Options and limitations of “Flying Triangulation”

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“Flying Triangulation” is an optical 3D measurement principle, where a single-shot sensor acquires a series of sparse 3D views which then are automatically aligned to each other in real time. Due to its motion robustness and a real-time feedback, complex objects can be measured in a very intuitional way. In this paper we investigate the options and limitations of this principle.

1 Introduction

In [1, 2] we introduced the new optical measurement principle “Flying Triangulation”. A handheld single-shot sensor based on active triangulation is freely moved around the object under test while acquiring a series of sparse 3D views along projected lines. The single views are automatically aligned to each other via specifically developed registration algorithms. This enables a motion-robust capturing of dense 3D models without requiring any external tracking device. The measurement result is displayed in real time during the acquisition. A dense 3D model can be comfortably acquired within a few seconds.

We introduce a sensor family for different tasks. Furthermore, we show how texture information is mapped onto an acquired 3D model. Moreover, we pose a major information-theoretical question: What is the maximum achievable density of 3D data within one exposure of a single-shot sensor and how can this limit be achieved? Several options will be discussed.

2 Flying Triangulation sensor family

The Flying Triangulation sensor principle has been developed since 2007 at the Chair of Optics in Erlangen [1]. Our current sensor family consists of three Flying Triangulation sensors for different size ranges and measurement requirements (see Fig. 1).

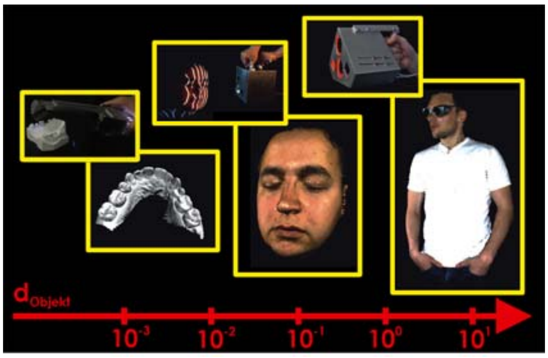

Fig. 1 *Flying Triangulation sensor family. The principle is scalable and permits measurements of objects in the mm-range up to meter range.*

The *dental scanner* [1] is designed for complex objects in the *mm*-range with high surface dynamics, particularly teeth. Dense 3D data of a whole dental cast can be acquired via free-hand motion within 10 seconds showing a local measurement uncertainty below 30µm. The measurement volume is 20 x 15 x 15 mm^3.

With the *face scanner* [3], objects in the *100mm*-range can be measured, e.g. feet, small sculptures, or human faces. During the measurement, the color texture of the object is acquired. The local uncertainty of measurement is under 150µm in a volume of measurement of 150 x 200 x 100 mm^3.

The *body scanner* [4] has been developed to measure objects in the *m*-range, like furniture, sculptures, or entire human bodies. A laser is used as light source whereas the other Flying Triangulation scanners use white-light LEDs due to speckle reduction. Color texture is also acquired and the local measurement uncertainty is below 1.1mm. The measurement volume is 800 x 800 x 550 mm^3.

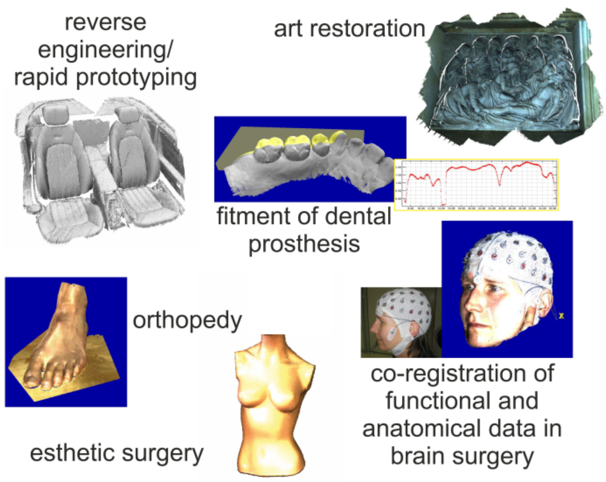

Fig. 2 *Possible examples of applications for the Flying Triangulation sensor family.*

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Figure 2 displays possible examples of applications and some measurement examples for the Flying Triangulation sensor family.

3 Texture acquisition

By a texture mapping, the sculptural impression of the measured 3D model can be substantially improved. Further, texture data contain important information about the object surface.

To acquire texture, a color camera is integrated in the sensor setup (see Fig. 3) and calibrated with the other sensor components. A color picture of the illuminated field of measurement is taken at defined time points. After the termination of the measurement, selected color pictures are projected onto the generated 3D model.

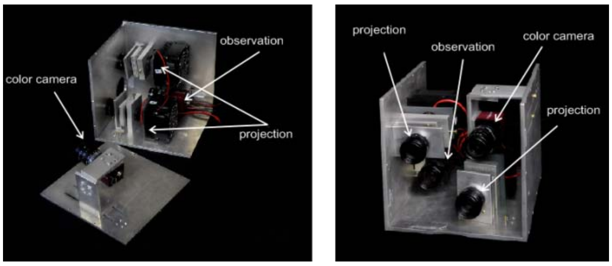

Fig. 3 *Sensor setup of the face scanner with integrated color camera.*

Figure 4 shows an acquired 3D model of a human face before and after texture mapping. The sculptural impression improves significantly with texture.

Fig. 4 *Acquired 3D model before and after the texture mapping sequence.*

4 Increasing the data density

Flying Triangulation is a single-shot sensor principle based on the well-known light sectioning. Single-shot principles only need one acquired camera image to generate 3D data. This property results in a motion-robustness of the single-shot principle, because a movement between adjacent camera images is allowed.

But most single-shot methods also display a certain drawback: A pixel-dense measurement is not possible. The available spatial bandwidth is reduced. This is the price one must pay for motion robustness. Currently, the *face scanner* projects about 10 lines (each with 1000 pixels), reaching an about 30-fold lower data efficiency than theoretically possible. To get amounts of data which are comparable to a full-scale measurement with a 1Mpixel camera, at least 100 shots are needed. This corresponds to a recording time longer than 4s at a measurement frequency of 30 Hz. During this period of time, the object and sensor can move if there is no elastic deformation of the object.

In order to shorten the recording time, the line density needs to be increased. This requires at first a solution of the problem of incorrect line indexing caused by indexing ambiguities. Due to this, we are working on line encoding [2] and unwrapping methods.

Summing up the options and limitations of the Flying Triangulation principle one can say that its great advantage is the comfortable hand-guided acquisition of 3D data and the scalability that enables measurements of a large class of objects. However, presently its limitation is certainly the extended acquisition time for obtaining a dense 3D model of an object.

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, Fringe Proc. 2009, S. 768–771 (2009).

[2] 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-Proc., A13 (2009).

[3] F. Willomitzer, Z. Yang, O. Arold, S. Ettl, G. Häusler. 3D face scanning with “Flying Triangulation“, DGaO-Proc., P18 (2010).

[4] F. Huber, O. Arold, F. Willomitzer, S. Ettl, G. Häusler. 3D body scanning with “Flying Triangulation“, DGaO-Proc., P30 (2011).

[5] Movies of measuring sequences: *http://www.youtube.com/user/Osmin3D*