Calibration of the optical 3D sensor "Flying Triangulation"

M. Schröter, F. Willomitzer, O. Arold, S. Ettl, G. Häusler

Institute of Optics, Information and Photonics
Friedrich-Alexander University Erlangen-Nürnberg, Germany

mailto:maximilian.schroeter@physik.uni-erlangen.de

The optical 3D measurement principle “Flying Triangulation” enables an acquisition of 3D surface data of complex objects. To get metric 3D data with best possible accuracy, a calibration of the sensor is needed. The current calibration of our sensor is difficult, time-consuming and requires high user interaction which does not mirror the spirit of our measurement principle. We present an easy, fast, and accurate novel method for calibration.

1 Introduction

In [1] we introduced the optical 3D measurement principle "Flying Triangulation". A hand-guided, easy, motion-robust measurement of complex objects is possible. No external tracking is necessary, due to sophisticated registration algorithms. The sensor principle is freely scalable, which allows to build sensors for a wide range of complex objects (see Fig. 1).

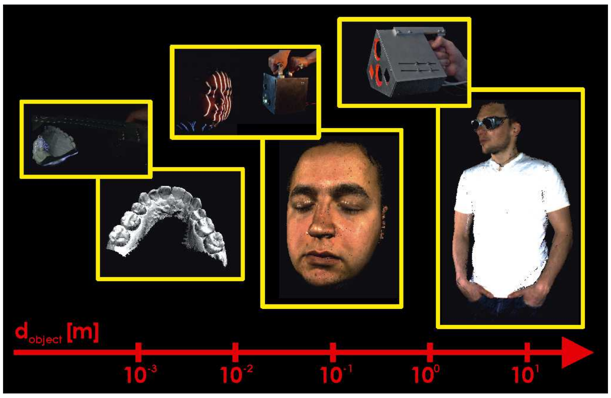

Fig. 1 *The principle Flying Triangulation enables a motion-robust 3D acquisition of a wide range of objects [2].*

To get metric 3D data with best possible accuracy, a calibration of the sensor is needed. Currently, we apply a model-free calibration method which has some weaknesses: It is time-consuming, requires a high amount of user interaction and some expensive tools. However, the FlyTri measurement process is easy, fast, and accurate, which should be inherited by our calibration as well.

2 Sensor properties

Flying Triangulation is based on an extension of the well-known light-sectioning principle.

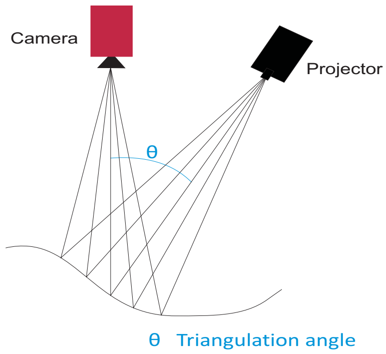

Fig. 2 *Setup sketch of the Flying Triangulation measurement principle.*

A multiple line pattern is projected onto an object and observed by the camera under the triangulation angle θ (see Fig. 2). This way we obtain sparse 3D data along those lines for each camera image. While moving around the object a dense 3D point cloud already arises after a few seconds. Since both the projector and the camera are optical systems affected by aberrations, both require a calibration.

3 Current calibration method

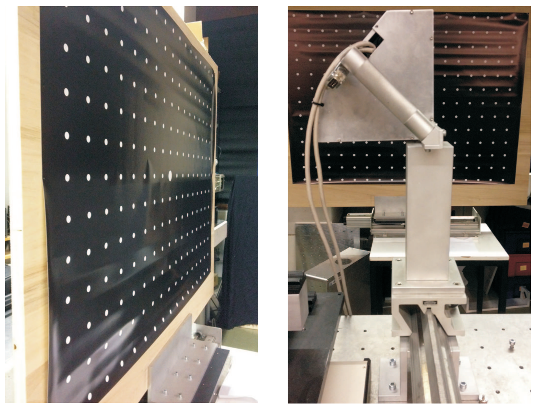

Fig. 3 *Left: Current calibration body. Right: Positioning of the sensor on a steel bar. A waviness of the marker plate, which reduces the accuracy, is clearly visible.*

Up to now we apply an enhanced standard light-sectioning calibration approach (see e.g. [3]). First, *Z*-calibration on a white plate is performed, followed by an *XY*-calibration on a marker plate. Each of these steps has to be repeated for several distances of the sensor to the two calibration plates. Afterwards, a calibration function fits the measured pixel positions with the plate information. Drawbacks are high user interaction, geometric descrepancies between the calibration bodies (see Fig. 3), and uncertainties in parameters required for calibration.

4 New calibration method

The new calibration feature is that we determine internal and thereupon external parameters of the camera and of the projector *simultaneously*. The basic idea of our new approach is the use of a special calibration tool.

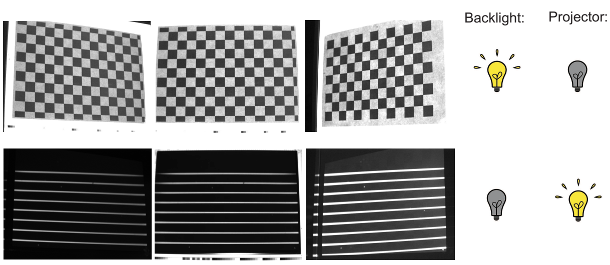

Fig. 4 *Observation of the calibration body from 3 different positions. Top: The chessboard pattern is visible with backlight. Bottom: Without backlight, the white screen is visible for the projector calibration.*

We employ one single calibration body which is either self-luminous for *XY*-calibration or can be used as a projection screen for *Z*-calibraion (see Fig. 4). It is realized by printing a chessboard pattern onto the backside of a paper and gluing it onto a luminescent plate, that can be controlled by software. Photogrammetric methods determine the position of the sensor relative to the calibration body, while the illumination of the chessboard pattern is automatically triggered. With that information we are able to build a pixel to real world coordinate transformation which enables us to fit a mathematical calibration function after a few repositioning steps (see Fig. 5). This way the only manual interaction left is to change the position of the sensor several times, while the calibration software gives positioning advices in real-time.

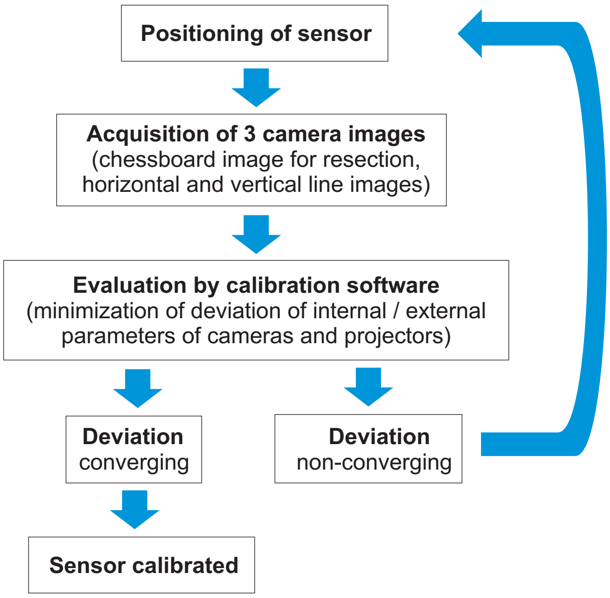

Fig. 5 *Workflow of the new calibration method.*

5 Results

Like the measurement principle Flying Triangulation, the new calibration approach can be performed in a fast and easy way, without loosing accuracy (see Tab. 1). Furthermore we eliminate some drawbacks of the current method coming from the use of two seperate calibration plates.

	current calibration	new calibration
easy	no	yes
fast	no	yes
accurate	60 µm on 100mm (face)	to be determ.

Tab. 1 *Comparison of the two calibration methods.*

References

[1] 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 free-hand motion”, DGaO-Proc., A13 (2009).

[2] S. Ettl, O. Arold, Z. Yang and G. Häusler, "Flying Triangulation - an optical 3D sensor for the motion-robust acquisition of complex objects", Appl. Opt., vol. 51, pp. 281-289 (2012).

[3] K. Veit and G. Häusler, B. Girod, G. Greiner, H. Niemann, H.-P. Seidel, "Metrical calibration of a phase measuring triangulation sensor", Proceedings of Vision Modeling and Visualization, pp. 33-38 (Aka GmbH, 2000).