INTearNet: INtelligent Tear break-up time prediction Network

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Abstract

Dry Eye Disease (DED) is a frequent and chronic pathology with a substantial impact on the quality of life, often underestimated and underdiagnosed. The Tear Break-up Time (TBUT) is one of DED examination tests, it is a widely employed test for evaluating tear film stability in individuals suffering from DED. However, this test is subject to variability and reliant on the ophthalmologist expertise. To address these limitations, our study seeks to harness the power of Artificial Intelligence (AI) to automate the TBUT assessment, reducing subjectivity and fostering consistency and reliability.

Employing a digital slit-lamp, we recorded TBUT measurements for each of the 54 study participants following a predefined protocol. Video frames were extracted from the recordings and subsequently categorized into four classes: blinking, normal tear film, broken tear film, and unknown class. The dataset was divided into 40 videos for training, 7 for validation, and 7 for testing. Two distinct approaches were proposed: The baseline model, a conventional neural network, was implemented to classify normal and broken tear film classes utilizing 124,500 frames, EfficientNet-B0-Noisy Student as backbone, and a BinaryCrossEntropy (BCE) loss function. Additionally, a novel method called the "Dual-Task Siamese Network (DTSN)" was developed. This approach involved generating 124,500 image pairs, employing the same backbone as the baseline model, and a weighted sum of three losses: two BCE for the classification task and a contrastive loss for similarity learning task.

In the classification task, the baseline model achieved an AUC of 0.92, while the DTSN approach surpassed expectations with an AUC of 0.98. Furthermore, we leveraged the outcomes from the classification to TBUT prediction. Applying a Gaussian smoothing filter to the predictions and a decision threshold of 0.5, our predicted TBUT was determined to be 5.36 $\pm$ 3.69 seconds. Remarkably, these results demonstrated negligible differences when compared to ground-truth measurements (5.35 $\pm$ 3.79 seconds), with a Wilcoxon p-value greater than 0.05.

Our study has exhibited the considerable potential of the AI-based approach in quantifying TBUT with remarkable accuracy. However, we recognize the possibility for further enhancement through the integration of additional data and further expert annotations by ophthalmologists. These developments hold the key to refining and elevating the TBUT quantification approach we have proposed, paving the way for even more robust and insightful evaluations in the realm of Dry Eye Disease assessment.

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