Robust pattern indexing methods for “Flying Triangulation”

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The measurement principle “Flying Triangulation” enables a motion-robust 3D-shape acquisition of even complex objects with a freely hand-guided sensor. Although of high precision, the resulting 3D data may contain outliers caused by incorrect pattern indexing. Intersecting with correct data they prevent an automated a posteriori removal. We present several approaches and show recent results.

1 Introduction

The measurement principle “Flying Triangulation” [1] enables a comfortable and motion-robust acquisition of 3D data. The handheld sensor, based on light sectioning, is freely moved around the object, while generating a series of sparse 3D views. These views are aligned to each other “on the fly” and the current measurement result is displayed in real time. A dense 3D model is acquired within a few seconds.

A crucial part of this process is a correct identification of the projected lines. If an object part is observed within the measurement volume of the sensor, so-called "regions of uniqueness" guarantee that no errors occur. However, object parts outside the measurement volume lead to incorrect indexing. Since the sensor is freely hand guided, such outliers are unavoidable, see Fig. 1. An automatic a- posteriori removal is commonly impossible, since the outliers might intersect with correct data.

We will present methods to overcome this problem, by combining hardware- and software-based approaches. Measurement examples will be given to demonstrate the improvement.

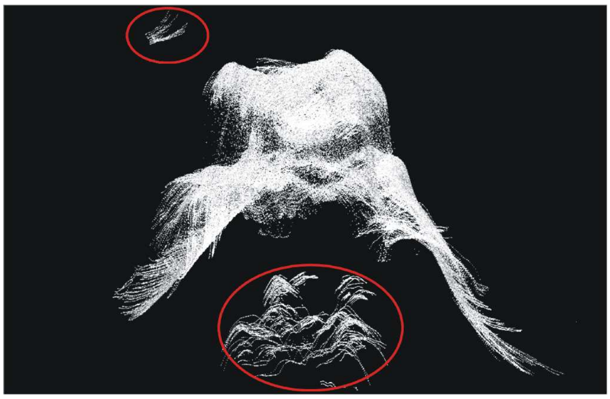

Fig. 1 *Flying Triangulation sensors are based on light sectioning. If the projected pattern is wrongly indexed, outliers occur (circles).*

2 Measurement principle

The key idea of the measurement principle “Flying Triangulation”is depicted in Fig. 2: A single-shot active triangulation sensor acquires 3D profiles along projected multi-line patterns of each camera image with 30 fps. These 3D views are aligned to each other and displayed in real time. The user who freely guides the hand-held sensor can use the visual feedback to correct the sensor motion in order to efficiently acquire dense 3D data of the object under test. For further details see [1].

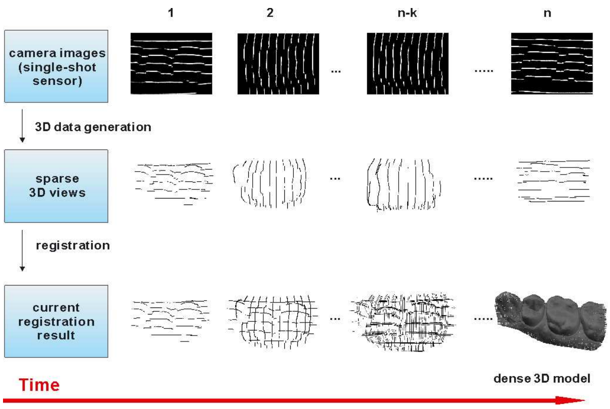

Fig. 2 *Camera images are acquired with 30 fps. Each image delivers 3D data along lines. The data are aligned and visualized in real time. After a few seconds, a dense 3D model of the object is obtained [2].*

Although the sensor has been optimized to reach the physical limits - i.e. it has a minimized measurement uncertainty and an optimized depth of measurement volume, the resulting 3D data shows outliers when acquiring data outside the underlying volume of measurement, as shown in Fig. 1. Since there is only a virtual boundary of the volume of measurement, it is almost impossible to always guide the sensor inside the volume. We will now investigate this problem.

3 Indexing problem

In case of wrong line indexing in a camera image, outliers occur (see Fig. 1). Since they might intersect with correct data, they might be inseparable from their surrounding by automated post-processing methods, requiring new approaches.

When acquiring object information inside the volume of measurement, each observed line stays within a certain range in the camera image (see Fig. 3), making the indexing unique. Outside the volume of measurement, however, the indexing remains ambiguous and requires additional solutions.

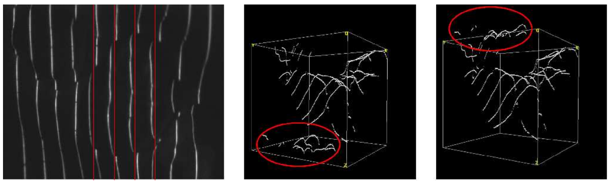

Fig. 3 *Left: Observed lines may leave their "region of uniqueness" (straight lines) when the measured object part has been captured outside the volume of measurement. Middle: This results in outliers (circle) in the generated 3D data. Right: Corresponding correct data (circle) in the absence of outliers.*

4 Solution approaches

We pursue several hard- and software-based strategies to yield correct line indexing outside the volume of measurement. While the hardware-based strategies improve the sensor positioning, the software-based strategies detect and correct the wrong indexed data.

Hardware-based strategies for proper sensor positioning:

- additional light signals for guidance
- additional spacer

Software-based strategies for line indexing correction:

- line width determination
- plausibility assumptions
- temporal and spatial context information

Depending on the sensor choice, an appropriate combination of the options described above can be selected.

We will conclude with some results and typical measurement situations for the current members of the "Flying Triangulation"sensor family, consisting of an intraoral teeth sensor [3], a face sensor [4], and a body sensor [5].

5 Results

A realized software-based method employs the line width as parameter. Due to the limited depth of field of the illumination, the line width varies over the entire volume of measurement. This effect turned out to be advantageous for improving the indexing robustness. For non-volume-scattering and homogeneously reflecting surfaces, the method yields good results, see Fig. 4 a) and b). For other surfaces, see Fig. 4 c) and d), these methods cannot be applied.

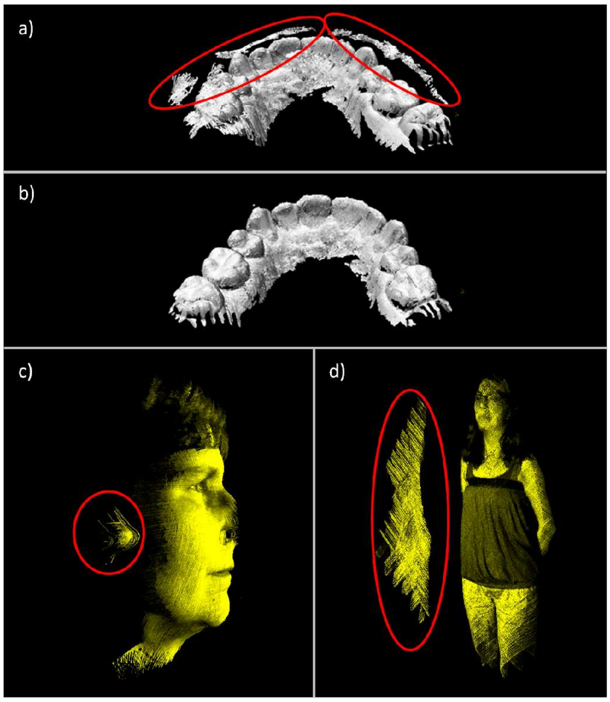

Fig. 4 *a) and b): Outliers in dental data detected and removed with "line width" strategy. c) and d): Typical outliers in face and body data. Here, the line width method cannot be applied.*

References

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