3D body scanning with "Flying Triangulation"

Franz Huber, Oliver Arold, Florian Willomitzer, Svenja Ettl, Gerd Häusler

Institute of Optics, Information and Photonics
University of Erlangen-Nuremberg

mailto: Franz.Huber@physik.uni-erlangen.de

Based on the measurement principle "Flying Triangulation", we present a motion-robust sensor for objects within the meter range, especially for human bodies, sculptures, or rooms. The principle requires neither external tracking nor a still-standing sensor or object. The current measurement progress is displayed in real time. We show recent results and potentials.

1 Introduction

In [1] we introduced a new optical 3D measurement principle which we call "Flying Triangulation" enabling a comfortable and motion-robust 3D data acquisition. It combines a single-shot sensor with sophisticated algorithms. Based on this principle we have developed a sensor for objects of sizes in the meter range such as bodies, sculptures, or entire rooms.

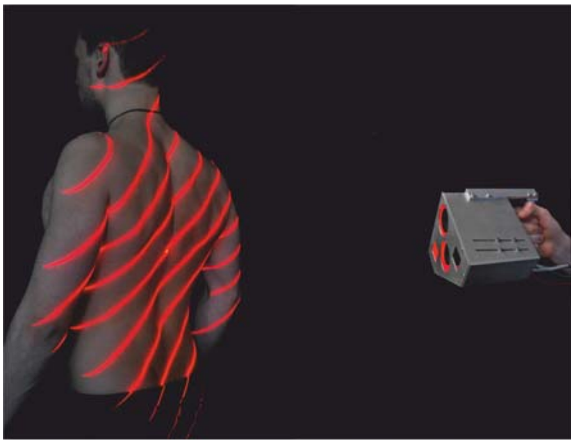

Fig. 1 *Measurement of a back with the sensor prototype.*

During the measurement, neither the sensor nor the object have to stand still. The handheld sensor, based on light sectioning with multiple-line patterns, can be freely moved around the object (see Fig. 1) while a series of sparse 3D views is generated. Sophisticated algorithms align these views to each other and display the current measurement progress in real time - without requiring any external tracking devices or markers on the object.

2 Setup and measurement principle

The basic measurement principle is shown in Fig. 2. The sensor is based on light sectioning with line patterns in two orthogonal triangulation planes (see Fig. 3). Two perpendicular patterns are alternately projected onto the object and observed by the camera. For each 2D camera image 3D data is acquired along the observed lines yielding a sparse 3D view.

To obtain a dense 3D model, the sensor is freely guided around the object while taking a few hundred sparse 3D views. These views are consecutively registered to each other by self-developed algorithms in real time resulting in a dense 3D model of the object [2]. Simultaneously, the current measurement progress is visualized, hence presenting real-time feedback.

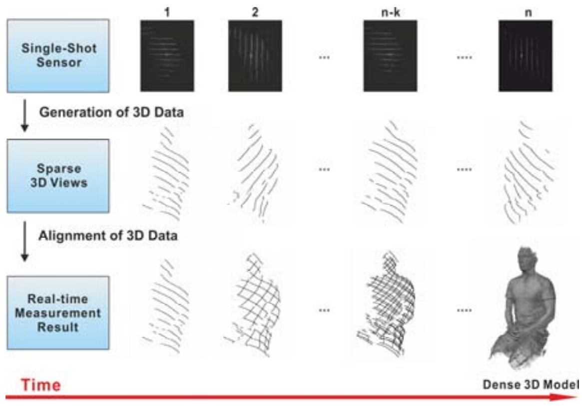

Fig. 2 *Measurement principle of "Flying Triangulation". From each camera image a sparse 3D view is generated. The views are registered to each other online yielding a dense 3D model.*

3 Sensor specifications

The goal is to develop a handheld sensor for stable and comfortable all-around measurement for objects of dimensions in the meter range, working at the physical limit. Therefore, certain parameters have to be optimized: The projectors should enable short exposure times to guarantee motion robustness and avoid motion blurring. The triangulation angle has to be chosen small enough to avoid shading but large enough to fulfill the requirements for the measurement uncertainty [3].

To achieve this, a new laser projection system consisting of low-aberration diffractive optics and 160mW lasers has been developed. The projectors are controlled by a low-noise CCD camera running at 30 frames per second. Optimally adjusted apertures of the projectors and of the camera minimize the influence of speckle noise on the measurement uncertainty. All components are built in a small housing with the dimensions of *160 x 160 x 120 mm³*. The resulting measurement volume is *800 x 800 x 550 mm³* $(\Delta x \cdot \Delta y \cdot \Delta z)$ with a statistical measurement uncertainty of less than *1.1mm* over the entire measurement volume for single 3D views on white paper. To acquire color texture information, an additional color camera is implemented in the housing [4].

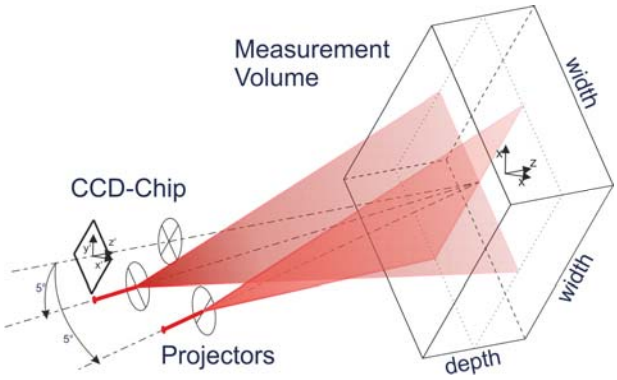

Fig. 3 *Schematic setup of the Flying Triangulation sensor with two laser projectors in two independent triangulation planes.*

4 Experimental results

Objects under test are the interior of a car and a ballet dancer. Figure 4 shows the shaded measurement result of the car´s seats. The sensor was freely moved inside the car and acquired 1,500 images in 50s yielding about 10.2 million 3D points.

Figure 5 depicts the triangulated 3D model of the ballet dancer with color texture and the corresponding raw data in the upper left corner. The point cloud contains about 2.5 million points from 800 images.

Fig. 4 *3D point cloud resulting from the measurement of a car interior.*

Fig. 5 *Triangulated 3D model of dancer with color texture and corresponding raw data.*

5 Conclusion and Outlook

We have presented a handheld 3D sensor based on Flying Triangulation for objects with dimensions in the meter range. The single-shot principle allows to acquire 3D data from each single camera shot. This enables a motion-robust measurement without any external and restricting tracking systems. In addition, colored texture taken by a separate color camera can be mapped onto the object for a more realistic impression.

The sensor has a wide field of applications such as cultural heritage, reverse engineering and quality control, virtual reality, and medicine. It only consists of simple and non-expensive components. It does neither require expensive digital light processing (DLP) nor high-speed cameras for data acquisition.

The next step is to make the measurement and registration more stable and to reduce outliers. Furthermore, we want to increase the speed of the acquisition and the data density obtained from each camera.

References

[1] S. Ettl, O. Arold, P. Vogt, O. Hybl, Z. Yang, W. Xie, G. Häusler. “Flying Triangulation”: A motion-robust optical 3D sensor principle, Proceedings of Fringe 2009, W. Osten and M. Kujawinskaja, eds., pp 768-771 (2009).

[2] O. Arold, Z. Yang, S. Ettl, G. Häusler. “A new registration method to robustly align a series of sparse 3D data”, DGaO-Proceedings, 110, P20 (2009).

[3] S. Ettl, O. Arold, P. Vogt, O. Hybl, Z. Yang, W. Xie, G. Häusler. “Flying Triangulation” - A new optical 3D sensor enabling the acquisition of surfaces by freehand motion, DGaO-Proceedings, 110, A13 (2009).

[4] F. Willomitzer, O. Arold, F. Huber, S. Ettl, G. Häusler. Options and limitations of „Flying Triangulation“, DGaO-Proceedings, 112, P29 (2011).