REALISTIC 3D RECONSTRUCTION – COMBINING LASERSCAN DATA WITH RGB COLOR INFORMATION

Abmayr T., Härtl F., Mettenleiter M., Heinz I., Hildebrand A., Neumann B., Fröhlich C.

Zoller + Fröhlich (Z+F) GmbH, Simoniusstr. 22, D-88239 Wangen, Germany
Phone: +49-7522-9308-0; www.zf-laser.com; info@zf-laser.com

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ABSTRACT:

Laserscanners are used more and more as surveying instruments for various applications. With the advance of high precision systems, capable of working in most real world environments under a variety of conditions, numerous applications have opened up. The developed IMAGER 5003 is a state-of-the-art, high precision, high speed laser scanner that provides accurate measurements.
In order to monitor scenes by means of range and reflectance images, the IMAGER 5003 is based on a phase-shift measurement principle. In combination with a newly developed scanning system, the system provides a wide field of view of 360° (horizontal) x 310° (vertical) with an image resolution of up to 20000 x 20000 pixels within one single image. Scanning time for a full scan depends on the section to be scanned and the number of measured points – for a standard image 360° x 310°, 10000 x 10000 pixels less than minutes. The IMAGER 5003 measures both, range and reflectance images at the same time. The range image generates geometric dimensions of the environmental scenes whereas the reflectance image generates a photographic like impression of the scanned environment which is used for feature extraction, visual inspection, object segmentation, surface classification and documentation purposes.
To realise surveying tasks in architectural, archaeological and cultural landscapes conservation, a high resolution line scan camera is used: The camera was developed by the German Aerospace (DLR) and enables the mapping of 2D RGB color information onto the 3D point cloud of the scanner unit in a simple manner.
This paper introduces into the main features of the Z+F IMAGER 5003 as well as of the DLR line scan camera and explains the way, how scanner data and RGB image data are combined. It shows results from cultural landscape conservation projects as well as from industrial applications. Finally it gives an outlook to further work in the laser scanning development area.

1. INTRODUCTION

Reconstructing buildings and scenes in a realistic fashion is a popular topic in virtual reality projects. Whereas in recent years the main focus of research concentrated on 3D reconstruction based on 2D image data, laser scanning technology nowadays gets more and more popular: Geometric 3D laser scan data is combined with high resolution and high quality 2D RGB color camera information. In order to produce three dimensional geometric measurements with colour information, we use two systems: the IMAGER 5003 for geometry and reflectance measurements in combination with a high resolution CCD line scan camera. This paper introduces the main features of these two systems and shows how RGB color information can be mapped onto a 3D point cloud. The paper concludes with examples.

2. SYSTEM FEATURES AND DATA ACQUISITION

The first part of this chapter deals with the main features of the two systems, followed by an overview of the software of both systems. In the third part it is shown how the information of both sensors can be combined.

2.1 The IMAGER 5003

SYSTEM FEATURES

The visual laser scanner IMAGER 5003 of Z+F (Figure 1) is an optical measuring system based on the transmission of laser light (see [Frö02], [Ste02], [Hae01], [Hei01]). The environment is illuminated on a point by point basis and then the light reflected by an object is detected. The laser scanner consists of a one-dimensional measuring system in combination with a mechanical beam-deflection unit for a spatial survey of the surroundings.

Figure 1: The figure shows the IMAGER 5003

The laser scanner is designed for non-tactile, high performance measurements and stands out for high robustness and accuracy. This is necessary for exploration by surveying industrial plants and production halls, as long down times in production have to be avoided; but it is also required for cultural sites like churches or castles where people visiting the site should not be disturbed. Due to the large field of view of the scanner, 360° horizontally (azimuth) and 310° vertically (elevation), the scene to be modelled has to be surveyed only from a few points of view.

Beside the 2D reflectance information the laser scanner provides 3D range information in addition. Both information – reflectance and 3D range information – correspond to each pixel one to one. So by extracting features in an accurate way, the combination of image processing methods and 3D geometric information is possible.
The system itself has different scanning modes, which differ in the spatial point distance. The mode can be selected according to the requirements and application from Super High Resolution (20,000 pixel per 360° horizontally and vertically) to Preview (1,250 pixel per 360° horizontally and vertically) mode.
The acquisition time is very short: The mode for example, which is most popular in industrial environment applications (10,000 points horizontally and vertically) takes just 3.20 minutes for a full 360° scan.
Another big advantage of laser scanning technology is that you can operate in total darkness as well as in daylight. This facilitates measurement as no additional illumination is needed.

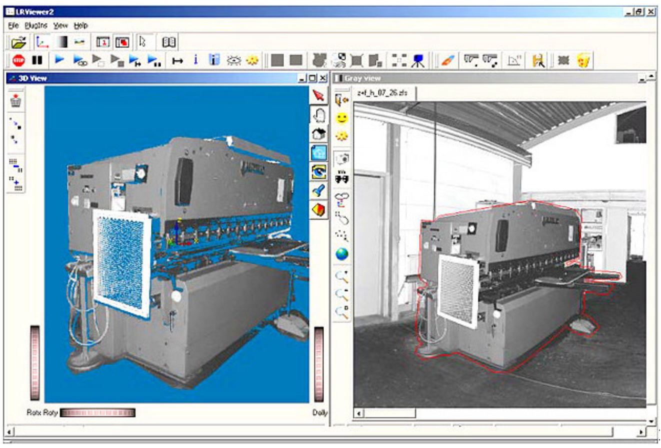

Figure 2: The figure shows Z+F Viewer's desktop.

SOFTWARE

There are two software tools, which were specially developed and optimised for the IMAGER 5003: The Z+F Viewer is the basic software for operating the scanner and performing simple measurement tasks. Based on this the LFM builds up: This software enables the conversion from 3D point clouds into CAD objects and offers a comfortable interface to standard CAD programs of more than 250 scans (10,000 x 10,000 pixel) through a database.

Z+F Viewer

The operator software is designed for scanning in the field (see Figure 2). The software is very easy to handle by using predefined settings for the scanning. This allows the operator to select between five predefined buttons for setting the application specific scanner parameters. By selecting the preview mode – enabling more than 12 million points to be scanned in less than 20s – a preview of the area to be scanned in detail can be measured and afterwards selected to be rescanned using a higher point density.
The Operator integrates the software package Z+F Viewer for visualisation purposes and online data measurements by means of a so called "virtual surveying" functionality.
Directly after measuring, the first results can be seen on the computer: Usually the reflectance image is used to get a photorealistic impression of the scanned area. It is similar to a black-and-white photograph and therefore does not require much experience for interpretation.
After each scan, the surveyor can see the objects which have been captured directly in the reflectance image (Figure 3). When objects are hidden by other objects, it may be necessary to rescan this region from a different point of view.

Another way of checking the scan is through the grey-coded range image. It is the complimentary image to Figure 3, viewing the same area: but range is displayed rather than reflectance. In the range image, every range has its own grey level; the greater the distance to an object, the lighter the object is represented. Objects which are near by the sensor are almost black. As this is not natural to the human eye, some experience is needed to gain useful information from this view. The range image is important for the control of the ambiguity interval, as the operator can easily see which objects are far away and therefore are measured with a lower point density. This image can also help the user to decide where exactly to take the next scan.

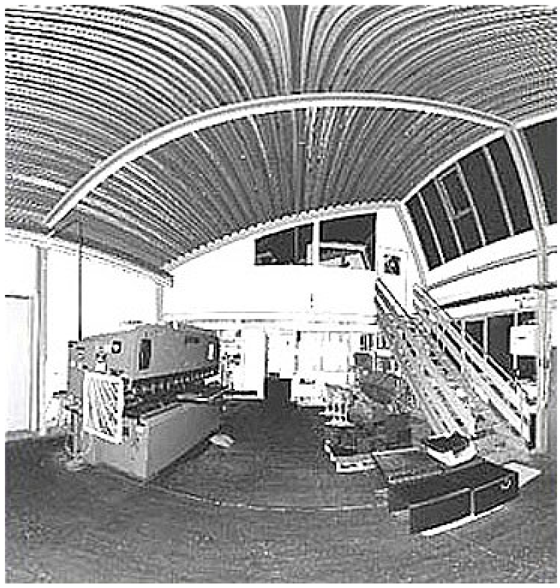

Figure 3: The figure shows a reflectance image. There is a one to one correspondance between the reflectance image and its complimentary image, the range image.

To get an overall view of the scanned area, the 3D window is essential (Figure 4). All measured points are transformed to 3D so that the whole point cloud is shown as a three dimensional image which gives a good impression of the scanned region. The user can turn the object and zoom in and out to see the object from any point of view. Like in the reflectance image, in this view hidden areas can be detected easily.

Simple measuring features allow the user to get the most important measures on site and a feeling for the dimensions.

The user just needs to click on two points and the program calculates the distance between them. This feature allows the user to perform data evaluation tasks in the field already.

Figure 4: The figure shows a 3D point cloud.

Another feature is the semi-automatic target finder [Abm04]: By clicking somewhere on a 10cm by 20 cm chess-pattern (see figure 5), the user gets the target centre with subpixel accuracy, and its corresponding 3D value respectively. This calculation needs to be precise and accurate, as this 3D information is the basis for calculating the orientation of each scan: For calculating the orientation itself for several scans bundle adjustment with standard tools is used.

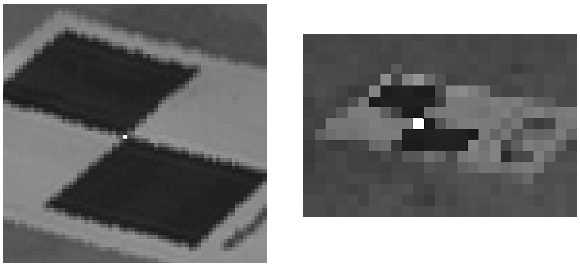

Figure 5: The figure shows the result of the target finder. *Left*: The target is taken with the high resolution mode (10000 pixel horizontally and vertically per 360° scan, in approx. 5m distance). *Right*: The target is taken with the preview mode (1250 pixel horizontally and vertically).

LFM

Light Form Modeller (LFM) has been developed specifically to convert 3D point clouds into 3D CAD models. A Conversion from point data to CAD objects is achieved by the application of analysis algorithms which have been generated to facilitate swift points-to-primitives translation.
The modelling of small or large structures dictates that significant numbers of images need to be taken from a number of different viewpoints and consequently, building a 3D CAD model can quickly become a very complex undertaking. For this reason, LFM provides seamless support for the user to allow rapid registration of multiple images from several viewpoints in order to compose the 3D CAD model (see Figure 6).

Model construction takes place on a hierarchical basis, that is to say objects can be constructed from smaller components and grouped to form an assembly. Once a complex object has been created it can be cloned or saved as a library component. Using a unique method of connectors, objects having these connectors can be simply snapped together to form larger groups of objects. This approach is particularly useful where a complex object appears in a model many times and the user needs to instantiate another instance of an object at a specific place.

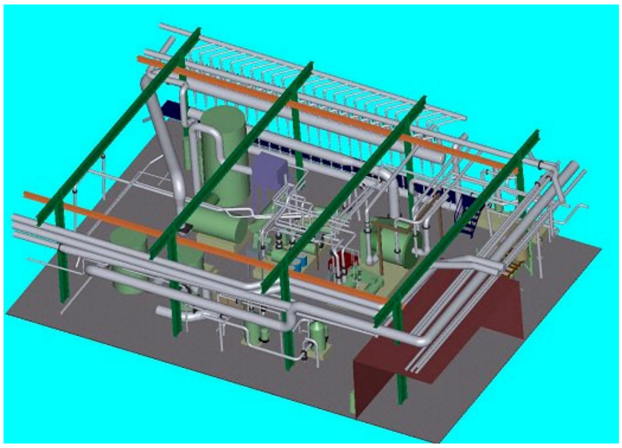

Figure 6: 3D CAD model of a chemical plant: The production facility has been surveyed from several different viewpoints. Targets have been used to match the scans together and to refer each scan to the local coordinate system of the facility.

Conversion from 3D point data into CAD objects is facilitated by using a range of specifically generated fitting algorithms which have been developed to be both robust and accurate. It is an interactive conversion process, as the user selects specific groups of points and then directs the program to automatically find the best fit for a CAD representation of this object. This approach leads to very swift construction of the model even for users new to the system. After carrying out an automatic segmentation, a semi-automatic fitting of pipes, planes and other primitives is possible with some interaction required. The LFM fitting algorithms are extremely robust to noise and outliers, so that they still work even if the quality of the points is not as high as usual, which may happen at certain very dark surfaces.
Meshing is another method of processing the data obtained by the laser scanner. It is extremely useful for objects with complex and free form surfaces like statues or castles. Meshing takes the cloud of data points and produces a triangular mesh which closely approximates the surface formed by the cloud of points. These Point clouds can vary immensely in density, overall size and surface complexity, so the meshing system has been designed to be able to deal with this on an automatic basis.

LFM includes interfaces e.g. for AutoCAD 3D, Microstation SE & J, PDS (Geometry) through Microstation, PDMS (Geometry) through IMPLANT, CATIA, RobCAD, Polyworks, Laser Gen, Cloudworx and all other CAD systems which are open to Microstation and AutoCAD inputs.

2.2 The DLR camera Eye Scan

The next section introduces the main features of the DLR line scan camera.

SYSTEM FEATURES

This camera Eye Scan (see Figure 7) is developed in a common project between an industrial company and the German Aerospace Center (DLR) for environmental documentation purposes. The camera consists of a rotating unit which rotates an integrated CCD line chip 360° to achieve a full view of the environment [Sch04]. By using three line chips with 10,000 elements each a very high resolution can be achieved. Three lines (RGB) provide each 16 Bit information of the environment and guarantee a high dynamic range with monitoring.

Figure 7: The figure shows the high resolution DLR line scan camera.

The resulting images consist of a maximum of 10200 by 500000 pixels each containing three 14bit RGB values. The image is stored by a specially developed frame grabber onto the hard disk of a computer. A typical scan (10000 x 30000) using a special optical lens system by 35mm optical focus length takes about 3 min (daylight) and up to 60 min (dark indoor illumination), mainly depending on the ambient illumination conditions and the number of rows to be measured with the camera.

SOFTWARE

The software for the camera enables the user to adjust typical camera settings like e.g. the shutter speed. For improving the homogeneity of the colours for different illumination conditions, it is possible to choose shading correction tables (e.g. daylight or indoor illumination). The software also includes a package for the geometric calibration, which enables a recalculation of the rawdata into a geometrically calibrated image.

In the next paragraph it will be described how 2D RGB color information can be mapped onto a 3D laser point cloud.

2.3 Combining camera and laser scanner data

In the photogrammetric field, a couple of techniques are known to map RGB data onto range data: Assuming that the distortion of both systems is already recalibrated geometrically, the overall mapping formula must in some way contain a translation (3 unknowns), rotation (3 unknowns) and perspective projection: In the following it will be shown how this 6-dimensional parameter space can be reduced to one parameter for the given set-up.

SETUP

The scanner and camera acquisitions are performed one after the other: After finishing a scan with the IMAGER 5003, the DLR Eye Scan camera is set onto the same tripod, by fixing an adapter onto it (see Figure 8). This adapter ensures that the location of the optical centre of the camera is (nearly) identical with the one of the scanner unit, as well as both horizontal rotation axis are. Thus the only unknown parameter, which must be calculated to transform both co-ordinate systems into each other, is the horizontal angle.

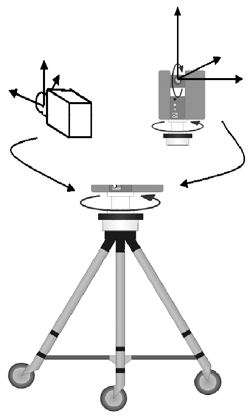

Figure 8: The figure shows the basic principle of the data acquisition (see text).

3. APPLICATIONS

ARCHITECTURE AND HERITAGE

For a lot of applications in the field of architecture and cultural heritage not only geometry is enough but also reflectance and if possible colour information is necessary to fulfil requirements of architects.

The following chapter presents examples using both systems:

3.1 Castle Neuschwanstein

In this example the results of a project between Z+F and the DLR are presented. The task was to scan and survey the inside of the drawnhall and create a 3D colour model.

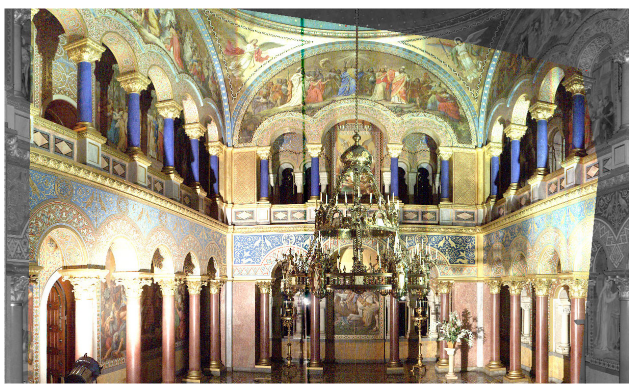

Figure 9: The figure shows the drawnhall of castle Neuschwanstein: The reflectance image of the Imager is overlapped with the corresponding RGB colour information of the Eye Scan camera.

Figure 9 shows the reflectance image overlapped with the corresponding coloured RGB values. A section of the colored 3D point cloud is shown in Figure 10.

Figure 10: The figure shows a part of the drawnhall of castle Neuschwarnstein as colored 3D point cloud.

3.2 Interior Design

The next example shows an application how it could be used for interior design (see Figure 11). The table is shown as a realistic coloured 3D point cloud. The clothes hanger shown in the figure for instance shows the high quality and details of the coloured point cloud.

Figure 11: The figure shows the coloured 3D point cloud of a table.

LANDSCAPE CONSERVATION

In this section an example of the project NATSCAN is presented: NATSCAN is a common project between several research institutes and industrial partners with the goal to develop perspectives and tasks for laser scanning technology in the field of environmental applications. In Figure 12 the coloured 3D point cloud of a group of trees is shown. In this example colour scanning is used for monitoring. The figure shows the 3D point cloud of the Imager partially combined with 2D colour information.

Another application is the quality check of wood: 3D data is needed to perform measurement tasks, like e.g. the calculation of the perimeter or length of a trunk. Quality properties of wood, like e.g. knotholes can be calculated by means of image processing methods on the 2D RGB colour image.

Figure 12: The figure shows the 3D point cloud of a group of trees in a forest, partially combined with colour information. There remain dark shadows, as the data acquisition was taken from just one viewpoint.

4. CONCLUSIONS

With the developed visual laser scanner, the control software and the software for model generation, there are very powerful tools available that are suitable for a lot of terrestrial surveying tasks. The developed laser scanner offers high accuracy measurements in conjunction with a high sampling rate and large dynamic range in reflective properties of object surfaces (highly reflective to absorbing). In combination with the DLR panoramic colour camera a precise and accurate monitoring of the actual environment by means of colour point clouds is achieved. This is unique due to its high precision and quality.
In a next step further improvements on mapping colour and geometry by means of raw data will be researched with several international partners in research projects.

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