Modern methods of documentation for conservation - digital mapping and automated 3D object documentation in software metigo®

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Abstract:

Several years of experience of heritage documentation have given the author a background to develop methods of cartography and digital evaluation. The outcome of which is the development of a 2D-mapping software with integrated image rectification over a period of more then 10 years.
Based on true to scale mappings quantity surveys of areas and lines can be calculated automatically.
Digital maps were used for the documentation of damage types, for planning of required action and for calculation of costs.
The combination of image processing and CAD-functionality makes operation of the programm user-friendly, both in the office and on-site. metigo MAP was developed in close cooperation with conservators and restorers.
Based on simple equipment consisting of digital camera, laser measuring instrument for measuring distances and standard notebook the mapping software is used in many restoration companies.

Digital stereo-photogrammetry allows users an automatic evaluation of the spatial dimension and the surface texture of objects. The integration of image analysis techniques simplifies the automation of evaluation of large image sets and offers a high accuracy.
In a first step identical points are detected in a set of images to combine pairs of them to stereo models and to calculate the photogrammetical orientation of each image.
An adapted expansion- and matching algorithm offers the possibility to scan the object surface automatically. The result is a 3D point cloud for each stereo model coloured by the images. With the integration of the iterative closest point- algorithm (ICP) these point clouds are fitted to a total point cloud.
After creation of the triangulated digital surface models (DSM) the texturing can be made automatically by using the images that were used for scanning the object surface. This textured surface model is the basis for calculation of true to scale ortho photos or digital 3D mapping.

1. MODERN METHODS OF 2D DOCUMENTATION

1.1. RECTIFICATION

Included image rectification and montage allow to create image plans as a true to scale mapping base. The projective image transformation can be used, if the object surface describes sufficiently precise a plane. For image rectification only distances measured on the object surface and geometric informations (rectangle, parallel lines) are needed. The image montage allows to combine several pictures with different qualities (resolution, scale, RGB/Greyscale) and content (infrared, UV-light, historical image) in one mapping project. Drawings and old mappings can be integrated by scaling function with a known object distance.
Through a CAD interface (Open Design Alliance) CAD files in DWG/DXF format can be imported and used as mapping base. Import functions support the continuation of already existing CAD mappings.

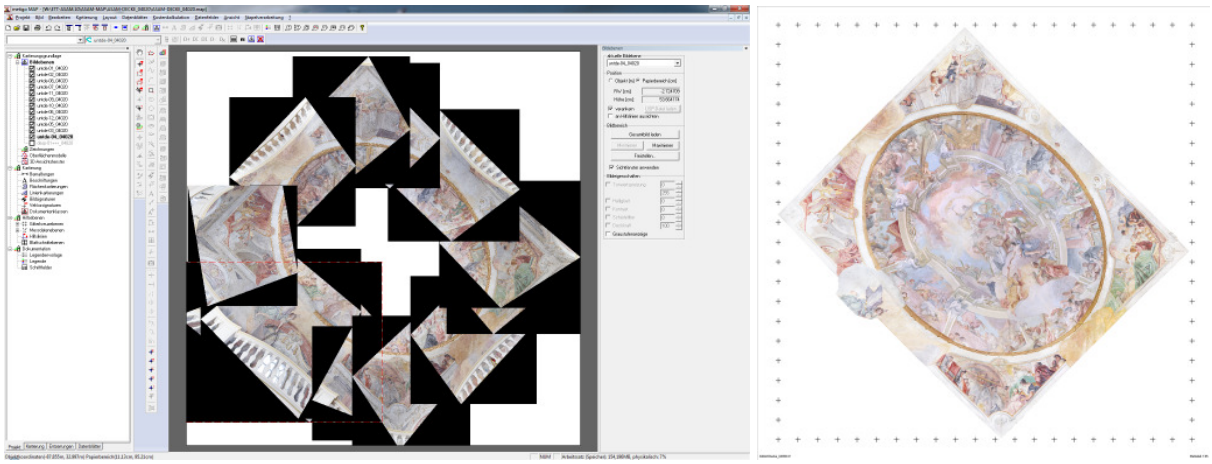

Figure 1: Image rectification and montage (left) allow true to scale object documentation, right: image plan of ceiling (original in scale 1:20, 400dpi), Castle Ettlingen, 'Asamsaal' (Germany), fokus GmbH Leipzig

1.2. STRUCTURE OF A MAPPING PROJECT

In a mapping project the user can define classes (layer, planes,shapes…) of different types (area-, line-mapping, detail photos, vector signatures, annotations and measurements). These classes can be grouped individually, e.g. for special combinations of classes of materials or damages for better interpreting of mapping. It is also possible to combine the mapping groups with different images (for example historic images, images before and after conservation, infrared or uv-light images…). On the base of the grouped classes a legend can be created automatically.
One finally created mapping project can be used as "mapping template" for new mapping projects of the same type.

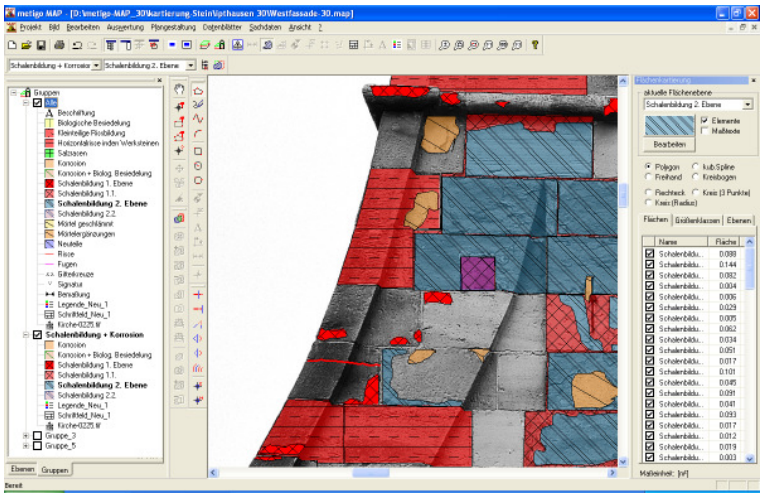

Figure 2: Mapping detail on stone-facade; Pilgrame church Ipthausen (Germany), H. Romstedt

1.3. DIGITAL MAPPING

Different drawing and construction tools can be used. There are different CAD-tools and cutting functions for processing the contours of bordering areas and working in enclosures. They allow an accurate and effective mapping. All mapping elements are vector based and always allow their editing and offer high quality for output in different resolutions.

Based on true to scale mappings quantity surveys of areas and lines are calculated automatically and sorted into user defined size classifications. So it is possible to evaluate the current statistic of mapping at all time. This statistic of mapping can be shown in the legend. The mapping classes can be defined and designed with the aid of a large library of hatchings, line types and colours.

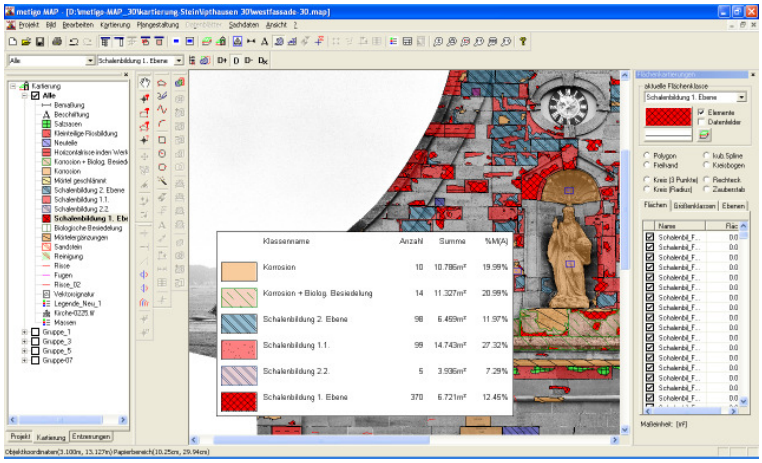

Figure 3: Mapping-legend with current statistic of mapping; Pilgrame church Ipthausen (Germany), H. Romstedt

For every mapping classification data fields can be created (e.g. for findings or technological information on planned conservation), that can be assigned with values.

1.4. OBJECT HIERARCHY

With the help of object hierarchy large conservation projects with many mapping projects can be managed and evaluated comprehensively. Subprojects can be adjusted over mapping templates. The complexity of object hierarchy is dependent of the object.

At first it is very easy to define a project-tree with different mapping templates and subprojects. The software organizes the project and image files on hard disc. In the next step the user can import a navigation map and define links (areas, lines and signatures) to the subprojects on it for better navigation.

By assignment of user defined project information (for example material, derivation, responsible conservator …) an easy evaluation of the mapping projects can be obtained. Thus, the link areas on navigation map are filled with different colours depending on the content of data fields of the subprojects.
In the same way it is possible to show the extent of damage of a special mapping class over all subprojects by filling the link areas of the navigation map with different colours.

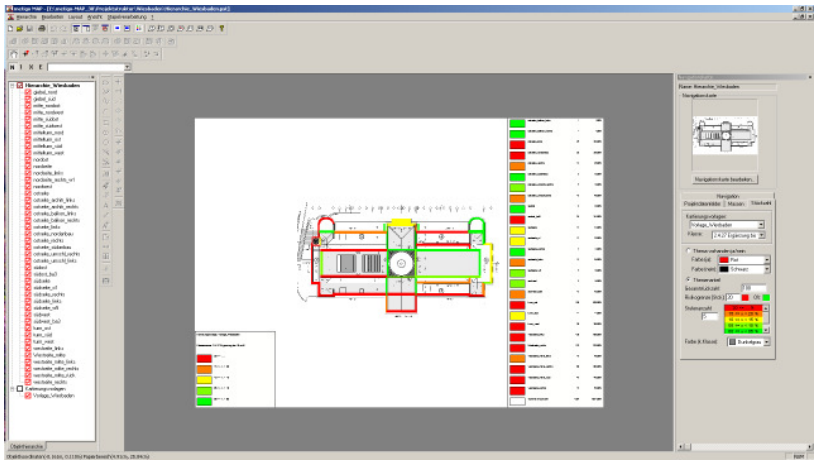

Figure 4: Navigation map of object hierarchy with coloured link areas for analysis of large mapping projects, Kurhaus Wiesbaden (Germany), J. Kaminsky

2. CURRENT DEVELOPMENTS

The mapping software is developed in close cooperation with our customers (conservators). Some of the current applications for the next version are presented in the following chapter.

2.1. AUTOMATED DETAIL RECTIFICATION WITH IMAGE MATCHING

Due to the substantial similarities of images of the same object, correlation techniques provide automated measurements of subpixel precision for corresponding image points. On the base of these identical points images can be congruently rectified.
Therefor it is necessary to rectify one image to scale. The resulting rectifed image is used as matching reference. The user has to define only an approximate rectangle on the first rectified image for each of the other images.
On the base of an existing documentation (e.g. previous state) additional documentations of preliminary results can be made during the conservation process and can be transformed to the first rectified image with the help of image matching. So all these images can be evaluated comparative in a single mapping project on the same object space.

In another example detail images with high resolution can be transformed to an existing image plan with the help of image matching. This can be made only for special details or to create a new documention in higher quality.

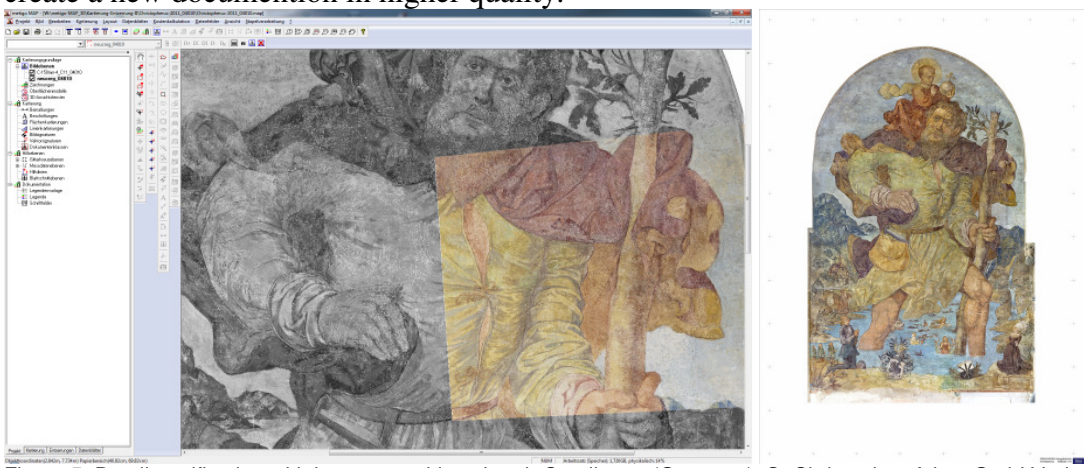

Figure 5: Detail rectification with image matching church Creglingen (Germany), St Christopher, fokus GmbH Leipzig (left: coloured detail on grey scaled image plan; right: final coloured image plan in higher resolution, original in scale 1:10)

2.2. AUTOMATED EVALUATION OF THERMOGRAFIC IMAGE SEQUENCES

For contact-free detection of local separation of mural paintings the temperature of interesting wall regions are changed in small steps by using heat emitters. This process is documented by infrared camera, where the resulting image sequence (fixed time steps) shows both the cooling as well as the heating. The varying heat conduction to underlying brickwork allows conclusions about the detachment of plaster from the wall.
By using thermographic reference points automated rectification of the whole image sequence can be done. The results can be integrated into a mapping project.

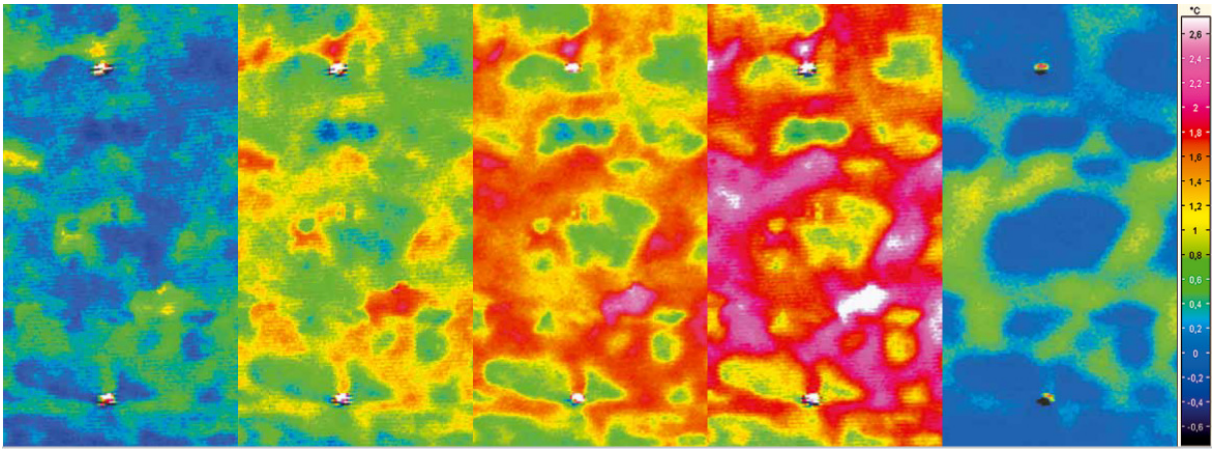

Figure 6: Thermografic image sequence (5 images of 132) taken by infrared camera of heated mural painting [8]; evangelical church Kuhren (Germany), C.Franzen

2.3. MODULE FOR CALCULATION

For a long time the quantity surveys of a mapping project were exported to chart calculation by the customer to process the further calculation there. Because of the complexity of this process and a lot, well structured information that already exist in a mapping project, the wish of integrated calculation functions grew.
In the preparation process of a mapping project, while creating mapping classes the user can include additional factors for work and materials. Thus, the workload can be described in

several work steps with persons of different skills. With different prices for material and working time several variants can be calculated and compared.
With the help of this module the better preparation, control and billing of the conservation action is possible. *All these calculation functions are collected in a separate module and can be purchased optional for metigo MAP.*

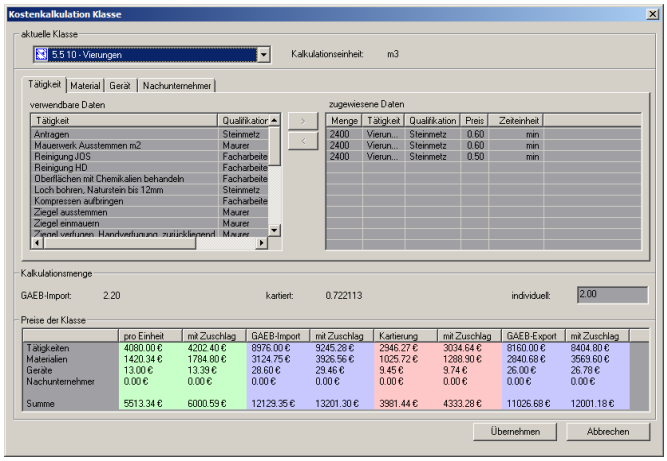

Figure 7: Different variants of calculation (coloured chart) for one class

2.4. 3D MAPPING

In the new version of the mapping software 3D surface models (STL, VRML, shp) can be imported as mapping base. These surface models can be created by scanning systems or by photogrammetric systems with automated image matching like in metigo 3D. This offers the base for true to scale mapping on the object surface.
For 2D output the user can define different views with orthogonal projection on the object surface, that allows a true to scale output of the mapping.

Like in many technologies that are developed and integrated in metigo MAP, we first establish the base for new work techniques to develop them in close cooperation with our customers on concrete projects.

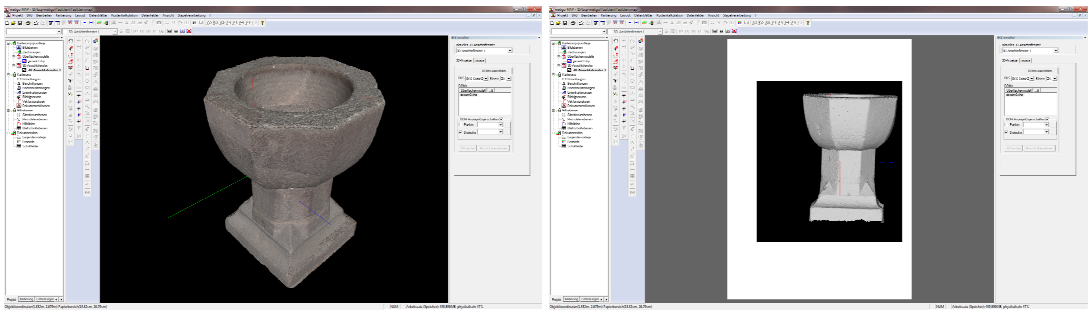

Figure 8: Mapping project with perspective view on 3D model (left) and orthogonal projection (right); medival font in evangelical chruch Kuhren (germany), fokus GmbH Leipzig

Before the development of bases for 3D mapping, an own software was developed that allows the conservator to generate 3D surface model in a simple way. This software can be used alternatively to expensive scanner systems.

3. AUTOMATED 3D OBJECT DOCUMENTATION

The purpose of the introduced project is to achieve a combination of photogrammetric measurement techniques and procedures of digital image analysis in one 3D evaluation system on the base of digital stereo images.

3.1. IMAGE RECORDING

At least one digital SLR cameras (full frame sensor) is used for 3D evaluation on the base of stereo models in an image set taken from the object. The used cameras have to be calibrated to the used focal length.

Images for each stereo model can be taken by hand. Using a receiving rail (on a tripod), where 2 cameras are attached, the workflow and the evaluation accuracy can be improved. For the scale distances at the object or between both cameras have to be measured. Additional three dimensional reference points at the object can be measured by tacheometer.
The accuracy of evaluation can be influenced by image quality and image scale.

Figure 9: Receiving rail for stereoscopic exposures with defined bases (left); image recording by hand (right)

Another recording configuration for plastic objects can be the usage of a rotation plate and the recording of single images in suitable step size.

3.2. AUTOMATED MODEL ASSIGNMENT, AUTOMATED MODEL ORIENTATION

After creating a project in the software the evaluation accuracy and resolution are defined, and the images are loaded into the project. The inner orientation is established for every image by linking the images to the corresponding camera.
Control points are automatically detected by the evaluation software in the images (identical points at the object). The calculation of orientation of both images of the stereo model is made on the base of the known control points.

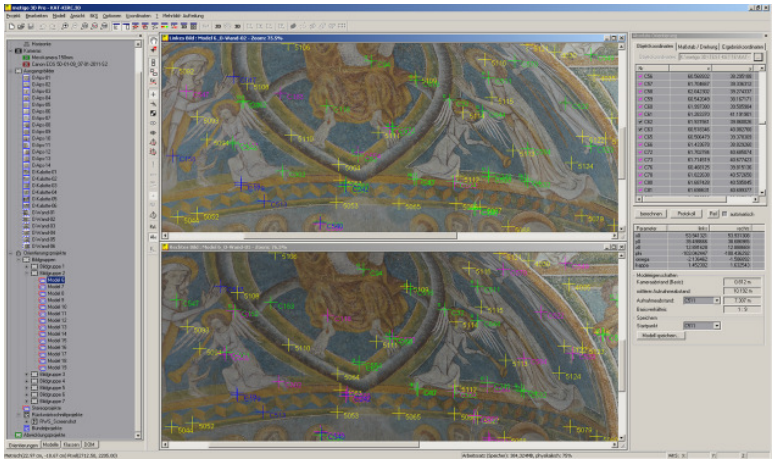

Figure 10: Orientated stereo model (coloured image coordinates with different states); castle Katzenstein, fokus GmbH Leipzig

3.3. AUTOMATED GENERATION OF POINT CLOUD

Due to the substantial similarities of stereoscopic image pairs, correlation techniques provide measurements of subpixel precision for corresponding image points. In addition to the single-point measurement object surfaces can be scanned with appropriate expansion algorithms [6]. With consideration of the evaluation accuracy for every stereo model the right step size (point distance) for matching is determined in dependence of the images scale. With batch processing all existing stereo models can be “scanned”.

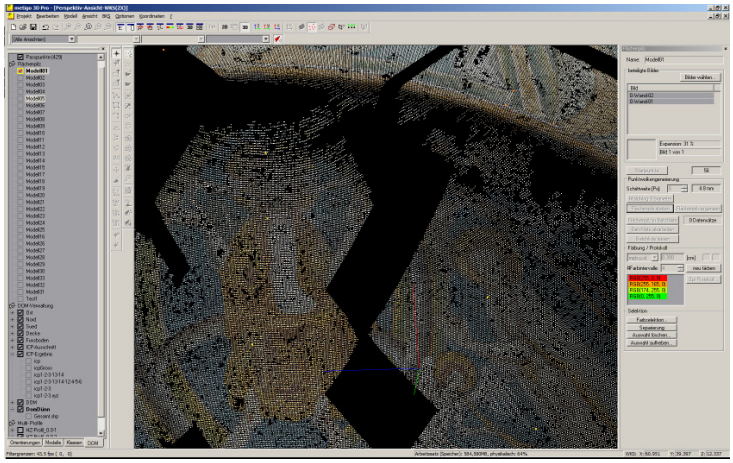

Figure 11: Calculation of 3D coordinates in stereo model by matching; castle Katzenstein, fokus GmbH Leipzig

3.4. AUTOMATED EVALUATION OF DIGITAL SURFACE MODEL

With a triangulation algorithm [6] a digital surface model is generated by a point cloud. In a second step, after editing the surface model, the images are mapped on it. Thus a three-dimensional digital documentation is possible.

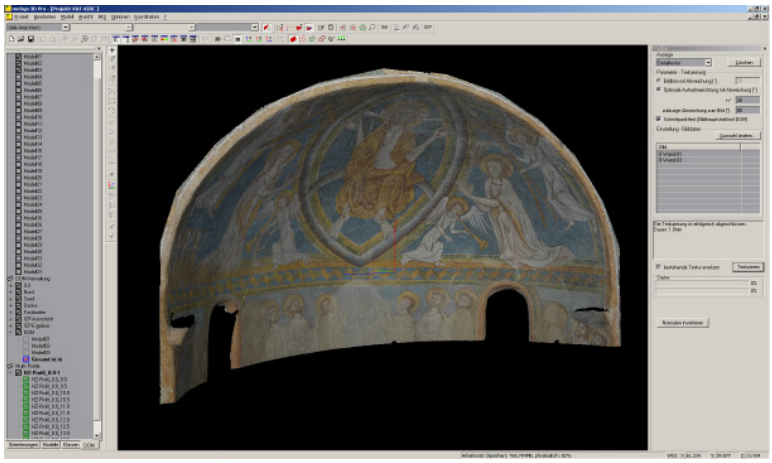

Figure 12: 3D surface model with image texture; castle Katzenstein, fokus GmbH Leipzig

3.5. UNWRAPPING / DIGITAL ORTHO PROJECTION

For the projection of images onto a plane or another unwrapping geometry, user coordinate systems can be defined related to overall coordinate system, with the help of a partial set of points (balancing plane) or with measured reference points taken by tacheometer on site. The ortho projection onto the unwrapping geometry is made in a user defined image scale and image resolution on the base of the orientated images and the surface model.

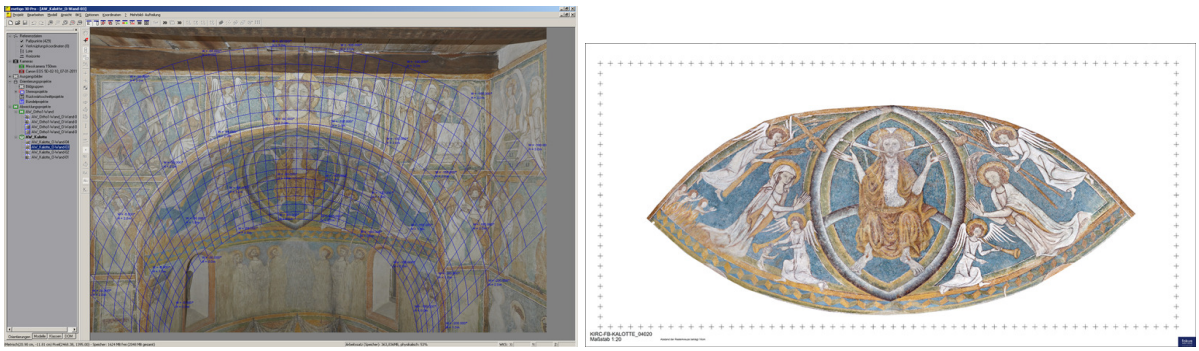

Figure 13: left: Orientated image of a calotte with projection of a cylinder; right: unwrapped image plan of a calotte (ortho projection onto cylinder); castle Katzenstein, fokus GmbH Leipzig

Figure 14: congruent unwrapped image plan of apse with ortho projection onto cylinder; left colour image; right UV-light image (Original in scale 1:10;400dpi); castle Katzenstein, fokus GmbH Leipzig

3.6. DEFORMATIONPHOTO

With the help of user defined coordinate systems it is not only possible to project textured surface models onto plane but also to show the deformations to user selected coordinate planes. Such orthophotos can be used as a base of a drawing and also for the evaluation in the mapping software metigo MAP.

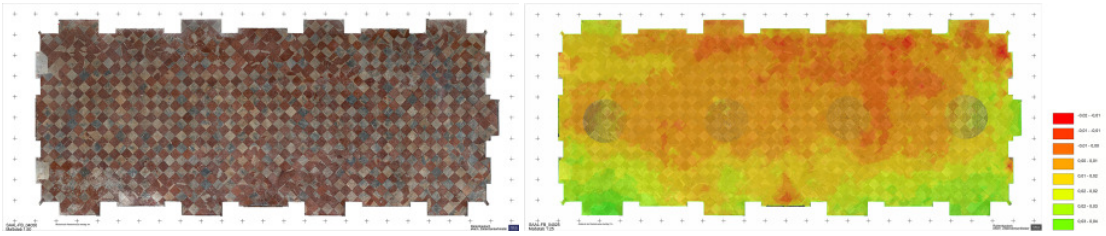

Figure 15: congruent image plan and deformation photo of floor; left: image plan (400dpi, scale 1:10) processed in metigo MAP; right: deformation photo on the base of point cloud (scanned by laserscanner); Steinerner Saal, Raitenhaslach (Germany), fokus GmbH Leipzig

4. SUMMARY

The mapping software metigo MAP was developed by fokus GmbH Leipzig and is on the market in Germany and other european countries since 2000. metigo MAP is available in german, english, french, polish, and since 2012 in spanish.
The mapping software is available in 32-bit or 64-bit version and can be used on Intel-based MAC by using Parallels® or VMware Fusion®.

The described functions for automated generation of 3D surface model are available within the software metigo 3D (currently only german) developed by fokus GmbH Leipzig.
Both developed software are stand-alone applications, so no further software is required.

5. REFERENCE:

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