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Analysing Epistemic and Aleatoric Uncertainty for Drusen Segmentation in Optical Coherence Tomography Images

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Introduction

- Segmentation of drusen is crucial for the early detection of Age Related Macular Degeneration (AMD).
- Varied sizes, appearances, contrast, annotation inconsistencies make drusen segmentation difficult..
- Uncertainty Quantification helps in interpreting the segmentation and allows the clinicians to intervene in the decision-making process.

Methodology

- U-Net model to detect drusen from OCT images
- Quantify the segmentation uncertainty using both the epistemic and aleatoric uncertainty
- Epistemic uncertainty estimated using MC-dropout.

$$p(y = c \mid x, D) = \frac{1}{T}\sum_{t=1}^{T} p(y = c \mid x, \boldsymbol{w}_t)$$

- Aleatoric uncertainty computed using test-time augmentation.

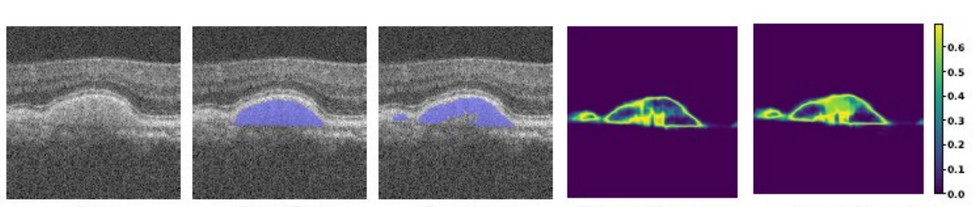
$$p(y = c \mid x, D) = \frac{1}{T}\sum_{t=1}^{T} p\left(y = c \mid M_t^{-1}(M_t(x)), \boldsymbol{w}\right)$$

- Compute uncertainty as entropy of the predictive probability distribution

$$\mathbb{H}\left[y \mid x, D\right] := -\sum_{c} p(y = c \mid x, D) \log(p(y = c \mid x, D))$$

Experimental Results

- Dataset: OCT volumes of 269 AMD subjects and 115 normal subjects
- 70% of images for training and rest for testing.
- Ablation Study: segmentation performance, correlation between uncertainty and performance, uncertainty visualization.



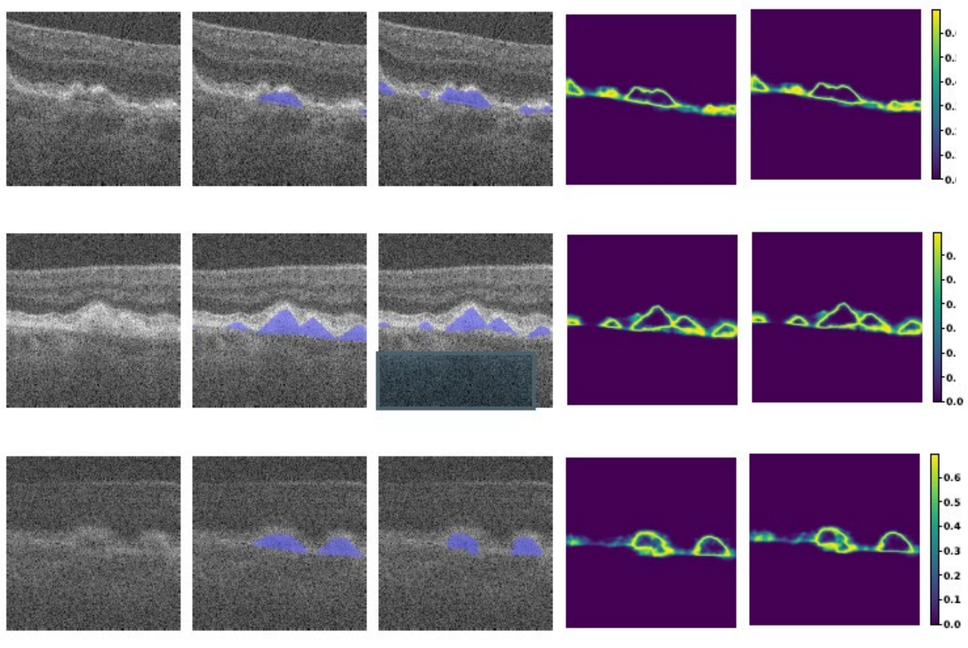


Fig: Drusen segmentation and uncertainty quantification

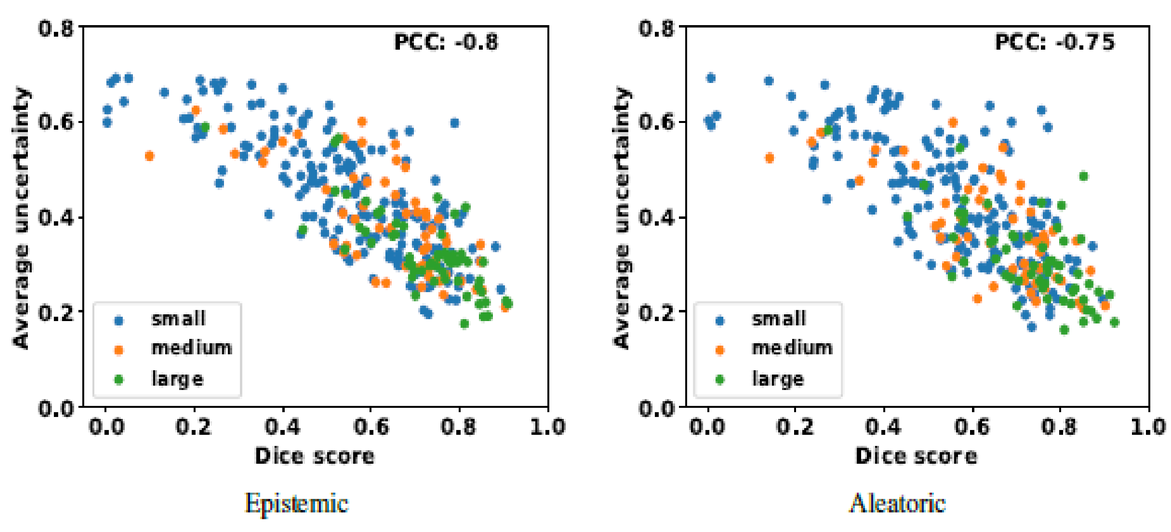


Fig: Correlation between uncertainty and segmentation accuracy

Methods	Large			Medium			Small		
	Dice	Precision	Recall	Dice	Precision	Recall	Dice	Precision	Recall
no-uncertainty	0.72	0.83	0.67	0.65	0.71	0.61	0.55	0.63	0.51
epistemic	0.72	0.84	0.65	0.64	0.72	0.58	0.53	0.68	0.48
aleatoric	0.73	0.83	0.67	0.64	0.71	0.6	0.54	0.64	0.5
epistemic-thresholded	0.8	0.93	0.72	0.71	0.85	0.64	0.57	0.75	0.5
aleatoric-thresholded	0.8	0.91	0.74	0.71	0.82	0.63	0.57	0.72	0.5

Table: Segmentation performance.

Conclusion

- Strong negative correlation between uncertainty and accuracy.
- Uncertainty quantification can help explain segmentation.
- Significance in clinical decision-making and building cost-effective model training strategies.