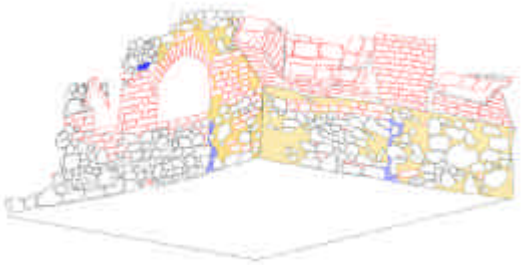
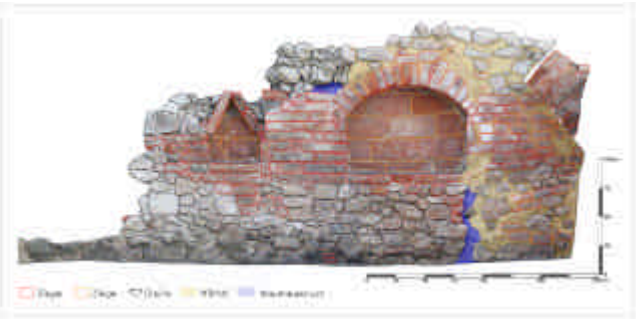
A comparison of Autodesk CAD Overlay and kubit PhoToPlan for the perspective rectification of photos in archaeology.

At the FHTW in Berlin Dominik Westermann, graduate in the subject of restoration/excavation techniques, wrote his diploma dissertation on the theme of *Photogrammetry and Digital Photography applied to the Technique of Excavation*.
For this he examined the practical application of rectifying individual images as a method of documentation on archaeological excavations. Amongst other things he compared the two rectification programmes PhoToPlan and CAD Overlay using a comprehensive practical test. The following article describes the results of the comparison. The complete work can be ordered direct from Mr Westermann (Dominik.Westermann@gmx.de).



Introduction

CAD Overlay is produced by Autodesk and PhoToPlan by kubit. Both programmes offer the functionality for rectification of digital images. The programmes differ both in their service philosophy and also in the mathematical methods employed for the rectification. The limits of the systems are described and attempts at solutions offered.



Rectification in archaeology

In building research the rectification of individual images serves as a flexible and wide-ranging tool for the rectification of planar surfaces, for example undecorated façades, walls or floors. In archaeological fieldwork this technique of documentation is still hardly ever employed, although in everyday excavations there are a great number of discoveries that could be documented with it. Above all the technique offers potential in areas in which building research and archaeological field research overlap, or in carrying out excavations with regard to man-made layers and the documentation of sections.

The programmes

Autodesk's **CAD Overlay** serves to facilitate and improve the manufacture and management of images, which is only possible to a limited degree with AutoCAD. Above all it is designed for use by architects and cartographers, and for the undertaking of the interpretation of photographs and telemetry. kubit actually programmed **PhoToPlan** for the photogrammetric interpretation of individual images and it is useful for scale-accurate, projective rectification of digital image data. Both are programmed as ARX applications and consequently are integrated seamlessly into the programme structure of AutoCAD.

Rectification methods

CAD Overlay rectifies digital image data on the mathematical basis of plane affine transformation. By using a higher number of control points they can also be rectified using a polynomial transformation. PhoToPlan works on the basis of projective transformation. For generating reference information two methods are offered: rectification using control points and rectification using geometry.

CAD Overlay – how it works

The rectification of individual images is always related to a certain plane (the rectification plane). This must be defined in the programme. In CAD Overlay the XY plane of the World Coordinate System (*WCS*) always serves as the rectification plane. That corresponds to plan view. For the rectification of sections, façades or similar vertical or sloping objects this means that the control points must be transformed into the World Coordinate System before rectification. Also, the finished rectified image is restricted to plan view and cannot be moved into another coordinate system. Consequently, no correctly oriented photographic representations of vertical or sloping objects can be produced. Due to this fact it also unavoidably follows that complex objects with several rectification planes can only be rectified with great trouble and time.

Using a special command the original image is loaded into the drawing, and is positioned next to the control points which are placed towards the edges of the image. Drawing file and uncorrected image must occupy the same file/folder.

Upon the command *Image-Correlate-Rubbersheet* rectification of the image is started. Firstly the image to be rectified is chosen on screen. Then the control points must be individually assigned to the uncorrected image. Using a cross cursor the position of each control point in the uncorrected image is selected and marked using the mouse. With a further click of the mouse the mark is linked to the control point. In order to define a control point precisely on the original image it is often necessary to zoom in quite considerably. For this CAD Overlay does not offer an additional tool; the enlargement tools of AutoCAD must be used. As a result the completion of the point correlation is unnecessarily complicated.

Once the correlation is finished a dialog box is displayed, which gives information about coordinates and the value of residual errors, as well as about which transformation can be used. Large errors often result from incorrect matching of source point and destination point, and can be recognised and removed by means of this dialog box. After this the rectification process is started. The programme calculates the image rectification and positions it over the utilized control points. The original image is thereby deleted.

If a large number of images are rectified in one drawing, CAD Overlay requires a lot of time to load and display these images. This makes working with extensive photographic plans virtually impossible.

PhoToPlan – how it works

PhoToPlan is the opposite of CAD Overlay – it is not bound to a fixed system of coordinates. This has the advantage that the rectification of objects in 3D using their original coordinates is possible. PhoToPlan always uses the XY plane of the drawing coordinate system [*UCS*] as the rectification plane. In order to define this plane two commands are at the user's disposal: vertical rectification plane and free rectification plane. If more than the three control points required for the definition of the plane are chosen, then an average plane is laid through all the chosen points, and consequently the divergence of the individual points from the plane is averaged out. As many rectification planes as you like may be defined within one drawing file. The control points are easily imported into the drawing using the command *Import Control Points*. The points can be read in from a text file, and are inserted into the drawing as numbered symbols.

Using another command the distorted scale image is loaded and positioned manually in the vicinity of the rectification points. Unlike in CAD Overlay, the image is inserted into the actual drawing coordinate system [*UCS*].

Using the command *Rectification by Control Points* the rectification process is started. Here also the image to be rectified is chosen on screen and the control points are inserted one after another in the image. After choosing each individual source point an enlargement function is offered, so that the position of the control point in the image may be better determined. After the choice of the control point, the view reverts to the original zoom mode. This function enables a quick and uncomplicated correlation of the control points. After the correlation is finished a dialog box is displayed, which shows coordinates and the value of residual errors. The latter assumes that more than four control points were utilized.

Since PhoToPlan does not change the original scale image, a file name must be defined for the rectified image. Upon the command *Rectify* the projective transformation is now started, and the image is rectified and positioned over the control points.

For each rectified image two records are created. In the image position record, which has the suffix *.ppb, information about the image position is stored. By using this record a rectified image that has been inadvertently deleted may be exactly reconstructed. The record of the image rectification, characterized by the suffix *.prk, contains all the information concerning the individual rectification parameters, such as name, description, size and scale of the distorted and rectified images, as well as the rectification parameters, the coordinates of the control points and the definition of the drawing coordinate system [*UCS*]. Using this record the rectification process of eachindividual image can be examined and archived.

Results

If more than four points are employed for the rectification, PhoToPlan calculates an adjustment in the projective transformation. On the strength of this the rectified image has a mean alignment. The position of the rectification plane relative to all the points to be measured is of prime importance for the quality of the rectification, rather than the number of control points themselves. The rectification plane can be defined by as many points as you like. According to circumstances it can be more

favourable to rectify over fewer points, the best possible in one plane, than over many points which exhibit great differences in height (or depth) from one another. This also explains why, for example, the rectification of a long-distance shot over five points can possess virtually the same averaged out discrepancy as one overseventeen points. For the generating of the rectification plane (drawing coordinate system) [*UCS*] in PhoToPlan, it therefore follows that no single factor should be overly influential. During the polynomial transformation in CAD Overlay there is likewise a mean alignment of the rectified image, and in addition an estimation, or rather an approximation, of the values between the rectification points. As a result of the mathematical algorithm there are fewer errors with CAD Overlay not only with long-distance shots but also with wide-angle shots. However, if in addition one compares the remaining areas of the image to the coordinates, then it may be perceived, that as a result of the above mentioned estimation orapproximation large distortions appear between the control points. The higher the chosen polynomial degree, the larger these distortions are outside the control points, and the smaller the value of the residual errors within the control points. This is especially noticeable with wide-angle shots, which suffer an additional large distortion by this means. Overall, the discrepancies in the use of PhoToPlan remain in a narrow frame, and are therefore calculable. With CAD Overlay on the other hand, the values vary more considerably, and above all due to the estimation and approximation of the values between the rectification points the anticipated result of the rectification is difficult to appraise.

Finishing

An important function in the production of photographic plans is the cropping of the image. In CAD Overlay there is a choice of various cropping options. Using the command *Crop Polygonal Region* a polygon may be defined on the screen, on which the rectified image is cut. In spite of this the cropping of the image progresses very laboriously and is irreversible once the image is cropped.

The cropping of the image in PhoToPlan progresses without problems. Using a polyline a cutting limit is defined, and on the command *Cut Image* this polyline is selected and used as a cutting edge. The image information is not deleted by the cropping, but rather it is simply hidden, and at any time it is at the disposal of the user.

Performance

The time taken by PhoToPlan to rectify is always longer than that required by CAD Overlay for the same photographic configuration. However, the storage space required for the rectified image is always less with PhoToPlan.

Manual

The manual delivered with CAD Overlay gives a large overview of the programme's range of performance. Detailed instructions for individual topics are not given. As a result, the user requires a longer period of training before he can usefully use the programme. A mere three sides are dedicated to rectification. The user is not given information concerning the lowest number of control points required, nor on how to work with polynomial degrees.

Besides this, the limits of the rectification are not defined. The PhoToPlan manual enables a quick introduction to the programme. Using two examples rectification by control points and rectification by geometry are described at length. Each topic is

given in full detail. In addition, pointers are given for the input of scale images and the limits of the programme are clearly defined. All technical problems with the programme may be solved using thismanual [!].

Price

The current price for CAD Overlay is 1,798 Euros. For this you get the programme and the user manual.

The price of PhoToPlan is at present 1,740 Euros. For this you get the programme and the extensive manual. The programme is protected with a dongle.

Conclusion

The finished series of tests has clearly shown that the different methods of transformation produce differences in the results of the rectification, which are not to be ignored. Moreover the calculation of the coefficients on the projective transformation has proved its worth.

On the grounds of acquired experience it may be established that the interpretation of individual images using PhoToPlan proceeds in a substantially more linear and calculable way than with CAD Overlay.

Principally by means of the possibility of generating a mean rectification plane and through the use of projective transformation PhoToPlan becomes a specific tool, which can also see large projects through without problem. CAD Overlay cannot accomplish this. Admittedly, CAD Overlay rubber sheets photos with reference to the coordinate values of the rectification points substantially more precisely, but in addition however, and because of this, the area between the rectification points is distorted. Altogether it is plain that CAD Overlay is not an adequate programme for the rectification of image data produced by excavations.

The work has shown that the rectification of individual images represents a sensible technique of documentation, which gives the user a greater measure of control. However for excavations this technique of documentation only becomes a functional resource through the employment of digital cameras, since they guarantee the smooth-running flow of data. The technique might above all be interesting for those circles of people who carry out excavations on a private business level. The limit of rectification cannot be exactly drawn, it is rather for the user himself to define on individual factors. If necessary the scope may be widened through complementary Total Station measurements. In spite of all technical possibilities however, the relationship with and the understanding of the object may not be neglected or forgotten. Measurement should on no occasion replace thinking. Unfortunately the technical and personal realities on excavations are often not sufficient for a significant use of the interpretation of individual digital images. If the technical and personal basis is lacking, it should not be exchanged for a system of this type.

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Overview of the results

CAD Overlay	PhoToPlan
Description of the Program	
-Management, transformation and adaptation of screens under AutoCAD -Part functionality: rectification (Bildentzerrung) -AutoCAD application	-Scale-accurate, projective rectification of digital image data -Help towards interpretation of rectified images -AutoCAD application
Mathematical basis for rectification	
-Affine transformation -Polynomial transformation, free choice of degree	-Projective transformation
Focal points of the range of application	
-Rectification, finishing and digitalising of scanned cards and plans -Adaptation, management and conversion of on screen data in AutoCAD	-Photogrammetric interpretation of plane objects, for example façades, excavation sections, mosaic floors, paintings -Availability and interpretation of standard photographic plans
Rectification plane	
-The rectification plane is the actual XY plane of the World Coordinate System → Rectification plane is fixed; rectification is only possible using World Coordinate System	-actual drawing coordinate system [UCS] → Optional adjustment of the rectification plane within the area is possible -Definition of the plane on three or more points (calculation of a mean plane)
Reference information	
-Control points -Number of control points: depends on the chosen mathematical basis	-Control points or control lines Number of control points: at least four
The rectification process	
-Calculation of adjustment and notification of the value of residual errors due to overqualification (number of control points higher than necessary) -Rectified image overwrites the original image	-Calculation of adjustment and notification of the value of residual errors due to overqualification (more than four control points) -Rectified image exists as an additional file
Image cropping	
-Irreversible; the image is stored with new dimensions	-Reversible; the removed areas of the cropped image are simply concealed -Irreversible cropping is also an option
Additional functionality	
-Different filters for image optimising -Alteration of colour depth/image density -Adaptation, resolution and correction of	-Recording function for rectification data Elevation evaluation

bitonal images -Help towards vectorisation of bi-tonal images	-Calculation and evaluation of surfaces -Image montage: the amalgamation of several individual images into complex photographic plans
Documentation/Help	
-Online help -The rectification topic is explained very crudely	-Online help as PDF -A detailed manual, providing quick familiarisation by means of examples