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FUSION OF PHOTOGRAMMETRIC AND LASER SCANNER DATA

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ABSTRACT:
Laser Scanners provide new data for the documentation of historical sites and monuments. Compared to photogrammetric approaches, they have some advantages, but also some disadvantages. To use the advantages of both approaches the data of both have to be compared and merged. A typical product is the digital ortho image. In an example an ortho image is derived from laser data. Finaly a ortho image mosaic has been created from two photo using the Digital Surface Model (DSM) derived from the laser scanner data.

KURZFASSUNG:
Laserscanner bilden eine neue Datenquelle für die Dokumentation historischer Stätten und Denkmäler. Im Vergleich zu photogrammetrischen Ansätzen haben Laserscanner gewisse Vorteile, aber auch Nachteile. Um die Vorteile beider Ansätze zu nutzen, müssen sie verglichen und kombiniert werden. Ein typisches Produkt ist das Digital Orthophoto. An Hand eines Beispiels wird ein Orthophoto aus den Laserscannerdaten hergeleitet. Schließlich wird ein Orthophotomosaik auf der Basis zweier Photos und des Oberflächenmodells des Laserscanners hergeleitet.

1. INTRODUCTION

A growing amount of laser scanner systems becomes available for the data acquisition at archeological and architectural sites. In many cases these systems are interpreted as competitor to photogrammetry. Compared to the photogrammetric approaches the use of the laser scanners has some advantages:

- Direct acquisition of 3D points.
- This systems deliver an enormous amount of 3D points on surfaces.
- Excellent technique for the description of irregular surfaces (reliefs, sculptures, pillar capitals).
- Results are available in a very short term.

On the other side, photogrammetry has some advantages:

- Colored Information is available.
- Unlimited range.
- Shorter data acquisition times at the site.
- Higher resolutions are available.
- Low price of the images.
- Possibility to use historical imagery.

It is possible to join both techniques and to eliminate the disadvantages of both techniques by a fusion of the acquired data. Both techniques require a control network, which demands a significant part of the campaign budget. The additional costs for the acquisition of photogrammetric imagery is limited, especially if photogrammetry has a further duty as fall back technique and to bridge gaps in the laser scanner data resulting from shadowing effects or a limited reflectance of the surface.

A well suited approach is to create digital ortho images by a parametric rectification using the digital surface model derived from the laser scanner data to describe the surface.

For large regular surfaces the usage of the laser scanner delivers no advantages compared to photogrammetry. Therefore it seams to be the best approach, to do a photogrammetric survey of the whole object and acquire additional data using a laser scanner system for the parts of the object where the laser scanner can use its special features.

2. LASER SCANNER

2.1 System Description

The Insitute for Navigation of the University of Stuttgart (INS) is working on different types of Laser Scanners. The presented system is a close range laser scanner with a 670 nm wavelength, designed for the survey up to an range of about 10 m. An advantage compared to other close range laser scanners is, that beside the range the intensity of the reflected laser is registered, delivering an additional information layer.

With this system a laser beam is directed over a room segment by two rotating mirrors to scan the surfaces (Fig. 1). Apart from the intensity of the reflected signal the phase of two measurement signals is also registered. From these phase measurements the distance between the system and the reflecting surface can be derived. The two skew angles and the object distance define a set of polar coordinates for the object points. The intensity of the reflected signal supplies additional information.

Distances and intensity are stored in raster files, the vertical skew angle defines the lines and the horizontal

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skew angles represent the columns. From these polar coordinates cartesian coordinates in a local system can be computed with simple formulas (WEHR 1997).

The survey can be done in segments of 400 × 400 or 800 × 800 points with an field of view of approximately 30° × 30° in azimuth and elevation. The range is limited to a few meters, depending on the intensity of the reflected signal. The intensity of the reflected signal is a function of the reflection characteristics of the objects surface, the wavelength of the carrier wave and the exposition of the surface in relation to incident light. The system is disturbed by glass at the object.

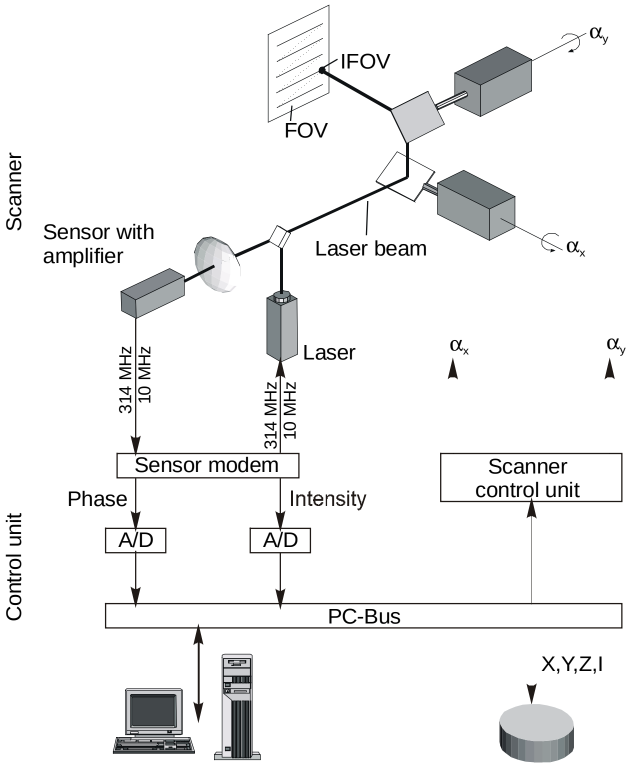

Fig. 1: Laser Scanner concept of the Institute for Navigation, Suttgart

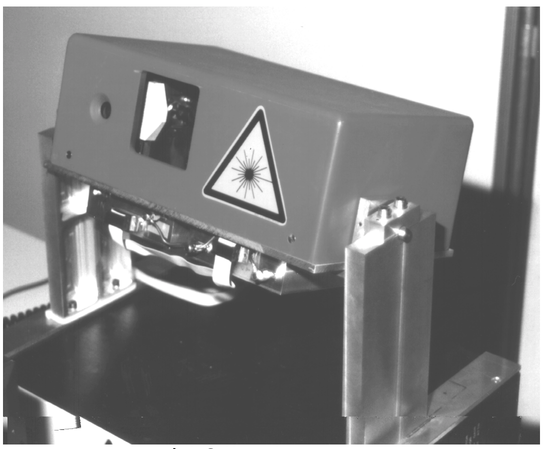

Fig. 2: Laser scanner

Classical planar control points signals can only be identified in the intensity image. With the help of the geodetic control points the individual spatial point clouds were transformed into the common coordinate system of the geodetic network.

2.2 Data Acquisition

As testing object a relief at the Technical University of Berlin has been selected. It is about 2.5 m high and about 1.5 m wide. It is placed in front of a plastered white wall and has a frame made of bricks. Twelve control points have been fixed on the background and the frame. they have been surveyed with geodetic methods afterwards.

Fig. 3: Section of an oblique image from a analogue camera Rolleiflex 6006 metric

During about 2-3 hours 7 data sets of 800 × 800 points have been acquired from a distance of about 4 m using the laser scanner. The point distance at the object was between 2 and 3 mm. Fig. 5 shows the raw intensity image of data set 2.

To reduce occluded areas, some of the data sets have been acquired from the side.

2.3 Data Processing

After the measurement the points, missing the demands according intensity, are eliminated from the data set. The second step is to calculate data sets carthesian coordinates x, y, z out of the polar coordinates and store them together with the intensity (i) in Ascii-files containing xyzi per point. Using horizontal and vertical distances at

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the object the opening angle can be controlled. The Cartesian coordinates are in an independent coordinate system for each data set.

Fig. 4: The intensity image of the raw result

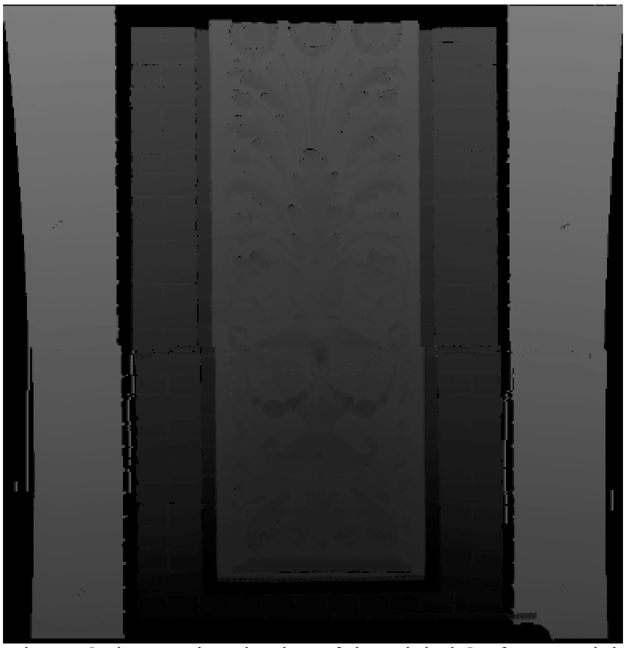

Fig. 5: Orthogonal projection of the Digital Surface Model of data set 2. The gray values represent the elevation. One gray level represents about 1.5 mm.

After this step, the data of each data set have been transformed using a 3D coordinate transformation into the local coordinate system selected as reference system. In this project we used data set 2 as local reference system.

In the next step all seven data sets have been merged to one large data set of the whole object. This are about 3.8 millions of raster points. The graphical representations (Fig. 7 and Fig. 8) printed here are created by an nearest neighbor interpolation from the transformed and merged xyzi-files with a resolution of 5 mm. Black areas represent occluded areas, for example on top of the relief. In areas covered only with one data set there are gaps in the data visible in the edge of the joint data set. As you see, the gaps in the data have been reduced significantly. A larger occluded area remain only on top of the brick frame, as no data where available from a higher point of view.

Fig. 6: Orthogonal projection of the intensity image of data set 2.

After this step the joint data set has been transformed to fit to the geodetic measured control points. The first transformation was a 3D transformation with a single scale. The main motions have been shifts and and a tilt angle of about 8 gon has to be used. In a second transformation a 2D affine transformation reduced the residuals at the control points from about 10 mm to about 1-2 mm. It seems that the horizontal scale is about 1-2% bigger, than the vertical scale.

2.4 Results

The point cloud is orthogonal projected to a planar projection surface. Therefore the operator receives a file with an elevation (Digital Surface Model) and a intensity value (Digital Ortho Image) for each grid mesh. The width of the grid meshes has to be adopted to the task.

There are different approaches for this purpose, like Finite Elements (EBNER et al. 1980) e.g. with the program HIFI or other algorithms for the interpolation of a regular grid with elevations.

One problem is the fact, that most of this DSM interpolation programs have been developed for the interpolation of terrain surfaces. But whereas the terrain surface is usually continuos, the surface of an architectural object consist of perpendicular planar or irregular surfaces with al lot of sharp edges.

This has to be mentioned, when the surface interpolation has to be done. Special surface interpolation algorithms well suited for architectural surfaces have to be developed. In this case only a nearest neighbor interpolation has been done with a median filtering for the blunder elimination.

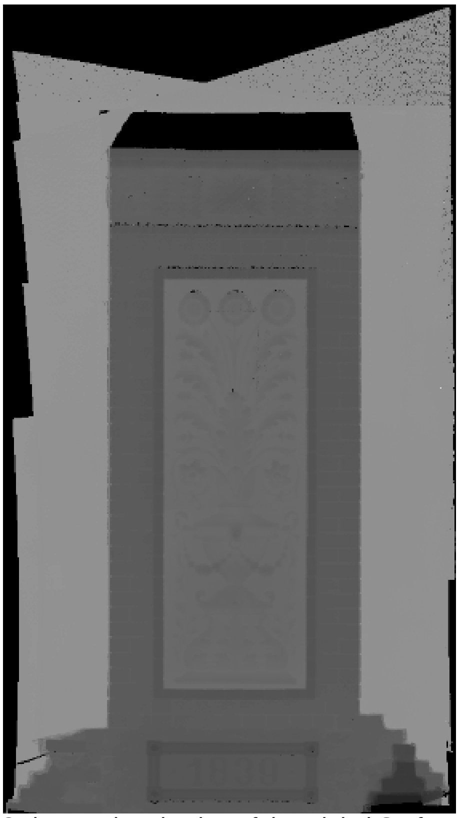

Fig. 7: Orthogonal projection of the Digital Surface Model of 7 merged data sets.

Fig. 8: Orthogonal projection of the intensity image of 7 merged data sets.

3. PHOTOGRAMMETRIC APPROACH

3.1 Interactive Measurements

If Digital Surface Models for facades are necessary, the traditional approach was to do an interactive survey of the object surface, e.g. with stereo photogrammetry, derive a CAD model consisting of faces and to develop the Digital Surface Model of this facade (WIEDEMANN 1996). This approach is only suitable for nearly regular surfaces.

3.2 Matching

An other approach is to create the Digital Surface Model based on digital image processing techniques, like least squares matching. This technique is suitable for irregular surfaces, but requires sufficient texture on the surfaces and appropriate initial values. On architectural surfaces, both conditions may be difficult to achieve. If the surfaces is plastered, there is insufficient texture, and if the surface is build up of different planes, you have to deliver different initial values according to the depth of each plane.

Fig. 10 Orthoimage mosaic of two rectified images using a laser scanner DSM

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Fig.: 9: Three Orthoimages derived from diffrent images

It will be necessary to develop matching strategies adapted for architectural surfaces.

4. DATA FUSION

Therefore the fusion of laser scanner techniques for the generation of Digital Surface Models and the differential rectification of digital images creating Digital Ortho Images seems to be the appropriate approach. First you have to bring laser scanner data and digital images into the same reference system, as described if section 2 and by image orientation using control points.

The ortho images derived from three different images are shown in Fig. 9. The black areas are occluded areas, where the images provided no data, the white regions are regions, where the DSM dosnt deliver any information for the calculation of the ortho images.

The next step was to merge two ortho images to elliminate occluded areas. As the left and the right image show similar radiometric parameters the have been chosen. The result is shown in Fig. 10.

5. CONCLUSION

The laser scanner data deliver an large amount of high quality data to describe the geometry of a surface. Photos delivers data with a higher geometric resolution in a short time and are also available in color. Therefore it is to be appropriate to merge the data, using the advantages provided by both techniques and deliver products of high quality. The potential of the data fusion has been shown.

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