Exploring Retinal Vascular Morphology via A Deep Learning Pipeline

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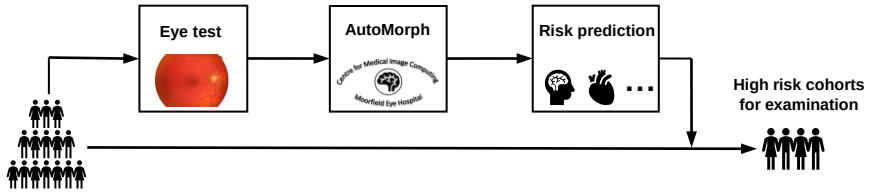
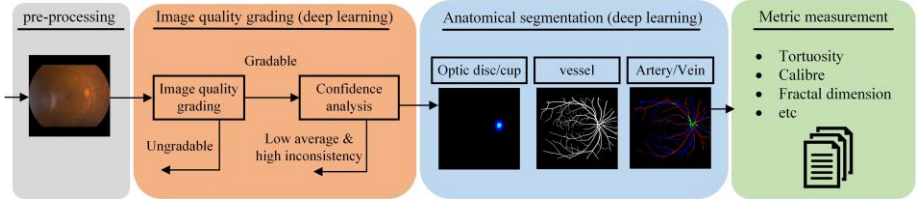
Research Purpose



Retinal vascular features provide valuable information for both ophthalmic disease and systemic disease (termed '**oculomics**'), e.g., atherosclerosis and diabetes mellitus, in a rapid and non-invasive way. To help recognise high risk cases of ophthalmic and systemic disease through observing the changes of retinal vascular morphology, we propose a deep learning pipeline to automatically analyse the vascular morphology (**AutoMorph***) which measures 12 kinds of metrics, such as vessel calibre and tortuosity.

Methods



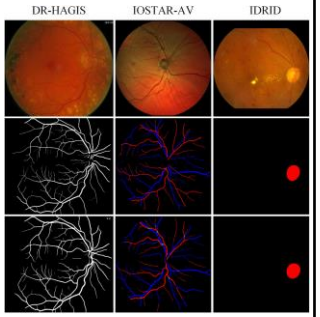
AutoMorph consists of four functional modules: image pre-processing, image quality grading, anatomical segmentation, including binary vessel, artery/vein, and optic disc/cup segmentation, and vascular morphology feature measurement. Image quality grading and anatomical segmentation use the most recent deep learning techniques# and are trained on 12 public datasets, e.g., DRIVE and CHASEDB1.

AutoMorph is externally evaluated using 5 public datasets: DDR, IOSTAR-AV, AV-WIDE, DR-HAGIS, and IDRID. This aims at testing the generalisability on out-of-distribution data, with different imaging devices and country of origin.

Experiment Results

	Image Quality Grading				Artery/vein Segmentation	
	EyePACS-Q test		DDR test		IOSTAR-AV	
	AutoMorph (internal)	Comparison[31] (internal)	AutoMorph (external)	Comparison* (internal)	AutoMorph (external)	Comparison[57] (internal)
Sensitivity	0.85	0.85	1	0.93	0.64	0.79
Specificity	0.93	NR	0.89	0.97	0.98	0.76
Precision	0.87	0.87	0.6	0.73	0.68	NR
Accuracy	0.92	0.92	0.91	0.99	0.96	0.78
AUC-ROC	0.97	NR	0.99	0.99	0.95	NR
F1-score	0.86	0.86	0.75	0.82	0.66	NR

	Binary Vessel Segmentation				Optic disc	
	Ultra-wide field: AV-WIDE		Standard field: DR-HAGIS		IDRID	
	AutoMorph (external)	Comparison[39,56] (internal)	AutoMorph (external)	Comparison[3,9,56] (internal)	AutoMorph (external)	Comparison[58] (internal)
Sensitivity	0.71	0.78	0.84	0.67	0.9	0.9
Specificity	0.98	NR	0.98	0.98	0.95	NR
Precision	0.75	0.82	0.73	NR	0.94	NR
Accuracy	0.96	0.97	0.97	0.97	0.99	0.99
AUC-ROC	0.96	NR	0.98	NR	0.95	NR
F1-score	0.73	0.8	0.78	0.71	0.94	NR



- ❑ The image grading module achieves comparable performance to the state-of-the-art method in EyePACS-Q, with an F1-score of 0.86.
- ❑ The binary vessel segmentation module achieves an F1-score of 0.73 on AV-WIDE and 0.78 on DR-HAGIS.
- ❑ The artery/vein module scores 0.66 on IOSTAR-AV.
- ❑ The optic disc/cup module achieves 0.94 in disc segmentation in IDRID.

AutoMorph performs well in external validation, being quantitatively on par with recent works in internal validation.

Conclusion

AutoMorph performs well even when the external validation data shows considerably different to training data. The fully automatic pipeline integrates recent technical work to facilitate 'oculomics' research.

* This tool will be publicly available soon
Personal website: https://vkzhou.netlify.app/
Contact: Yukun.zhou.19[at]ucl.ac.uk

[1] Zhou, Yukun, et al. "A refined equilibrium generative adversarial network for retinal vessel segmentation." Neurocomputing 437 (2021): 118-130.
[2] Zhou, Yukun, et al. "Learning to Address Intra-segment Misclassification in Retinal Imaging." MICCAI 2021.
etc.