Phantom and Porcine Eye Optic Nerve Head 3D Reconstruction

from Stereo Images Acquired Through a Slit Lamp Fitted with Low-Cost Add-Ons

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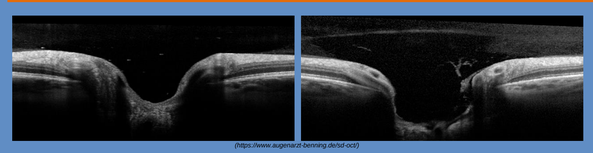
INTRODUCTION

Glaucoma is the second leading cause of blindness globally[1]

Early detection and treatment are essential to mitigate vision loss

(http://anandeyeinstitute.org/glaucoma/)

Morphological change of the optic nerve head (ONH) is a key indicator for early detection since it can precede vision loss[2]



(https://www.augenarzt-benning.de/sd-oct/)

The mainstay in clinics for ONH assessment (through the slit lamp or fundus images) is subjective and suffers from less than perfect inter- and intra- observer variability[3] leading to some cases being missed

Diagnostic accuracy (particularly in primary care) could be boosted with 3D imagers[3] such as

(http://techspirit.in/en-face-oct-newest-technology-glaucoma-management/)

OCT

&

(https://www.know-the-eye.com/instruments/heidelberg-retina-tomograph-hrt/)

HRT

However they are prohibitively expensive

Exploiting computer stereo vision on slit lamp images could be a cost effective solution

(https://www.wotol.com/product/zeiss-30-sl-m/1657930)

Slit lamp (available in practically every clinic)

Fit with low-cost add-ons

(DOI: 10.1109/IVS.2007.4290115)

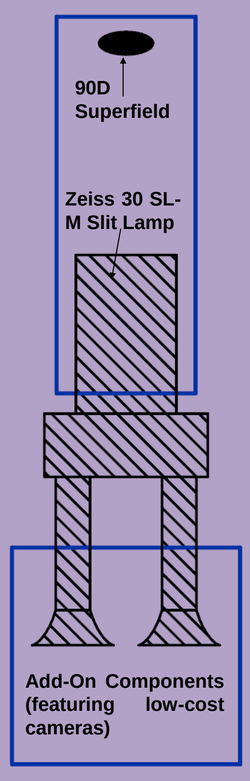
Apply Computer Stereo Vision Techniques

3D Stereo Reconstruction

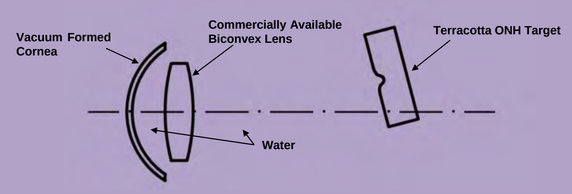
This work explored this idea

METHOD

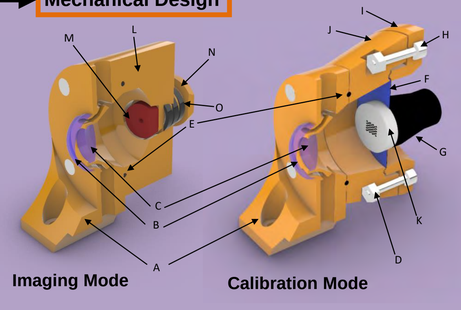
DEVELOPED PROTOTYPE → **DEVELOPED PHANTOM EYE[4]** → **DEVELOPED STEREO VISION PIPELINE** → **PERFORMED TESTING IN PHANTOM AND PORCINE EYE**



Optical Design (based on the Navarro Eye Model)



Mechanical Design

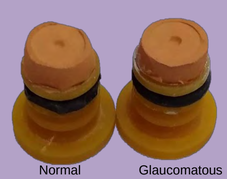


Imaging Mode **Calibration Mode**

***A** – Anterior Section*
***B** – HIPS Cornea*
***C** – Bi-Convex Lens*
***D** – M2 Nut*
***E** – Nitrile Rubber O-Ring*
***F** – Nitrile Rubber Sheet*
***G** – LED Mount*
***H** – M2 Bolt*
***I** – Posterior Section for Calibration Part 1*
***J** – Posterior Section for Calibration Part 2*
***K** – Calibration Pattern*
***L** – Posterior Section for Imaging*
***M** – Terracotta ONH Model*
***N** – ONH Model Mount*
***O** – Nitrile Rubber O-Ring*

Fabrication

Imaging Mode



ONH Models

Device Calibration

X 22

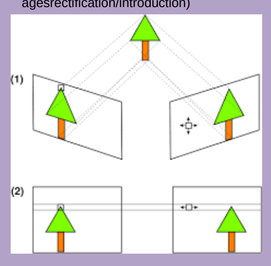
Calibration Toolbox for MATLAB®

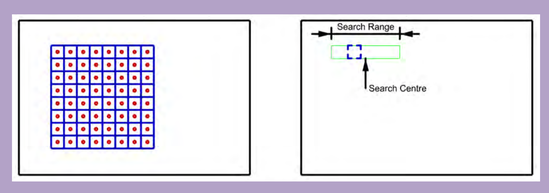
Intrinsic & Extrinsic Camera Parameters

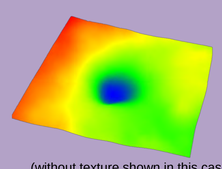
Calibration Images

Rectification → **Stereo Matching** → **Triangulation** → **Mesh Fitting** → **Reconstruction**

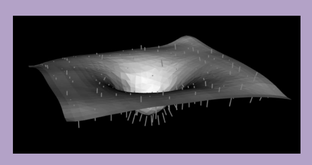
(https://sites.google.com/site/stereoimagesrectification/introduction)

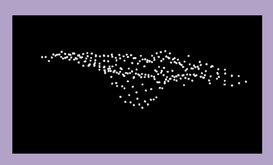






(without texture shown in this case)

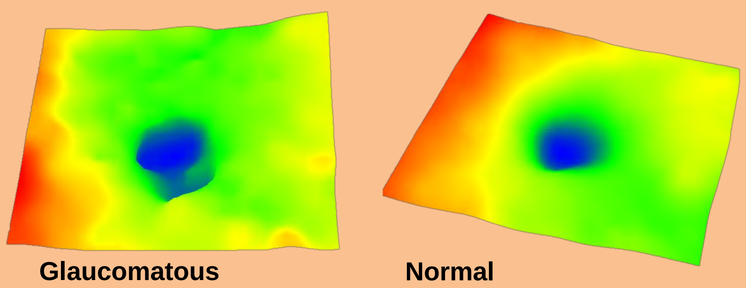




RESULTS

PHANTOM EYE RECONSTRUCTIONS OBTAINED → ***PORCINE EYE RECONSTRUCTION***

Textured Point Clouds

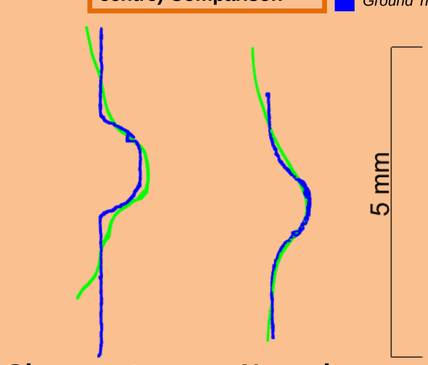


Glaucomatous
(RMS Error = 0.068 mm)*

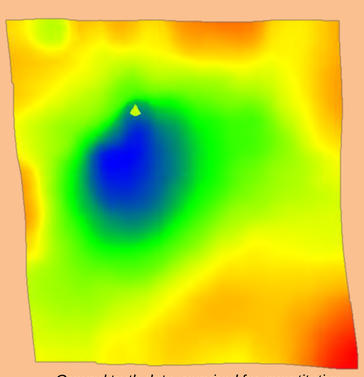
Normal
(RMS Error = 0.037 mm)*

Cross Section (through centre) Comparison

Reconstruction
Ground Truth



Glaucomatous **Normal**



Ground truth data, required for quantitative validation, was not available at this stage.

*As compared to ground truth data acquired using the Alicona Infinite Focus IFM G4

CONCLUSION

Goal

The goal of this work was to initially assess the feasibility of generating 3D reconstructions of the optic nerve head by applying computer stereo vision techniques to stereo images obtained using a slit lamp (which is available in practically every primary care clinic) fitted with low-cost add-on components. The technique was tested on a life-sized fluid-filled eye phantom and a porcine eye in this work.

Outcome

3D reconstructions of normal and glaucomatous ONH models were obtained (which closely matched ground truths), together with that of a porcine ONH.

Significance

The positive results warrant further work to assess the potential of the slit lamp to be used as a quantitate 3D retinal imaging device.

Acknowledgements

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4. Coghill, I., Black, R. A., Livingstone, I. A. T. & Giardini, M. E. Low-cost eye phantom for stereophotogrammetry-based optic nerve head topographical 3D imaging. in 42nd Annual International Conferences of the IEEE Engineering in Medicine and Biology Society (IEEE, 2020).