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Pictured Descriptions of Spatial Objects

Abstract: The desired documentation of an archaeological or architectural spatial object is a 3D building information system including (geo-)referenced images of the whole object, which are an essential part of the database. These Pictured Descriptions of Spatial Objects combine the advantages of pictorial descriptions and 3D documentations. The simple method of rectifying images with a projective transformation is well suited to generating reality-based textures for planar parts of spatial objects. For structured parts a more sophisticated approach is necessary: Digital orthophotos (DOP) created by differential rectification to a Digital Surface Model (DSM). It is time-consuming and expensive to provide a suitable DSM to match the requirements of high quality digital orthophotos. As digital orthophotos are geometrically correct 2D descriptions, they are well-suited to texture mapping on surfaces of spatial objects, providing all the information stored in the image.

Motivation

A central task in archaeology and architectural conservation is the documentation of information about the objects in the form of data which can be moved and duplicated, which requires a detailed description of the objects in question. Specialists in these fields need to be able to extract precise metric and topological information about the objects from these descriptions at any time and any place.

Nowadays there are two general types of geometrical 2D descriptions of spatial objects in common use *(Fig. 1)*. The first is line drawings in orthogonal projection to a reference plane, plans, sections and views. These are the result of a subjective interpretation supported by some objective measurements. The second is a central perspective photograph. These are acquired by physically describable and partially replicable processes and contain a large amount of information, which allows the user to extract the necessary information by and. However, 2D descriptions are by definition incomplete. Extra tools are necessary to make precise 2D measurements in single images and 3D measurements in sets of several images. These tools require photogrammetric expertise and sophisticated software, however. Common 3D measurement techniques (tacheometry, image matching, laser scanning) do not deliver the same level of detail as high quality image data, while artefacts and unmodeled details in the 3D data disturb the visual quality of the results.

Description of Spatial Objects

The objects of archaeology and architecture are spatial objects. Therefore the appropriate measurement techniques must be 3D measurement techniques. The most common are manual measurements, geodetic measurements (e.g. with total-station), photogrammetry (stereo or multi-image) and laser scanning (Wiedemann 2004, *Fig. 2*). All these techniques deliver 3D data sets, but demand a lot of manual work and significant budgets for data acquisition in the field and data analysis in the office. Most of this data is just single points, linear features or unstructured point clouds (i.e. CAD vector data or manual drawings), whereas the complete description of the object would request at least parametric surfaces (B-rep) or volumes (CSG). In many cases the data is reduced to 2D data sets for description.

A planar description is always aligned with a significant loss of information. Therefore a 3D description is preferred, at least as an intermediate description. 3D CAD models are also in common use, but they lack the ability to add attributes to the objects. Sometimes these 3D CAD models are often poorly readable *(Fig. 3)*. CAD software has been developed to show to the user the results of idealized 3D constructions in 2D presentations *(Fig. 4)*. All these techniques are well established for vector data. Often visualisations are derived with generic textures giving a realistic impression based on insufficient input data.

Fig. 1. Ortho-projected line drawing and central perspective photo.

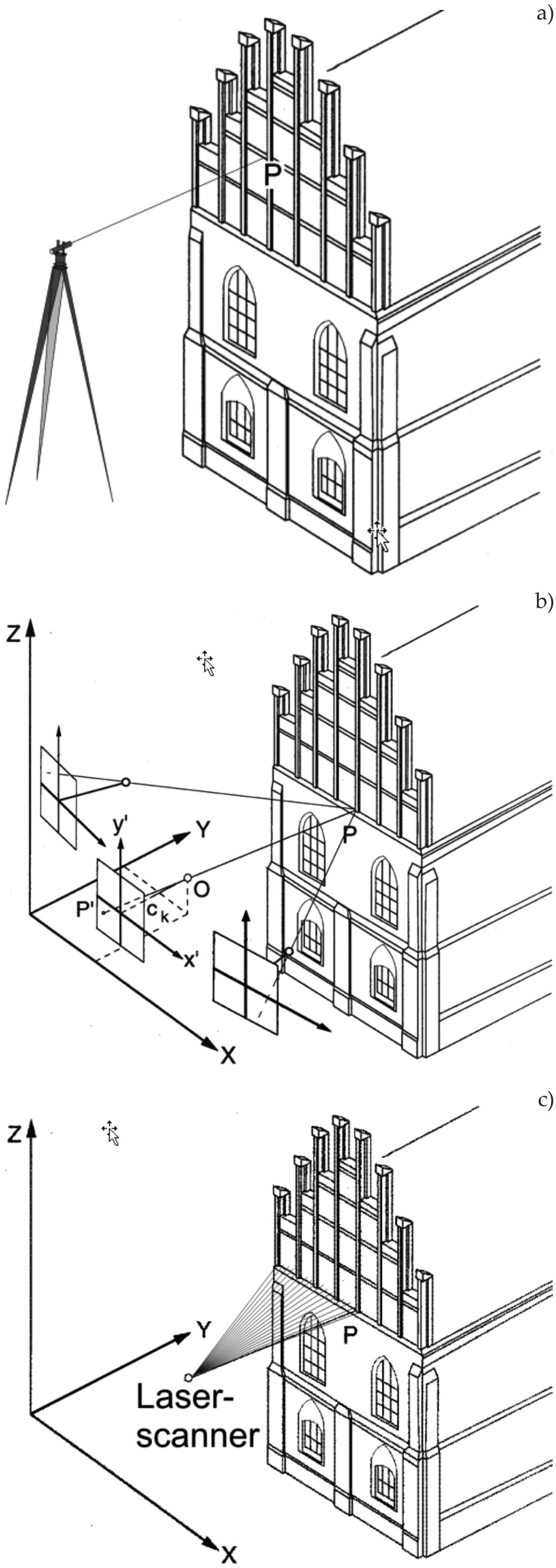

Fig. 2. 3D Measurement techniques: a) geodesy, b) photogrammetry, c) laser scanning.

On the other hand, there are Geographic Information Systems (GIS), whose data can have attributes, but have no full 3D capacity, only 2.5D (the height component is merely a function of the horizontal position). There is still a need to provide a *3D building information system* to store, analyse and visualize real 3D object description data. This 3D building information system should consist of a database, tools for modelling and analysis and suitable geometric, thematic and topological data (Weferling 2002). It is necessary to be able to derive any kind of 2D descriptions (planar visualisations) from the 3D database.

We all are familiar with reading and interpreting planar visualisations, and these documents can be simply managed and archived. Even our human viewing is 2D – the model is built in the brain. Therefore we need a wide variety of 2D descriptions showing all details of the object from each point of view.

The ideal presentation would be a detailed 3D model as B-rep model, consisting of faces which are illustrated by real textures, not generic textures. These models can be inspected from all sides and contain the full set of geometric and radiometric data. But it is very time-consuming to generate a consistent data model for this purpose. Each gap in the data model is visible *(Fig. 5)*, and each detail has to be modelled to give a suitable data base. It is an appropriate method if the object consists mainly of planar faces and simple projective rectifications can be used.

Fusion of 3D Data and Image Data

For planar surfaces, it is common to use realistic textures on the models by simple projective rectification (Hemmleb / Wiedemann 1997). But this technique fails or becomes inconvenient if the surface is

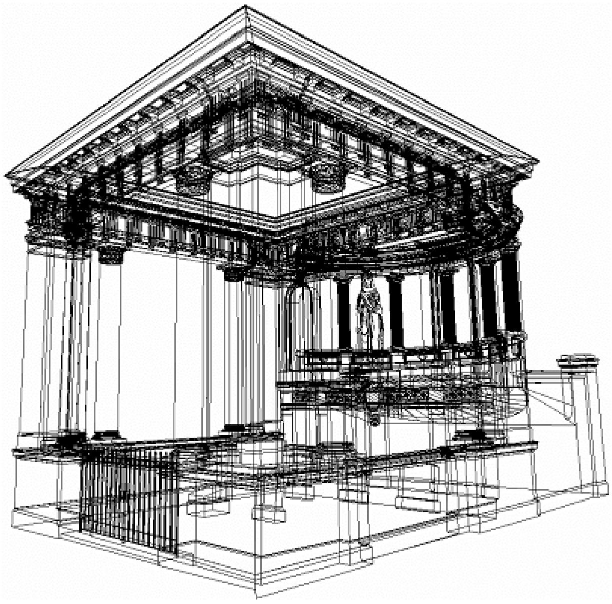

Fig. 3. CAD model (3D).

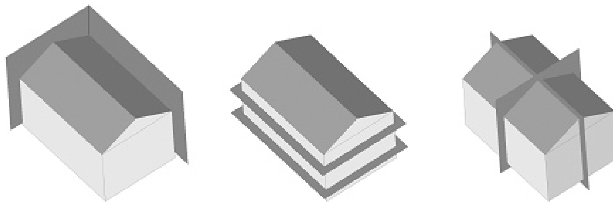

Fig. 4. 2D descriptions derived from 3D data sets: Façade views, floor plans and intersections.

not planar and needs individual handling for each facet of the surface.

A more flexible approach is to generate digital orthophotos (DOP), taking the 3D geometric form of the different façades into account *(Fig. 6)*. For this purpose, a Digital Surface Model (DSM) is necessary, representing the height of each point of the object surface above the reference surface. This is the greatest challenge in the entire process of generating DOPs.

DOPs based on DSM are commonly used in topography and mapping (Kraus 2007). In these applications, a usually continuous terrain surface can be well represented by a Digital Surface Model (or in this case a Digital Terrain Model) as discontinuities are exceptions. On façades the discontinuities represent the main details of the object. From an existing DSM, different DOPs can be derived based any available oriented image and the DOPs can be interwoven as an image montage. To avoid discontinuities over artefacts, the geometric resolution of the DSM must be the same as the geometric resolution of the desired DOP. For instance, for a plan 1 : 25 to be printed with 300 dpi the resolution on the object has to be about 2.1 mm for the DSM and for the DOP.

All 3D measurement techniques mentioned in the previous section can be used to determine the DSM. The geodetic method may be based on tachometric profile measurements (Juretzko 2002, Fig. 7). Intelligently selected profiles may make it possible to describe most of the surface geometry necessary to generate an adequate DSM. The photogrammetric measurements may be made in stereo models or on multi image restitution on images oriented in a bundle block adjustment (Luhmann 2000). Laser scanner data is also well suited for this purpose (Wiedemann 2001; Kern 2002; Sommer / Kersten 2007). If the resolution of the available data is insufficient, image based tools might help to densify the data where required. In many cases, extra tools are necessary for editing and qualitative analysis of the data, usually based on the available images. The derived DOPs will also form part of the quality analysis of the DSM.

Apart from the DSM, only the orientation data of the images is required for the differential rectification to generate the DOP pixel by pixel. The orientation data can be determined by bundle block adjustment. Each oriented image may then be differentially rectified to an individual DOP. The different DOPs will have different gaps, where parts of the object are occluded by other parts of the object or by obstacles in the foreground of the image. If several DOPs are generated from the same DSM, they also share their reference system and can be easily merged to-

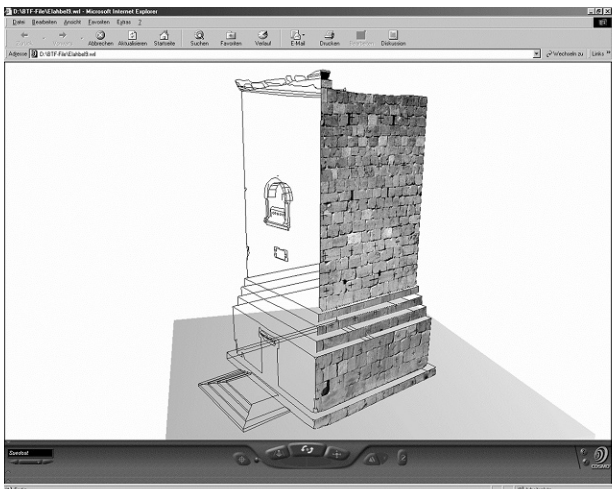

Fig. 5. 3D Model textured with real images.

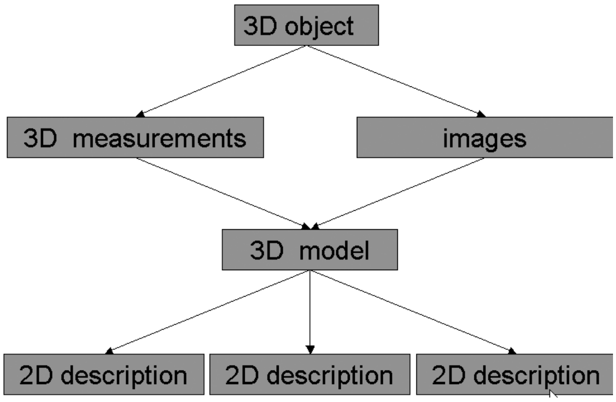

Fig. 6. Principle of data fusion.

Fig. 7. Digital surface model (DSM), digital orthophoto (DOP) and vector data.

gether to fill the gaps and hence cover larger parts of the object. This approach is similar to the so-called "True Orthophotos" (Mayr 2002) in topography.

Conclusion

The idea is to combine 3D measurements with images in a *3D building information system*. One of the central functions of the system is to extract 2D pictured descriptions of the spatial objects in the form of digital orthophotos out of this database using the included tools and methods. These tools allow the generation of a DSM from the 3D measurement data at a specified quality as an intermediate product, followed by a differential rectification to generate DOPs and mosaic tools to merge them together.

All in all, we still prefer 2D descriptions with added image data which can be switched on or off. The challenge is to find efficient techniques to attach good-quality image data to the 3D measurement data.

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