A Low-cost Device to detect Angle Closure Glaucoma

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Introduction

- A device using low-cost materials was developed to automate the **Standard Flashlight Test (SFT)**.
- PACG is a potentially preventable type of glaucoma if detected early enough with frequent screening. However, current screening techniques require professional supervision under a clinical setting [1].
- The SFT provides a cheap and convenient solution to accurately to identify risks of PACG in patients [3].
- By simply analysing the **shadow cast** over the iris by a beam of parallel light, the depth of the anterior chamber can be inferred, indicating if there is risk of PACG [Fig. 1, 4].

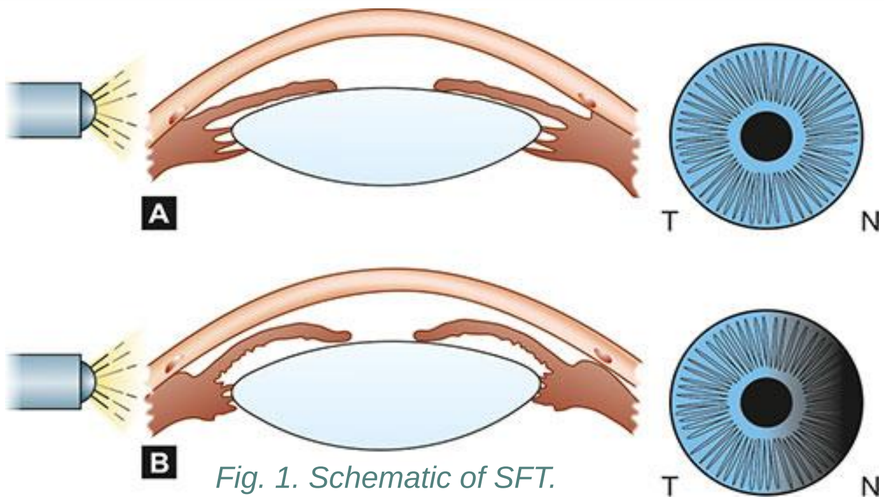

Fig. 1. Schematic of SFT.

Hardware Methodology

To automate the SFT process, these key items were used:

- A lightweight Raspberry Pi Zero microprocessor.
- Monocular-design casing 3D-printed with polylactic acid (PLA). Users simply rotate device to test each eye [Fig. 2].
- Tactile and audio prompts are given to the user during the SFT process when their vision is restricted.
- A silicon eyecup for users to position the tested eye.

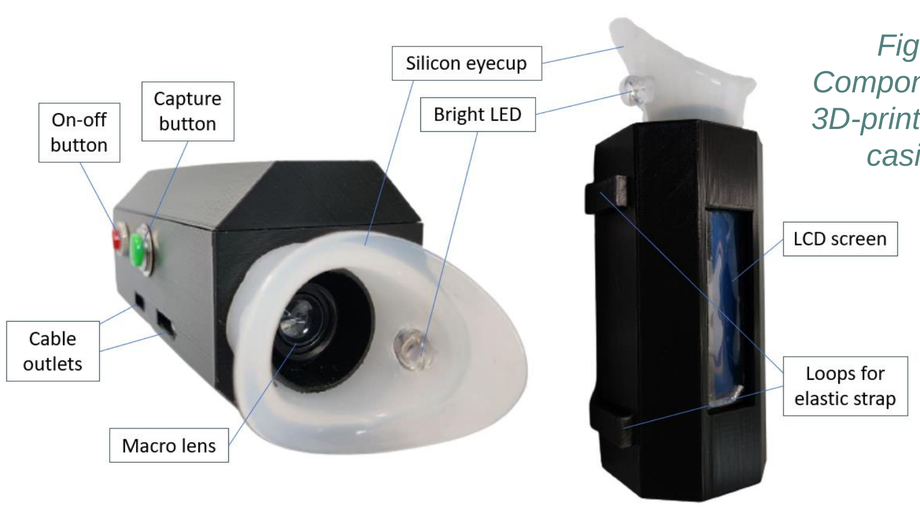

Fig 2. Components in 3D-printed PLA casing.

Software Methodology

A PyTorch deep learning algorithm was developed to identify 3 grades of PACG risk (Grades 1, 2, 3) [Fig. 3]. This stage focused on **iris segmentation**.

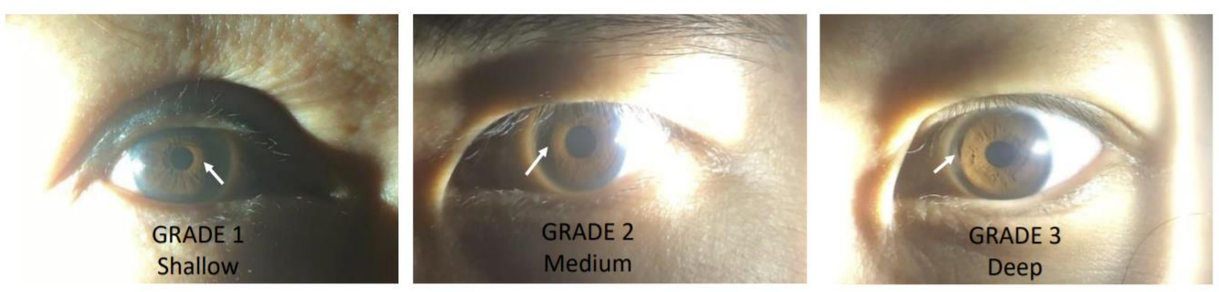

Fig 3. Categorisation of grades of PACG risk.

Building the Dataset

- 58 **Grade 3** and 4 **Grade 1** eyes.
- Segments: iris, shadow, pupil, others.
- All images were captured on device.

41 (train) | **17** (test)

4 (out-of-sample test)

Model Training and Testing

Training

- 100 epochs in total; data pulled, and best model saved every 10 epochs.

Testing

- Each model was tested on Grade 3 testing set and out-of-sample Grade 1 testing set

Results and Discussion

- Device was operated by the user with the help of an assistant of any skill level to guide their eyes [Fig. 4].
- Resulting images were of sufficient clarity, even capturing crypts with high definition, and the shadow cast on the iris by the light source can be clearly seen.

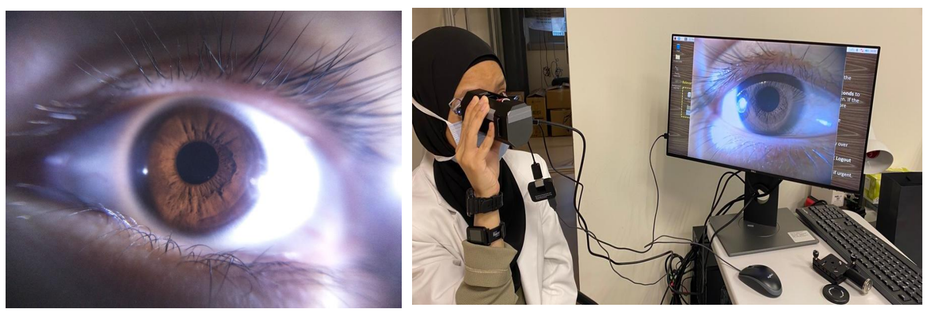

Fig 4. Example of resulting image (left) from the SFT process (right).

- Optimal number of training epochs: 70 epochs [Fig. 5, 6].

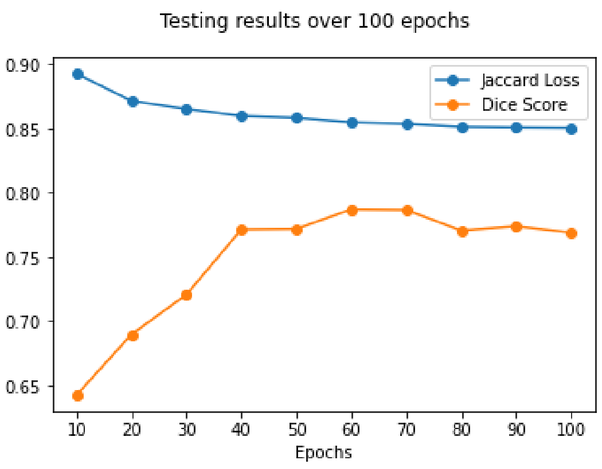

Fig 5. Testing results at each 10-epoch interval.

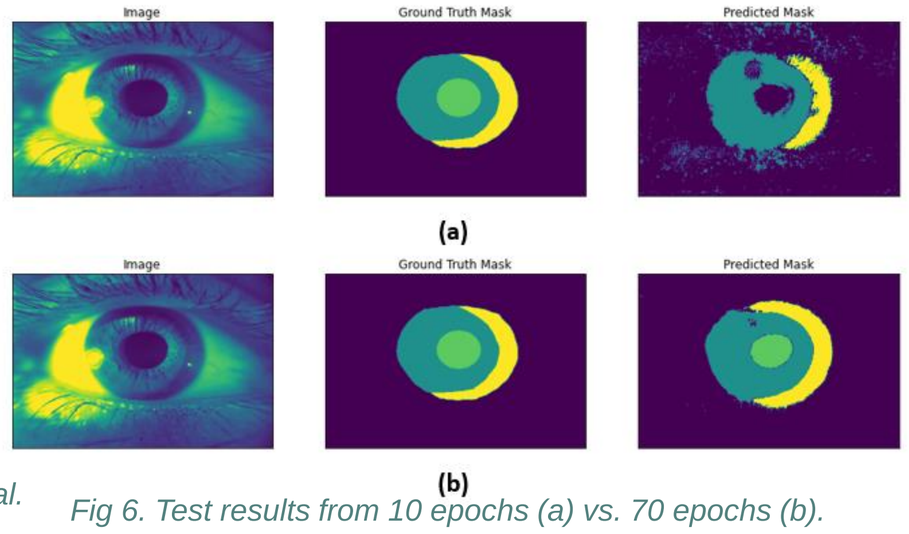

Fig 6. Test results from 10 epochs (a) vs. 70 epochs (b).

- While the segmentation of out-of-sample Grade 3 images was not as clean as those for Grade 1, the segments were still accurately identified [Fig. 7].

Fig 7. Test results on out-of-sample data from 70 training epochs.

- A **shadow-to-iris ratio** was calculated by taking the area of the shadow (yellow) against that of the whole iris (teal, green and yellow). The larger the shadow area, the higher the ratio, thus indicating a higher risk of PACG (i.e., Grade 1).

Average ratio for Grade 1 = 0.2 **Average ratio for Grade 3 = 0.199**

- The minute difference can be attributed to the much smaller dataset for Grade 1, making the ratio unrepresentative of all Grade 1 eyes.

References

[1] Sharma et al., 2008 – Diagnostic tools for glaucoma detection and management
[2] Shikino et. al, 2016 – Oblique flashlight test: Lighting up acute angle-closure Glaucoma
[3] Nongpiur et al., 2010 – Novel association of smaller anterior chamber width with angle closure in Singaporeans
[4] Sidhartha et al., 2014 – Relationship between iris surface features and angle width in Asian eyes

Conclusion

- The device was successfully used without professional supervision to capture high quality images of the iris for Grade 1 and 3 users.
- The segmentation model was successfully trained to perform segmentation and obtain a ratio for multiclass classification into respective risk grades.
- Further training with other grades will allow development of a robust classification algorithm. Other factors indicating PACG risk such as crypt presence and eye colour can also be considered [4].
- Integration of the model onto the Raspberry Pi Zero via ONNX is recommended.