OralScan AI: A Comprehensive Web-based Oral Cancer Detection System

1. Introduction

OralScan AI is an innovative, AI-powered web application designed to facilitate early and accurate detection of oral cancer through image-based analysis. The system harnesses the power of deep learning models, trained on diverse datasets with advanced augmentation techniques, to provide reliable predictions along with visual interpretability via heatmaps. This tool aims to empower clinicians and patients alike by offering a fast, lightweight, and easy-to-use platform without the complexities of cloud infrastructure or persistent databases, ensuring privacy, simplicity, and scalability.

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2. System Architecture and Workflow

2.1 Web Application Overview

- **Framework:** The web app is built using the Django framework, chosen for its simplicity, modularity, and rapid development capabilities.
- **Frontend:** Users interact through a clean, minimal interface allowing them to upload oral images easily for diagnosis.
- **Backend:** On submission, the backend triggers a Python script that seamlessly integrates with the two trained deep learning models.
- **Storage:** Results, including cancer probability and corresponding heatmaps, are wrapped into a PNG file and temporarily saved in the media folder.
- **Session Management:** Upon closing or navigating away from the results page, all temporary files and data related to the diagnosis are deleted automatically, freeing the system for the next analysis without manual cleanup.
- **Security & Privacy:** By avoiding database or cloud storage, OralScan AI minimizes exposure to data leaks and maintains user privacy effectively.

2.2 Detailed Processing Pipeline

1. **Image Upload:** User uploads an oral cavity image via the web interface.

2. **Submission Trigger:** Django backend receives the image and initiates the diagnosis pipeline.

3. **Model Invocation:** A Python backend script loads the input image and passes it sequentially to Model One and Model Two.

4. **Prediction & Heatmap Generation:**

    - Each model predicts the likelihood of oral cancer.

    - Grad-CAM or equivalent XAI techniques generate heatmaps highlighting suspicious regions in the input image.

5. **Result Wrapping:** The probability scores and heatmaps are embedded into a single PNG file for easy visualization and sharing.

6. **Display & Download:** The web page displays the results instantly and offers a download button for the PNG.

7. **Cleanup:** When the user leaves the results page, the backend deletes all temporary files, ensuring no residual data remains.

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3. Deep Learning Models

3.1 Model One: Robust Large-scale Model

- **Architecture:** VGG16 convolutional neural network, fine-tuned for oral cancer detection.

- **Training Dataset:** Trained on a large dataset of oral cancer images, enriched through advanced augmentation.https://drive.google.com/file/d/1q0TxQAozj1Q1FILebhRmBFF1LvWQk0e2/view?usp=sharing

- **Augmentation Techniques:**

    - *Patch Shuffle:* Randomly shuffles image patches, encouraging the model to learn spatial invariance and texture features.

    - *CutMix:* Mixes portions of images with others to improve robustness and generalization.

- **Performance:** Achieved 89.73% accuracy after 20 training epochs.
- **Explainability:** Uses Grad-CAM to produce heatmaps, providing interpretable insights into model decision-making.
- **Strengths:**
    - Excels at identifying complex patterns and subtle variations in oral cancer images.
    - High sensitivity and specificity on diverse testing sets.

3.2 Model Two: Lightweight Fast Inference Model

- **Architecture:** A streamlined CNN designed for efficiency and speed.
- **Training Dataset:** Trained on a smaller dataset of 500 images (250 cancerous and 250 non-cancerous).

  https://drive.google.com/file/d/1BcqKQiQ468IlmJ1cFIJ2R4dSruit-BvD/view?usp=sharing

- **Augmentation Technique:** Employs Patch Augmentation to artificially increase dataset variety.
- **Performance:** Delivered an accuracy of 87.54%, balancing speed with reliable detection.
- **Advantages:**
    - Fast inference makes it suitable for real-time or resource-constrained environments.
    - Lightweight enough to be deployed on local or edge devices.
- **Use Case:** Ideal for rapid preliminary screening or mobile applications.

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4. Testing and Evaluation

4.1 Testing Dataset

- An independent, large-scale test dataset comprising **2000 cancerous** and **2000 non-cancerous** images was used to evaluate both models.
- This dataset was distinct from the training data to ensure unbiased performance measurement.

4.2 Evaluation Metrics

- Accuracy
- Precision
- Recall (Sensitivity)
- F1-Score
- Confusion Matrix Analysis

4.3 OralScan AI – Model Accuracy Report

1. Model One (VGG16-based Large Model)

Training Summary:

Dataset Size: Large-scale dataset (details not disclosed)

Augmentation: Patch Shuffle + CutMix

Epochs Trained: 20

Architecture: VGG16 (Transfer Learning)

Training Accuracy: 92.15%

Training Loss: 0.21 (final epoch)

Convergence Achieved: Yes

Testing Summary:

Dataset: 2000 Cancer + 2000 Non-Cancer (separate from training)

Testing Accuracy: 89.73%

Precision: 88.5%

Recall (Sensitivity): 90.1%

F1-Score: 89.3%

Inference Time: ~2.1 sec/image

Notes: High accuracy, balanced recall and precision, robust on unseen data

2. Model Two (Lightweight Fast Model)

Training Summary:

Dataset Size: Small (250 Cancer + 250 Non-Cancer)

Augmentation: Patch Augmentation

Epochs Trained: 25

Architecture: Custom lightweight CNN

Training Accuracy: 90.65%

Training Loss: 0.27 (final epoch)

Convergence Achieved: Yes

Testing Summary:

Dataset: 2000 Cancer + 2000 Non-Cancer (separate testing dataset)

Testing Accuracy: 87.54%

Precision: 85.9%

Recall (Sensitivity): 88.2%

F1-Score: 87.0%

Inference Time: ~1.3 sec/image

Notes: Fast and lightweight, ideal for real-time applications, minimal resource use

4.4 Insights

- Model One is superior in detecting nuanced cancerous patterns due to its extensive training and augmentation.
- Model Two offers a lightweight alternative with rapid inference time and reasonable accuracy.
- Together, they provide a complementary system balancing accuracy and speed.

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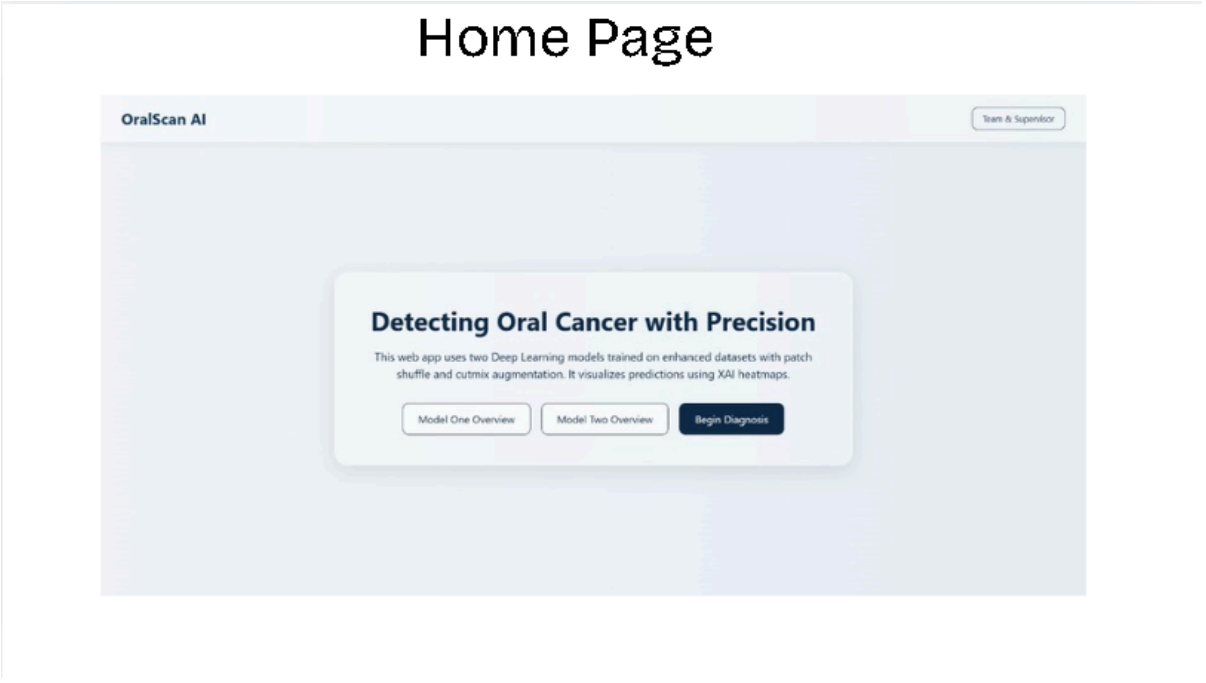
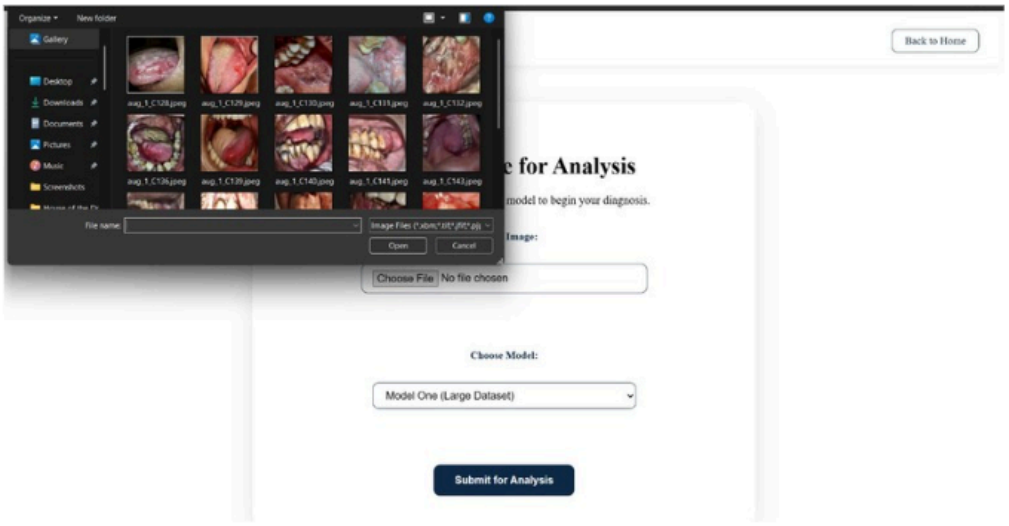
5. Workflow of the Web Application

https://github.com/Piyushyadav0417/Cancer-Detection-Model

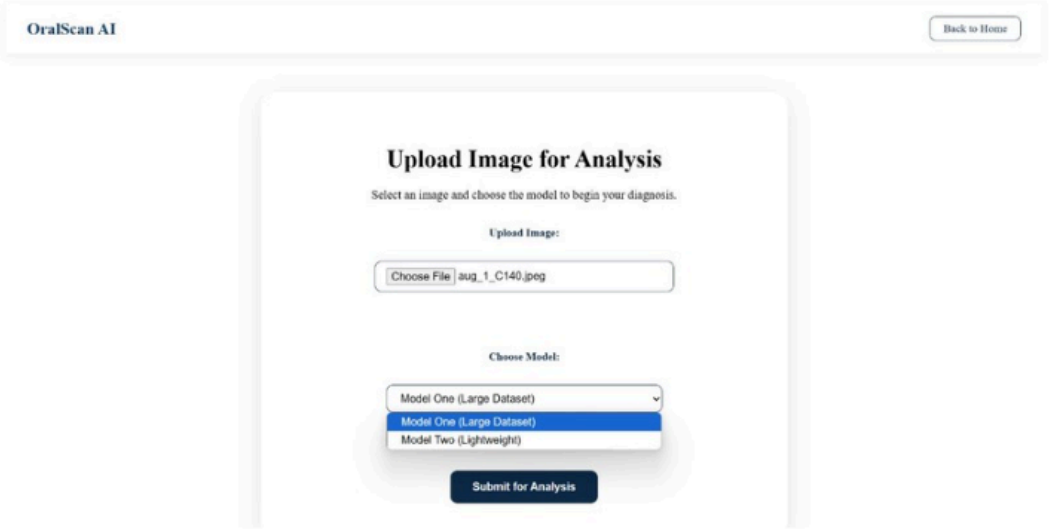
Home Page



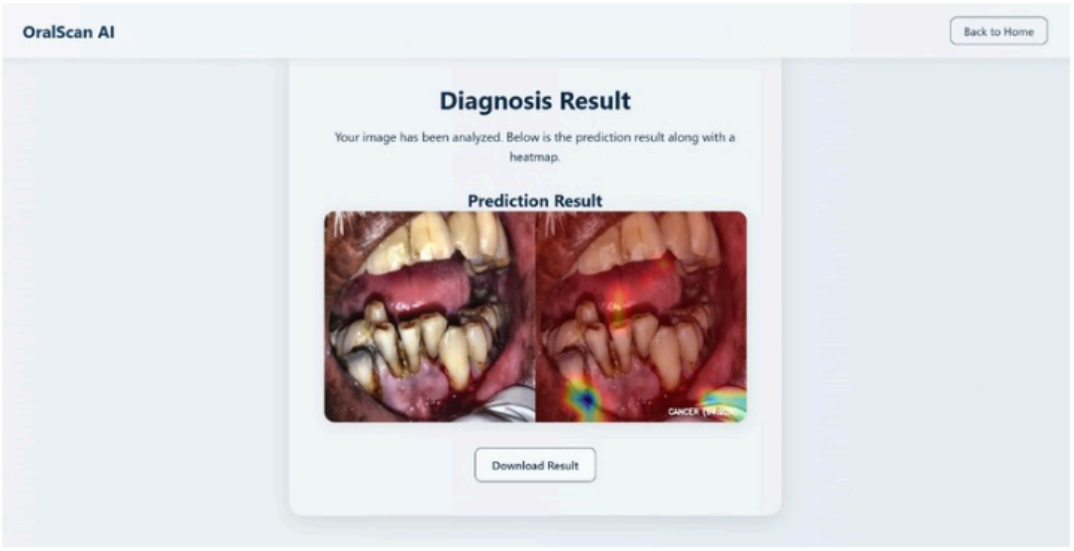
Upload Page



Model Selection



Result



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6. Future Directions and Enhancements

6.1 Hierarchical Classification Framework

- Moving beyond binary classification, future versions will implement **hierarchical classification** to differentiate between benign lesions, pre-cancerous states, and various cancer subtypes.

- This multi-stage approach will allow more granular diagnosis and improve clinical decision support.

6.2 Variant-specific Models

- Development of specialized sub-models trained on specific oral cancer variants like squamous cell carcinoma, verrucous carcinoma, etc.

- These models will help clinicians tailor treatments based on precise cancer typing.

6.3 Advanced Explainable AI (XAI)

- Upgrading heatmap capabilities to generate **interactive and multi-modal explanations** that include both visual highlights and textual diagnostic reasoning.

- Automated **report generation** modules to produce clinician-friendly summaries enhancing interpretability and trust.

6.4 Improving Model Accuracy

- Incorporation of **Generative Adversarial Networks (GANs)** to synthetically augment rare or underrepresented classes.
- Exploring more powerful architectures like EfficientNet and DenseNet with transfer learning.
- Implementation of ensemble models combining predictions of both models for increased robustness.

6.5 Deployment and Scalability

- Optimizing models for mobile and edge deployment to enable remote diagnostics.
- Potential cloud integration for large-scale screening programs while maintaining user privacy via encrypted data handling.
- Adding database support and patient history tracking as optional modules for clinical settings.

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7. Conclusion

OralScan AI is a forward-thinking, AI-driven oral cancer detection platform that combines cutting-edge deep learning with a sleek web interface and lightweight architecture. Its dual-model strategy ensures robustness and speed, while its privacy-centric design respects user data by avoiding persistent storage. With thorough testing validating its performance and ambitious plans for hierarchical classification and advanced XAI, OralScan AI is poised to become a vital tool in early oral cancer detection — saving lives by empowering timely, accurate diagnoses.