Design of a Quality Assurance Pipeline for Optical 3D Scanners, Including Novel Methods and Extended Standards

Michel Utz

Supervisor: Prof. Marcus Hudritsch
Institution: Bern University of Applied Sciences, Institute for Human Centered Engineering
Examiners: Prof. Marcus Hudritsch, Prof. Dr. Volker M. Koch

Introduction

Scoliosis, a spinal disorder affecting about three percent of school-age children worldwide, requires regular screenings to monitor the progression of the patient's spinal curvature. Traditionally, this is done by Cobb angle measurement based on radiography. Concerns about ionizing radiation and the related increased cancer risk led to the search for alternative methods. Since the surface topography of a human back correlates to parameters gained from radiographs [1], purely optical solutions can be considered. Recognizing that, a joint project between Bern University of Applied Sciences (BFH) and the Swiss Federal Institute of Technology in Zurich (ETHZ) aims to add to this research, proposing a cost-effective prototype and conducting clinical trials. The validation of close-range optical 3D scanners is of central importance to this endeavor.

Materials and Methods

To validate the cost-effective optical 3D scanner developed in the joint project, it was evaluated against a high-quality reference system using a newly proposed quality assurance pipeline. This pipeline is based on quality parameters with responding physical artifacts. These artifacts are scanned in a controlled measurement environment and evaluated using existing and novel algorithms. Aside from newly developed methods, some quality parameters, artifacts, and algorithms were adopted from the state-of-the-art guideline (VDI/VDE 2634 Part 2) and from previous work in the project. Several improvements were developed and proposed, including the determination of the lateral and axial structural resolution and statistical approaches to existing solutions.
The quality assurance pipeline was extended with skin-like artifacts made from epoxy resin, mimicking the subsurface scattering of human skin.

Results

The results were twofold. Firstly, a novel quality assurance pipeline was proposed for further use, improving on existing standards and adding additional value in the form of skin-like artifacts and novel algorithms. The main improvements are the interpretation of quality parameters using statistically based approaches and the proposed methods for determining the structural resolution. Secondly, a comparison between the reference system and the prototype was conducted. While the reference system was found to be superior, the prototype was still deemed usable for measuring the surface topography of a human back.

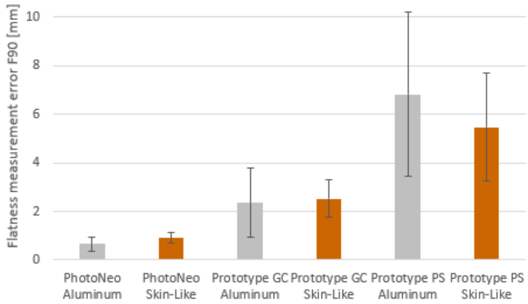

Fig. 1 The results of a single quality parameter (Flatness measurement error F_{90}) for all recordings, grouped by system under test and artifact material. Brown bars are recordings of skin-like artifacts, grey bars represent aluminum artifact measurements.

Discussion

The introduction of the quality assurance pipeline marks a substantial improvement of the validation of close-range optical 3D scanners. Particularly noteworthy is the introduction of skin-like artifacts, paving the way for many possible applications in the clinical or research setting. The proposed improvements to existing methods and the novel methods for determining structural resolution represent significant strides forward. This work has the potential to influence the standardization of quality assurance for optical 3D scanners, especially in the medical field.

References

[1] I. J. R. L. Navarro, B. N. da Rosa, and C. T. Candotti, "Anatomical reference marks, evaluation parameters and reproducibility of surface topography for evaluating the adolescent idiopathic scoliosis: a systematic review with meta-analysis," Gait & Posture, vol. 69, pp. 112–120, 2019

Acknowledgements

I am very thankful to Prof. Marcus Hudritsch for mentoring me. My gratitude also lies with the people in the BME and CPVR Lab for their support.