in July 2000 in Amsterdam (Grussenmeyer & Drap, 2000) was developed by using J.D.K. 1.1.8 and available from any hardware platform supporting a Web browser using this Java level (as for example Netscape™ Communicator 4.51 on PC).

Currently, we are working with the J.D.K. 1.3 which is available as a simple plug-in on all common browsers, enriched by Java Advancing Imaging library (J.A.I. 1.0.2.). To run ARPENTEUR 2.0, the packages required on the computer are only the J.D.K. 1.3 and J.A.I., downloadable from SUN' web site, possibly (but optional) Cosmoplayer as and additional VRML plug-in for the visualization of 3-D models. This last plug-in is not required to make the photogrammetric orientations. Another visualization tool is under development and should avoid the installation of this VRML plug-in in the future.

The use of ARPENTEUR (figure 1) goes through the following three steps:

1. **Connection** : the HTTP server (Hyper Text Transfer Protocol) allows the creation of a workspace by the registration page. The user has access to example projects or to his own projects protected by a password on the server.

2. **Managing Project** : the user can work on his own project and has a specific access to his workspace via FTP server (File Transfer Protocol). The FTP server allows to read files saved on the user workspace, to put images (GIF or JPG image formats, with a limited size recommended around 2MB), camera files and control point files on the server, and to get the result files generated in HTML format by the system.

3. **Photogrammetry and Modeling** : ARPENTEUR uses a lot of Java classes. The process is running in the cache memory on the client computer. The Java security restrictions do not allow an applet to read or write files on the client disk. A Java application server has been developed to solve the former problem. It runs on the server machine and is dedicated to save report files or 3D CAD models on the server disk. The objects are managed through the network by using the RMI (Remote Method Invocation) method. All files (camera, control points etc.) and images of each project are stored on the server and protected by a password.

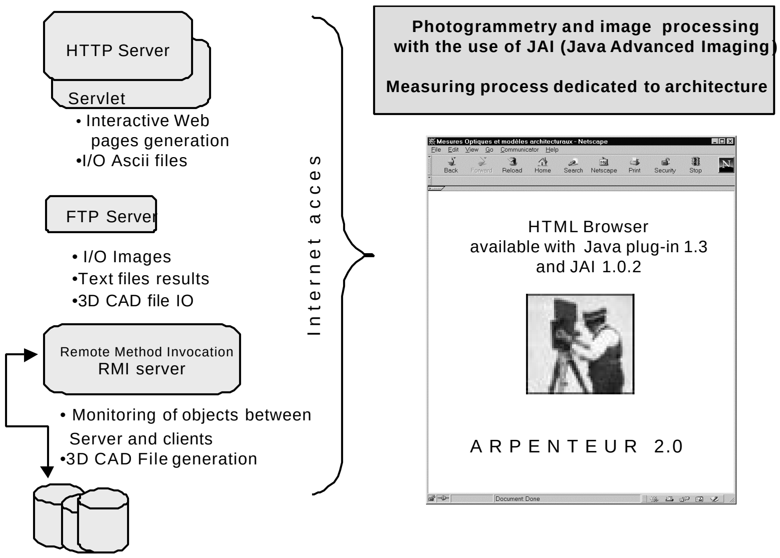

Figure 1. ARPENTEUR's project synoptic scheme

GRUSSENMEYER, P., DRAP. P. (2001) (invited paper). **ARPENTEUR, a web-based photogrammetry tool.**
Proceedings of SPIE. Videometrics and Optical Methods for 3D Shape Measurements VII, Electronic Imaging and Photonics Symposium, January 21-26, 2001, San José, California, ISSN 0277-7868, ISBN 0-8194-3987-8, pp. 117-225.

In short, the installation of JDK 1.3 plug-in and JAI 1.0.2 library is required on the user's computer. By selecting the WEB address www.arpenteur.net , the user will have the choice to start ARPENTEUR on one of the two servers located in Strasbourg or Marseille. User name and password are required to have an access to personal projects. By an anonymous login, all users will have access to different projects proposed as examples. By creating an own project, a directory will be created on the server and example models will be copied in the user's folder. Personal projects (images, control point and camera files) can then be up-and-downloaded on the server by FTP.

Since the Java plug-in 1.3 has been used (from ARPENTEUR 2.0), the Java security level is managed by a '.java.policy' file which has to be installed in the system directory of the computer. In order to use the Java Advanced Imaging library (JAI) previously installed on the client computer (JAI is freely distributed by SUN ™) the user has to grant the applet to read or write files on the client disk (an example of '.java.policy' file is available on the ARPENTEUR web server).

This install-free approach to distributing and running software is attractive. However, the performance of the system depends on the data transfer on Internet (which is still irregular!). The loading time can be important for large files as the software itself or the image files. But once the files and images are loaded in the remote computer, the work is possible by the use of the disk cache. New network tools with high data transfer are expected soon and should improve the working order of the web-based tools.

3. PHOTOGRAMMETRIC ORIENTATIONS ON THE WEB

The ARPENTEUR photogrammetric orientation approach is until now mainly based on two step orientations (relative and absolute orientations). A bundle bloc adjustment has been available since the version 1.4.2. but the modeling process is still based on the measure of homologous points visible on any image pairs from the project. Multi-image measuring in not available until now. For point measurement, we use area-based correlation as a combination of the maximum correlation coefficient and correlation in the subpixel range.

The usual steps of the orientation are :
1. Model definition and transfer of the image files, camera data and control points to the server;
2. Interior orientation of the images (left and right);
3. Exterior orientation (relative & absolute, or DLT & bundle adjustment);
4. Plotting & 3D-modeling (see paragraph 5 in this paper);
5. Results files in HTML format, CAD files in DGN format, visualization in VRML format.

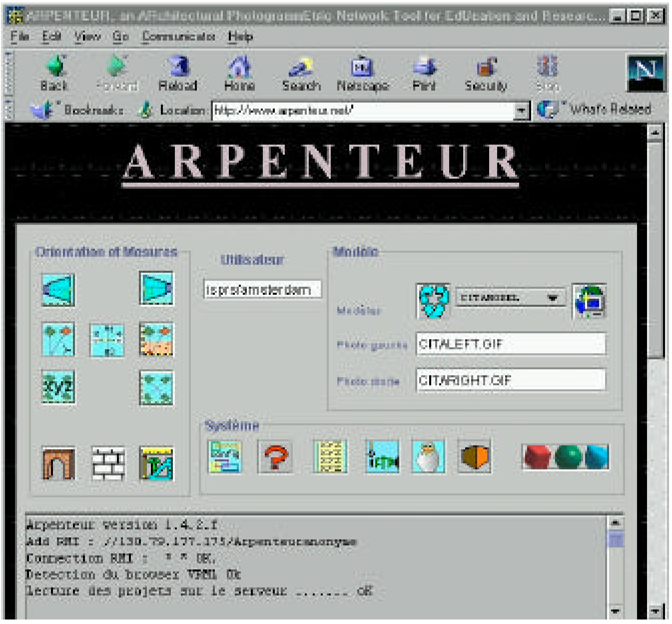

Figure 2. ARPENTEUR main frame available at http://www.arpenteur.net

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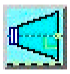
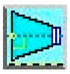
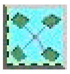

Interior orientation (left image of the model)


Interior orientation (right image of the model)


Relative orientation of the model

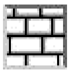

Absolute orientation of the model

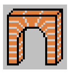

Absolute orientation based on distances and vertical lines


Control point and tie point measurement in preparation for the bundle adjustment


Computation of the bundle adjustment (two or more images of a project)

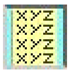

Simple 3-D measurements (points, , lines …) or Semi-automated Primitive Measurement Method

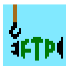

Measurement process based on stone by stone surveying, see an example in (Drap et al., 2000)


Measurement process based on formalization of architectural and geometrical knowledge, see an example in (Drap et al.,1999)

Configuration (correlation matrix , colors, VRML editor…)


Help file

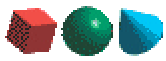

Results of the orientation process (in HTML format)



Specific access to the user's workspace by FTP (File Transfer Protocol), to up and download files.


Creation of a new model


3D viewer (developed in Java™ within Arpenteur)


3D viewer (visualization in Cosmoplayer™ and generation of VRML)

For the inner orientation, ARPENTEUR can operate with different kinds of digital images (equipped or not with fiducial marks or réseau crosses, or more generally images from point and shot digital *amateur* cameras). Camera parameters are stored in a separate text file. The calibration has to be done separately with other software.
The required data are :

- number and co-ordinates of the fiducial marks, or réseau crosses, or corners (non-metric small format images), or pixel size (digital camera);
- co-ordinates of the principal point and calibrated focal length;
- distortion curve (table of the radial distortion).

An affine transformation is used to compute the pixel or photo co-ordinates. During the inner orientation, a correlation process can be applied to measure automatically réseau crosses in the image. For the inner orientation of digital images, the four corners are located automatically. GIF or JPG image formats are usable with ARPENTEUR.

Different solutions are available for the outer orientation. The given co-ordinates of object points are recorded in a so-called control point file. The three methods presently proposed in ARPENTEUR are:

1. Orientation in two steps : that means for a start a set of homologous points evenly distributed in the model (relative orientation), then measurement of control points (three at least) to scale and transform the three-dimensional model in relation to the reference system. As soon as a relative orientation is computed, homologous points can easily be measured by indicating the epipolar line in the model;

2. A simple but roughly solution to orient the model is also possible by measuring a distance and a vertical line (for simple projects), without any control points;

3. Orientation in one step : all measured points are matched in a bundle adjustment. The initial approximate values of the adjustment (camera rotations and co-ordinates of the center of perspective) can be achieved by a Direct Linear Transformation if at least six control points are already measured in the images. This third solution is also appropriate for convergent photos. The control and tie points are measured on the images arranged in pairs in the bundle acquisition module. The set of images is afterwards computed separately in a block adjustment with the help of another applet.

A detailed example of a photogrammetric project management with ARPENTEUR has been presented in (Grussenmeyer & Drap, 2000).

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4. IMAGE PROCESSING & JAVA ADVANCED IMAGING

1. Correlation

Area based correlation is used to determine the required sub-pixel position in the digital image. In fact the measurement is done semi-automatically. The user has to measure exactly the required point on only one image (left or right image), and to point roughly its homologous on the other one. The task is to find the position of a geometric figure (called reference matrix) in a digital image. If the approximate position of the reference matrix in the image is known, then we can define a so-called search matrix. The size of the reference and search matrix can be defined by the user in a configuration menu.The semi-automatic measuring function is available at the different steps of the software (réseau measurement, outer orientation and plotting module).

After the adjustment of the relative orientation, a simplified correlation along the epipolar line is also proposed to the user.

More details about the coupling of the correlation process and our Semi-automated Primitive Measurement Method are given in paragraph 5.

2. Image processing

Image processing techniques from Java Advanced Imaging API (J.A.I.) are used for manipulating and displaying images. The J.A.I. extends the Java platform for developing image processing applications and applets in Java. It streamlines the process of creating powerful imaging software solutions. The Java Advanced Imaging API 1.0 Specifications was developed by Sun Microsystems, Inc., Autometric, Inc., Eastman Kodak, Inc., and Siemens Corporate Research, Inc. It offers advantages for imaging professionals and provides platform-independent and extensible image processing framework.

From ARPENTEUR 2.0 release, several image editing functions are proposed to the user by clicking on the right button of the mouse (for each displayed image):

- to zoom in & out;
- to choose the interpolation method (nearest neighbour, bilinear or bicubic transformation.) used for image manipulation (as zoom for example);
- to handle an image editor for extracting image parts;
- to enhance the image (brightness, color to B/W, etc.);
- to rotate the images in the window;
- to display a stereo window to allow the observation of selection of the stereomodel by the so-called anaglyph technique (figure 3);
- to display a magnified additional view for each image (figure 4);
- to change the shape, the size and the color of the cursor index.

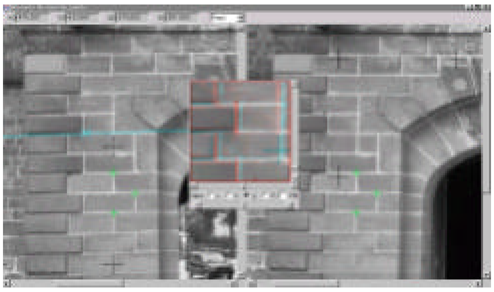

Figure 3. Stereo-window in the middle of the screen (anaglyph technique)

Figure 4. Optional additional views (zoom) for each image

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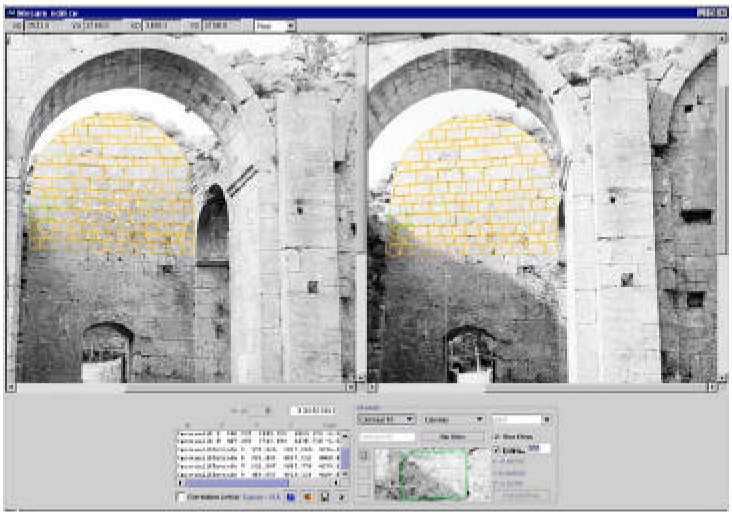
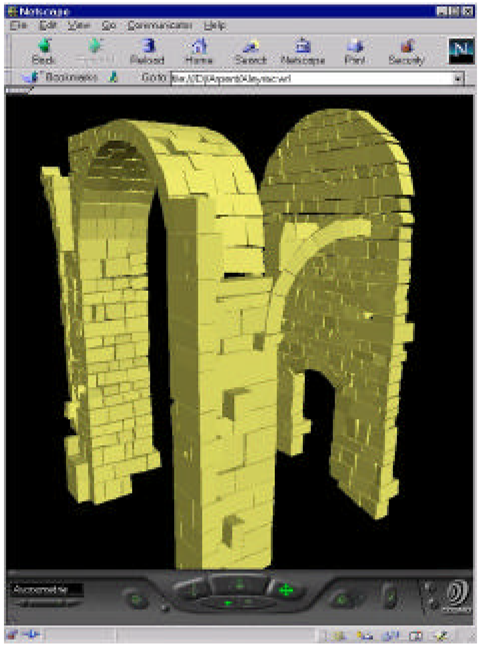
5. ARCHITECTURAL MODELING WITH ARPENTEUR

Different modeling tools have been developed for research purposes in the frame of ARPENTEUR since 1999.
A measurement process based on formalization of architectural and geometrical knowledge for the survey of geometrical primitives of architectural elements was presented at the last CIPA symposium in Olinda, Brazil (Drap et al., 1999).
At the ISPRS Congress in Amsterdam (Drap et al., 2000), a so-called ‘stone-by-stone surveying method’ for the modeling of archeological sites was introduced (figures 5a,b). The method is based on a previous analysis of the edifice. In the example shown below (Notre Dame d’Aleyrac -Romanesque priory church- in Provence, France) the characteristics as well as the chronology of the construction and the properties of all the measured architectural entities have been defined by Andreas HARTMANN-VIRNICH, archaeologist at the LAMM UMR CNRS Laboratory, in Aix-en-Provence, France. As the photogrammetric survey is limited to the visible part of the blocks, we need the approximate depth for each type of stone in order to compute its volume. An extrusion vector is computed to complete the geometrical description of the stone blocks. A polyhedron representation of the object morphology follows the step of block measurement. Each element is added to a data structure according to topological or geometrical rules. The result is therefore a collection of ordered blocks that includes relations between adjacent blocks.





Figures 5 a, b. Measurement process based on stone-by-stone survey, from a project in Aleyrac (Drôme, France), and visualization of the resulting VRML model.

In ARPENTEUR 2.0 (October 2000), new measuring features have been developed (figure 6):
- 3-D data as points, lines, linestrings, curves and polygons are available in Bentley’s Microstation DGN format, in addition to ASCII files;
- a new measuring method of digitizing 3-D points which is based on the coupling of image correlation and geometric primitives as planes, cylinders, cone and sphere shapes of the object : Semi-automated Primitive Measurement Method.

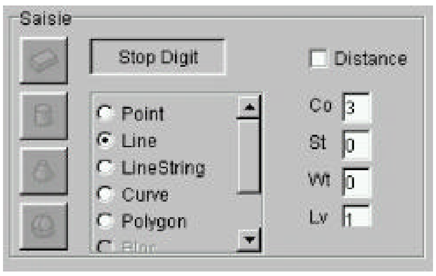


Figure 6. New 3D modeling menu available in ARPENTEUR 2.0
(four primitives available in the left column)

In architecture, the geometric parameters of so-called architectural entities are part of the basic data required for the modeling process. Our idea is to compute those different architectural entities. The object is first decomposed in geometrical primitives as planes, cylinders, cones or spheres shapes.
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 (in figure 7, there are entities related as planes, cylinders and spheres).

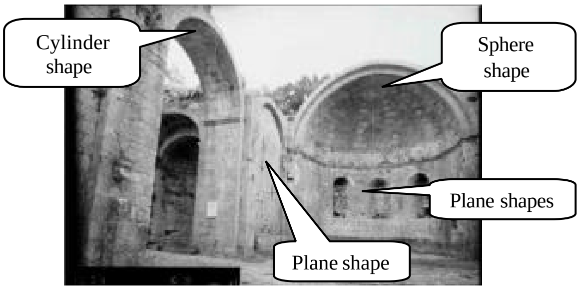


Figure 7. Wild P32 image of the Aleyrac site (France).

The result of each primitive adjustment is used to simplify the measuring process. That means that for a computed primitive of an object, from one measure on one image you can compute and measure by correlation its homologous in the other images.
We consider 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 a couple of images :

- A point **P** can be computed from one image by intersection of an image ray (p1, O1) and the geometric primitive (the cylinder in figure 8 is defined by 7 parameters in an earlier process from a set of 3-D points);
- **P** is projected as p2 onto the second image;
- The point p2 is used as approximate position to initiate the area based correlation process;
- The 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 **P1**.

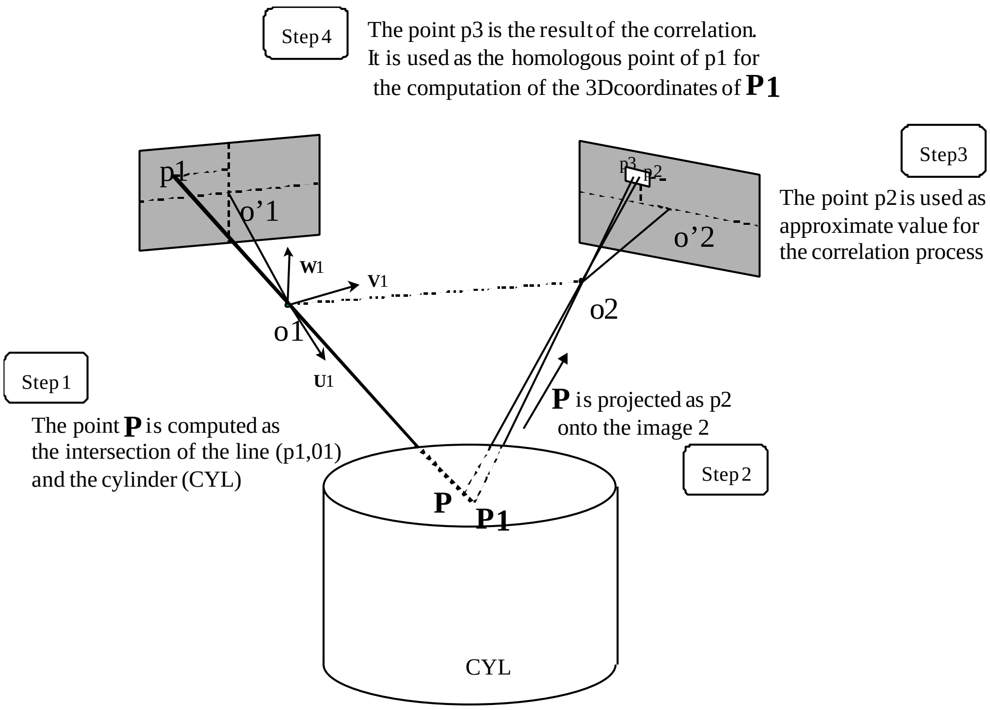


Figure 8. Steps of the Semi-automated Primitive Measurement Method in ARPENTEUR

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 cylinder shape of an 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 3D 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.

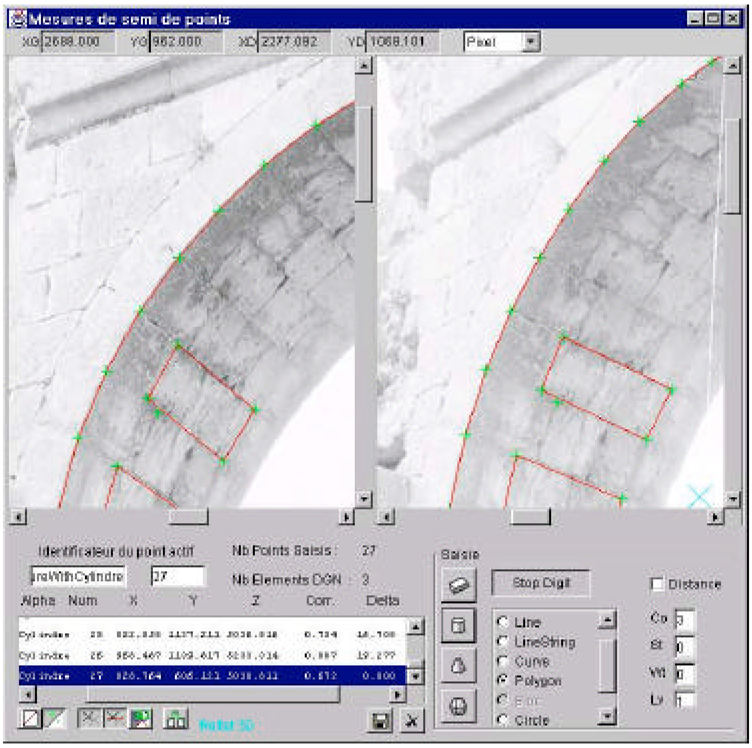


Figure 9. Aleyrac project : Semi-automated Primitive Measurement Method applied to a cylinder shape.

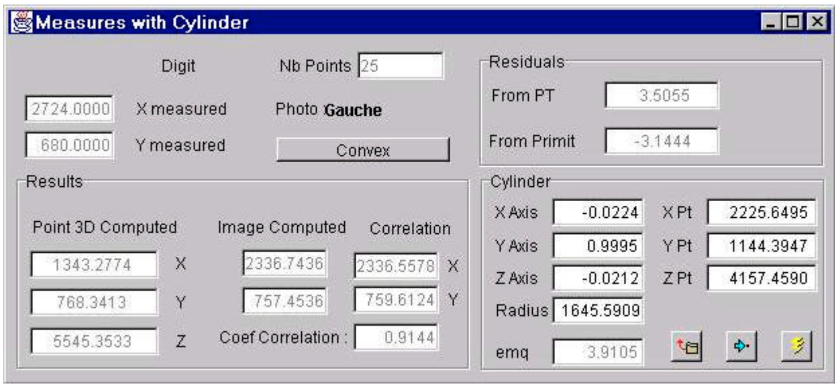


Figure 10. User interface of the processing module related to the Semi-automated Primitive Measurement Method

Our Semi-automated Primitive Measurement Method is a useful tool for fast object-modeling. The method is interactive since the operator follows and analyses the result of the adjustment directly on the images. For archeologists, architects or civil engineers, the object-geometry parameters given by the process make the interpretation of the object-building available for several computed-assisted applications. More geometric primitives could be added in the process and applied to other applications as industrial ones.

6. CONCLUSION

The concept of running a photogrammetric package on a web platform is in constant updating due to the fast developments of the Java Technology. Distributing software on any platform, in any place connected to the Internet, reducing updating versions, is of course very interesting for the users. Even if the data flow on the Internet is still irregular (while waiting faster network tools with high data transfer), ARPENTEUR is nevertheless operational with 'small format' images. Various solutions for the orientation of the photogrammetric models as well as for modeling buildings are now included in the software package. The Semi-automated Primitive Measurement Method presented in this paper as an example of 3-D modeling in architectural photogrammetry could easily be applied to other domains as object modeling in industrial applications. In our concept of modeling, the measurement process is monitored by the knowledge of the visible space. The software must guide the operator during the 3-D plotting phase. The next step of the process will be to link the geometrical data observable on the measured object (for the moment limited to simple geometrical primitives), the Semi-automated Primitive Measurement Method and image processing techniques to propose rectified images (plane rectification, cylinder development, etc.) or visual models according to the measured primitives.

7. ACKNOWLEDGEMENTS

The authors wish to thank Gilles Gaillard (Marseille) for his contribution to the development of the ARPENTEUR software package in 2000 during his postgraduate studies at MAP-gamsau.

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