FUSION OF TERRESTRIAL LASER SCANNING AND DIGITAL PHOTOGRAMMETRY

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ABSTRACT:

Terrestrial laser scanners are introduced in the market in various construction forms, dispose of various measuring principles and are used in the most different areas of application. Combining the information of the gray-scaled point cloud with the geometry informations of rgb-colored images results in improved possibilities of object interpretation and measurement. The coalescence of both data springs - under special consideration of the metric of the measuring image - offers possibilities of an enlarged use.
The article refers to the hybrid measuring system consisting of 3-D scanner and digital camera, which in the following will be characterized by the expression “image scanner”. A systematic view of market-current systems, their functions and designs will be given. This includes consequences concerning data quality, geo-referencing and in the end object recognition and evaluation process.

KURZFASSUNG:

Terrestrische Laserscanner sind in diversen Bauformen in den Markt eingeführt, verfügen über verschiedenartige Messprinzipien und werden in den unterschiedlichsten Anwendungsgebieten eingesetzt. Werden die Informationen der Punktwolke mit der Geometrieinformation eines Farbbildes kombiniert, so kann allein auf Grund der verbesserten Bildinterpretation von einer effizienteren Auswertung ausgegangen werden. Die Fusion beider Datenquellen – unter besonderer Berücksichtigung der Metrik eines Messbildes – bietet Möglichkeiten einer erweiterten Nutzung.
Der Beitrag beschreibt ein hybrides Messsystem, bestehend aus 3D-Scanner und Digitalkamera, das als „image scanner“ bezeichnet wird. Es wird eine Markübersicht aktueller Systeme sowie ihrer technischen Auslegungen und Funktionen gegeben. Dies beinhaltet Aspekte zur Datenqualität, der Georeferenzierung sowie des kombinierten Auswerteprozesses.

1. INTRODUCTION

Terrestrial laser scanners are introduced in the market in various construction forms (i3mainz, 2006), dispose of various measuring principles and are used in the most different areas of application. A common feature of the systems is that they deliver structures of three-dimensional coordinates, grid-shaped in point clouds as a raw product. In addition, the intensity value of the reflected laser signal is acquired as a fourth information. If the intensity values of the point clouds are displayed in a gray value spectrum (e.g., 12bit = 4096 grey scale values), a nearly photographic image of the object arises as a function of the capture density of the scanner. The "photo" corresponds in its structure to that of a digital image acquisition, connects every pixel with a coordinate-tripel, nevertheless, shows if necessary image distortion. Due to the use of a laser beam which works in the close infrared, the picture virtually shows a black-and-white infrared admission. This disposes of a low contrast circumference and no plasticity (Kraus, 2004).

Figure 1 shows the intensity image of a scan with the Zoller and Fröhlich Imager 5003 in comparison to a colour photo with a 4 megapixel digital camera. The raised information content of the colour image is seeming, e.g., by the allocation of objects to their classes (steel construction, pipes, material flows etc.). Combining the information of the gray-scaled point cloud with the one of rgb-colored images results in improved possibilities of object interpretation and measurement. The fusion of both data sources – under special consideration of the metrics of the image – may increase the benefit.

Figure 1. Intensity image (left.) versus. coloured picture (right)

2. THE "IMAGE SCANNER" - A HYBRID MEASURING SYSTEM

In the following the term “image scanner” describes a hybrid measuring system consisting of 3-D scanner and digital camera.

2.1 Functions – current situation

The basic function of a digital image within an image scanner can be subdivided in the ranges of interpretation as well as image measurement. A look at the systems available in the market clearly shows that the interpretative approach stands in the foreground. Images are used with priority:

- as a guidance within the measurement procedure to define scan ranges (What is visible? Which objects can be acquired? Which scan resolution is to be used?),
- to improve the possibilities of interpretation of the point clouds about associated colour information from the images,
- within the scope of an evaluation (e.g., to be able to carry out a saved object identification by the allocation of primitives),
- for texture mapping on meshed object surfaces (Sparchholz, 2005).

The function range “image measurement”, for the purposes of an use of available metrical image informations, is very much limited in the current scanner-software tools. Indeed, the manufacturers have recognised the advantages of a data fusion absolutely, nevertheless, conversions within the scope of current products keep waiting.

2.2 Designs

With the construction of image scanners different concepts are realised. Essential differences consist in it, whether the camera

- is used in parallel with scanner, nevertheless, without any mechanical connection,
- is an "add-on" element, connected temporarily with the scanner or, however
- is an integral component of the scanner.

In addition, the digital cameras being used differ in their construction principles. On the one hand classical systems are used with area array chips, on the other hand, so-called panoramic cameras with integrated line sensors. Essential information for all used cameras is the knowledge of their metrics (interior orientation), i.e. the system is calibrated and disposes the features of a measuring camera.

2.2.1 Digital Consumer cameras: Digital image acquisition on the basis of consumer cameras accompanies a scan campaign in view of purely interpretative questions. Here the image should close prior informal gaps which originate by analysis of the point clouds. Claims to the metrics of the camera do not exist, so that there are no immediate linkages between the geometry of the point cloud and radiometry as well as geometry of the image. Normally the interior orientation of the camera is unknown.

2.2.2 Digital cameras as a scanner "add-on": If a camera system is adapted near a scanner, on this occasion, three aspects stand in the foreground:

- for the (at least) duration of a scan campaign a mechanically solid respect should consist between both subsystems,
- scanners and in particular the camera should be also usable as independent components,
- by the exchange of the camera or from camera components the user can react at special requirements for the digital image flexibly (e.g., image resolution and/or image scale).

Scan and image capture can occur simultaneous or be processed also sequential. In view of a metrical use of the image information a stable calibration of the camera is necessary. In case colour information from the digital image should be transmitted on the point cloud it is to be paid attention to the fact that the eccentricity between scan head (scanner origin) and lense (projection centre) is to be held as low as possible to minimise faulty colour assignments in consequence of parallax.

2.2.3 Digital cameras as an integral component of the scanner: The integration of a camera in the total concept of the scanner has been realised by different scanner manufacturers. This approach comes up conceptual advantages, because of

- the partial components of the system are normally well adapted,
- the camera is inserted in the frame of the scanner,
- the data flow between both sensors is realised,
- under a uniform user interface functionalities in the flow of operations are solidly defined,
- the metrics of the camera is known.

On the other hand side in particular updates of the camera hardware, in view of an improvement of technical data and functions, as a rule are not possible or very time-consuming.

2.3 The Geometry of the image sensor: area array versus line sensors

The development of digital area array sensors in the last decade is marked by two trends:

- general availability of high-resolution sensors (1995: 1.5 Mpixel, in 2006: 33 Mpixel),
- significant price reduction of the sensors in the consumer segment as well as in the high-level range of performance (price factor in 1995: 1, price factor in 2006: 0.1)

Today high-resolution digital cameras on the basis of area array sensors are an essential part of optical 3-D measuring systems. Long-standing experiences in the modelling of the sensor properties (Tecklenburg et al., 2001) as well as the general availability of photogrammetric software packages for image triangulation (bundle block adjustment for image orientation and 3-D point determination) are the bases for precise and reliable measurements.

While digital cameras with line sensors a few years ago found application almost exclusively in the reproductive technology, today this technology has led to a renaissance of the panoramic cameras (KST, 2006, Spheron, 2006). The utilization of such rotation lines cameras (with her special geometry) for measuring applications is an object of current researches (Schneider & Maas, 2004).

The extremely high image resolution (up to 1 Gpixel) as well as the scan principle, which corresponds basically to that of a laser scanner, lets appear such systems – at first sight – as an optimum component in the overall system of the image scanner. Also a comparison of the duration for a whole photographic panorama with the measuring duration of panoramic scanners (Wehr, 2005) shows clear common characteristics: as a function of the image resolution this amounts between 3 and 10 minutes (example of KST EYESCAN M3). Nevertheless, these entries for exposures with daylight can increase drastically in case of indoor measurements, so that up to 60 minutes per panorama are needed (Abmayr et al., 2004), a period often in practice is not available. Also the long-term stability is normally guaranteed in industrial environments. The efficient lighting systems which could limit this basic lack are not currently in the market. An exception is given with the system I-SiTE 4400LR, which combines scanner and camera in one device (figure 2). The company developed a special underground light for geological photography (i-SiTE, 2006).

Figure 2. I-SiTE 4400L with underground light

The universal use of an image scanner equipped with a panoramic camera is therefore strongly limited. Furthermore necessary developments of the geometrical camera model as well as their integration in photogrammetric software products are still in progress. As a consequence, at the present time, the device fusion of scanner and panoramic camera to a new measuring system at least seems premature.

2.4 The metrics of the digital camera

The use of a (digital) camera within the scope of a measuring process assumes the knowledge of her current geometry, in photogrammtry defined by the interior orientation. This form of parameter definition is sufficiently known (Luhmann, 2003) and part of market-currently close-range photogrammetric measuring systems. Cameras especially designed with regard to photogrammetric requirements, e.g. stability of the interior orientation, are very expensive. On the other hand, the number of off-the-shelf CCD and CMOS cameras is growing rapidly. Consumer-type cameras provide ever increasing resolutions, digital SLR cameras are becoming less expensive. Due to the fact the process of camera calibration becomes more and more important. On the one hand depending on accuracy requirements and, on the other hand, from the mechanical long time stability of the camera, these parameters can be used for sequence applications or the camera system must be calibrated once again.

A consideration of the image scanners currently located in the market (table. 1) clearly shows that often digital SLR cameras of the middle price range are used as a system component. These are to be associated unambiguously to the category partial measuring camera. Hence, regular calibrations as well as activities to stabilize the camera geometry are indispensable (Studnicka et al., 2004a, Wendt & Dol,d, 2005). Besides, for continuing photogrammetric image evaluation, the position of the camera must be known in the scanner system.

2.5 Image scanners in the market – present situation and perspectives

Table 1 gives an overview of current image scanners for geodetic applications. The performance of the used digital cameras strongly varies, but area array sensors are used in majority. Besides, cameras integrated in the scanner construction often dispose of low image resolution, while cameras (afterwards adapted in the scanner) show improved performance. The functionality realised by the manufacturers with regard to the image information is reduced to interpretative tasks as well as – with few exceptions – to the colouring of the 3-D point cloud. The cameras rather take over the function of add-ons; they are not a component of an advanced measuring system, which takes advantage of photogrammetric techniques. Most near this possible hard- and software concept the Riegl LSM-Z scanners (figure 3), in connection with the RiSCAN PRO evaluation software, are situated (Studnicka et al, 2004b).

As a prospect the combination of scanner and digital camera stands at the beginning of their development. The integration of accordingly efficient cameras with stable geometrical properties seems to be convenient in this context. Exemplarily the camera system AIC modular LS developed by Rollei Fototechnic has to be mentioned (Rollei Fototechnic, 2006). The use of metrical lenses in combination with a to solidly mounted digital image back with up to 22 Mpixel resolution, guarantees high performace images combined with stable image geometry (figure 4).

scanner	camera	sensor	resolution [pixel]	mount	function
Trimble GS	video	AA	768 * 576	I	IP / RGB
Leica HDS 2500	video	AA	480 * 480	I	IP
Leica HDS 3000	N/A	AA	1024 * 1024	I	IP / RGB
Optech ILRIS-3D	N/A	AA	3000 * 2000	I and E	IP / RGB
CALLI-DUS CP 3200	Video	AA	460 TV Linien	I	IP
FARO LS 880HE	Nikon D 70	AA	3008 * 2000	A	IP / RGB
Riegl LSM-Z Serie	Nikon D100 Canon EOS 1Ds Mark II	AA	3008 * 2000 4992 * 3328	A	IP / RGB / PE
I-SiTE Pty. Ltd.	I-SiTE 4400LR	L	37 Mpixel	I	IP / RGB
Z&F Imager 5003	KST EYE-SCAN M3(*) Spheron Pano Cam	L L	10200 5400	E	IP / RGB

Table 1. Image-Scanner (I – integrated; A – adapted; E – extern; L – line-sensor; AA – area array sensor; IP – interpretation; RGB – coloured point cloud; PE – photogrammetric evaluation; (*) not launched on the market – prototypical installation)

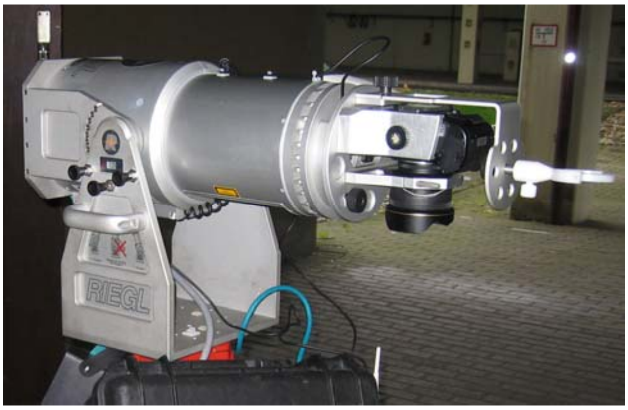

Figure 3. Riegl LSM-Z420 with fixed mounted digital SLR camera

Figure 4. Rolleiflex AIC modular LS

Different reasons speak for the realisation of such a system:

- the availability of efficient image sensors,
- an extensive choice in high-capacity lenses,
- clearly improved image quality in comparison to previous used cameras,
- long-standing experiences of the manufacturer in building metrical, i.e. cameras for photogrammetric applications.

An accordingly equipped high-end image scanner (in a camera version as well as panoramic version) which is to be classified by its hardware concept offers conceptual the best requirements for a combined use of image and scan data.

3. COMBINED EVALUATION OF 3-D POINT CLOUDS AND HIGH-RESOLUTION IMAGES

The aim of a combined analysis of point clouds and image data can be summarised in two essential aspects: to equalise conditioned disadvantages of one technology by the advantages of the second one, to form the overall system more efficiently. In addition, photogrammetric evaluation concepts – with long-standing experiences in automatic processing of high dimensioned data volumes – should be transferred to the processing of point clouds.

A whole consideration leads to following possible aspects or from it to deductive products, which were already taken up by manufacturers and developers partly, are in development or up to now display only models of thought:

Data quality / accuracy

- scanner data deliver homogeneous accuracy in all 3 coordinate directions,
- using photogrammetric measurement technologies the coordinate accuracy gets worse depending on the direction (object deepness) with the square of the distance.

Geo-referencing / calibration

- Orientation of scan and image data on the basis of photogrammetric processes (e.g., spatial block adjustment with independent models, bundle block adjustment),
- simultaneous calibration and orientation of the hybrid system image scanner within the scope of a bundle block adjustment.

Object detection

- the digital image delivers colour information,
- the resolution of photographic images is (currently) higher than the one of the scanners,
- the (manual) identification of spatial structural elements (lines, edges, single points) in a digital image is more simple or can be carried out also semi-automated by accordingly available algorithms,
- the digital image allows the capturing of nearly all object surfaces and materials (e.g., glass).

Evaluation / results

- possibility of the superimposition of scan data and image data,
- possibility of the superimposition of evaluated objects in the image data (variance comparison),
- a direct production of image-based products, e.g., geo-referenced panoramas, ortho-images, textured surfaces, virtual rooms etc.

4. CONCLUSIONS

The image scanner, a hybrid measuring system is found – technically realised from different manufacturers – at the market. Nevertheless, the scanning systems are prior 3-D scanners, the value of the digital cameras is rather low. The actual quality of current image sensors is not reflected in the systems up to now.
The recognizable deficits of the classical evaluation programs for 3-D point clouds continue in the range of image analysis. The program systems which allow a combined evaluation (Becker et al., 2004) are rare, functionalities – in particular in view of automation – are strongly limited.

From this perspective look the fusion of terrestrial laser-scanning and digital photogrammetry is in its beginnings. Positively seen it displays a future-oriented project.

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