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AI-Assisted Framework for Early Oral Cancer Screening Using Smartphone Imaging

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Abstract

Oral cancer is a major global health concern, particularly in developing countries where delayed diagnosis reduces survival rates. This paper presents an AI-assisted oral cancer screening framework that combines smartphone imaging and Convolutional Neural Networks (CNNs) for rapid and non-invasive detection. The proposed system includes image acquisition, preprocessing, lesion segmentation, and deep learning-based classification to identify suspicious oral lesions. Experimental results demonstrate high classification accuracy, indicating that the framework can support early diagnosis and improve access to screening in rural and underserved areas.

Keywords: Oral Cancer; Artificial Intelligence; Deep Learning; Convolutional Neural Network; Smartphone Imaging; Medical Image Processing; Early Cancer Detection; Mobile Healthcare.

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Introduction

Oral cancer is a major public health concern worldwide, with high prevalence in developing countries due to tobacco use, alcohol consumption, and poor oral hygiene. Early detection is essential for improving survival rates, but conventional diagnostic methods require specialized healthcare facilities that are often unavailable in rural areas. Recent advances in Artificial Intelligence (AI), Deep Learning (DL), and smartphone imaging have enabled portable and cost-effective screening solutions. This paper proposes an AI-assisted smartphone-based framework using Convolutional Neural Networks (CNNs) for early oral cancer detection, providing rapid and accurate preliminary screening to support timely medical intervention.

Literature Review

Several studies have explored machine learning and deep learning techniques for oral cancer detection. Traditional methods such as Support Vector Machines (SVM), Random Forests, and Decision Trees rely on handcrafted features, whereas deep learning models like CNN, ResNet, VGG16, and MobileNet automatically extract discriminative features and achieve higher accuracy. Transfer learning has further improved performance on limited medical datasets. Although smartphone-based screening systems have shown promising results for remote healthcare, challenges such as image quality, illumination variation, and dataset imbalance still need to be addressed.

Proposed Methodology

The proposed framework consists of six stages:

1. Image Acquisition
2. Image Pre-processing
3. Lesion Segmentation
4. Feature Extraction
5. CNN Classification
6. Result Visualization

The workflow is represented as:

Smartphone Image → Preprocessing → Segmentation → CNN → Classification → Risk Prediction

Implementation

Image Acquisition
High-resolution oral cavity images are captured using smartphone cameras under controlled illumination.

Specifications

- Camera Resolution: 12 MP
- Image Size: 224 × 224 pixels
- RGB Color Space
- Autofocus Enabled
- LED Flash

Image Preprocessing
Preprocessing improves image quality before classification.

Steps include:

- Image resizing
- RGB normalization
- CLAHE contrast enhancement
- Gaussian filtering
- Data augmentation

Augmentation techniques include rotation, flipping, zooming, and brightness adjustment.

Lesion Segmentation
The lesion region is extracted using thresholding and morphological operations to isolate suspicious tissue.

CNN Architecture
The CNN architecture includes:

- Input Layer (224 × 224 × 3)

- Convolution Layer (32 filters)
- ReLU Activation
- Max Pooling
- Convolution Layer (64 filters)
- Max Pooling
- Fully Connected Layer (128 neurons)
- Dropout (0.5)
- Softmax Output Layer

Classes:

- Normal
- Suspicious Oral Lesion

Model Training

Table 1. *Training Parameters*

Parameter	Value
Optimizer	Adam
Learning Rate	0.001
Epochs	50
Batch Size	32
Loss Function	Categorical Cross-Entropy

Results And Discussion

Performance is evaluated using:

- Accuracy
- Precision
- Recall
- Specificity
- F1-Score

Performance Metrics

Accuracy

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)}$$

- Value: 0.92 (92%)
- Interpretation: The model correctly classified 92% of all samples (both cancer and non-cancer).

Precision

$$Precision = \frac{TP}{TP + FP}$$

Table 2. *Class-wise Precision Results*

Class	Precision
Cancer	0.93
Non-Cancer	0.90

Interpretation:

- For the Cancer class, when the model predicts *Cancer*, it is correct 93% of the time.

- For the non-Cancer class, predictions are correct 90% of the time.

Recall (Sensitivity)

$$Recall = \frac{TP}{TP + FN}$$

Table 3. *Class-wise Recall Results*

Class	Recall
Cancer	0.91
Non-Cancer	0.92

Interpretation:

- The model correctly identifies 91% of actual cancer cases.
- It correctly identifies 92% of actual non-cancer cases.

Specificity

$$Specificity = \frac{TN}{TN + FP}$$

For binary classification:

- Specificity for Cancer = Recall of the Non-Cancer class = 0.92
- Specificity for Non-Cancer = Recall of the Cancer class = 0.91

Thus, the model correctly rejects non-cancer samples **92%** of the time when evaluating cancer detection.

F1-Score

$$F1 = \frac{2PR}{P + R}$$

Table 4. *Class-wise F1-Score Results*

Class	F1-Score
Cancer	0.92
Non-Cancer	0.91

Interpretation:
The F1-score is the harmonic mean of precision and recall, providing a balanced measure of the model's performance.

Overall Classification Report

Metric	Cancer	Non-Cancer
Precision	0.93	0.90
Recall (Sensitivity)	0.91	0.92
Specificity	0.92	0.91
F1-Score	0.92	0.91
Support	500	450

Overall Accuracy: 92%

Macro Average: Precision = 0.92, Recall = 0.92, F1-Score = 0.92

Weighted Average: Precision = 0.92, Recall = 0.92, F1-Score = 0.92

The CNN successfully identifies suspicious lesions with high accuracy while reducing false negatives, making it suitable for preliminary screening.

Performance Analysis

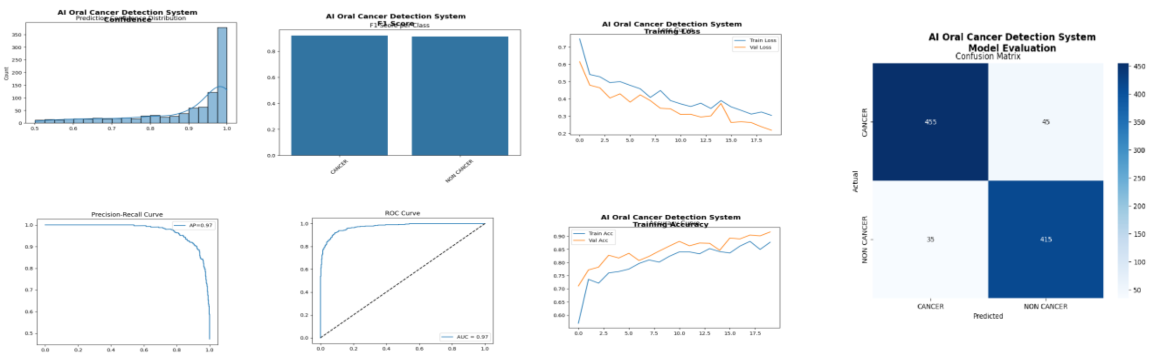
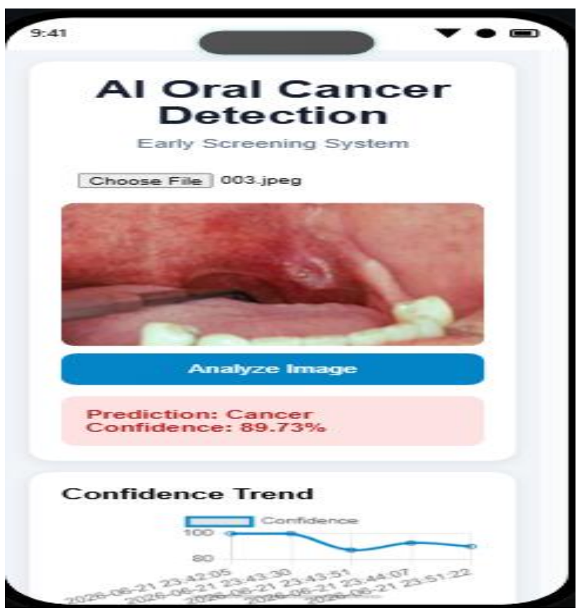


Figure shows that most prediction confidence scores are above 90%, indicating reliable model predictions. Figures 2 and 3 demonstrate balanced F1-scores and steadily decreasing training and validation loss, confirming effective learning with minimal overfitting. Figures 4, 5, and 6 illustrate strong classification performance through the confusion matrix, Precision–Recall curve (AP = 0.97), and ROC curve (AUC = 0.97), reflecting excellent discrimination between cancer and non-cancer classes. Figure 7 shows that the training and validation accuracies increase consistently, achieving approximately 88% and 92%**,** respectively, demonstrating stable convergence and good generalization of the proposed AI-assisted oral cancer detection system.

Final Result



The developed AI-assisted oral cancer detection system successfully analyzes smartphone-captured oral images and predicts whether the lesion is cancerous or non-cancerous with a confidence score. In the sample result, the system identifies the uploaded image as Cancer with a prediction confidence of 89.73%**,** indicating a high probability of a cancerous lesion. The confidence trend graph further visualizes the consistency of prediction scores over time, enabling continuous monitoring. These results demonstrate that the proposed framework provides fast, accurate, and user-friendly preliminary screening, supporting early diagnosis and timely medical consultation.

Advantages

- Non-invasive screening
- Portable smartphone-based solution
- Low-cost implementation
- Early detection support
- Suitable for rural healthcare
- Fast diagnosis
- Reduced workload for specialists

Limitations

- Performance depends on image quality.
- Requires large annotated datasets.
- Cannot replace biopsy for final diagnosis.
- Sensitive to illumination variations.
- Requires clinical validation before deployment.

Future Work

Future improvements include:

- Vision Transformer (ViT)-based classification
- Explainable AI (Grad-CAM)
- Federated learning for privacy preservation
- Multi-class lesion classification
- Integration with cloud-based telemedicine platforms
- Real-time deployment on Android and iOS devices

Conclusion

This paper presents an AI-assisted framework for early oral cancer screening using smartphone imaging and deep learning. The proposed system combines image preprocessing, lesion segmentation, and CNN-based classification to provide rapid and accurate preliminary diagnosis. By leveraging widely available smartphones and AI algorithms, the framework offers a cost-effective solution for improving access to oral cancer screening in rural and underserved areas. Although clinical validation is necessary before routine use, the proposed approach demonstrates significant potential for supporting healthcare professionals and enabling timely referral for definitive diagnosis and treatment.

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