

Early Oral Cancer Detection with AI: Design and Implementation of A Deep Learning Image-Based Chatbot

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Abstract: *Oral cancer is one of the leading causes of cancer-related deaths worldwide, primarily because the disease is often identified at an advanced stage. Early diagnosis plays a vital role in improving treatment effectiveness, patient survival rates, and overall healthcare outcomes. However, limited awareness, shortage of specialized medical facilities, and delayed clinical consultation continue to create significant challenges, especially in rural and underserved regions. To address these issues, this study proposes an Artificial Intelligence (AI)-based chatbot system for the early detection and preliminary assessment of oral cancer using deep learning and medical image analysis techniques.*

The proposed system combines deep learning models, Natural Language Processing (NLP), and conversational healthcare support to create an intelligent and user-friendly screening platform. The chatbot allows users to upload oral cavity images and interact through symptom-based conversations. Multiple Convolutional Neural Network (CNN) architectures, including CNN, DenseNet121, DenseNet169, DenseNet201, and InceptionV3, were implemented and evaluated for oral lesion classification.

Keywords: Artificial Intelligence (AI), Oral Cancer Detection, Deep Learning, Convolutional Neural Network (CNN), InceptionV3, DenseNet, Medical Image Analysis, Healthcare Chatbot, Natural Language Processing (NLP), Class Activation Mapping (CAM), Early Diagnosis

I. INTRODUCTION

Oral cancer is one of the most serious health problems affecting millions of people worldwide. It mainly develops in the tissues of the mouth, tongue, lips, cheeks, throat, and oral cavity. The disease has become a major public health concern because it is often diagnosed at an advanced stage, resulting in high mortality and reduced survival rates. Early symptoms such as mouth ulcers, white or red patches, swelling, and persistent pain are frequently ignored by patients, leading to delayed treatment and severe health complications. The increasing consumption of tobacco, alcohol, betel nut products, and poor oral hygiene are considered major risk factors responsible for the rapid growth of oral cancer cases across many countries [1].

Early detection of oral cancer plays a significant role in improving treatment success and reducing mortality rates. Traditional diagnostic methods such as biopsy testing, clinical examination, histopathological analysis, and medical imaging are commonly used for oral cancer diagnosis. Although these methods provide reliable clinical results, they are often expensive, time-consuming, and dependent on specialist healthcare professionals. In many rural and underserved regions, access to oncologists and advanced healthcare facilities remains limited, which further increases the risk of delayed diagnosis and poor patient outcomes [2].

Recent developments in Artificial Intelligence (AI) and Deep Learning (DL) technologies have transformed modern healthcare systems by enabling automated disease detection and intelligent medical image analysis. AI-based healthcare systems are capable of analysing large amounts of medical data rapidly and accurately. Deep learning



models, especially Convolutional Neural Networks (CNNs), have shown remarkable performance in image classification, feature extraction, and disease prediction tasks. These technologies are increasingly being used in healthcare applications such as skin cancer detection, diabetic retinopathy diagnosis, radiology, and pathology analysis [3].

Convolutional Neural Networks are widely used in medical imaging because of their ability to automatically extract complex visual features from healthcare images. Advanced CNN architectures such as DenseNet, ResNet, EfficientNet, and InceptionV3 have demonstrated high efficiency in detecting abnormalities within medical datasets. In oral cancer diagnosis, these models can analyse oral lesion images and classify them into cancerous and non-cancerous categories with considerable accuracy. The use of deep learning helps improve diagnostic speed, reduce manual effort, and support healthcare professionals in clinical decision-making [4].

Healthcare chatbots powered by Natural Language Processing (NLP) have also become important digital healthcare tools in recent years. Chatbots are intelligent conversational systems that interact with users through text or voice communication. In healthcare environments, chatbots are used for symptom checking, appointment scheduling, patient counselling, healthcare education, and disease awareness. NLP techniques enable these systems to understand user queries and generate meaningful responses in a human-like conversational manner [5].

II. PROBLEM STATEMENT

Oral cancer is a rapidly growing global health problem that causes a large number of deaths every year due to delayed diagnosis and lack of timely treatment. Many patients fail to recognize the early symptoms of oral cancer, such as ulcers, red or white patches, swelling, and persistent mouth pain, resulting in diagnosis at advanced stages when treatment becomes more difficult, expensive, and less effective. In many rural and underserved regions, access to specialized healthcare professionals and diagnostic facilities is limited, which further increases the risk of late detection and poor survival rates.

III. OBJECTIVES

1. To design and implement a user-friendly chatbot capable of analysing oral lesion images through deep learning models.
2. To evaluate the performance of different convolutional neural network (CNN) architectures such as CNN, DenseNet121, DenseNet169, DenseNet201, and InceptionV3 for oral cancer classification.
3. To identify the best-performing deep learning model based on evaluation metrics including accuracy, sensitivity, specificity, diagnostic odds ratio (DOR), and Cohen's Kappa.
4. To integrate Natural Language Processing (NLP) with image-based analysis for interactive symptom assessment and patient guidance.
5. To implement Class Activation Mapping (CAM) techniques for highlighting suspicious lesion regions and improving model interpretability.

IV. LITERATURE SURVEY

1. "Early Oral Cancer Detection with AI: Design and Implementation of a Deep Learning Image-Based Chatbot" — Ormeño-Arriagada P., Márquez G., Taramasco C., Gatica G., Vasconez J.P., Navarro E. (2025), Applied Sciences.

Ormeño-Arriagada et al. (2025) proposed an Artificial Intelligence-based chatbot system for early oral cancer detection using deep learning and conversational technologies. The study integrated Convolutional Neural Networks (CNNs), Natural Language Processing (NLP), and Class Activation Mapping (CAM) to create a patient-centred healthcare support platform capable of analysing oral lesion images and providing probability-based feedback. The research evaluated multiple deep learning architectures including CNN, DenseNet121, DenseNet169, DenseNet201, and InceptionV3 using publicly available oral cancer datasets collected from Kaggle and Roboflow. The preprocessing



stage involved image resizing, noise reduction, duplicate removal, and dataset partitioning to improve model reliability and classification performance.

2. “A Guide to Deep Learning in Healthcare” — Esteva A., Robicquet A., Ramsundar B., Kuleshov V., DePristo M., Chou K., Cui C., Corrado G., Thrun S., Dean J. (2019), Nature Medicine.

Esteva et al. (2019) presented a comprehensive overview of deep learning applications in healthcare and discussed how AI technologies are transforming medical diagnosis and patient care. The study highlighted the role of Convolutional Neural Networks (CNNs) in medical image analysis for diseases such as skin cancer, diabetic retinopathy, and radiological abnormalities. The researchers explained that deep learning models can automatically extract complex features from large-scale healthcare datasets and provide high diagnostic accuracy. The study emphasized the importance of data-driven healthcare systems capable of improving clinical decision-making and reducing diagnostic errors.

3. “Natural Language Processing: State of the Art, Current Trends and Challenges” — Khurana D., Koli A., Khatter K., Singh S. (2023), Multimedia Tools and Applications.

Khurana et al. (2023) reviewed the advancements in Natural Language Processing (NLP) and its growing importance in conversational AI systems and healthcare applications. The study explained how NLP enables machines to understand, process, and generate human language for intelligent communication. The research discussed various NLP frameworks and techniques such as tokenization, sentiment analysis, machine translation, and chatbot development. It highlighted the increasing use of NLP-based healthcare chatbots for patient counselling, symptom checking, mental health support, and medical information delivery. The paper also emphasized the role of AI-powered conversational agents in improving healthcare accessibility and user engagement.

4. “Artificial Intelligence–Based Chatbots for Promoting Health Behavioral Changes: Systematic Review” — Aggarwal A., Tam C.C., Wu D., Li X., Qiao S. (2023), Journal of Medical Internet Research.

Aggarwal et al. (2023) conducted a systematic review of AI-based healthcare chatbots designed to promote behavioural and lifestyle changes among patients. The study analysed various chatbot systems used for disease awareness, chronic disease management, smoking cessation, and mental health improvement. The research concluded that AI-powered chatbots can effectively increase user engagement, improve healthcare awareness, and encourage preventive healthcare practices through personalized communication. The study highlighted the advantages of chatbots such as 24/7 accessibility, reduced healthcare burden, and real-time guidance. It also emphasized the integration of machine learning and NLP technologies to improve user interaction quality. However, the review identified several limitations including lack of clinical validation, data privacy concerns, and limited diagnostic capabilities in existing chatbot systems.

V. PROPOSED OF SYSTEM

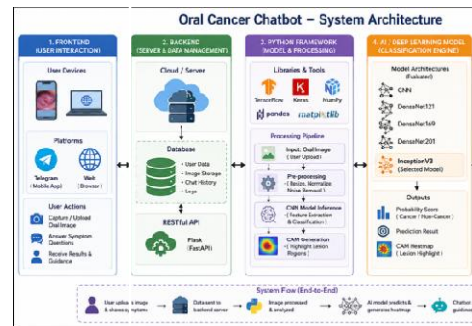


Fig 1: Block Diagram



A. Frontend Module (User Interaction)

The frontend module acts as the user interaction layer of the oral cancer chatbot system and provides a simple, responsive, and user-friendly interface through which users can communicate with the chatbot using smartphones, tablets, or web browsers. The module supports platforms such as Telegram and web-based applications, allowing users to upload oral lesion images and answer symptom-related questions regarding swelling, ulcers, mouth pain, or oral discomfort. It also displays prediction results, probability scores, healthcare recommendations, and awareness information generated by the AI system. The frontend is designed to ensure accessibility, smooth interaction, and easy communication for users with minimal technical knowledge while improving healthcare accessibility in remote and underserved regions

B Backend Module (Server & Data Management)

The backend module serves as the central processing and coordination layer of the oral cancer chatbot system by managing server-side operations, communication handling, and secure data storage. It connects the frontend interface with the AI-based deep learning framework and ensures smooth communication between all system components through RESTful APIs developed using Flask or FastAPI. The backend stores uploaded oral images, user records, chat history, and system logs securely using cloud/server infrastructure. It also transfers uploaded images to the AI processing framework for analysis and returns prediction results to the chatbot interface. This module plays an important role in maintaining data privacy, scalability, reliability, and efficient real-time response generation.

C. Python Framework Module (Model & Processing)

The Python framework module functions as the computational engine of the oral cancer detection system and is responsible for image preprocessing, machine learning implementation, and deep learning-based image analysis. The module uses Python libraries such as TensorFlow, Keras, NumPy, Pandas, and Matplotlib for implementing AI operations and healthcare analytics. When a user uploads an oral image, preprocessing operations such as resizing, normalization, and noise reduction are performed to improve image quality and maintain consistency for model inference. The processed image is then passed through the CNN inference stage, where important visual features are extracted and classified into cancerous or non-cancerous categories. The module also generates Class Activation Mapping (CAM) heatmaps to visually highlight suspicious lesion regions responsible for predictions, thereby improving explainability and transparency.

D Deep Learning Model Module (Classification Engine)

The AI/Deep Learning module acts as the intelligent classification engine of the chatbot system and contains multiple deep learning architectures trained to classify oral lesion images into cancerous and non-cancerous categories. The evaluated architectures include CNN, DenseNet121, DenseNet169, DenseNet201, and InceptionV3, among which InceptionV3 achieved the highest performance in terms of accuracy, sensitivity, specificity, and Diagnostic Odds Ratio. The module analyses uploaded oral images using advanced convolutional operations and feature extraction techniques to identify abnormal lesion patterns and generate probability-based prediction results. It also produces CAM heatmap visualizations that highlight suspicious image regions influencing the prediction outcome, thereby improving interpretability and user trust in the AI system.

E Chatbot & Output Module (Response to User)

The chatbot and output module is responsible for generating conversational responses and delivering healthcare guidance based on AI-generated prediction results. This module integrates Natural Language Processing (NLP) and conversational AI techniques to communicate effectively with users and provide educational information regarding oral cancer symptoms, risk factors, and preventive healthcare measures. The chatbot manages conversation flow, understands user queries, and delivers probability-based prediction results along with personalized healthcare recommendations and doctor consultation suggestions. The output is provided through Telegram or web interfaces, ensuring accessibility across multiple devices. This module improves user engagement by transforming technical AI predictions into understandable healthcare guidance and encouraging timely medical consultation.



F Hardware Requirements

The oral cancer detection chatbot system requires suitable hardware resources to support deep learning training, medical image analysis, and real-time communication. The recommended hardware configuration includes an Intel Core i5 or AMD Ryzen 5 processor or higher, a minimum of 8 GB RAM, and at least 256 GB SSD storage for efficient processing and data management. GPU support is recommended to accelerate deep learning model training and improve computational performance. Additional hardware components such as a smartphone or webcam are required for capturing oral cavity images, while a stable internet connection is necessary for cloud communication, chatbot interaction, and real-time data transfer within the healthcare system.

VI. SYSTEM DESIGN

A. Frontend Design

The frontend of the proposed oral cancer detection chatbot system is designed to provide a simple, interactive, and user-friendly interface for patients and general users. The system supports communication through smartphones, tablets, and web browsers, allowing users to access healthcare assistance conveniently from different locations. Through the frontend interface, users can upload oral cavity images, answer symptom-related questions, and receive AI-generated healthcare guidance. The interface displays prediction results, probability scores, awareness information, and medical recommendations in an understandable format. The frontend is developed to ensure smooth navigation, responsive performance, and accessibility for users with minimal technical knowledge, thereby improving healthcare reach in remote and underserved areas.

B. Backend Design

The backend design acts as the central communication and processing layer of the chatbot system. It is responsible for handling server-side operations, API communication, user request management, and secure data storage. The backend connects the frontend interface with the AI and deep learning modules, ensuring efficient transfer of oral lesion images and prediction results. RESTful APIs developed using Flask or FastAPI enable real-time communication between different system components.

C. Image Processing and Python Framework Design

The image processing and Python framework design forms the computational core of the proposed system. This module is responsible for preprocessing oral lesion images, implementing machine learning operations, and managing deep learning inference processes. Python libraries such as TensorFlow, Keras, NumPy, Pandas, and Matplotlib are integrated to support healthcare analytics and AI model execution. The uploaded images undergo preprocessing operations including resizing, normalization, noise reduction, and image enhancement to improve classification quality and consistency. After preprocessing, the images are passed to the deep learning framework for feature extraction and prediction.

D. AI and Deep Learning Model Design

The AI and deep learning model design represents the intelligent classification engine of the oral cancer detection chatbot system. Multiple deep learning architectures including CNN, DenseNet121, DenseNet169, DenseNet201, and InceptionV3 are implemented and trained using oral cancer image datasets collected from Kaggle and Roboflow. These models analyse oral lesion images and classify them into cancerous and non-cancerous categories using advanced convolutional operations and feature extraction techniques.

E. Chatbot and Output Design

The chatbot and output design focuses on generating conversational healthcare responses and delivering prediction-based guidance to users. This module integrates Natural Language Processing (NLP) and conversational AI techniques to communicate effectively with users and provide healthcare awareness regarding oral cancer symptoms and preventive measures. The chatbot understands user queries, manages conversation flow, and generates personalized responses based on AI prediction results. The output includes probability-based oral cancer risk assessment, healthcare recommendations, awareness information, and doctor consultation suggestions.



VII. RESULTS

Diagnostic Odds Ratio Comparison

The accuracy comparison graph represents the overall classification performance of different deep learning models used for oral cancer detection. The graph shows that InceptionV3 achieved the highest accuracy among all evaluated architectures, demonstrating superior capability in correctly classifying oral lesion images into cancerous and non-cancerous categories. DenseNet169 and DenseNet201 also produced comparatively good performance due to their efficient feature extraction mechanisms. The accuracy comparison graph demonstrates that InceptionV3 outperformed all other deep learning models. Its superior feature extraction capability and multi-scale convolutional operations enabled more accurate classification of oral lesion images. DenseNet169 and DenseNet201 also achieved relatively good accuracy due to their dense layer connectivity and improved learning efficiency

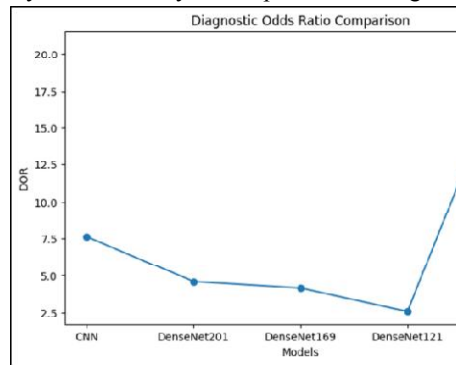


Fig 2: Graph 1

Sr. No.	Deep Learning Model	Accuracy (%)
1	CNN	65.06
2	DenseNet121	68.94
3	DenseNet169	73.36
4	DenseNet201	71.45
5	InceptionV3	77.65

Specificity Comparison Graph

The specificity comparison graph illustrates the ability of each deep learning model to correctly identify non-cancerous oral lesion images. Higher specificity indicates lower false positive predictions and improved reliability in distinguishing healthy tissues from suspicious lesions. The graph demonstrates that InceptionV3 achieved the highest specificity value, indicating better discriminative capability compared to the remaining models. DenseNet architectures showed moderate specificity performance, while DenseNet121 achieved the lowest specificity value.

Sr. No.	Deep Learning Model	Specificity (%)
1	CNN	57.05
2	DenseNet121	42.92
3	DenseNet169	50.81
4	DenseNet201	48.44
5	InceptionV3	77.68

From the graph, InceptionV3 achieved the highest specificity value of 77.68%, which clearly indicates its superior performance in correctly classifying non-cancerous cases. This shows that InceptionV3 has strong discriminative capability and produces fewer false positive predictions compared to the other models. The CNN model achieved moderate specificity with 57.05%, while DenseNet169 and DenseNet201 showed lower specificity values of 50.81%



and 48.44% respectively DenseNet121 produced the lowest specificity value of 42.92%, indicating weaker performance in differentiating non-cancerous lesions

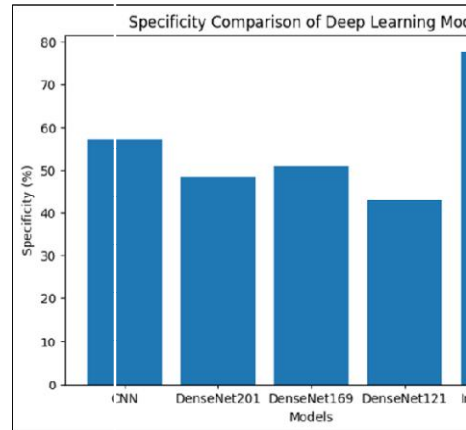


Fig 3: Graph 2

Sensitivity Comparison Graph

The sensitivity comparison graph represents the capability of each deep learning model to correctly identify cancerous oral lesion images. Sensitivity is an important evaluation metric in healthcare applications because it measures how effectively the model detects actual positive cancer cases. The graph shows that InceptionV3 achieved the highest sensitivity value, demonstrating strong capability in detecting suspicious oral cancer lesions accurately.

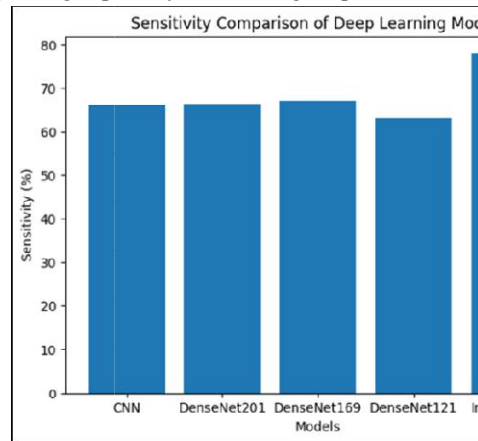


Fig 3: Graph 3

Sr. No.	Deep Learning Model	Sensitivity (%)
1	CNN	65.90
2	DenseNet121	63.01
3	DenseNet169	67.05
4	DenseNet201	66.21
5	InceptionV3	78.02

VIII. CONCLUSION

The proposed Artificial Intelligence-based oral cancer detection chatbot system demonstrates the significant potential of integrating Deep Learning, Natural Language Processing, and conversational healthcare technologies for early



disease screening and healthcare awareness. Oral cancer remains one of the major global health concerns due to delayed diagnosis, lack of awareness, and limited access to specialist healthcare services in many rural and underserved regions. The developed system addresses these challenges by providing an intelligent, accessible, and user-friendly platform capable of analysing oral lesion images and offering preliminary healthcare guidance through an interactive chatbot interface..

IX. FUTURE SCOPE

The proposed Artificial Intelligence-based oral cancer detection chatbot system provides a strong foundation for future advancements in digital healthcare and intelligent disease screening technologies. Although the current system demonstrates promising performance in oral lesion classification and healthcare guidance, several improvements and extensions can be implemented to enhance its accuracy, scalability, and real-world clinical applicability. Future research can focus on integrating more advanced Artificial Intelligence models, improving dataset quality, and expanding healthcare functionalities to create a more reliable and efficient healthcare support system.

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