Geometric Self-Supervised Learning: A Novel AI Framework Towards Quantitative and Explainable Diabetic Retinopathy Detection

Pu, Lucas (School: North Allegheny Senior High School)

Diabetic retinopathy (DR) is the leading cause of blindness among working-age adults. Early detection is crucial to reducing DR-related vision loss risk but is filled with challenges. Manual detection is labor intensive and often misses tiny DR-lesions, necessitating automated detection. However, existing automated systems are rarely used in clinical practice, solely classifying DR severity into different groups through an uninterpretable black-box process without providing valuable quantitative insight for precision medicine applications. In contrast, a quantitative detection system that identifies individual DR-lesions would overcome these limitations and enable diverse applications in screening, treatment, and research settings, but remains impossible to develop. The reason is that manually annotating diverse lesions is very time-consuming and challenging, limiting the amount of reliable data available to train an accurate model. To address this issue, this study presents a novel framework for training a deep learning model without any human labels as ground truths to detect and segment the four most prevalent types of DR-lesions (i.e., microaneurysms, hemorrhage, hard exudate, and soft exudate) on retinal images, making it possible to utilize the millions of retinal images available for training. Geometric rule-based vision algorithms are utilized to identify and differentiate high-probability normal/abnormal regions and then extract image patches for training a U-net model. This novel framework was extensively verified on two public datasets, significantly outperforming all available studies in detecting and segmenting DR-lesions. It enables self-supervised training of any AI model for this task, and its mechanism is generalizable to other segmentation tasks.

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