A Minor Project Synopsis on

Hybrid Bayesian-Transformer Model for Uncertainty-Aware Diabetic Retinopathy Detection

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Introduction

Diabetic Retinopathy (DR) is a severe complication of diabetes that affects the retina, leading to vision impairment and potential blindness. The traditional deep learning models for DR detection lack uncertainty estimation, which is critical for clinical applications. This project proposes a **Hybrid Bayesian-Transformer Model** that integrates **EfficientNetB0, Swin-Transformer, and Bayesian Approximation** to enhance reliability, interpretability, and classification performance. The model also incorporates **explainable AI (XAI) techniques** to improve trust among clinicians. Furthermore, the project aims to integrate **GAN-based augmentation** to balance datasets and **contrastive self-supervised learning** to reduce reliance on labeled data.

Motivation

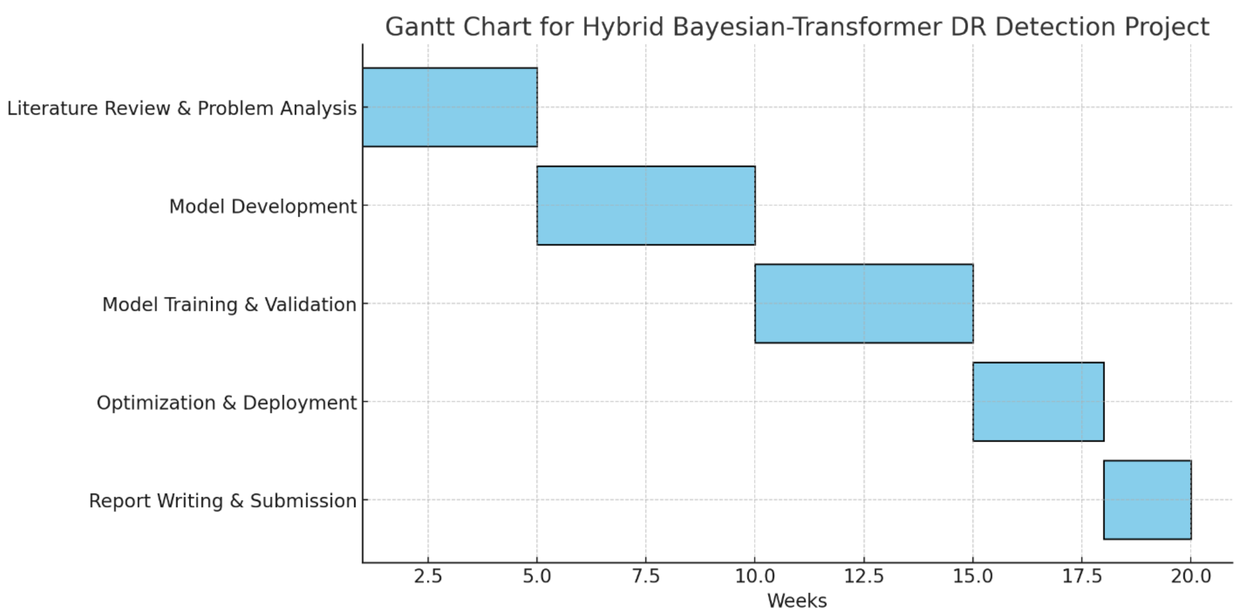
The motivation for this research stems from the limitations of existing DR detection models:

- **High False Positives/Negatives**: Traditional CNN models often misclassify cases due to lack of uncertainty quantification.
- **Limited Explainability**: Deep learning models operate as "black boxes," making it difficult for doctors to trust automated decisions.
- **Class Imbalance in Datasets**: Severe DR cases are underrepresented, affecting model generalization.
- **High Computational Cost**: Transformer models demand significant resources, making real-time DR detection difficult.
- **Lack of Multi-Modal Analysis**: Existing models rely solely on fundus images, ignoring patient clinical data.

This project aims to overcome these challenges by **combining Bayesian inference, transformers, explainability mechanisms, contrastive learning, and GAN-based data augmentation** to develop a clinically useful DR detection model.

Statement of Problem

Existing Methods	Pros	Cons
CNN-based Models (EfficientNet, ResNet)	High accuracy in feature extraction	Lack of uncertainty estimation; poor interpretability
Vision Transformer (ViT, Swin-Transformer)	Better contextual feature learning	High computational complexity
Bayesian Neural Networks (BNN)	Provides uncertainty quantification	Computationally expensive; slow inference
DR-GAN (Synthetic Data Generation)	Improves class balance	Can generate unrealistic artifacts
Contrastive Learning	Reduces labeled data dependency	Needs large-scale data for meaningful contrast
Multi-Modal Learning (Clinical + Image)	More personalized diagnosis	Requires integration of multiple data sources



Methodology/ Planning of work:

Phase 1: Literature Review & Problem Analysis

- Review existing DR detection models.
- Identify dataset challenges (APTOS, EyePACS, Messidor, DDR).
- Study contrastive learning, Bayesian inference, and GAN-based augmentation techniques.

Phase 2: Model Development

- **Preprocessing:** Apply **adaptive histogram equalization** and **segmentation techniques**.
- **Feature Extraction:** Use **EfficientNetB0** for feature extraction.
- **Transformer Integration:** Use **Swin-Transformer** for DR grading.
- **Uncertainty Estimation:** Implement **Bayesian Approximation (Monte Carlo Dropout)**.
- **Explainability:** Use **LIME and Grad-CAM** for interpretability.
- **Multi-Modal Data Fusion:** Combine fundus images with clinical patient data.
- **Contrastive Learning Module:** Implement self-supervised learning for improved feature extraction.

Phase 3: Model Training and Validation

- Train on **APTOS, EyePACS, DDR datasets**.
- Use **GAN-based augmentation** to generate balanced data.
- Evaluate with **AUC-ROC, Accuracy, Sensitivity, Specificity, and Uncertainty Metrics**.

Phase 4: Optimization and Deployment

- Optimize computational efficiency.
- Deploy as a **web-based DR detection system**.

Facilities required for proposed work:

Hardware	**Purpose**
GPU (NVIDIA RTX 3090 or higher)	Model training
Cloud computing (Google Colab/AWS)	Scalable training

Bibliography/References

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