# Investigating the Minimum Key Performance Criteria of a Multi-Pattern Projector for Reflection-Based Medical 3D Scanners to Propose an Optimized Low-Cost Solution

Marco Wyss

Supervisors: Prof. Dr. Theo Kluter, Prof. PD Dr. Volker M. Koch
Institution: Bern University of Applied Sciences, Institute for Human Centered Engineering
Examiners: Prof. PD Dr. Volker M. Koch, Prof. Dr. Theo Kluter

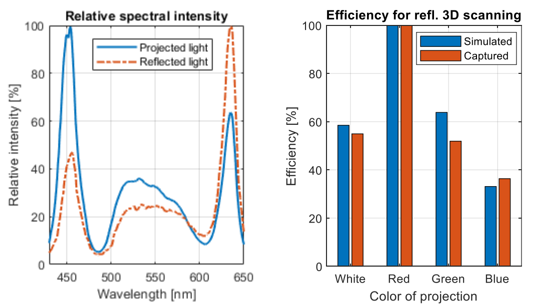
## Introduction

Numerous studies in the medical field have shown that optical 3D scanners that are free of ionizing radiation have great potential to improve the scoliosis management and reduce X-rays during follow-up examinations. However, currently there are only a few high-priced 3D scanner systems for the evaluation of spinal deformities. All of them are based on active 3D scanner modalities and therefore require a projector to generate coded patterns. The aim of this study was to find the minimum key performance criteria for a multi-pattern projector for reflective 3D scanning of the human back and to propose an application-optimized low-cost solution.

## Materials and Methods

Experiments were performed on the minimum required projector luminosity, resolution, frame rate, focus and image size range, as well as the optimal light spectrum. The operating conditions were considered in terms of the relative projector position, the artificial ambient light and the spectral reflectance factor of the human skin. For this purpose, special silicone skin phantoms were fabricated and verified against human skin. Simplification tests for the two main projector components, the DMD controller board and the RGB light engine, as well as a market research for a cheaper pattern projector EVM were conducted.

Outcome measures included the luminosity as a photometric, and radiotmetric quantity, the projected and resulting resolution for SL and AS, the captured and spectral intensity and electrical power of the RGB light engine.




a) b)

*Fig. 1 The left plot **a)** with the relative spectral intensity of the projected and reflected white light shows a high reflection in the red ($\lambda_{peak}$ = 635 nm), and a low reflection in the blue ($\lambda_{peak}$ = 455 nm) wavelength range. The right plot **b)** confirms this with the highest efficiency for the red LED derived from the captured image intensity and the measured electrical power consumption of each LED.*

## Results

The white RGB projector light is on average 40.3 % less efficient for reflection-based 3D scanning of human skin than its red component (normalized to 100 %). The limiting factor for high frame rates for this application could be traced back to the camera exposure time. This in turn depends significantly on the projector luminosity, its spectral footprint, and the spectral reflectance of the human skin. Multiple proposals for an optimized low-cost pattern projector were presented.

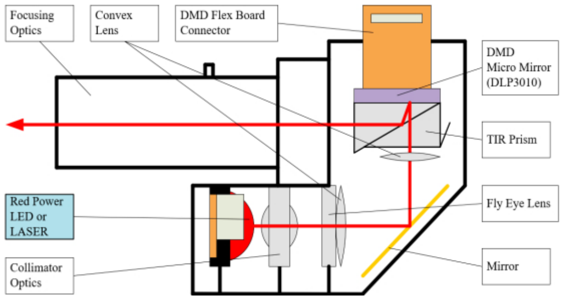



*Fig. 2 The illustration shows the proposed single-red-LED light engine concept based on the pattern projector EVM (DPM-E3010LC). The simplification saves two LED boards, both dichroic mirrors, two collimators and one convex lens.*

## Discussion

Numerous studies show that across all skin tones (Fitzpatrick scale 1-6), the best spectral reflectance in the visible band is in the red wavelength range [1]. This explains the high efficiency of the red LED for reflective-based 3D scanning of human skin. This is mitigated by the camera quantum efficiency, which is best in the green wavelength range, and by the LED efficiency of the light engine in converting electrical into radiant power, where the red LED performed worst. Whether the proposed single-LED solutions can achieve the required radiant power by optimizing the light path has to be proven by further tests.

## References

[1] J. F. Dlugos and J. L. Taylor, Materials characterization: UV/Vis/NIR spectroscopy, 2019

## Acknowledgements

The important contributions of Mirko Kaiser with the development of the Minimal Thorcam SDK, the HuCE optoLab with the regular loan of the VIS spectro-meter, and the BFH Ethics Committee for the ethics clarification, are gratefully acknowledged.