

THE IMPACT OF GPS TAGGING ON IMAGE BASED DOCUMENTATION AND 3D RECONSTRUCTION OF CULTURAL ASSETS

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ABSTRACT:

Since digital technology removed the darkrooms from photography not only photogrammetric methods migrated to new concepts. A wide range of so far not imaginable applications of electronic image processing became popular. The classic photogrammetric procedures, known as mono-plotting and stereo-plotting, running on desktop environments today, making use of epipolar line geometry, autocorrelation, feature extraction, automatic texture extraction e.g. In CAD environments one can find numerous texture mapping and photo matching functions. And finally computer vision breaks into the field.

Despite the hype of laser scanning, due to the accessibility of digital compact cameras and single lens reflex cameras in conjunction with GPS loggers, the photograph as a container of high information density plays an important role in the field of data capture and object reconstruction of cultural heritage objects. Range based methods require additional image information to provide photo realistic 3D models, whereas photographs contain range and radiometric information.

This paper discusses the possibilities of GPS tagging and GEO coding and figures out some applications with aspects of digital photography, photogrammetry and computer vision. Amongst others it instructs into GeoSetter, the KML 2.2 photo overlay tag, taking use of the ARC 3D web service and discusses on what terms pictures can be used in photogrammetry.

1. INTRODUCTION

Today people share pictures in photo communities. End of 2007 the Yahoo software Flickr hosted more than two billion images world wide. Adding global position information to the EXIF data of an image is known as GPS tagging. GEO coding is the process to extend image data with non-coordinate based geographical information. Those kind of meta data is important for searching and finding pictures in a global world-wide data base of images. Google released Panoramio, extended Google Maps with Streetview and upgraded the Google Earth Browser with functionality for displaying very large images and panoramas. Microsoft Photosynth takes a large collection of photos from an object, analyses and displays them in a reconstructed 3D space.

The above mentioned technologies therefore take effect to documentation and object reconstruction of cultural assets. It has to be considered that the methodologies named here, work like the wiki principle. People publish material world-wide for a large community. Googles 3D warehouse and the campus and city modelling contribution exemplify that principle.

From the point of view of cultural heritage documentation 3D object reconstruction is still being considered as a supplemental. High quality object reconstructions with respect to the structure of CAD systems are time consuming. There are surface models or solid models, both polygonal or curved based, known. Texture mapping reduces the effort in geometric modeling and yields to photo realistic looking models. Utilizing scanning technologies is leading in point clouds of high density. Mesh models, generated from those point clouds approximate an objects outer skin. Existing image information can be used for additional texture mapping.

This contribution was acquired as a preparation for a future project mainly build from photographs. GEO referencing seems to be the proper method, ordering the huge amount of photos. A major focus points to software tools available from the Web. 3D object reconstruction in terms of usability will be discussed.

2. GPS TAGGING

A digital still camera (DSC) stores embedded in the image data some kinds of metadata. Additional information is related to image data structure, recording offsets, characteristics and other tags. Among this metadata 31 tags are defined for GPS information.

The standard for storing interchange information in image files is EXIF (exchangeable image file format). EXIF is part of the design rule for camera file system (DCF), operated by the Japan Electronics and Information Technology Industry Association (JEITA www.jeita.or.jp). The file recording format is based on existing formats. Compressed files are recorded as JPEG with application marker segments inserted. Uncompressed files are recorded in TIFF format. The specification is available from www.exif.org.

While GPS tagging deals with coordinate based geographical information, GEO coding extends image data about non-geographical based elements like postal addresses related to the coordinate data. A specification for storing text information related to image content is the IPTC (International Press and Telecommunications Council) standard. The standard enables interchanging of metadata between image agencies and archives. Another format for storing metadata is the extensible metadata platform (XMP).

Linking GPS data to image data is performed simultaneously by clicking the camera shutter if applying the appropriate hardware or by software synchronising camera time with the recorded track.

Nikon digital SLR cameras are compatible to Garmin and Magellan GPS receivers via the serial interface. Mobile navigation devices mounted on the flash adapter can be directly connected to the camera. Red Hen (www.redhensystems.com) provides an adapter for Nikon cameras and off-the-shelf GPS units to directly capture geospatial referenced images. The GPS mounts on top of the camera putting it in full view of satellites and records latitude, longitude and altitude data to the EXIF header of each image. The physical integration provides hands-free use and the GPS data is displayed on the camera LCD.



Figure 1: GPS logger I-GotU, Sony GPS-CS1 and the Garmin etrex mobile navigation unit

Sony provides a small GPS logger for recording the position where photographs are taken. The GPS-CS1 is a small (9 cm / 3.5 in, weight 100 gram / 2 ounces) cylindrical device which the photographer carries with him while shooting pictures. It records the location and time. The supplied GPS image tracker software synchronizes the images with the latitude, longitude and time readings from the GPS-CS1 device.

A new GPS logger is I-gotU from Mobile Action, Taiwan. This device is only 47 x 29 x 12 millimetre small and weighs 21 gram. The storing capacity is 17,000 track points. Connection to the computer is realized via bluetooth or USB cable. The I-gotU GPS logger is targeted to the hobby photographer.

All units export data in multiple sharable file formats and are therefore compatible with mainstream software and web albums.

The Telepointer GTA (www.gta-geo.de) links the position together with the orientation, (direction of the exposure axis or viewing direction) directly to the image data. GTA uses that information in their software products supporting the process of texture mapping to buildings. So each photo carries the answer to the question "Where was it taken and in which direction is it looking.?" GTA provides service for 3d modeling and is targeted to the professional market.

Figure 1 illustrates the GPS-logger I-GotU (50 \$US) and the GPS-CS1 (100 \$US) compared to a Garmin etrex Venture (200 \$US). Prices in parenthesis are roughly rounded. The

differences in pricing can be taken as a performance indicator for the units. It has to be stated, that there is no barrier to act with a GPS mobile device during photo taking due to a high price or a bulky handling of a system.



Figure 2: Telepointer GTA mounted on a SLR camera (image source www.gta-geo.de)

Mobile GPS navigation devices like Garmin or Magellan do not record only the position. It is possible marking waypoints, saving tracks and finding positions in the field. Maps, waypoints and routes can be loaded into the internal memory from external sources. Easy to handle communication software between device and external computer belongs to standard delivery.

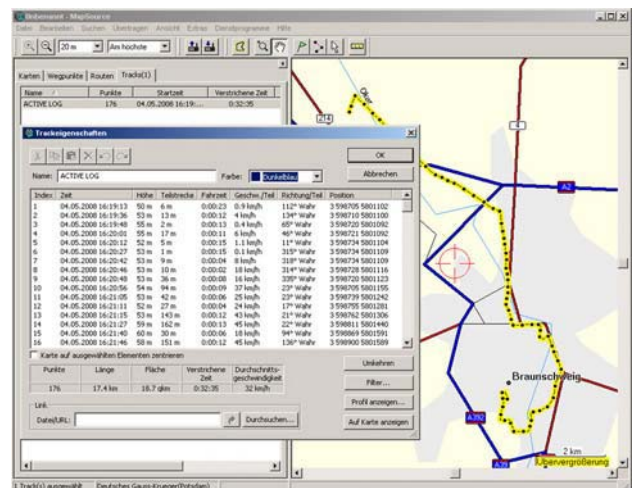


Figure 3: Garmin Trip & Waypoint Manager, import of the track log

Garmin comes with the Trip & Waypoint Manager software (see figure 3 for a screenshot) for reading out and storing data. A recorded track log contains time and GPS position. If a track is saved for tracing back, the timestamp will be lost for saving storage capacity. With this information in mind we focus to the application of loading the track log information into the EXIF data of the images using a Garmin etrex with the Trip & Waypoint Manager and a freeware named GeoSetter. GeoSetter can be downloaded from www.geosetter.de. It is a multi-language freeware.

GPS tagging of images with GeoSetter starts with downloading the digital images from a camera into a subdirectory. In the same directory the GPS track log should be stored as a GPX format. GPX is a XML-based standard for GPS data. If one is interested in the complete GPS data set in NMEA format, use of software like visual GPS is recommended. Visual GPS is freeware and can be downloaded from www.visualgps.net.

Working with GeoSetter enables selection of images combined with a track log by synchronising camera time and GPS time. Connection between photo position and track is automatically interpolated and can be edited manually via the integrated Google map information. During updating the images the IPTC information is offered by standard information coming from the Google database. Output of a complete track can be saved in a KML file format and imported directly into Google Earth. GeoSetter does not write in the original image files, it stores a copy of the images including the updated information.

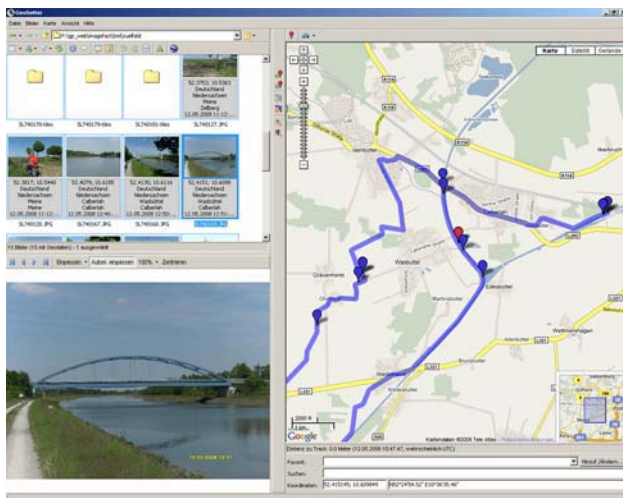


Figure 4: GeoSetter interface with images, track and image position markers

3. IMAGE PUBLICATION AND DISTRIBUTION

3.1 Photo Communities

Picasa is a software application for organizing and editing digital photos, originally created by Idealab now owned by Google. Picasa acts as a Web album, people can upload their photos into web space and share the albums with an authorized community. Picasa started as Shareware. Google began offering Picasa for free download since July, 2004.

Flickr is an image and video hosting website, web services suite, and online community platform. It was one of the earliest Web 2.0 applications, developed in Canada by Ludicorp, a company founded in 2002. Yahoo bought that company in 2005. Flickr is a popular Web site for users to share personal photographs. Bloggers use Flickr as a photo repository. Its popularity became Flickr by its organization tools, allowing photos to be tagged and browsed by folksonomic means. As of November 2007, it hosts more than two billion images

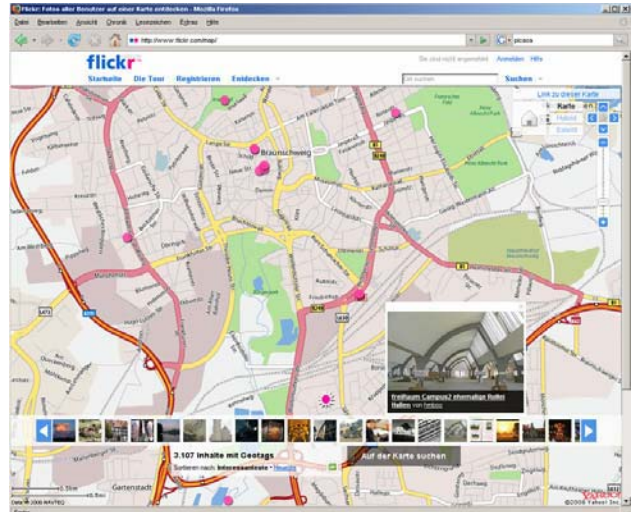


Figure 5: Screenshot of Flickr

Panoramio is a geolocation-oriented photo sharing website. Currently, some of the photos uploaded to the site can be accessed as a layer in Google Earth, with new photos being added at the end of every month. The site's goal is to allow Google Earth users to learn more about a given area by viewing the photos that other users have taken at that place (source: en.wikipedia.org). Panoramio is reachable under www.panoramio.com.

3.2 Google StreetView

Google Street View is a feature of Google Maps that provides 360° panoramic street-level views and allows users to view parts of selected cities and their surrounding metropolitan areas at ground level. It was launched on May 25, 2007. Google Street View displays photos that were previously taken by a camera mounted on an automobile, and can be navigated using either the arrow keys on the keyboard or by using the mouse to click on arrows displayed on the screen. Using these devices, the photos can be viewed in different sizes, from any direction, and from a variety of angles. (source: en.wikipedia.org).

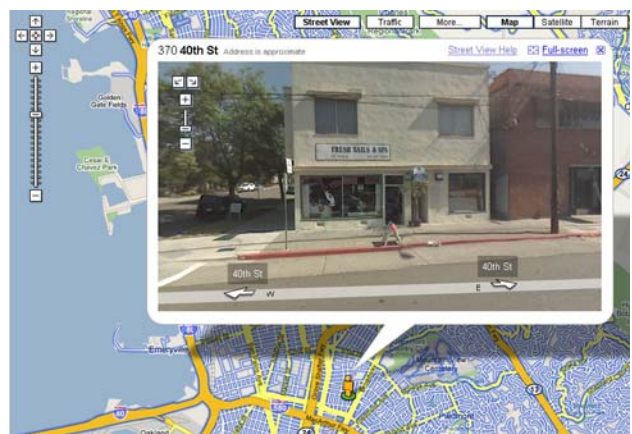


Figure 6: Screenshot of Google StreetView

With Street View Google comes under criticism. People are afraid that their privacy protection may be hurt by the image recording (Smile! You're on Google's camera).

3.3 Google Photo Overlay

With Google Photo Overlay it is possible to publish very huge pictures or panoramas inside Google Earth. An image has to be prepared as an image pyramid with tiles of 256 px. The sample given here is a panorama of original size 8176 x 1126 px. The image is divided into 231 tiles numbered in a predefined order. The KML description reads as:

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.2">
<Document>
<PhotoOverlay>
  <name>Ramingsmuehle</name>
  <description>Ramingsmuehle</description>
  <Camera>
    <longitude>7.5642</longitude>
    <latitude>52.5498</latitude>
    <altitude>34.0</altitude>
    <heading>0</heading>
    <tilt>90</tilt><roll>0</roll>
  </Camera>
  <Style>
    <IconStyle>
    <Icon>
      <href>http://www.imagefact.de/kml/
        raming/ramingsmuehle-tiles/
        ramingsmuehle_$(level)_$(x)_$(y).jpg
      </href></Icon></Style>
    <shape>cylinder</shape>
    <ViewVolume>
      <near>10.0</near>
      <leftFov>-180.0</leftFov>
      <rightFov>180.0</rightFov>
      <bottomFov>-23.396235</bottomFov>
      <topFov>23.396235</topFov></ViewVolume>
    <roll>0</roll>
    <ImagePyramid>
      <tileSize>256</tileSize>
      <maxWidth>8176</maxWidth>
      <maxHeight>1126</maxHeight>
      <gridOrigin>upperLeft</gridOrigin>
    </ImagePyramid>
    <Point>
      <coordinates>7.5642,52.5498</coordinates>
    </Point>
  </PhotoOverlay></Document></kml>
```

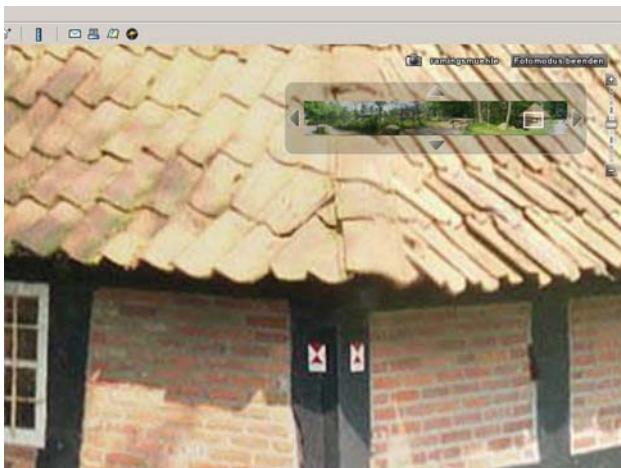


Figure 7: PhotoOverlay details of a 8000 x 2000 panorama

The code snippet of the KML file demonstrates the photoOverlay tag. Including the tags for the shape, viewpoint (camera) and image pyramid information. It is obvious, that dividing the image into a pyramid of tiles requires a software-tool. I used the software PhotoOverlayCreator from the Centre

for Advanced Spatial Analysis , UCL. Downloadable as a Java Archive from:

<http://www.casa.ucl.ac.uk/software/photooverlaycreator.aspna>
The above given sample, displayed in figure 7, can be viewed from www.imagefact.de/kml/raming/ramingsmuehle.kml.

3.3 Microsoft PhotoSynth

Photosynth is a new technology to view photos on a computer platform. It was developed in a collaboration between Microsoft and the University of Washington.

A large collection of photos of a site or object is taken by Photosynth to analyses them for similarities, and displays them in a reconstructed 3-dimensional space. An object needs between 20 and 300 photos for 3D reconstruction. Pictures can be taken with different focal length lenses but must be presented in full format, since photosynth uses the EXIF data for further processing. After selecting the photos, no more interaction is required. The result will be uploaded automatically to the Web.

A user can navigate inside the scene by selecting the angle of view and the zoom factor. Information about the photo position in relation to one another is provided. With Photosynth fast access to gigabytes of photos is realized.

Photosynth needs installation of a plug-in for MSIE or Firefox and is running under Windows XP and higher. Access to Photosynth is given by <http://labs.live.com/photosynth>. Visit www.photosynth.com for the latest release of the software. Figure 8 is a screenshot from a photosynth portal www.nrw3d.wdr.de. The broadcast station WDR collects from its audience photos of selected monuments and brings them together as a synth. Approximately 100 photos are brought together for that reconstruction.



Figure 8: "Synth" of Hermannsdenkmal, a German monument

4. 3D OBJECT RECONSTRUCTION

3D object reconstruction is the most sophisticated container of documentation . It allows examination from any point the user selects, generation of video sequences and virtual walk through. Geometric modeling complies to the structure of the modeling tools. We distinguish surface models and solid models, polygon based or curved based, and hierarchical polygon models. Sources of modeling are range based or image based recordings. Imaged based modeling speeds the time for recording on site and provides range and radiometric information. Surface models often provide only the textured skin of an object. The structure of buildings are represented by solid models. Automatic shape recordings result in point clouds

and polygon models. In this chapter we focus to some principals and applications of image based methodologies photogrammetry and computer vision.

4.1 CAD Photo Matching

Today one can find photo matching functionality in most CAD software packages. Photo matching is designed for two different tasks. First there is the problem to match a photo into a geometric model for texturing the environment or to visualize how a construction fits into its surrounding. The other task is to model 3D geometry from one photo.

For a successful photo matching, two pairs of parallel lines on perpendicular surfaces have to be set into the photos and an approximate scale is required. We follow here a sample worked out with SketchUp. In figure 9 one can detect the red lines for the x-direction and the green lines for the y-direction of the buildings local coordinate system. From the matched photo it is now possible to construct geometry in 3D space and to cut out automatically the textures needed.

One must consider, that in practice it isn't such easy as written in the manual. A result with good quality is automatically done only in particular cases. Most often a lot of time consuming fine tuning has to be carried out. Observe the shadow in the final rendering or detect other artefacts like the lantern in figure 10.

In SketchUp the photo matches are handled as scenes, defining camera position and orientation. Applying the GPS reference of the photo to those values enables global positioning of the model.

The kind of photo matching in Google SketchUp is known from the earlier Apollo Photo 3D software.

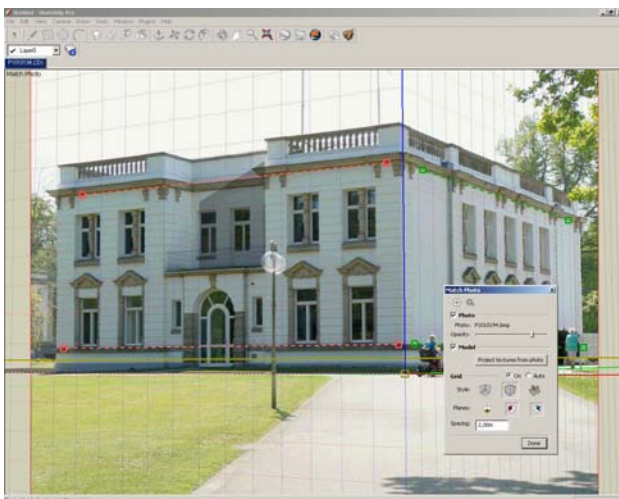


Figure 9: Photo matched by setting parallel line pairs onto perpendicular surfaces.

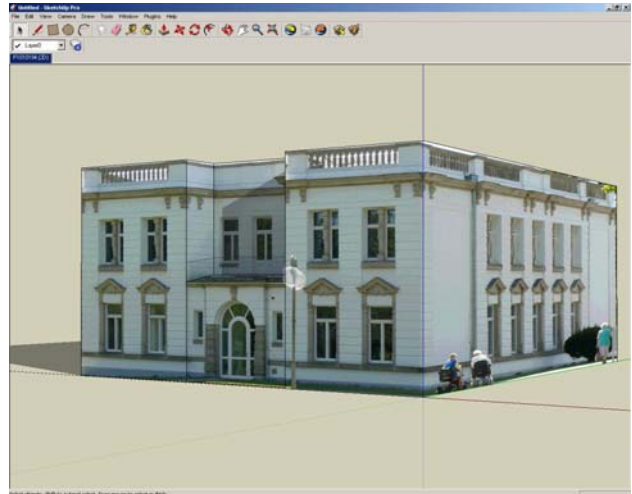


Figure 10: 3D model constructed from one photo with texture extraction

4.2 Photogrammetry

Photogrammetry is defined as recording, measurement and interpretation of images or digital pictures with non-contact recording systems.

Applying photogrammetry minimizes the recording time on site and provides results with a high and reliable accuracy. Conditions for the adoption of photogrammetry are availability of a calibrated camera, the appropriate evaluation software and the operators profound knowledge.

The methodologies are grouped according to the numbers and arrangement of photos. There are single image measurements (mono-plotting), stereoscopic evaluations (stereo-plotting) and multi-image evaluations existing. Particular cases are the single image rectification and the orthophoto production.

Single image rectification takes advance from the projective relationship between an object surface and the image surface. With for control points on the object plane or two pairs of parallel lines, the transformation matrix can be determined to rectify an image.

A calibrated metric camera is not required. The rectified image is still a perspective, but the impact of camera rotations is eliminated. Image rectification is a common method in architectural applications. By knowing the ground dimensions from digital maps, elevation data can be easily derived from photographs.

Figure 11 displays the result of a workflow targeted to 3D modeling and use of non professional equipment, described in detail on the web under www.imagefact.de/rectify.



Figure 11: 3D modeling from rectified photos and digital maps

It is not possible, to get exact geometrical information from one image. If only one image is available, additional object information is required. Mono-plotting is the process, to intersect measurements in metric photos with object shapes. The **orthophoto**, rectified to a digital terrain surface model stands as a sample for such a method.

Two photos, taken with parallel exposure axis from a bar contribute to a stereo model. The stereo model can be viewed and evaluated by special equipment in 3D.

The first step in **stereo-plotting** is the interior orientation and image refinement. In case of images taken with digital cameras, the interior orientation (measurement of fiducial marks) is not necessary. But the image should be refined about the correction of camera parameters, the principle point position and lens distortion correction. The values are coming from the calibration certificate.

As a second step, reconstruction of the relative positions of both images to each other is required. This relative orientation can be done today automatically, by filtering interest points, as applied in the Z-GLIF Software from Menci. The result is a stereoscopic model.

Next a true scale and local coordinate system must be referenced for the absolute orientation of the model. Most common are control points in the object or a minimum definition of a local orientation and an object distance to evaluate in true scale.

After that two step orientation process, the evaluation of details applying point, line and polyline measurements in a CAD like environment can be accomplished. The parallax or disparity measurements can be taken in the stereoscopic model (anaglyph filtering) by setting a floating mark onto the model surface or in monoscopic mode placing the crosshair to the same point in both images. Automatic procedures are known as on-eye stereo.

Figure 12 is a screenshot from the Z-GLIF software, displaying the mono mode with two crosshairs and a depth map. Raw measurements should be overworked to the final CAD model and positioned into a global coordinate system as stated below.

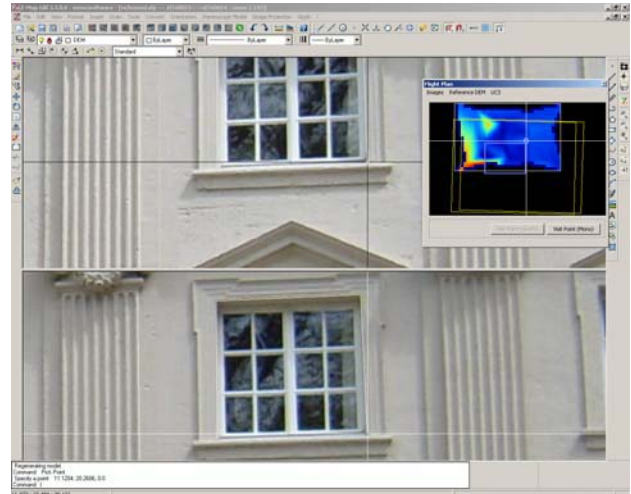


Figure 12: Z-GLIF stereoscopic evaluation Software

The most flexible method in recording complex objects is the **multi-image** arrangement, working after a triangulation principle. The orientation is an iterative triangulation process. It starts from a left and right image. Comparing corresponding points yields to the model. From now on a change between resection and intersection in space let grow the field of orientation points and camera stations. A final bundle adjustment combines photogrammetric measurements with additional observations in the object space and reports about accuracy and reliability of the image bundle. The measurement protocol of detailed vector information has to be refined with CAD software as well. A common used software system of this type is Photomodeler from EOS Systems Canada.

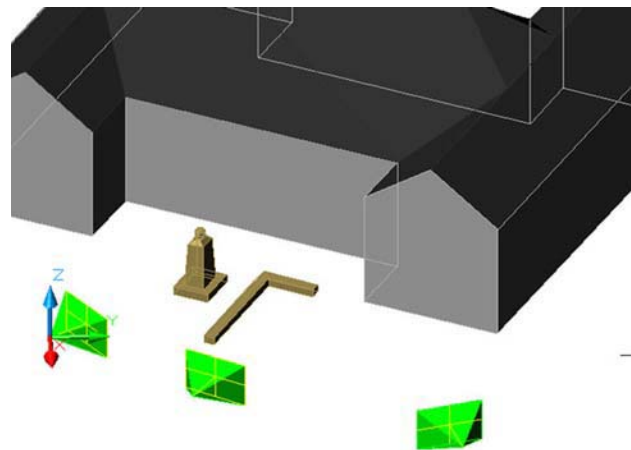


Figure 13: Exposure arrangement for multi-image photogrammetry with minimum of 3 photo positions

Image modeler from Real Viz follows the philosophy to generate a complete complex model structure from basic shapes inside the photo evaluation software. Modeling takes place directly in the photos up to mesh editing functions. Direct texture extraction is a pro for this workflow. Autodesk has overtaken (amongst others) the company Real Viz in mid of 2008. That indicates the importance of 3D modeling by photographs and the possible growing demand on that kind of software tools.

4.3 Computer Vision

Use of calibrated cameras and manual operating seems to be a disadvantage of photogrammetry. Computer vision methods target to the use of non calibrated cameras and totally automatic model reconstruction approximating the object geometry by triangular surface meshes, textured with image data. A solution resulting in a disparity map, confidence map, triangular surface meshes and the texture mapped scene by stereo image pairs was introduced by Koch. (Reinhard Koch, 1994).

Part of the agenda of EPOCH (network of European cultural institutions) is the development of cost-effectiv 3D acquisition technologies. The ARC3D web service (www.arc3d.be) offers the possibility to upload an image sequence, utilizing the ARC 3D image uploader, to a server and analyse the 3D reconstruction downloaded from the server with the ARC3D model viewer (Vergauwen, Van Gool 2006).

After processing on the web network, the client downloads the findings as a compressed archive. The archive contains a file including the reconstruction information, for each image a thumbnail and the image texture, the camera data as a manifest file, the dense depth maps and the quality maps. The model viewer reconstructs on the client computer the 3D information. It is possible to mask the images, eliminating sky e.g., before reconstructing the surface meshes and surface texture. Final results can be stored in several formats.

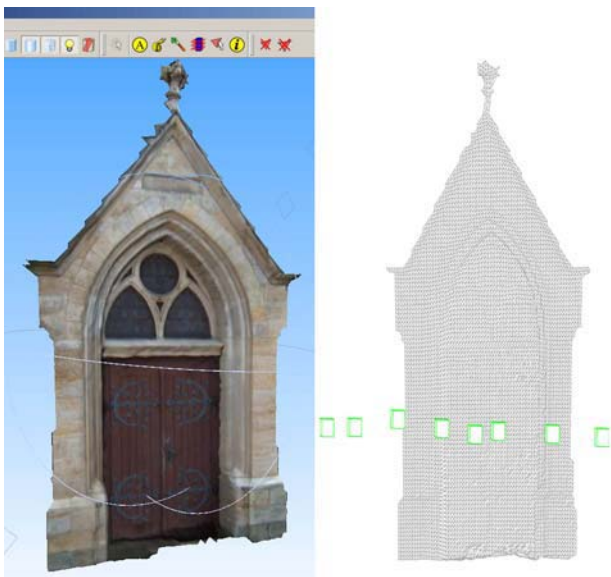


Figure 14: MeshLab output, textured model and meshes including camera positions

In a second step the model can be refined with the MeshLab software tool, provided by the Visual Computing Lab, Italy, vcg.isti.cnr.it. MeshLab is a mesh processing system for editing and rendering unstructured 3D triangular meshes. Since the ARC3D web service does not require any coordinate information, the geometric model is not referenced to a higher order system. Figure 14 displays the textured model of a portal on the left. Shown on the right are the 3D meshes including the camera positions. Positioning the origin of the object system into a camera position enables the global positioning via GPS tagging as explained in the following chapter.

5. OBJECT ORIENTATION

Photogrammetric processing can be performed in model coordinates or local object coordinate systems. Image orientation is known as relative and absolute orientation. While measuring buildings, a local system fixing (parallel to one façade) is common. Such a definition uses the seven degrees of freedom of a coordinate system. Three translations, three rotations and one scale. Additional measurements at the object (control point information, distance measurements) applied to a bundle adjustment improve the reliability. In most cases a model refinement is required. From raw measurements a consistent CAD surface model or solid model has to be constructed. Compilation of the raw measurements into a CAD format must be performed. Converting the camera stations as well enables for absolute orientation of the model. Transformation of the origin of the local coordinate system into a photo position facilitates the orientation.

As introduced in chapter 2, the camera stations are GPS tagged. Calculation of the azimuth between two stations of proper distance provides complete orientation of the model, translation and rotation. One point of the base line is identical with the models local origin. The azimuth confirms by complete model rotation. Converting the model to KML results in a placemark, referencing the geometry to the Collada format. We only have to alter the latitude and longitude in the KMZ archive. A 3D photogrammetric model is now positioned with satellite accuracy.

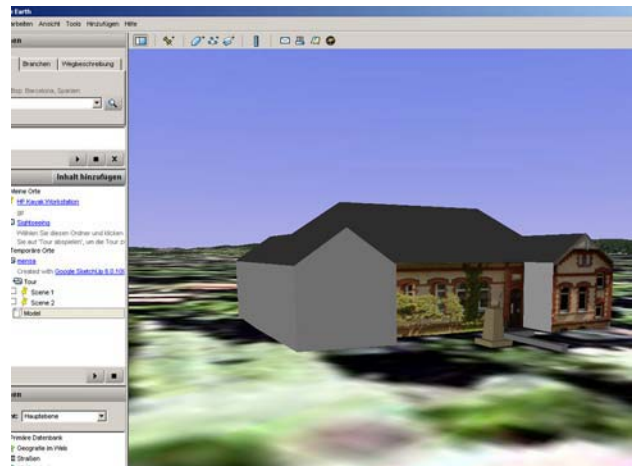


Figure 15: The textured model compiled to Google Earth

6. CONCLUSION

A photo is a container of high information density. Apart from drawings, text reports, measurements taken with scales, total stations or laser scanner the photo is a major tool for documentation of cultural assets. A photo hosts geometric and radiometric information. Utilising GPS tagging adds time and position of picture taking to the image data. Furthermore GEO coding refers to non-coordinate based geographical identifiers.

Those metadata can help searching after a variety of location-specific information. GPS tagging and GEO coding is the basic condition that people can share their photos in Web communities. The Web albums Picasa, Flickr and Panoramio have been introduced.

Google Street View, Google Photo Overlay and Microsoft Photosynth stay for new methodologies how photos can be

presented via the Web in a 3D manner. Research goes in the direction of navigating in gigapixel images.

3D object reconstruction from photos starts from photo matching in CAD system, is performed by photogrammetric methods up to the fully automated computer vision systems. The quality of a model must be seen with respect to a users requirement.

Including the camera stations into the reconstruction enables world-wide global positioning of a 3D model generated from photographs.

According to computer graphics rendering procedures the following statement is cited:

If you like it photo real, go out and take a picture.

Today we can extend:

... and don't forget your GPS logger.

Remark: All the small examples presented in the text are used as a feasibility study for administrating a future large project. Selection of the objects is accidentally. Usefulness depends on the particular requirements.

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www.flickr.com *Photo sharing community*

www.maps.google.com *Visit Google maps for streetview*

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www.eos.com *Photomodeler software*

www.realviz.com *Autodesk iImage Modeler, Stitcher and Movimento*

www.arc3d.be *Web service for 3D reconstruction from photos*

vcg.isti.cnr.it *MeshLab software for working with 3D surface meshes*