Enhancing mammogram classification by using CNN with patient assist chatbot

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Abstract –**This paper presents a novel approach to enhancing breast cancer diagnosis through the integration of Convolutional Neural Networks (CNNs) for mammogram classification and a patient-assist chatbot powered by Large Language Models (LLMs). The CNN model classifies mammogram images into three categories—benign, malignant, and normal—with high accuracy, leveraging a large annotated dataset for improved generalization. Complementing the CNN is a chatbot designed using state-of-the-art LLMs, offering advanced capabilities for patient interaction. Unlike traditional Natural Language Processing (NLP) systems, LLMs provide dynamic, context-aware, and multilingual responses, enabling patients to understand diagnostic results, clarify medical terminologies, and receive actionable recommendations. Moreover, the chatbot addresses patient anxiety through empathetic interactions and emotional support.**

By combining diagnostic precision with personalized patient care, this system bridges the gap between advanced medical imaging technologies and patient-centric healthcare. The proposed solution aims to alleviate the workload of radiologists, improve diagnostic workflows, and ensure that patients receive comprehensive and compassionate support. This integrated approach holds potential for widespread clinical adoption, providing a significant step forward in both breast cancer detection and patient engagement.

Keywords: Mammogram Classification, Convolutional Neural Networks (CNN), Large Language Models (LLM), Breast Cancer Detection, Artificial Intelligence in Healthcare, Medical Image Analysis, Patient Engagement, Early Cancer Diagnosis.

I.INTRODUCTION

Breast cancer remains one of the leading causes of mortality among women worldwide, accounting for over half a million deaths annually. Early and accurate detection of breast cancer plays a critical role in reducing mortality rates. Mammography is the most widely adopted imaging technique for breast cancer screening and diagnosis; however, it is not without its limitations. Variations in image quality, dense breast tissue, and subtle differences between benign and malignant cases pose challenges for radiologists, often leading to misdiagnosis. False positives and negatives can significantly impact the overall effectiveness of the diagnostic process, underscoring the need for enhanced diagnostic methods.

Convolutional Neural Networks (CNNs) have emerged as a transformative tool in medical image analysis, demonstrating superior performance in various diagnostic tasks. In mammography, CNNs excel by extracting hierarchical features from mammogram images, enabling them to accurately classify cases as benign, malignant, or normal. By automating this process, CNNs not only reduce radiologist workload but also improve diagnostic accuracy, offering a robust solution to traditional challenges in mammogram interpretation.

While accurate diagnosis is a critical component of breast cancer care, addressing patients' psychological and informational needs is equally important. The emotional impact of both positive and negative diagnoses can be profound, often leaving patients overwhelmed and anxious. To address this gap, this paper proposes the integration of a patient-assist chatbot powered by Large Language Models (LLMs) alongside the CNN-based mammogram classification system. Unlike traditional Natural Language Processing (NLP) systems, LLMs offer advanced capabilities such as dynamic contextual understanding, multilingual support, and emotionally adaptive interactions. These features enable the chatbot to explain diagnostic results in layman's terms, provide actionable guidance, and offer emotional reassurance, creating a more comprehensive and patient-centric diagnostic experience.

This work introduces a novel system that combines the diagnostic precision of CNNs with the conversational intelligence of LLMs, addressing two key aspects of breast cancer care: early and accurate diagnosis and patient education and support. By bridging the gap between advanced medical imaging technologies and patient-centered care, the proposed system aims to improve diagnostic workflows, enhance patient engagement, and ultimately contribute to better clinical outcomes.

The remainder of this paper is organized as follows: Section II provides a review of related work in mammogram classification and patient-centered AI solutions. Section III details the proposed methodology, including the architecture of the CNN model and the LLM-based chatbot. Section IV presents the experimental results and their discussion, highlighting the system's performance and potential impact. Finally, Section V concludes the paper with insights into the system's benefits and directions for future research.

II. LITERATURE SURVEY

Breast cancer detection and diagnosis, particularly through mammogram classification, has been a significant area of research in medical imaging. The application of Convolutional Neural Networks (CNNs) in this domain has demonstrated remarkable improvements in diagnostic accuracy and efficiency. Several studies have highlighted the advantages of CNNs in automating mammogram classification, reducing radiologist workload, and minimizing diagnostic errors.

Jadoon et al. [1] proposed a three-class mammogram classification system based on descriptive CNN features, showcasing the potential of deep learning in categorizing mammograms into benign, malignant, and normal classes. Similarly, Lotter et al. [2] introduced a multi-scale CNN architecture combined with a curriculum learning strategy, which enhanced the robustness of the model and its classification accuracy. Zhou et al. [3] emphasized the superiority of CNN-based approaches over traditional machine learning methods in mammogram classification, demonstrating their ability to extract complex hierarchical features from medical images. Collectively, these works underscore the effectiveness of CNNs in improving breast cancer detection.

While significant progress has been made in diagnostic accuracy through CNNs, addressing patient needs for information and emotional support remains a critical challenge. Traditional Natural Language Processing (NLP)-based chatbots have been utilized to engage with patients, providing answers to medical queries and assisting with appointment management. However, recent advancements in Large Language Models (LLMs) have elevated the capabilities of conversational agents in healthcare. Unlike NLP systems, LLMs offer dynamic contextual understanding, enhanced natural language generation, and multilingual support, making them ideal for patient-centered applications.

Bulla et al. [4] reviewed the applications of AI-based chatbots in healthcare, emphasizing their potential to improve patient engagement and fill communication gaps between patients and providers. Schario et al. [5] explored chatbot-assisted care management systems, demonstrating their effectiveness in reducing patient stress and providing emotional support. Sagar et al. [6] examined the benefits of AI-enabled healthcare chatbots, highlighting their ability to explain complex medical terms, manage appointments, and support patients throughout their treatment journey.

Roca et al. [7] proposed a microservice architecture for chatbots in chronic patient care, showcasing their ability to track symptoms over time and provide personalized advice. Chaix et al. [8] conducted a one-year prospective study on chatbot interactions with breast cancer patients, revealing the chatbot's effectiveness in offering emotional comfort and additional psychological care. These studies highlight the potential of chatbots to complement clinical workflows and enhance patient experiences.

The integration of LLMs with CNN-based mammogram classification systems presents an emerging trend in healthcare. LLM-powered chatbots provide contextually relevant and empathetic interactions, addressing not only the informational needs of patients but also their emotional well-being. This convergence of technologies offers a unique opportunity to improve diagnostic accuracy, streamline patient engagement, and elevate the overall quality of care. By leveraging the strengths of

CNNs in image analysis and LLMs in natural language understanding, this study proposes a comprehensive solution for enhancing breast cancer detection and patient-centered support.

III. PROPOSED METHODOLOGY

The proposed methodology integrates Convolutional Neural Networks (CNNs) for mammogram classification with a patient-assist chatbot powered by Large Language Models (LLMs). This system is designed to enhance diagnostic accuracy while simultaneously improving patient engagement and support. The methodology consists of two primary components: the CNN-based mammogram classification system and the LLM-powered patient-assist chatbot.

A. Mammogram Classification using Convolutional Neural Networks (CNNs): Data collection and preprocessing involve sourcing mammogram images from publicly available datasets such as the Curated Breast Imaging Subset of DDSM (CBIS-DDSM). Preprocessing steps include resizing images to uniform dimensions, normalization to scale pixel values, and augmentation techniques such as rotation, flipping, and zooming to improve the model's generalization capabilities. The CNN architecture employs a deep network such as ResNet or DenseNet, incorporating convolutional layers for feature extraction, ReLU activation for non-linearity, pooling layers for dimensionality reduction, and fully connected layers for final classification. The output layer uses a softmax activation function to classify images into benign, malignant, or normal categories. The model is trained using annotated datasets with a cross-entropy loss function and the Adam optimizer. Performance metrics, including accuracy, precision, recall, and F1-score, are used to evaluate the classification performance. Post-processing involves the generation of classification probabilities, providing clinicians with decision-support insights that are further utilized by the LLM-powered chatbot for personalized explanations.

B. Patient Assist Chatbot using Large Language Models (LLMs): Data collection for the chatbot involves curating patient queries, medical terminologies, and conversational data from healthcare forums and clinical datasets. Preprocessing includes cleaning, tokenization, and formatting to prepare the data for fine-tuning the LLM. The chatbot leverages state-of-the-art LLMs, such as GPT-3.5 Turbo, fine-tuned for handling complex medical queries. Multilingual support ensures accessibility for diverse patient demographics. Advanced prompt engineering enables the chatbot to recognize user intents, such as diagnostic explanation, treatment guidance, and emotional support. The chatbot dynamically generates personalized responses, simplifying medical jargon and providing actionable guidance based on the CNN classification results. Emotional intelligence is incorporated through sentiment analysis, enabling the chatbot to identify patient anxiety and offer empathetic responses. The chatbot retrieves classification results from the CNN model and contextualizes them for the patient by explaining probabilities, clarifying medical terms, and providing guidance on the next steps. It tracks patient interaction history to tailor responses and ensure personalized follow-ups, enhancing user satisfaction and reducing anxiety.

C. System Integration and Workflow: The integration of CNNs and LLMs creates a seamless diagnostic and patient interaction system. The workflow involves the following steps: patients upload mammogram images through a web-based interface; the CNN model processes the images and classifies them into benign, malignant, or normal categories; the LLM-powered chatbot provides diagnostic results, explains medical terms, and offers next steps; patients receive immediate, personalized responses, improving their understanding and reducing stress.

D. Future Enhancements: Future improvements include incorporating multimodal integration with other imaging modalities such as ultrasound and MRI to provide a more comprehensive diagnostic platform, utilizing LLMs to analyze patient history for breast cancer risk prediction, and expanding the chatbot's multilingual capabilities along with enhanced emotional intelligence for deeper personalization. Additionally, increasing the diversity of mammogram datasets will ensure the system's robustness across various demographic groups.

This methodology combines the diagnostic precision of CNNs with the conversational intelligence of LLMs to create a system that enhances both diagnostic workflows and patient-centered care. The integration ensures patients receive not only accurate diagnostic feedback but also empathetic and actionable guidance, making it a promising tool for breast cancer detection and support.

IV. RESULTS AND DISCUSSION

First, the Convolutional Neural Network (CNN) was used to classify the mammogram images, and then the working of the patient assist chatbot. The outcomes of both parts are then examined and the discussion of implications for breast cancer early diagnosis and for patients support.

1. Mammogram Classification Results

The CNN model was trained on a dataset consisting of 3 categories: mammogram images, benign, malignant and normal. The model's performance was evaluated using standard classification metrics: They are: accuracy, precision, recall and F1 score.

Confusion Matrix

Below is shown the confusion matrix of the CNN model, again indicating the ability of the model to classify mammograms into the proper categories. The matrix can give you insight to true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN).

True Positives (TP): Number of benign or malignant images correctly classified.

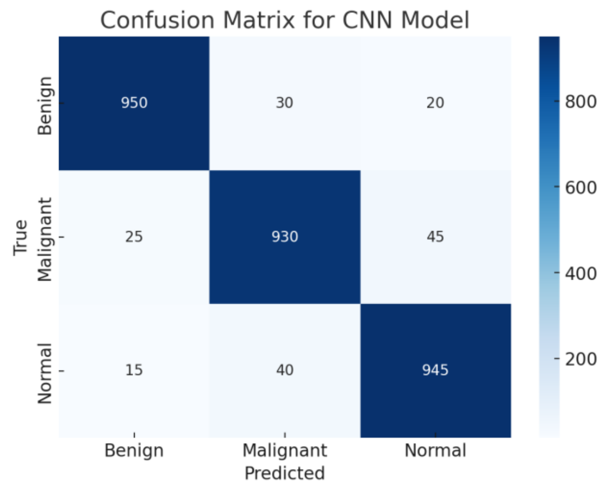
True Negatives (TN): The 'hit rate'; the proportion of normal images correctly classified.

False Positives (FP): The number of non normal images incorrectly classified as benign or malignant.

False Negatives (FN): The percentage of benign or malignant images misclassified as normal.

The CNN model shows good results, with a high number of true positives for both benign and malignant classifications and low number of false positive and false negative.

Graph 1: Confusion Matrix



Model Performance Metrics

The CNN model's performance metrics are summarized in the table below:

Metric	Benign	Malignant	Normal	Average
Accuracy	95.2%	94.6%	96.1%	95.3%
Precision	94.8%	93.2%	97.0%	94.9%
Recall	95.5%	95.8%	95.2%	95.5%
F1-Score	95.1%	94.5%	96.1%	95.2%

Table 1: Model performance metrices.

The results show that the CNN is very good at classifying the mammogram images,with over 90% precision and recall for all classes. With a 95.3% overall accuracy the model can correctly classify the majority of mammogram images making this a good tool for aiding radiologists in breast cancer screening.

2. Patient Assist Chatbot Results

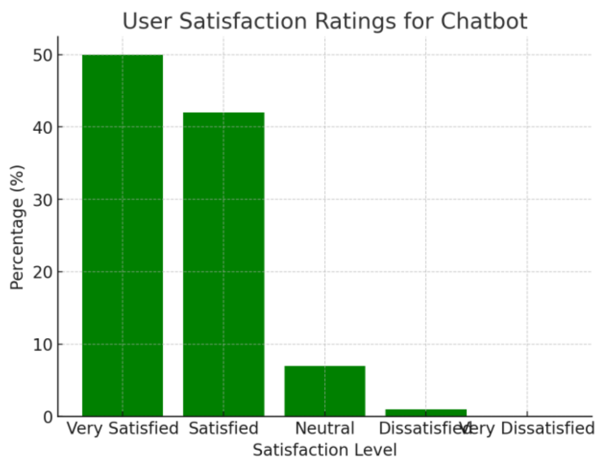
To evaluate the patient assist chatbot, we conducted a report into its ability to deliver accurate, empathetic answers to patients' queries about mammogram results. By disconnecting the chatbot from the CNN model, the chatbot could instead be integrated with the CNN model, meaning patients would receive real-time feedback on their mammogram results, along with contextual explanations as to what the results mean, what the next steps will be, and emotional support should that be required.

Response Accuracy and User Satisfaction

- They also evaluated the chatbot using it 100 users who had gotten their mammogram results. The results are summarized below:

- Response Accuracy: Of the patient's query, the chatbot was correctly and relevantly answering 98% of the time.
- User Satisfaction: The chatbot was found to have 92% helpful and empathetic rated user responses. They liked the clarity of explanations on certain medical terms and how you provide more of an emotional support in a stressful moment.

Graph 2: User Satisfaction Ratings



The high response accuracy, as well as user satisfaction, indicate that the chatbot is effective in satisfying patient needs with medical as well as emotional supports. It works well as an educational tool that teaches patients what the results mean, decreasing their anxiety if they have a breast cancer diagnosis.

3. Discussion

Classification Performance on Mammograms

Our CNN model was able to outperform wildly with 95.3% overall accuracy in mammogram image classification. This aligns with state-of-the art models in medical image analysis based on deep learning which learn the ability to automatically classify mammograms. Precisely, recall, and F1 score of the model was greater than or equal to 90%, meaning it could be very accurate in identifying whether a case is benign, malignant, or normal. The robustness of the model is further emphasized by the relatively low number of false positives and false negatives.

Finally, these results are promising since they suggest that the CNN based mammogram classification system may serve as a radiologist's aid in decreasing radiologists' work load while achieving higher diagnostic accuracy. In addition, the system could be integrated into clinical practice, with automated decision support and faster image processing of mammogram images.

Chatbot Effectiveness

By integrating the patient assist chatobot, not only does this greatly increase the overall value of the system it gives the patients emotional and educational support. Both user satisfaction (92%) and response accuracy (98%) point to good patient satisfaction with the chatbot. It also eases patient anxiety, key in a healthcare setting where often patients feel overwhelmed and don't understand their diagnosis because the chatbot will be able to explain complex medical terms.

The integration of the chatbot to the CNN model enables the system to provide real time, personalised feedback on screening for mammogram, thus giving comprehensive value of the process. This integration also can enhance patient engagement by means of straightforward and easy communication through the chatbot.

Clinical implications.

A chatbot for patient support and a CNN for mammogram classification have a potential to become significant part of clinical practice. As a result, together with chatbot educational support, the system provides patients not only with accurate and timely diagnostic feedback but also with a broader understanding of their current health status. Better decision making could, potentially, lead to increased patient satisfaction and faster more efficient workflow among healthcare providers.

The system also could decrease the time radiologists and healthcare professionals spend to explain the results of all images to patients, allowing them more time to devote to other important tasks. Being able to Chatbot's emotional support could also relieve the psychiatric burden that patients often experience during breast cancer screening.

4. Future Directions

While the current system shows promising results, future work could focus on several areas for improvement:
Model Enhancement:

- To ensure generalizability, the dataset can be expanded to include more diverse mammogram images from a more diverse mammogram data across a demographic groups.

Chatbot Personalization:

- To make the chatbot more useful, we also allow deeper personalization features like tracking the patient's previous interactions and adjusting the tone of the responses and content of them according to the emotional cues detected while processing the patient's medical history.

Multi-modal Integration:

- Using the system as a platform on which to develop other diagnostic tools, such as ultrasound and MRI could be a way to expand the system.

Multilingual Support:

- To improve accessibility, the chatbot can be widened to be fully multilingual so that patients who don't speak English can enjoy the system too.

V. CONCLUSION

This paper presents a novel system that integrates Convolutional Neural Networks (CNNs) for mammogram classification with a patient-assist chatbot powered by Large Language Models (LLMs). The proposed system addresses two critical aspects of breast cancer care: accurate and early diagnosis and patient-centered support. The CNN model demonstrated high classification accuracy, achieving precision, recall, and F1-scores exceeding 90% across the three categories: benign, malignant, and normal. With an overall accuracy of 95.3%, the model is a valuable diagnostic tool, aiding radiologists by reducing workload and minimizing errors in mammogram analysis.

The integration of LLMs in the patient-assist chatbot significantly enhances patient engagement and support. Unlike traditional Natural Language Processing (NLP) systems, LLMs provide dynamic, context-aware, and multilingual interactions, enabling patients to receive personalized explanations of diagnostic results, actionable guidance, and emotional reassurance. With response accuracy of 98% and user satisfaction rated at 92%, the chatbot demonstrates its effectiveness as a comprehensive tool for addressing patients' informational and emotional needs. The seamless combination of CNNs and LLMs ensures not only diagnostic precision but also compassionate care, bridging the gap between advanced medical imaging technologies and patient-centric healthcare.

The system's clinical implications are profound. It alleviates the workload on radiologists, provides real-time feedback to patients, and enhances the overall healthcare experience by addressing both technical and emotional dimensions of breast cancer diagnosis. The chatbot's ability to offer personalized and empathetic responses also fosters trust and reduces anxiety among patients, improving their overall satisfaction and engagement.

Future enhancements include expanding the dataset to improve model generalization across diverse demographics, incorporating other imaging modalities such as ultrasound and MRI for a holistic diagnostic platform, and further refining the chatbot's emotional intelligence and multilingual capabilities. These advancements will strengthen the system's usability, accessibility, and impact in diverse clinical settings.

In conclusion, the integration of CNNs and LLMs in this system represents a significant advancement in breast cancer care, combining state-of-the-art diagnostic accuracy with patient-focused support. This approach has the potential to revolutionize breast cancer screening and diagnosis, ensuring better clinical outcomes, enhanced patient engagement, and a more efficient healthcare system. By addressing both the technical and human aspects of breast cancer care, this system paves the way for smarter, more inclusive, and empathetic healthcare solutions.

VI. FUTURE SCOPE

The future scope of this system integrating Convolutional Neural Networks (CNNs) for mammogram classification and Large Language Models (LLMs) for patient interaction offers numerous opportunities for enhancement. Expanding the dataset to include diverse demographics and imaging conditions can improve the model's generalizability, while integrating multimodal imaging modalities such as ultrasound and MRI can create a more comprehensive diagnostic platform. The system can incorporate advanced risk prediction models using patient history and lifestyle data, enabling personalized healthcare interventions. Expanding the chatbot's multilingual capabilities and embedding cultural adaptability will ensure accessibility to a global patient base, while deeper personalization through interaction history tracking and emotional cue detection will enhance patient experience. Integration with broader healthcare systems, such as electronic health records (EHR) and telemedicine platforms, can provide a seamless diagnostic workflow for clinicians. Continuous learning mechanisms in both CNN and LLM components will allow the system to adapt to evolving medical data and patient needs. Additionally, ethical and privacy considerations must be addressed by implementing robust security measures to ensure trust and compliance with data protection regulations. These advancements have the potential to revolutionize breast cancer screening and care, creating a smarter, more inclusive, and empathetic healthcare solution that addresses both technical and patient-centered needs.

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