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Course Title: Research Methodology in Computer Science

Course Code: AI800

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Hand-in Method: Online Submission via E-Learning.

Assignment Report 2: Breast cancer detection and diagnosis using artificial intelligence

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Problem Statement

Advancing Artificial Intelligence Models for Enhanced Breast Cancer Diagnosis and Prognosis

Description of the Problem:

The management of breast cancer still one of the leading causes of cancer deaths worldwide, and early detection is still one of the most crucial means for improving outcomes.

Traditional imaging techniques like mammography, ultrasound, and MRI work well, but their success heavily relies on the subjective interpretation by a radiologist, which is naturally exposed to human error and variability.

Artificial intelligence has emerged as a promising solution to increase diagnostic accuracy by identifying patterns and anomalies beyond human capability. Current AI systems, however, have significant limitations: Most of the models, particularly CNNs, report high false-positive rates that result in undue interruption and patient anxiety.

Generalization of AI models often suffers because most models are developed using homogenous data from single sources, which deeply impacts their performance variability across diverse populations and imaging systems.

The black-box nature of deep-learning models vacillate a lack of confidence among clinicians due to its decision-making opacity.

Radiomics-based approaches provide interpretability but often lack the predictive power needed for early detection or complete diagnostics.

Significance:

Such improvements have a many-sided impact. Better AI could establish early, more accurate, and personalized diagnoses, directly impacting mortality rates and improve the quality of life in patients. Furthermore, increasing interpretability and strength of such models can engender great trust among clinicians to hasten clinical acceptance. Beyond the clinic, optimized AI for breast cancer diagnosis has the potential to cut healthcare costs through prevent of overtreatment and better resource allocation to those patients in whom malignancies have been confirmed.

Solutions: Current solutions to AI-driven breast cancer diagnosis span a wide spectrum but can be categorized into three strands:

Deep Learning Models:

CNNs have widespread application in imaging modalities; mammography and MRI are two examples of tasks applied widely for the detection of tumors. While very powerful, these models regularly fall victim to overfitting when trained on small or homogenous datasets, making them less appropriate for deployment in real-world scenarios.

Radiomics-based approaches aim at the extraction of quantitative imaging features related to tumor characteristics, with partial interpretability. However, they usually provide low predictive performance compared to deep learning systems and may require an intensive manual feature engineering process.

Multimodal Imaging: Integrating information from various imaging modalities, such as mammography and MRI, has been shown to hold great promise. However, these techniques require significant computational resources and large, well-curated datasets that are not always available.

Rationale for Research:

Despite these advancements, significant gaps remain. The lack of generalizability across diverse populations raises equity concerns, particularly in underrepresented regions with unique patient demographics. Additionally, the absence of robust interpretability frameworks limits clinicians' ability to trust and integrate AI into workflows. This research seeks to bridge these gaps by developing an optimized AI framework that prioritizes accuracy, interpretability, and generalizability, to make sure its utility in both resource-rich and resource-limited settings.

Research Objectives

The study aims at developing a next-generation AI framework for the diagnosis of breast cancer to overcome existing limitations by improving accuracy, interpretability, and generalizability across varied clinical settings.

Specific Objectives:

To design A hybrid AI model combining the strengths of CNNs and radiomics-based approaches leverages multimodal imaging data-including mammography, MRI, and DCE-MRI-to enhance its diagnostic performance..

To evaluate It is also used to analyze the effect of multi-center datasets with different demographics, imaging devices, and clinical settings on the generalization capability of the model.

To develop an Interpretability framework of the work that will provide clear insights for clinicians into AI decision-making processes, building trust and usability.

To compare The comparative performance of the proposed model with existing solutions using different metrics, such as sensitivity and specificity, false-positive rates, and computational efficiency.

To propose Actionable guidelines for integrating the AI framework into clinical workflows, addressing regulatory, ethical, and operational considerations.

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