Calibration of multi-line light-sectioning

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Besides physics and technology, it is the calibration which severely influences the quality of a sensor. We present a simple and accurate method for the calibration of multi-line light-sectioning which only uses one simple, non expensive calibration target. An inexperienced user can perform the calibration anywhere on site.

1 Introduction

In 2009 [1] we introduced the optical 3D sensor "Flying Triangulation" (FlyTri) which is based on multi-line light-sectioning. It enables a hand-guided, motion-robust measurement of complex objects without external tracking via sophisticated registration algorithms.

Besides physics and technology, it is the method of calibration which severely influences the quality of a 3D sensor based on light sectioning. Until now, a model-free calibration was applied which displays several weaknesses, including the requirement of an expensive and inflexible setup.

In the following, we present a comfortable and accurate method for the calibration of multi-line light-sectioning which only uses one simple calibration target (see Fig. 1).

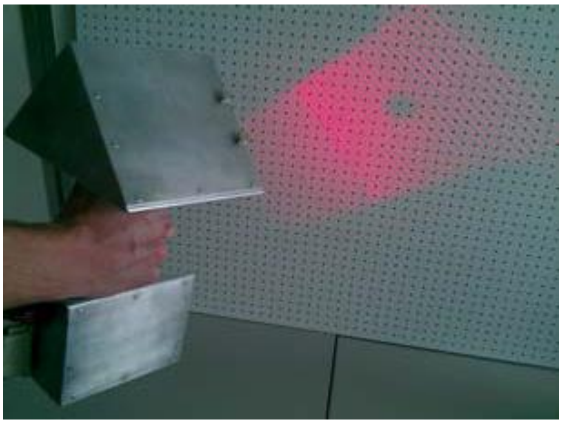

Fig. 1 *Snapshot of the novel calibration for a multi-line light-sectioning sensor (here a FlyTri sensor).*

2 Sensor Properties

Multi-line light-sectioning is an extension of the well-known light-sectioning principle: A multiple line pattern is projected onto the object and is observed, under a triangulation angle, by a camera (see Fig. 2).

Since both sensor components, camera and projector are afflicted by optical aberrations, a calibration is required.

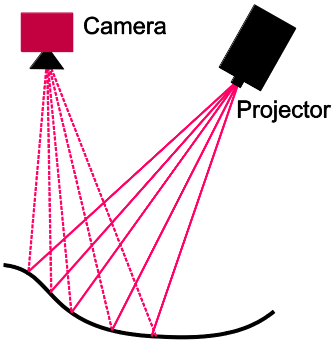

Fig. 2 *Sketch of a typical multi-line sectioning setup.*

3 State-of-the-art calibration

Up to now an enhanced standard light-sectioning calibration method is employed in FlyTri (see for example [2] for more details).

It is a model-free approach and is split into two steps: first, a longitudinal calibration on a white marker plate, and second a lateral calibration on a marker plate are performed.

For each calibration step, the plates are mounted onto a linear stage and are moved to several, precisely known positions in 3D space. At every position images are taken and its contained information is used to calculate the parameters of the used model-free calibrations functions.

Drawbacks of the currently applied calibration method are the high user interaction, discrepancies between the positioning of both calibration targets, possible deformation of the calibration target. Additionally shearing of the coordinate system can occur if the calibration target is not mounted orthogonal to the movement axis of the linear stage.

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The current calibration cannot be performed on site and requires a complex and expensive laboratory setup.

4 New calibration method

Instead of the state-of-the-art-method based on a model-free approach, we use common photogrammetric techniques [3] to overcome the earlier-mentioned drawbacks.

By using the well-known bundle adjustment for the internal camera calibration and also for the acquisition of the geometry of the calibration target; highly accurate and therefore expensive, calibration gauges are no longer required.

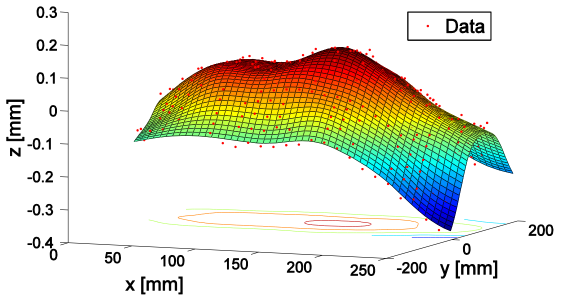

Fig. 3 *Approximated surface of a calibration target calculated with bundle adjustment (all units in mm).*

After the calibration of the camera, the projector needs to be calibrated. This novel method is an extension of the approach presented at the DGaO conference 2012 [4]. The projector uses information provided by the camera calibration.

The basic idea is as follows:

First, the calibration target is manually positioned at different positions $P_1,\ldots,P_n$ in the measurement volume along the optical axis (see Fig. 4). An exact positioning like in the former approach is not necessary anymore.

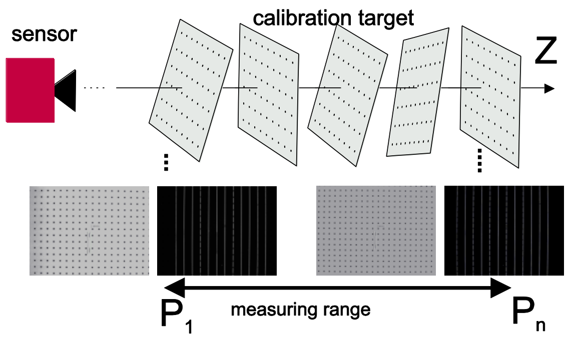

Fig. 4 *For each calibration plate position P, an image of the plate is acquired, without and with multi-line pattern projection. By resection, the positions of each observed point on the plate can be determined.*

At each position P_i an image without projected lines is captured. Due to resection the external parameters, in particular the orientation of the calibration target in relation to the observing camera, are calculated. Together with the approximated target surface (see Fig. 3), every image yields known (x,y,z) coordinates for each sub pixel precise image coordinate (u,v).

The spatial coordinates (x,y,z) are calculated with a mathematical projection of the image coordinates through the pinhole center onto the target. Before the image coordinates (u_{meas}, v_{meas}) are projected, they have to be decompensated for optical distortion by employing the undistortion functions.

After the acquisition of the target`s orientation at specific Position P_i, an image at the same Position P_i with projected lines is captured. Now, the image coordinates (u,v) along each line at the target yields known space coordinates (x,y,z).

With a set of several positions $P_1,\ldots,P_n$ similar to the current method, the entire volume is calibrated with a polynomial approximation.

5 Discussion

The introduced calibration method is fast and requires only little user interaction.

A precise and expensive linear stage, as well as a perfect plane calibration target is no longer required.

We expect that the major error source is directly related to the resection quality. So, the method should be as accurate as state-of-the-art photogrammetry.

A validation with precise calibration targets will be pursued next.

In the long term, a model based calibration of the projector is pursued, as we expect an easier evaluation of our data with ray optics than with the calibration functions we presented in [2].

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