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GEODETIC AND PHOTOGRAMMETRIC PRODUCTS JUST-IN-TIME AND AT THE SITE

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ABSTRACT:
The demands of architects, civil engineers, planers and conservation specialists on fast available, detailed and accurate data are still growing. To satisfy this demands during the limited time of a field campaign with limited personal resources, modern geodetic and photogrammetric equipment and survey concepts are required. In this paper the measurement concepts, the chances and limits of modern near real-time geodesy and photogrammetry for the architectural survey are presented. The examples are from the Ninfeo Bramantesco, at Genazzano, Italy, a building from the Renaissance. The survey has been done mainly by students during field campaigns in 1997 and 1998. The other example is the ruin of the antique Maxentius-Basilika at the Forum Romanum, Rome, Italy, were joint surveys have been done in 1998 and 1999.

KURZFASSUNG:
Die Anforderungen von Architekten, Bauingenieuren, Planern und Denkmalpflegern nach schnell verfügbaren, detaillierten und genauen Daten steigen ständig. Um diese Forderungen während der begrenzten Zeit einer Feldkampagne und mit begrenzten personellen Ressourcen zu befriedigen, sind moderne Ausrüstung und Meßkonzepte erforderlich. Diese modernen Meßkonzepte, die Möglichkeiten und Grenzen moderner und zeitnaher Geodäsie und Photogrammetrie für die Bauaufnahmen werden vorgestellt. Die Beispiele sind vom Ninfeo Bramantesco, in Genazzano, Italien, aus der Zeit der Renaissance. Die Arbeiten wurden 1997 und 1998 durchgeführt. Das andere Objekt ist die Maxentius-Basilika auf dem Forum Romanum, Rom, Italien, wo gemeinsame Messungen 1998 und 1999 stattgefunden haben.

1. REQUIRED DATA

1.1 Quality and Quantity of Required Data

Architects, civil engineers, planers and conservation specialists, summarized as *data users*, require a large amount of data, necessary to create a detailed description of a building. This description is necessary to derive information on the buildings status, on the buildings history and to provide the data for planing purposes. The data users ask surveyors or photogrammetrists, summarized as *data providers*, to deliver this data. But the acquisition of data is expensive, depending on the required amount of details, the required completeness and required accuracy, the scale of the products and the local circumstances. Therefore the first step for the data user is to define his requirements, e.g. based on the levels of detail and accuracy defined by ECKSTEIN & GROMER [1990].

The high demands according to completeness, accuracy and reliability and the limited resources of time and manpower require the use of modern techniques to satisfy the data users.

1.2 Time Schedule

As buildings have a long life expectancy there is normally no requirement to rush the survey of buildings. Therefore the traditional procedure for the data provider is

- to visit the object, to determine the required data for the measurement planing,
- to make a measurement concept and a measurement plan,
- to do the measurements and the image acquisition,
- to calculate the results, do the restitution and image processing and create graphical products,
- to control the results and
- to deliver the products to the data user.

This procedure in six steps usually lasts a few weeks, as the single steps are independent and are done when they can be done most convenient. But in more and more cases the data acquisition has to be done in a very short term:

- If the building is endangered or already damaged by environmental catastrophes, war, heavy traffic or building activities in the neighborhood [MEYDENBAUER 1896, VOLZ et. al. 1997].

- During joint field campaigns of data users and data providers, when the data users are waiting for the results of the data providers [TOZ & WIEDEMANN 1999].

In this cases, the data provider has to merge the above mentioned steps, whereas the only a priori information is provided by the data user in form of plans, sketches and photos. The data provider has to be prepared for adverse environmental conditions, few local support and very difficult objects. Therefore the data provider has to mention redundancy in terms of equipment, personal and the measurement concepts.

2. CONTROL NETWORK

A cornerstone of an architectural measurement campaign is the design, documentation, survey and signalizing of the control network. The control network consists of two types of reference points. The first are the instruments stations. Usually this points are marked at the ground by nails, tubes or chisel marks. This points allow the reconstruction of all measurement elements, points, level, intersection planes etc. The instruments stations are used to survey the control points at the building using polar measurements or ray intersections. The control networks delivers a homogeneous and accurate geometric reference covering the whole site

If no site covering reference system is available, each result of any measurement stays alone. To join different results, they have to be mosaiced. This is a process, leading to additional erros. The results are usually inhomogeneous especially at the edges of the working sheets, the probability of blunders is much higher.

2.1 Requirements to Control Points

The selected control points should be used for different purposes:

- defining and signalizing the location of selected horizontal intersection levels and vertical intersection planes,
- connect the manual measurements of the architects into the site covering geodetic reference system and
- act as control points for the orientation of photogrammetric images and the rectification.

2.2 Definition and Signalizing

The selection of the best locations of control points for the above mentioned purposes should be done in an joint inspection of the object. First the data users has to define his horizontal intersection levels and vertical intersection planes. This can be realized by using horizontal or vertical rotation lasers. The projected line can be fixed at the walls using chalk or adhesive tape and a pencil. This markings of the intersection lines may also be useful for the geodetic and photogrammetric measurements to follow.

The next step is to locate the points required for the manual measurements by the data users. They may mark this points as already mentioned. After this step, the photogrammetrist will select locations for additional control points. This can be natural points, documented using analog or digital photos and sketches, or signalized points

The final signalization can be done with special designed point marks. This marks shall satisfy the following demands:

- stay stable at the wall, resistant against adverse weather and gambling children,
- can be well measured with a theodolite
- showing an interactive readable point number
- can be reliable measured by an automatic point measurement algorithm, even in images with very different scales
- showing a code, which can be interpreted by an automatic point identification algorithm.
- leave no significant damage at the building, when they are withdrawn

Therefore marks have been designed as shown in Fig.1. A program produces postscript files which can be printed on a laser printer. For indoor purposes or in dry areas the paper marks can be fitted to the wall with adhesive tape. If the points have to resist rain, it is better to laminate the paper or glue it on thin styropore, and fit this marks to the walls with transparent silicone from a hardware shop. If laminated paper is used, only a thin film of transparent silicon will stay on the objects surface when the marks are withdrawn. Depending on the value of the objects surface other fixing techniques may be used.

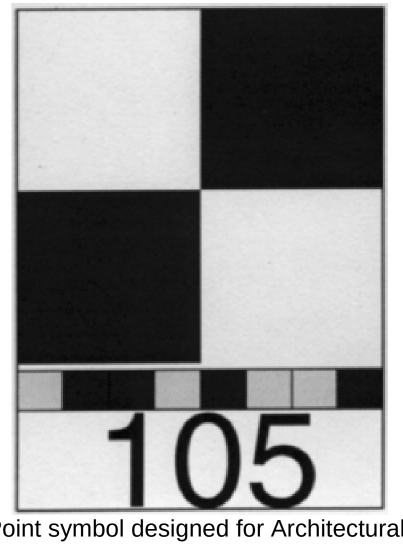

Fig. 1: Point symbol designed for Architectural Survey

2.3 Measurement

The measurements should be done with modern equipment, at least a tachymeter is demanded. Faster results may be achieved with a modern total station, allowing a reflector-less distance measurements to higher control points.

If no reflector-less measuring total station is available, the measurement of high control points has to be done by ray intersections. To avoid a point mismatching a laser pointer may be used to define the point to measure from at least two stations.

Depending on the experience of the surveying team a sufficient redundancy has to be achieved with the measurements: if an experienced team is at work, it may be sufficient to measure three or four elements (angles or distances) per point, if students have to do the measurements, at least six elements should be measured per point.

It is necessary to optimize the data flow and to calculate measurements and results for control purposes using a geodetic adjustment on a laptop at the site or in the evening hours at the accommodation. The network adjustment is a very sophisticated technique for the optimization of results of geodetic measurements. It allows the combined adjustment of measurements with different accuracies, allows the determination of accuracies for each evaluated parameter and coordinate and supports the operator when he analyses the results, for example with techniques for the automatic detection of blunders. Weak areas of the network can be determined and eliminated by additional measurements during the final days. This reduces the probability that an additional campaign becomes necessary or important points have to be withdrawn.

3. GEODETIC PRODUCTS

In most cases the data users expect not only a control network to fit his manual measurements in an site covering network, but other geodetic products. As data users in the most cases think in 2D plans they usually ask for horizontal or vertical intersection plans. The measurement of this products is done from the stations of the reference system like the measurement of the control network by polar measurement or ray intersection. It is much easier to measure for the surveyor if the data user has marked the required points, e.g. with chalk, before the measurement starts.

3.1 Point Plots

The primary result of geodetic measurements are lists of points with their, usually three-dimensional, coordinates. If this plans are plotted, the resulting plan is usually very intricate, even when plotted on large paper, what is usually not available during a field campaign. Such a data set may be created with simple programs from the coordinate list.

After the creation of such a point plot, it is necessary to draw the connections between the points on the screen, using a drawing or CAD program, or manually on a print out. This is time consuming and susceptible to error.

3.2 Coded Survey

If a well considered point enumeration concept and an appropriate software package has been installed, a real CAD model can be derived nearly automatically from the results of the adjustment program. Such results are much clearer arranged and interpretable.

Depending on the point numbers, keyed in during the measurement at the total station, a data transfer program

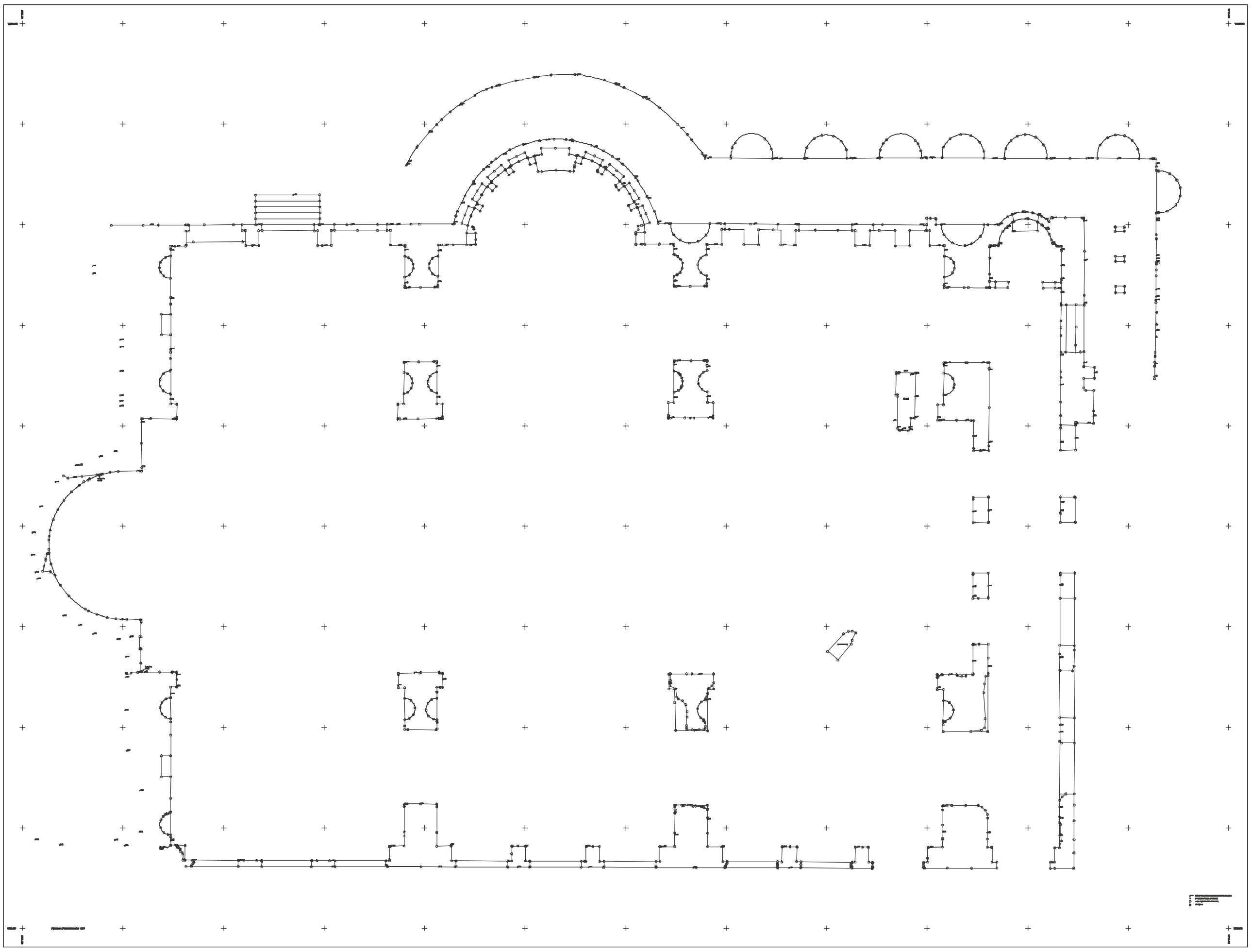

Fig. 2: Horizontal plan of Maxentius-Basilika, in Rome, Italy, measured with coded survey

knows which points are to connect. During the transfer of the data from the total station to the computer, the geometric measurement elements and the graphical attributes, depending on the point code, are separated. After the adjustment of the measured elements the calculated coordinates and the point code are merged and transfered in an appropriate manner to the CAD software.

It is desirable to deliver first products on paper already during the campaign, e.g. using portable printers with paper up to an size of A3. Gaps in the plans and contra-dictions between the plans and the local impression can be eliminated just in time. Architectural researchers can draw and document their findings in these preliminary plans.

Figure 2 shows a horizontal ground plan derived from such a coded survey. A similar product on A3 has been delivered during the field campaign. After the campaign only some text has been added, point ennumeration has been moved and a frame has been added. Such reviewed plans are usually delivered after the campaign.

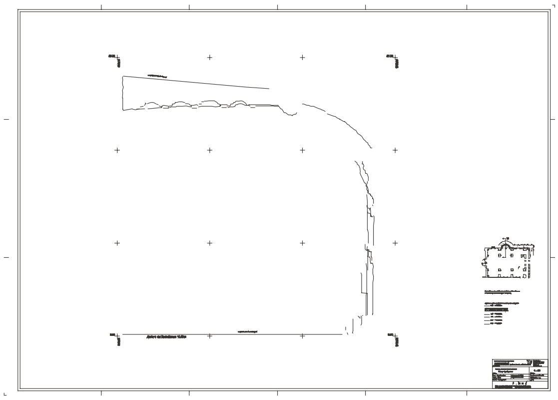

Fig. 3: Vertical cut through Maxentius-Basilika, in Rome, Italy, measured with coded survey

Fig. 3 shows a vertical plan measured with coded survey, but supplemented by some photogrammetric measure-ments.

A more advanced approach is, to use field computers with displays, also usable as touch-pads, which can be used to draw digital sketches on them. If an intelligent fusion with the digital field book can be achieved, as presented by Wunderlich & Helm (1999) the sketches may be develop into plans.

As new motorized and programmable reflector-less total stations occur at the market, programs can be developed to do a nearly automatic measurements of typical products like horizontal and vertical intersections.

4. PHOTOGRAMMETRIC PRODUCTS

One of the advantages of the photogrammetric approach for the architectural survey is the separation of data acquisition and restitution. This means, that the time consuming restitution task can be done independent at different locations and at any time. It is very economic, to acquire a lot of data on images, to have them available if any lack in the plans or new questions occur later.

On the other hand, the demand on near real-time products grow, because the data users want to use the photogrammetric products as geometric basis for the documentation of their results. To fulfil this demands, new approaches are necessary.

4.1 Digital Image Acquisition

One new approach is to acquire the images with digital cameras. The quality of digitally acquired images and areas covered by these images can be evaluated during the campaign. Today's digital cameras are insufficient in image quality and handling or much too expensive. For a precise 1:25 facade mapping you need a resolution at the object better than a few millimeters, therefor with cheap digital cameras you can only display patches of a few meters per image. This situation will change in the next years.

Fig. 4: Image acquired with the Digital Camera Olympus 1400L. Plumb lines with control points are placed at the site.

Fig. 5: Digital Rectified Image derived during the field campaign from Fig. 4. The areas outside the rectification plan are shown brighter.

But even today, the digital images are immediately available and can be used as geometric reference for the

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drawing results, if the demands are not very high. Further on, they may be used for the documentation of some details (Fig. 4).

On the other hand, even analogue images are available in one day, if fast photo labors are available. This allows it during longer campaigns, to use this images like original digital acquired images.

4.2 Rectification

Better suited than raw images for the documentation of results are digital rectified images [Hemmleb & Wiedemann 1997]. Digital rectifications can be carried out on a laptop at the site, delivering a further product just in time, well suited for the purposes of the architectural researchers. The in-situ rectification requires nearly planar surfaces and sufficient control points on this surfaces. The 3D coordinates of the control points of the reference system have to be transformed to 2D coordinates according the projection plane.

Fig. 6: Image of an vault acquired with a professional camera

Simpler versions of this technique may also be used if no reference system is available. For this purpose a small local network of distances or a special arrangement of local control points can be used (Fig. 4). This can be achieved by using control points on a plumb line, measuring the horizontal distance between the plumb lines and the vertical difference between the control points and a horizontal line determined with a rotating laser or a leveling pipe (Fig. 5). Further on, the disadvantages of lack of the site covering network has to be mentioned.

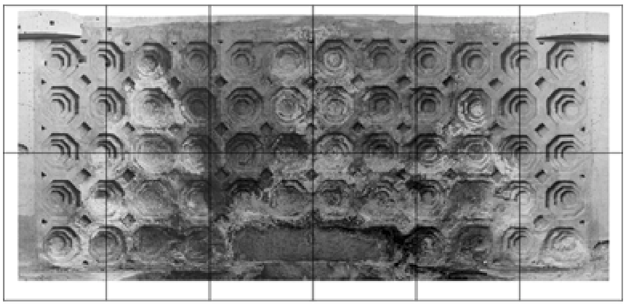

Fig 7: Digital developed image mosaic derived from three images

In many cases the operator has to struggle with gaps in the data, resulting from occluded areas in the images, like the lower corners of the rectified images in Fig. 5

If more complicated rectification techniques, like the development of curved surfaces ore a mosaicing are necessary, it seem to be better to do such work after the campaign at the office. An example is presented in Fig. 6, Fig. 7 and Fig. 8.

4.3 Orientation at the Site

If control point coordinates are available, the orientation of the images can be done there, showing the demands for additional control points or the marking of well suited tie points. This is easier to do, if signalized points as shown in 2.2 are used. In this case a full automatic point measurement can be carried out.

Because usually no resititution will be done during the campaign, the value of such an orientation at the site is limited. It may make more sense to use the spare time during the campaign for geodetic measurements and the acquisistion of additional images.

4.4 Off-line Products

Most of the photogrammetric products will be delivered after the field campaign, as mentioned above. This will not change during the near future, as approaches for the automation in architectural photogrammetry will require still a lot of time to become as flexible, as the variety of architectural forms requires. But time for the interactive restitution will decline in near future based on digital image processing techniques (Wiedemann & Rodehorst 1997).

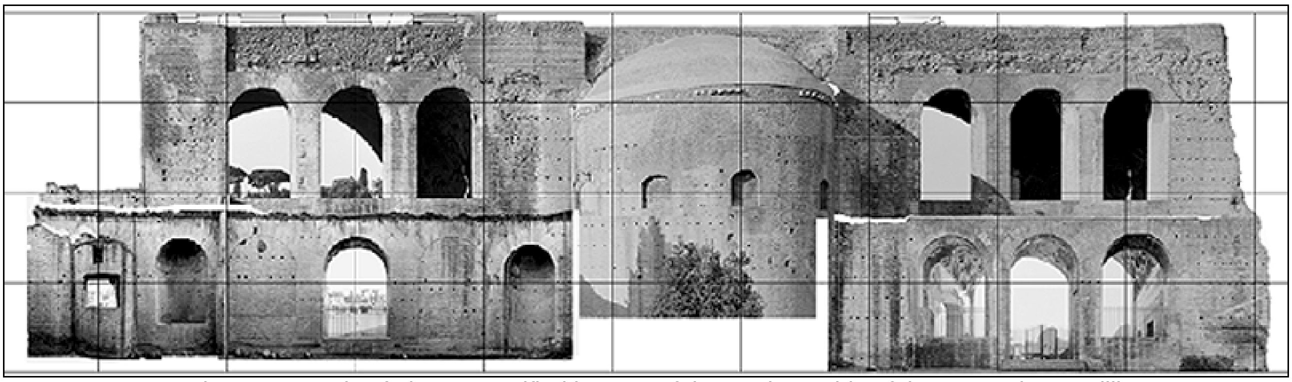

Fig. 8: A mosaic of about 8 rectified images of the northern side of the Maxentius-Basilika

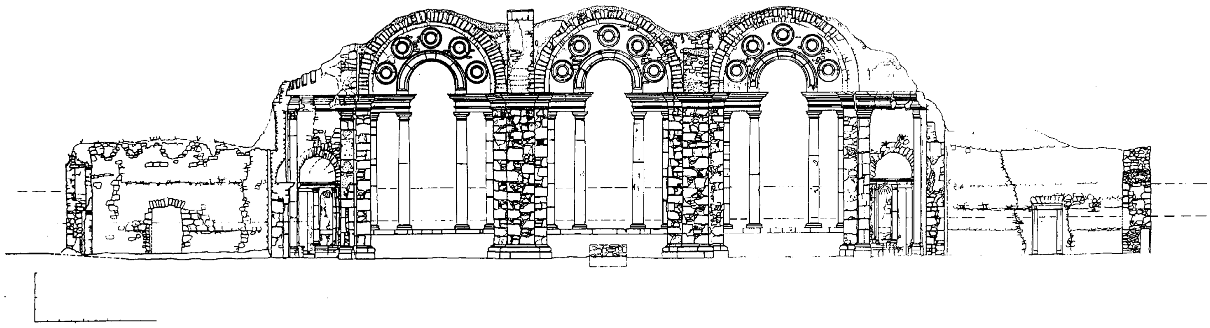

Fig. 9: A view of the serliana plane of Ninfeo Bramantesco, manually drawn based on the results of geodetic and photogrammetric survey and manual measurements.

But for the near future, stereo-restitutions, bundle based restitutions, the creation of image developments and ortho images or mosaics great numbers of rectified images (Fig. 8) will still require a few weeks.

5. FUSION OF GEODETIC AND PHOTOGRAMMETRIC PRODUCTS

Even when a significant part of the work of the data producers has to be done during a first campaign and in the restitution phase according to this campaign, there have to be simple methods to retransfer his results from the data sets back to object, to allow the data users the manual measurements of further data during upcoming campaigns. For example the grid shown in Fig. 8 has been transferred to the surface of Maxentius-Basilika for further measurements.

The traditional way to merge the results of geodetic and photogrammetric survey and the manual measurements of architects at the site is to put them on common plans, as shown in Fig. 9 and Fig. 10. This products are of a high value but they lack flexibility. If other views, other intersections or graphical presentations are required, a time consuming new drawing starts, and in some cases additional measurements are required. If no photo-grammetric images are available this means, that a new campaign may become necessary.

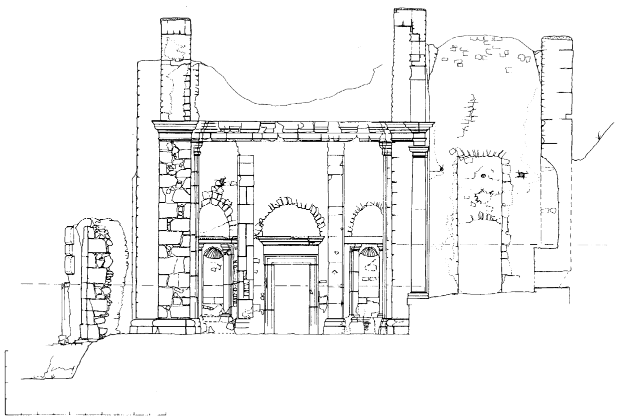

Fig. 10: Vertical Intersection through the Ninfeo Bramantesco.

A better way seems to merge the measurements during the post-processing of the campaign, when even all photogrammetric products are available, all results to a CAD model, covering the whole object in an homogeneous accuracy. Available images may solve the discrepancies between the results of the different data acquisition techniques and used to determine better parameters on reliability and accuracy of the different approaches

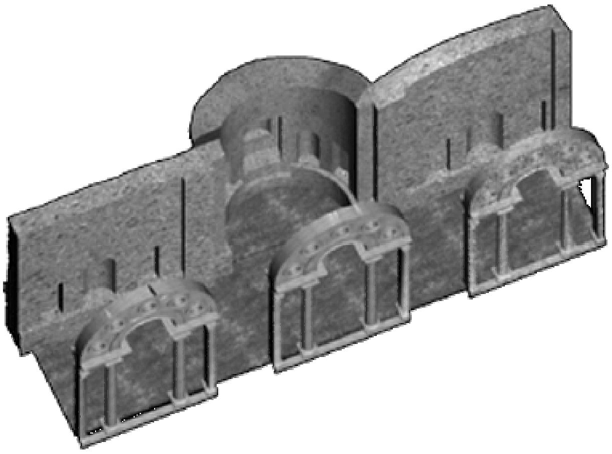

Fig. 11 : A photorealistic 3D model of Ninfeo Bramantesco, with generic textures

The joint CAD model may be used to derive all required plans, models, or visualizations. If the CAD model consists of faces, the extraction of different new products may be done fully automatically, if the CAD model is only a wire model, new intersections have to be constructed using the CAD toolbox. Whereas the data user of today insists on 2D plans of high quality, he may ask for the final CAD model as well.

An other possible product is a photorealistic 3D model, as presented in Fig. 11. If high quality data are used to build up the 3D model, the model will also have a high geometric quality beside its well known esthetic qualities.

6. CONCLUSION

The presented examples result from cooperations of surveyors and photogrammetrists from the Department for Photogrammetry and Cartography of the Technical University of Berlin, Fokus Gmbh, a private company from Leipzig, and academic personal and students from the Department on Architectural History of the Architectural

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Faculty of the Technical University of Berlin. Most products have been derived already at the site and during the field camapigns.

A still increasing part of the work of data users and data providers can be done at the site and just-in-time. This are measurement, adjustment and visualisation of the control network and some highly recommended intersections, like horizontal ground plans can be produced in the field. These products and digital rectifications can be used as geometric reference for manual measurements in the site covering reference system by architectural surveyors already during the campaign.

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