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Automated analysis of meibography images: Comparison between intensity, region growing and deep learning-based methods

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IT-DED³

SCIENTIFIC OBJECTIVE

Meibomian gland dysfunction (MGD) is present in a majority of patients suffering from dry eye disease. Infrared (IR) Meibography is a well-established method to depict Meibomian glands (MG). However, the manual analysis of the acquired images requires user interaction and is subjective.

Therefore, our objective is to implement and compare three automated image segmentation methods based on intensity, region growing and deep learning in order to find the best approach that would be user friendly, reliable, accurate, objective and reproducible.

METHODS

- For intensity-based approach python-based software was written that involves automatic ROI selection and glands detection
- For region growing-based method MeVisLab tool was used that involves manual ROI selection and semi-automatic glands detection
- In deep learning-based approach, python based TensorFlow library, Mask R-CNN and U-Net architectures were used for automatic glands detection
- In total 157 anonymized IR meibography images of both upper (87) and lower (70) eyelids were acquired using the OCULUS Keratograph 5M from Uniklinik Köln

RESULTS

1. Intensity Based Segmentation

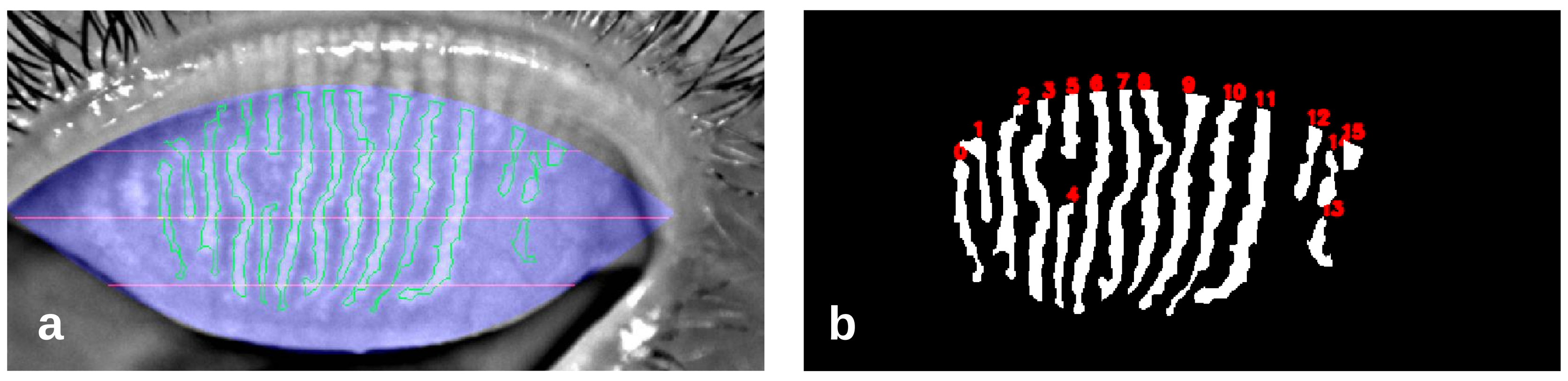

Figure 1a: ROI (violate) and MG (green) detection in an IR meibography image based on intensity. b. Detected number of glands

2. Region growing Based Segmentation

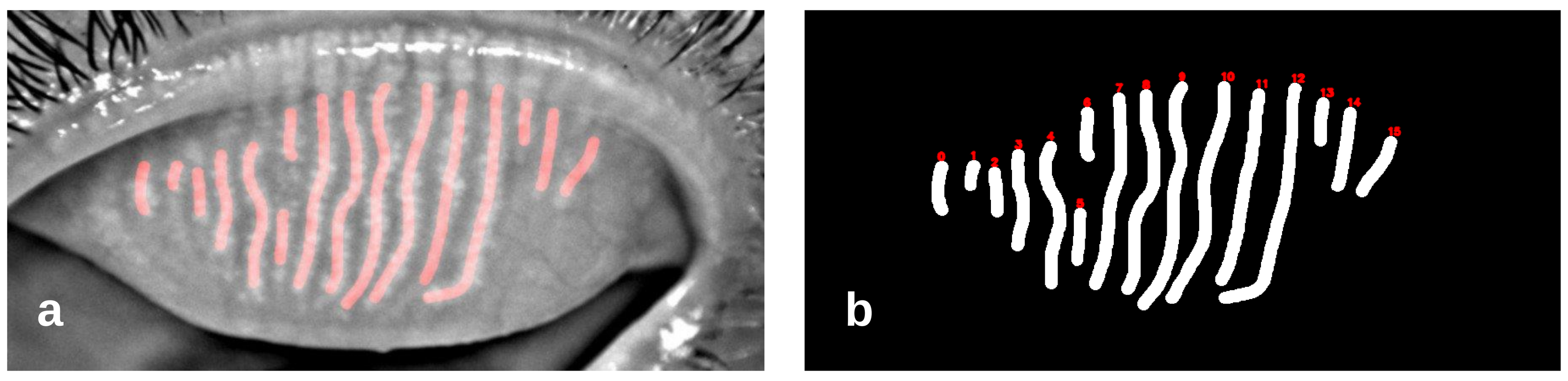

Figure 2a: MG (red) detection in an IR meibography image based on region growing using MeVisLab tool. b. Detected number of glands

3. Deep learning Based Segmentation

- **Mask R-CNN architecture**

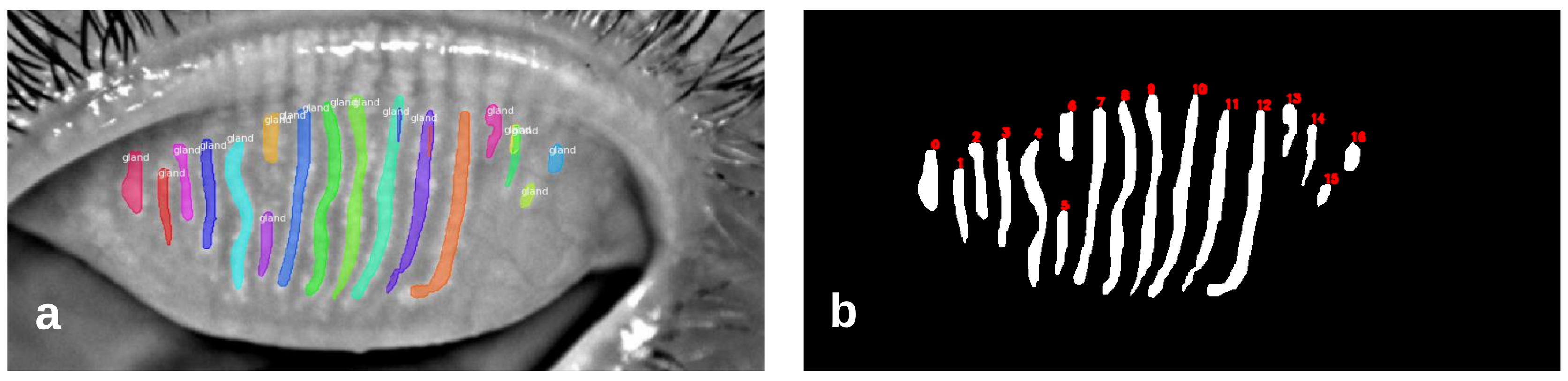

Figure 3.1: MGs (multicolor) detection in an IR meibography image based on deep learning using TensorFlow and Mask R-CNN. a. Upper Eyelid with detected glands. b. Detected number of glands

Table 1: Statistical information of Mask R-CNN based MGs detection.

Eyelid	Total number of Images	Training images	Training Accuracy	Validation Images	Validation Accuracy
Upper Eyelid	87	70	93%	17	87%

- **U-Net architecture**

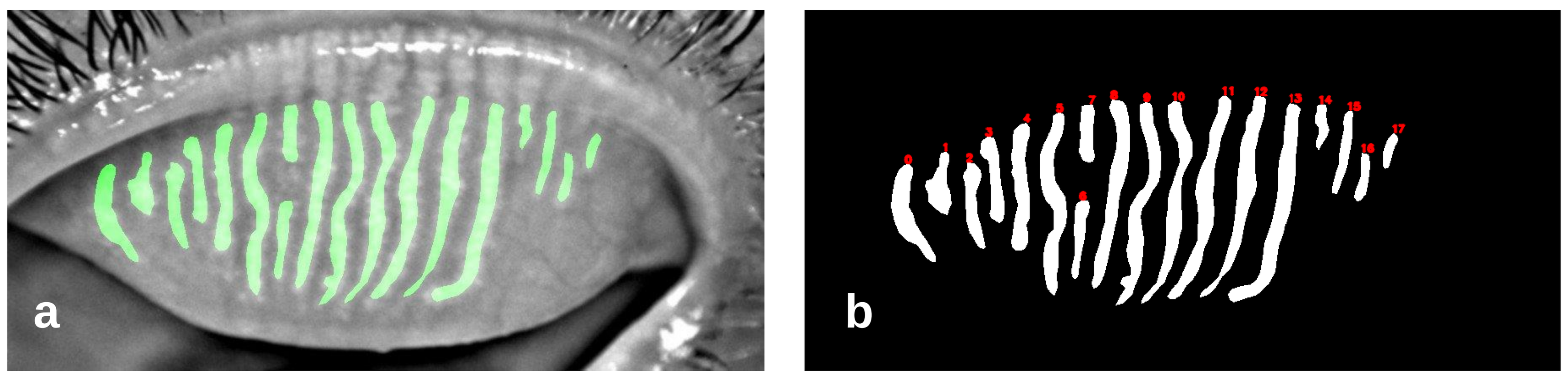

Figure 3.2: MGs (green) detection in an IR meibography image based on deep learning using TensorFlow and U-Net. a. Overlay of raw image and predicted mask. b. Detected number of glands

Table 2: Statistical information of U-Net based MGs detection.

Eyelid	Total number of Images	Training images	Training Accuracy	Validation Images	Validation Accuracy
Upper Eyelid	87	70	97%	17	94%

Table 3: Comparison between intensity, region growing and deep learning-based segmentations

Method		Number of glands detected	Total gland area (pixels)	Mean gland width (pixels)	Mean gland heigth (pixels)	Mean intergland gap (pixels)	False detection	Miss detection	Single image processing time(s)
Intensity		15	37361	8.13	96.94	14.82	1	3	4.07
Region Growing		16	112056	14.8	152.38	24.18	0	2	180
Deep Learning	U-Net	18	116803	14.54	150.67	23.31	0	0	1.6
	Mask R-CNN	17	79251	11.16	120.18	23.65	0	1	1.72

CONCLUSIONS

- Intensity and region growing-based segmentation provides automatic and semi-automatic gland detection respectively. However, the accuracy heavily depends on image quality. Also the morphological structure of MGs in region growing is not represented accurately in detail.
- Deep learning-based segmentation is superior than intensity and region growing because it is faster, more reliable and objective. However, the accuracy depends on training methods and number of training datasets.
- Deep learning-based methods require further validation procedures.

References

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