Out-of-Distribution Detection via Uncertainty Learning for Robust Glaucoma Prediction

Homa Rashidisabet [1,2], R.V. Paul Chan [1,2], Thasarat S. Vajaranant [1,2], Darvin Yi [1,2]

[1] *Illinois Eye and Ear Infirmary, Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago*

[2] *Artificial Intelligence in Ophthalmology (Ai-O) Center, University of Illinois at Chicago*

INTRODUCTION

- Glaucoma is one of the leading causes of irreversible blindness globally.
- Deep learning (DL) has emerged as a promising approach for the automated diagnosis of glaucoma.
- Challenges persist in translating these advancements to clinical settings. Conventional DL classification methods often exhibit overconfidence and lack robustness when faced with a shift in training data distribution, posing challenges in out-of-distribution (OOD) scenarios.
- These issues raise concerns about the suitability of current glaucoma DL diagnostic algorithms for real-world clinical deployment, potentially impacting patient safety.

METHODS

DATA

- We trained our deep learning models on 712 fundus images from the Illinois Eye and Ear Infirmary
- We evaluated the models on 8 public fundus datasets and 5 non-medical image datasets

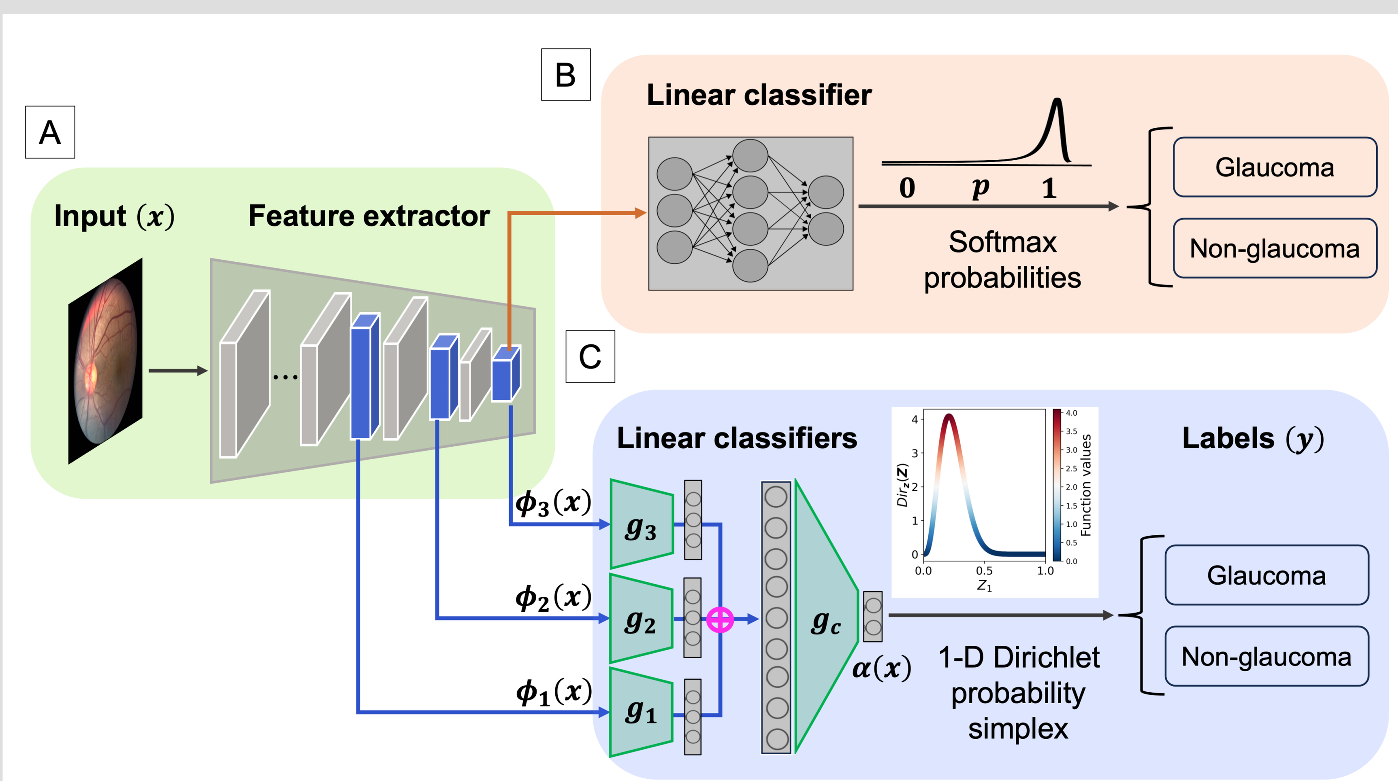

FIGURE 1
Glaucoma classification models. (A) Schematic illustration of base architecture, VGG-16 feature extractor. (B) Baseline softmax classifier. (C) Proposed Dirichlet classifier.

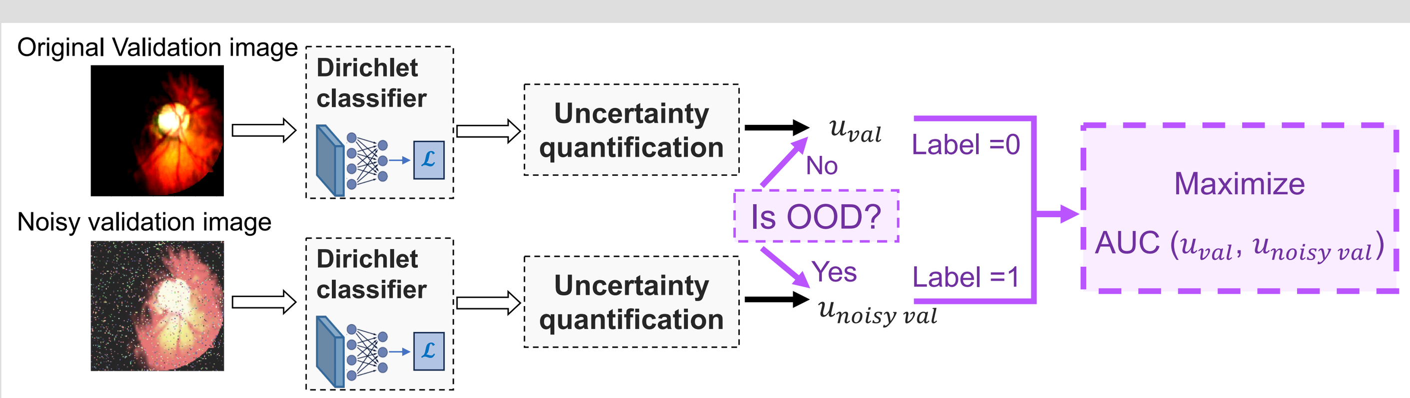

FIGURE 2
Proposed Out-of-Distribution (OOD) detection through uncertainty quantification pipeline.

RESULTS

OOD DETECTION RESULTS

OOD Datasets	Fundus?	Label?	Mean AUC [95% Confidence Interval]	
			Dirichlet	Softmax
RIMONE-DL	✓	✓	**76.0 [75.4, 76.6]**	54.7 [53.9, 55.5]
O-RIGA	✓	✓	**75.1 [74.4, 76.0]**	69.2 [68.6, 70.1]
REFUGE	✓	✓	**64.4 [63.2, 65.6]**	59.4 [58.4, 60.3]
LAG	✓	✓	**60.0 [59.9, 60.3]**	42.4 [41.9, 42.7]
GL-S	✓	X	**82.6 [86.1, 86.2]**	73.5 [73.3, 73.7]
Kaggle	✓	X	**63.3 [63.0, 63.7]**	58.4 [58.0, 58.7]
MESSIDOR-2	✓	X	**80.4 [80.1, 81.0]**	65.1 [64.8, 65.8]
IDRiD	✓	X	**90.2 [89.8, 90.9]**	84.4 [83.9, 85.3]
CIFAR-10	X	X	**95.3 [95.3, 95.4]**	92.9 [92.8, 92.9]
Omniglot			**98.0 [97.8, 98.0]**	95.2 [95.1, 95.2]
F-MNIST			**98.0 [97.9, 98.0]**	95.1 [95.0, 95.1]
SVHN			**98.3 [98.3, 98.3]**	95.1 [95.0, 95.1]
KMNIST			**98.0 [98.0, 98.0]**	95.6 [95.5, 95.6]

TABLE 1
OOD detection results for Dirichlet versus softmax model. Max performance in bold.

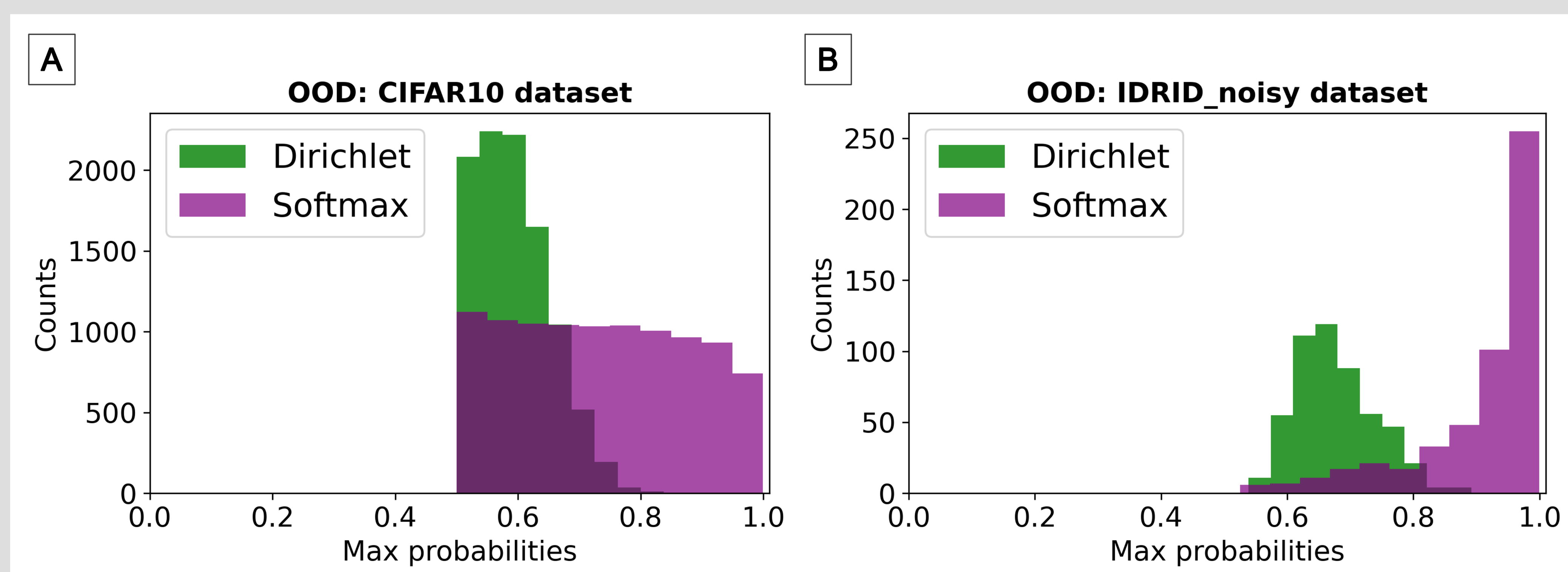

FIGURE 3
Histogram of maximum probabilities predicted by Dirichlet versus Softmax models. Evaluation on (A) CIFAR-10 OOD image dataset, and (B) IDRID OOD fundus image dataset.

CONCLUSION

- We showed that when an image is far away from training samples, conventional deep learning models using the Softmax function:
  - Fail to provide reliable predictions
  - Experience a loss of performance
- Our proposed uncertainty-aware Dirichlet model effectively outperforms the Softmax model in the OOD detection task
- Our proposed method achieves comparable glaucoma classification performance across diverse domains, extending its utility beyond the initial training dataset
- Our proposed method mitigates over-confident glaucoma diagnosis and improves the reliability of conventional models for glaucoma assessment
- Incorporation of uncertainty scores in our model could alert users to instances where the model lacks sufficient information for a confident decision

REFERENCES

[1] M. Shen, Y. Bu, P. Sattigeri, S. Ghosh, S. Das, and G. Wornell, ***Post-hoc Uncertainty Learning using a Dirichlet Meta-Model***, In Proceedings of the AAAI Conference on Artificial Intelligence, 2022.

[2] T. Araojo, G. Aresta, and H. Bogunovic, ***Deep Dirichlet Uncertainty for Unsupervised Out-of-Distribution Detection of Eye Fundus Photographs in Glaucoma Screening***, ISBIC 2022 Int. Symp. Biomed. Imaging Challenges, Proc., 2022

FINANCIAL DISCLOSURES

Homa Rashidisabet, R.V. Paul Chan, Thasarat Vajaranant, and Darvin Yi report no financial disclosure.

SUPPORT

All work done for this project was supported by the Research to Prevent Blindness (RPB) Foundation.

Supported By
Research to Prevent Blindness