IJCLR 2021

Explainable Diabetic Retinopathy Classification Based on Neural-Symbolic Learning

Se-In Jang, Michaël J.A. Girard and Alexandre H. Thiery

Massachusetts General Hospital and Harvard Medical School; Singapore Eye Research Institute; National University of Singapore
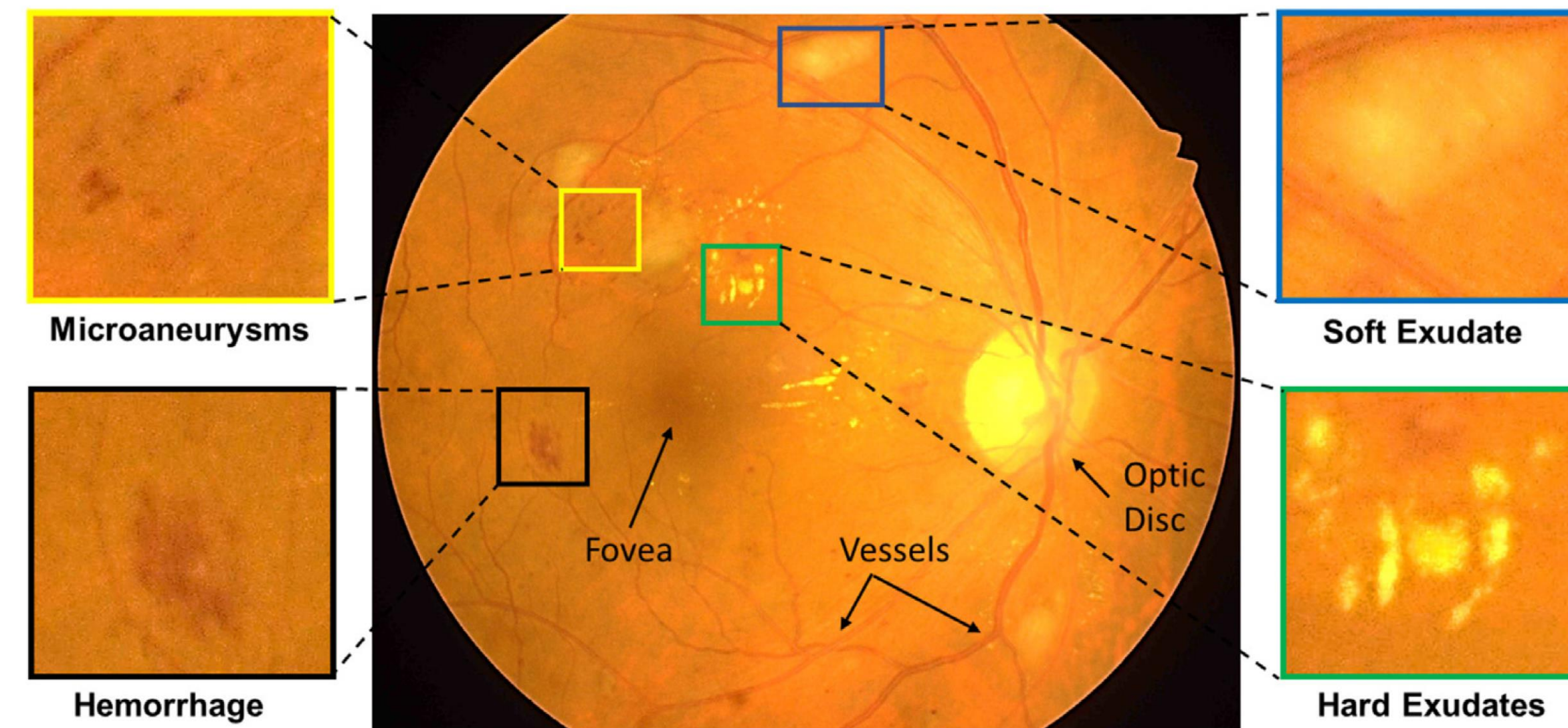
Abstract

- Explainable diabetic retinopathy classification
- Generation of a high-level symbolic representation
- A taxonomy style of diabetic retinopathy characteristics related to eye health conditions

Introduction

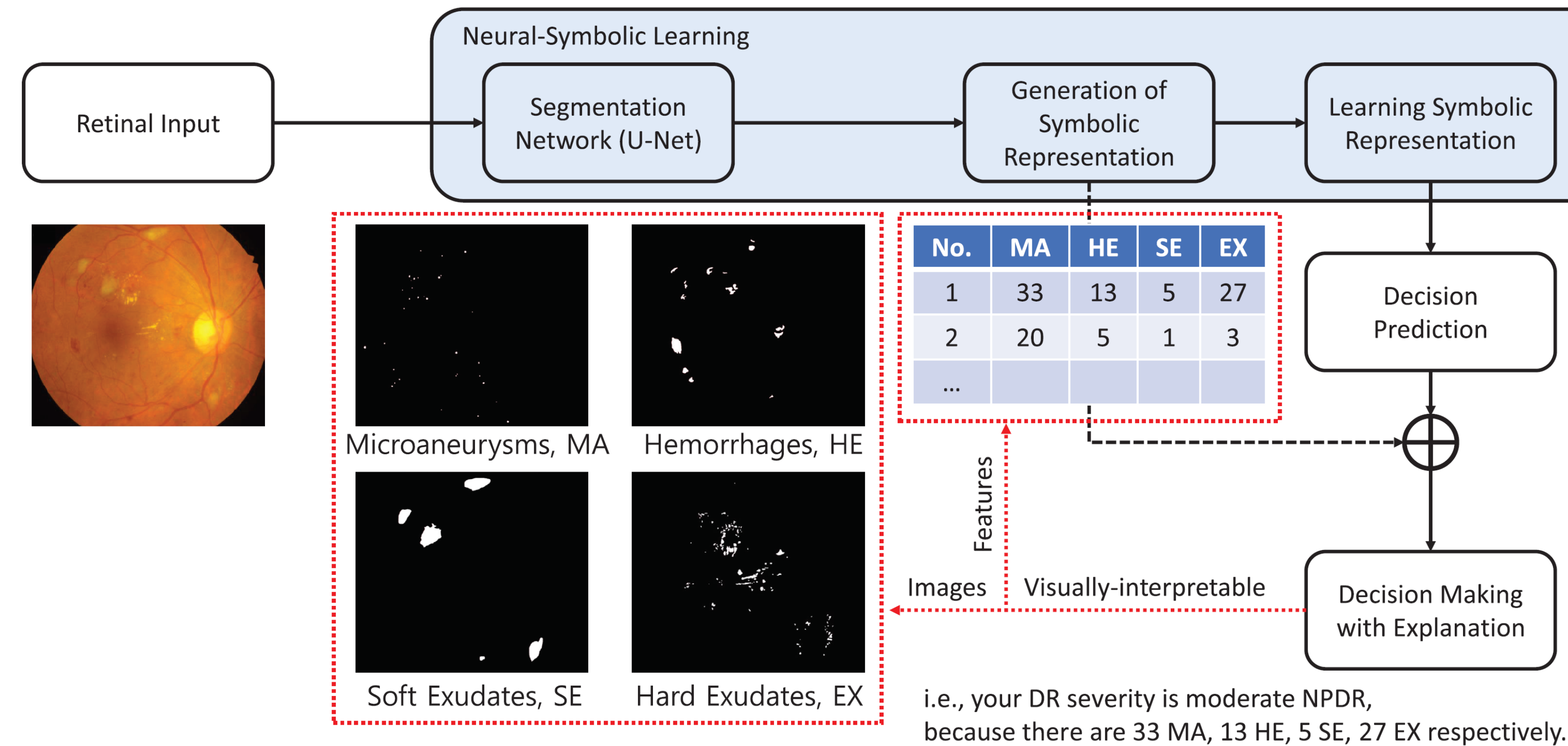- Illustration of diabetic retinopathy abnormalities

Microaneurysms · Soft Exudate · Hemorrhage · Hard Exudates · Fovea · Vessels · Optic Disc

- Diabetic retinopathy severity grading criteria

Severity Grade	Description
No DR:	No visible sign of abnormalities
Mild NPDR*:	Presence of MAs only
Moderate NPDR:	More than just MAs but less than severe NPDR
Severe NPDR:	> 20 intraretinal HEs, Venous beading, Intraretinal microvascular abnormalities, No signs of PDR
PDR**:	Neovascularization, Vitreous/pre-retinal HE

*NPDR: Non-Proliferative DR, **PDR: Proliferative DR

Proposed Explainable Diabetic Retinopathy (ExplainDR)

- An overview of the proposed ExplainDR

Neural-Symbolic Learning: Retinal Input → Segmentation Network (U-Net) → Generation of Symbolic Representation → Learning Symbolic Representation

No.	MA	HE	SE	EX
1	33	13	5	27
2	20	5	1	3
...				

Microaneurysms, MA · Hemorrhages, HE · Soft Exudates, SE · Hard Exudates, EX

Decision Prediction · Decision Making with Explanation

i.e., your DR severity is moderate NPDR, because there are 33 MA, 13 HE, 5 SE, 27 EX respectively.

- The generated high-level symbolic representation
  - The numbers of segmented regions in MA, HE, SE and EX

$$F_{sym} = \left[\left|S^1\right|, \left|S^2\right|, \left|S^3\right|, \left|S^4\right| \right] \in \mathbb{N}^4,$$

- Extension of the above symbolic representation
  - Considering the sizes of the segmented regions
  - E.g. small, medium and large (sml) sizes

$$F_{sml} = \left[\left|S^1_{small}\right|, \left|S^1_{medium}\right|, \left|S^1_{large}\right|, \ldots, \left|S^4_{small}\right|, \left|S^4_{medium}\right|, \left|S^4_{large}\right| \right] \in \mathbb{N}^{12}$$

Results

- Segmentation results of the proposed ExplainDR

Input Image · Microaneurysms (MA) · Hemorrhages (HE) · Soft Exudates (SE) · Hard Exudates (EX)
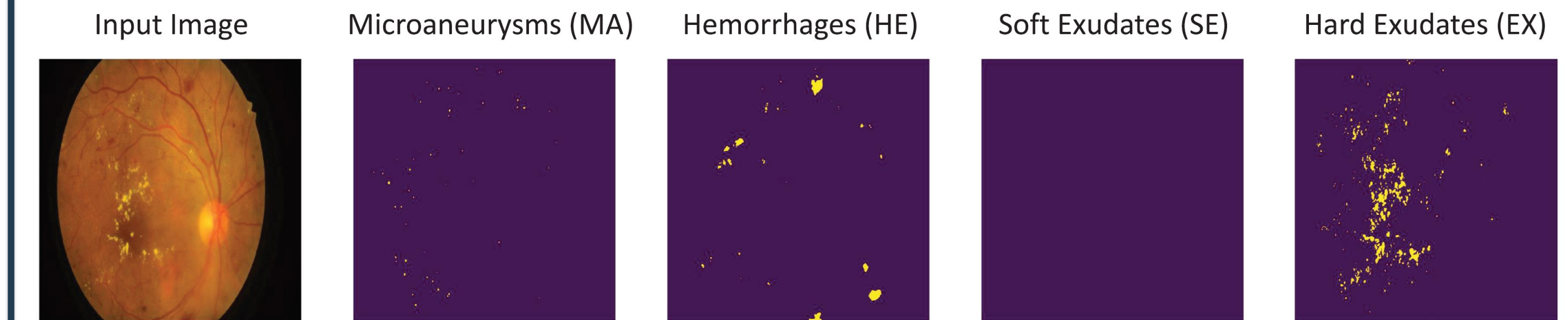
- The numbers of the segmented regions in each abnormality
  - smlMA: 37, 0, 0, smlHE: 26, 2, 2, smlSE: 0, 0, 0, smlEX: 197, 5, 3

- The generated explanation
  - The test image is classified as severe NPDR because 37 small MAs, 26 small HEs, 2 medium HEs, 2 large HEs, 197 small EXs, 5 medium EXs and 3 large EXs are detected.

- An ablation study

Name	Accuracy
ExplainDR + Simple Symbols	0.4757
ExplainDR + Extended Symbols	0.6019

- The leaderboard on the DR and DME test sets in the IDRiD challenge

Name	Accuracy	Approach	Input Size	External Dataset
LzyUNCC	0.6311	ResNet + Deep Aggregation	896 × 896	Kaggle
ExplainDR + Extension	0.6019	Symbols + FCN	1024 × 1024	-
VRT	0.5534	CNN	640 × 640	Kaggle, Messidor
Mammoth	0.5146	DenseNet	512 × 512	Kaggle
HarangiM1	0.4757	AlexNet + GoogLeNet	224 × 224	Kaggle
AVSASVA	0.4757	ResNet + DenseNet	224 × 224	DiaretDB1
HarangiM2	0.4078	AlexNet + Handcrafted	224 × 224	Kaggle