Interpretable AI for Trustworthy Ocular Disease Diagnosis

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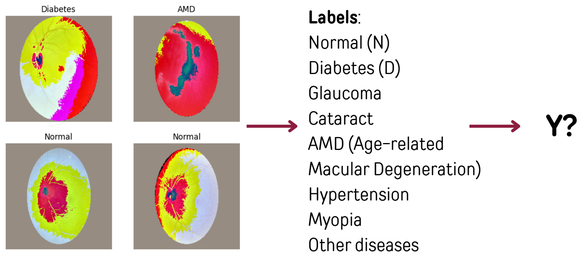
How can Concept Bottleneck Models (CBMs) combined with multi-modal Question Answering improve interpretability & accuracy in ocular disease classification?

Introduction

This project aims to improve ocular disease diagnosis through an **explainable**, **trustworthy interpretable** model that uses Concept Bottleneck Models (CBMs) combined with GPT-4 and domain expert-generated Q&A pairs.



What is Concept Bottleneck Model (CBM)?

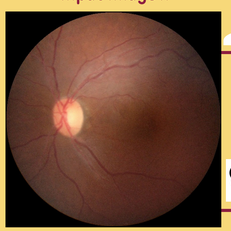


Fig. Fundus scan from ODIR-5K

Human Designed Concepts

- **Vessel Abnormalities: "hemorrhages," "blood vessels"**
- **Optic Disc Issues: "optic disc cupping," "pallor"**
- **Macula Issues: "macular edema," "retinal layers"**
- **Retinal Issues: "retinal detachment," "pigmentation"**
- **Tumor/Neovascularization: "choroidal tumor"**

LLM Generated Concepts (Q&A)

- **Are there dark spots indicating potential hemorrhage?**
- **Is the optic disc grayish or pale, suggesting optic neuropathy?**
- **Are there irregular blood vessels in the retinal region?**

Predicted Label: Diabetic Retinopathy

Prompt: Describe markers of diabetic retinopathy in a Fundus scan

References

- N. M. Selvaraj, X. Guo, A. W.-K. Kong, and A. Kot, "Improving Concept Alignment in Vision-Language Concept Bottleneck Models," Nanyang Technological University, Singapore, 2024.
- Y. Yang, A. Panagopoulou, S. Zhou, D. Jin, C. Callison-Burch, and M. Yatskar, "Language in a Bottle: Language Model Guided Concept Bottlenecks for Interpretable Image Classification," University of Pennsylvania, CVPR 2024.

Methodology

Human-Aligned Post-Hoc Explanation:

- Align with how a clinician might reason through a diagnosis
- Post-hoc explanation would highlight features as the key markers that influenced the decision.

Example:

```
if diagnosis == "Diabetic Retinopathy":
    features = ["presence of microaneurysms", "retinal hemorrhages"]
```

Trustworthy human-interpretable model

- Providing transparency in how it reaches its conclusions
- Users can comprehend the steps or logic behind the model's predictions
- Mechanisms, such as decision trees, feature importance scores, or visual prototype paths

QnA Dataset

Examples: Diabetes (D),Do the retinal vessels show signs of abnormal growth (neovascularization)?,"Yes"
Cataract (C),Is there a yellowing of the lens that may affect the quality of the image?,"Yes, the lens shows signs of yellowing."

Model Design

Data Generation and Concept Creation

Q&A pairs → GPT - 4 + Domain Expert

Bottleneck Layer Creation

Concepts evaluated using GPT-4 responses

Uniqueness | Relevancy

Challenge with Decision Trees

non-exclusive symptoms (e.g., a symptom may appear in multiple diseases). Like: Retinal Hemorrhages occur in Diabetes & Hypertension

Prioritize Features in Decision Path Construction

Initial Question: "Are there microaneurysms present?" (Highly specific to diabetic retinopathy);
Next: "Is there drusen in the retina?" (Specific to AMD)

Baseline Model Results

ResNet50 model achieved an overall accuracy of 57% and ROC AUC of 83.44, showing moderate discriminatory ability across eight eye disease.

Class	Precision	Recall	F1-Score	Support
Normal	57	8	65	1108
Diabetes	53	49	51	650
Glaucoma	52	31	39	114
Cataract	68	59	63	124
AMD	69	29	41	100
Hypertension	100	7	13	55
Myopia	86	83	84	100
Other diseases	34	10	16	306

Fig. Classification Report Table

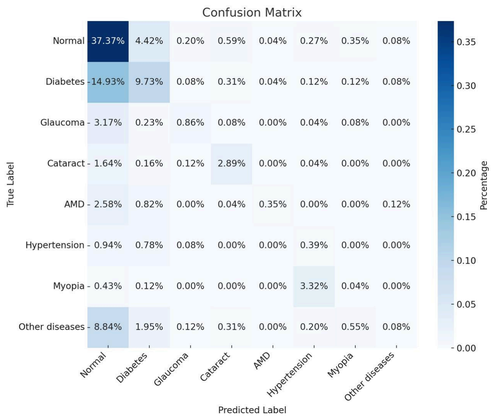


Fig. Normalised Confusion Matrix

-Myopia: Best performance (F1-score 84).
-Glaucoma and AMD: Moderate precision, low recall (F1-scores 39 and 41).
-Hypertension: High precision (100), very low recall (07), F1-score 13.
-Other Diseases: Poor results (F1-score 16), indicating classification challenges.

Results

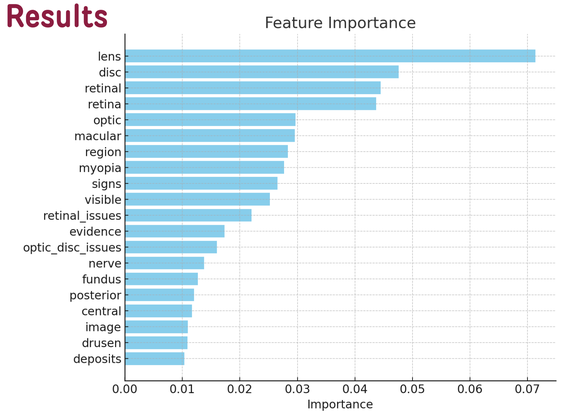


Fig. Feature Importance for Ocular Disease Detection

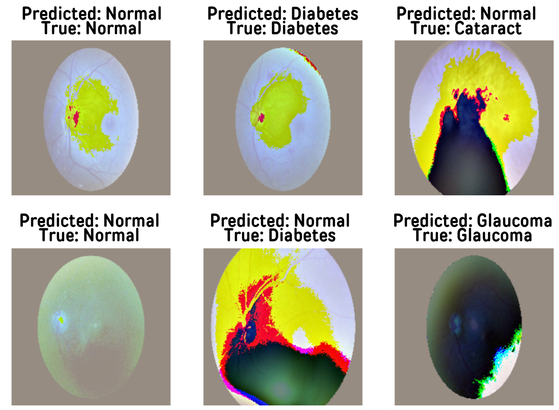


Fig. Improved Model Prediction

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