Detection and correction of line indexing ambiguities in Flying Triangulation

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The problem of ambiguous signal correspondences emerges in a wide field of 3D-metrology principles. Mostly, correct correspondences can only be guaranteed by exploiting temporal or lateral context information, which reduces the information efficiency of the related sensor. We present a new correspondence approach for the indexing process in multi-line triangulation systems. It avoids the usage of temporal and lateral context information as well as the use of an additional modality, such as color. The method works in real time, during the measurement.

1 Introduction

As soon as a 3D measurement system aims for a high data density to be acquired in a short period of time, it is prone to ambiguities, resulting from non unique correlation of signals. In general, this problem is solved by exploiting temporal or lateral context information or by introducing an additional modality. Well-known examples are the phase-shift in fringe projection (temporal context) or the detection of corresponding points in stereo-photogrammetry (spatial context).

In the long term, we aim for the information-theoretically optimized real-time "3D movie camera" [1]. By this, we understand a 3D sensor which is able to acquire all kinds of object shapes, in real-time, with high data density, within a large measurement depth. Since the sensor should be able to measure fine details by one single camera exposure, neither temporal nor lateral context information can be exploited. Due to a possible coloration of the object, the usage of color based 3D-sensor principles is problematic. Principally, our recently developed "Flying Triangulation (FlyTri)" principle [2] is suitable for such a 3D movie camera because it fulfills most of the criteria mentioned above. However, there are a few weak spots: Indexing errors occur, if high data density and large measurement depth are required at the same time. These errors create outliers in the 3D model (see Fig. 1) and may disable the whole data acquisition process.

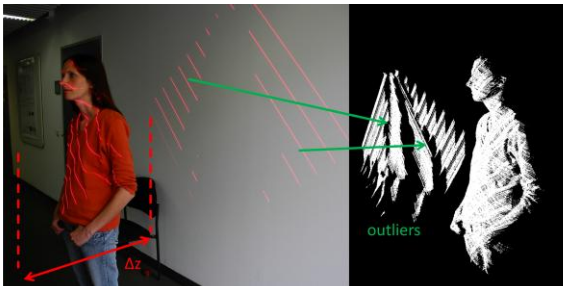

Fig. 1 *Outliers in the 3D model caused by index errors outside the measurement depth.*

2 Ambiguities in the current indexing method

The data acquisition of FlyTri is based on multi-line light sectioning. For a certain triangulation angle, it is not possible to increase the number of projected lines without reducing the depth Δz, in which a unique line indexing is possible. In other words: High data density requires a low depth of field Δz. Object segments outside Δz cause outliers in the generated 3D model. Figure 2 illustrates the origin of such outliers: Surface points, measured inside Δz by intersection with the projected lines L1, L2, L3 are automatically imaged within a unique corresponding area A1', A2', A3' on the camera chip, where the correct indices are found. The projected line L4, however, intersects the object surface outside Δz. The related signal is imaged

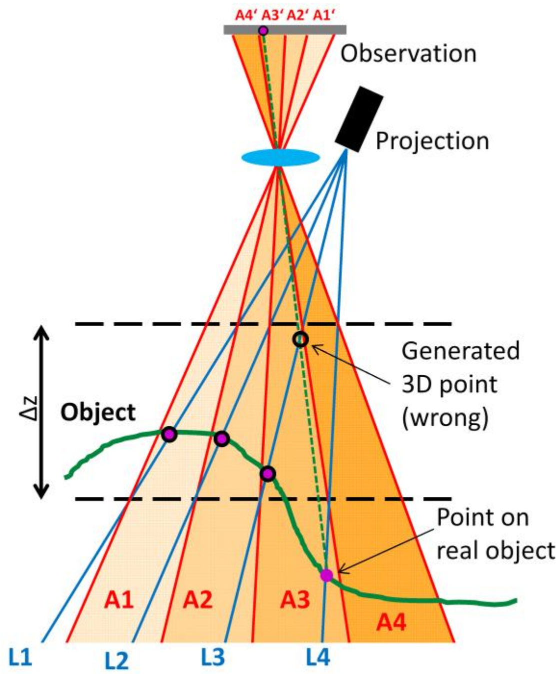

Fig. 2 *Illustration of false line indexing: The signal of line L4 is acquired outside the measurement depth Δz. At the camera chip, it is assigned to area A3' and gets attached the false index 3. The generated 3D point is false.*

onto area A3' on the camera chip and gets the wrong index (3 instead of 4) which yields a wrong 3D data point.

3 Solution approach: the "Stereo-Method"

Indexing errors can be interpreted as lack of information. Other approaches use a sequence of pictures or project a coded or colored pattern to overcome the information deficit. We avoid the disadvantages of these approaches by the simultaneous acquisition of images with several cameras.

This novel "Stereo-Method" is able to detect and even correct false 3D data: A second camera acquires exposures simultaneous to the single 3D views. Each generated 3D point (data could be falsely indexed!) is back-projected onto the chip of the second camera. The obtained position is compared with the real line signal on the chip. If the positions of signal and back-projection match, the 3D point is correct. If not, there is an index error. Further processing is as follows: A first, simple and efficient approach is just to delete falsely indexed points, in order to prevent registration failure. As a consequence, only surface segments within Δz remain (see Fig. 4c).

However, for high data density, the measuring volume will degenerate to a thin layer. We can solve this by a simple trial-and-error algorithm for the correction of falsely indexed points (see Fig. 4b) and expand the effective measurement depth significantly.

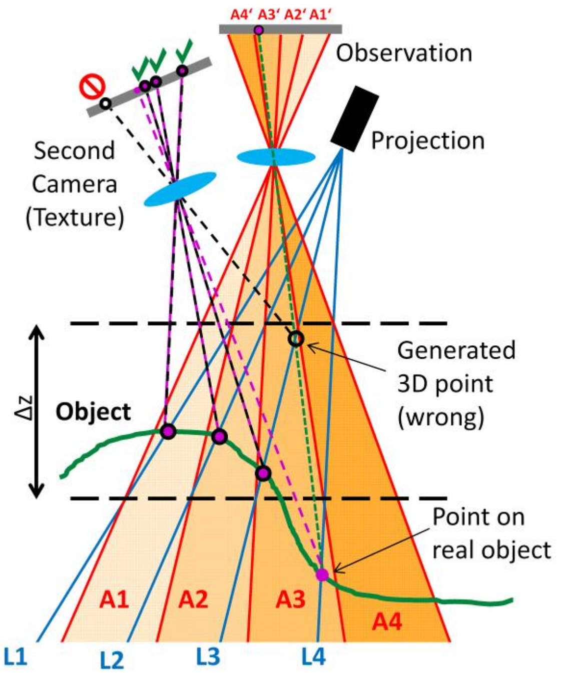

Fig. 3 *"Stereo-check": Evaluated 3D points (black rings) are back-projected onto the chip of the second camera. Here, the positions are compared to the real line signal from the object surface (pink dots).*

4 Results and discussion

A first experiment was performed with a human body in front of a wall that is located outside the measurement depth (see Figs. 1 and 4a). From 1 Mio acquired 3D points (4a), 250.000 were identified as false. Figure 4c displays the result after simple deletion of false points, Fig. 4d shows the result after index correction. In the final data sets, no remaining outliers are visible.

However, there is a small possibility that a false point passes the stereo-check. Methods to prevent this will be discussed in a further paper.

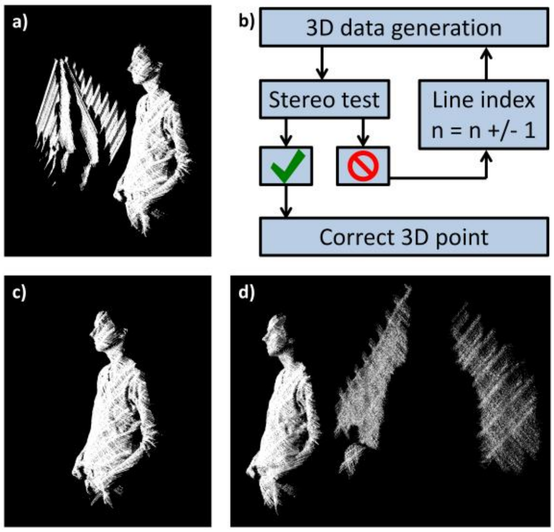

Fig. 4 *Sparse measurement of a human body in front of a wall (see Fig. 1). a) Raw data. c) Identified outliers deleted (no more outliers visible). d) Outliers corrected. 3D data of the wall are correctly indexed. b) Scheme of the applied correction-algorithm.*

The considerations of the last sections provide an interesting consequence: If, due a large number of projected lines, the measuring volume approaches a thin layer, the task of generating a correct 3D point is no longer a task of 3D evaluation. It becomes solely a task of indexing! A measurement principle that follows exactly this approach is the "Tomographic Triangulation" [3]. It can be interpreted as an extension of the "Stereo-Method" with a large number of cameras.

References

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[3] G. Häusler, F. Willomitzer, P. Dienstbier, C. Faber. Tomographic Triangulation, DGaO-Proc. 2013, A16 (2013).