A Novel Hybrid Approach for Cervical Cancer Detection Using Multi-Stage CNN and Elastic Net Regression

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Abstract

This study presents a novel approach for the early detection of cervical cancer, leveraging the integration of Multi-Stage Convolutional Neural Networks (CNN) and Hybrid Elastic Net Regression (ENR) to achieve enhanced diagnostic accuracy. Traditional methods for cervical cancer screening, such as Pap smears and HPV testing, have limitations in sensitivity and specificity. Our method combines the robust feature extraction capabilities of multi-stage CNNs with the effective feature selection and regularization properties of hybrid ENR. Evaluated on SIPaKMeD and Herlev datasets, the model achieved diagnostic accuracies of 97.7% and 98.18% respectively, outperforming existing methods. This integrated approach not only enhances predictive power but also ensures reliable screening, potentially leading to earlier and more accurate diagnosis of cervical cancer.

Keywords—cervical cancer, convolutional neural networks, elastic net regression, image classification

Ⅰ. Introduction

Cervical cancer remains a significant global health concern, especially in low-resource settings where regular screening is limited. In 2022 [1], there were an estimated 662,301 new cases and 348,874 deaths, according to the World Health Organization (WHO) (Fig. 1). Traditional screening methods, including Pap smears and Human Papillomavirus (HPV) tests, while effective, often suffer from limitations in sensitivity and specificity, leading to false negatives and positives. These limitations can result in delayed diagnosis and treatment, adversely affecting patient outcomes [2]. Therefore, there is a critical need for more accurate and reliable screening methods to improve early detection and reduce mortality rates.

Recent advancements in machine learning, particularly deep learning, offer promising solutions to these challenges. CNNs have demonstrated remarkable success in medical image analysis, including tasks such as image classification, object detection, and segmentation. However, the performance of CNNs can be hindered by overfitting and poor generalization, especially when dealing with limited data. In addition, overfitting occurs when a model learns the noise in the training data rather than the actual signal, leading to poor performance on unseen data [3].

To address these challenges, we propose an integrated approach combining multi-stage CNNs with Hybrid Elastic Net Regression (ENR) to enhance diagnostic accuracy and reliability. The multi-stage CNN architecture processes cervical cytology images

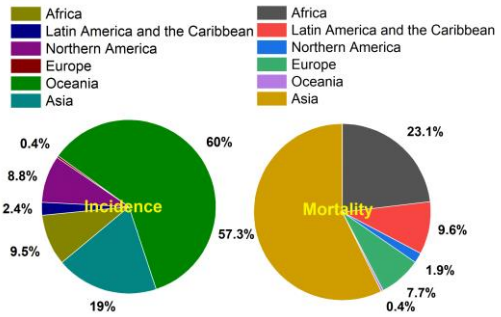

Fig. 1. WHO "International Agency for Research on Cancer": Incidence and Mortality Rate of Cervical Cancer 2022 [1]

at different scales, capturing intricate details and patterns, while the hybrid ENR model mitigates overfitting and selects the most relevant features for accurate classification. This integrated approach leverages the strengths of deep learning for robust feature extraction and regularization techniques for effective feature selection, potentially leading to improved early detection of cervical cancer.

II. Materials and Methods

A. Data Collection and preprocessing

The paper utilized two publicly available datasets: the Herlev dataset with 917 images and the SIPaKMeD dataset with 4049 images classified into five types: superficial-intermediate (SIC), parabasal (PC), koilocytotic (KC), dyskeratotic (DC), and metaplastic

(MC) cell. Fig. 2. shows a sample pap smear image from the SIPaKMeD dataset.

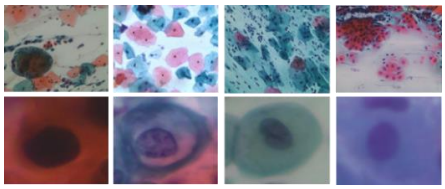

Fig. 2. Sample dataset of Pap smear images

B. Data Preprocessing

Data preprocessing plays a vital role in improving the quality and consistency of input images for CNNs, involving several key steps. Data augmentation techniques, including rotation, scaling, flipping, and contrast adjustment, are applied to expand the dataset size and enhance model generalization capabilities. Normalization is performed to ensure images have zero mean and unit variance, significantly aiding in the acceleration of the training process convergence. Additionally, resizing images to a uniform dimension of 224x224 pixels is crucial to align with the input size specifications of pre-trained CNN models utilized for effective feature extraction [4].

III. Model Architecture

Fig. 3. shows the proposed model, that integrates a Multi-Stage Convolutional Neural Network (CNN) for feature extraction and a Hybrid Elastic Net Regression for classification.

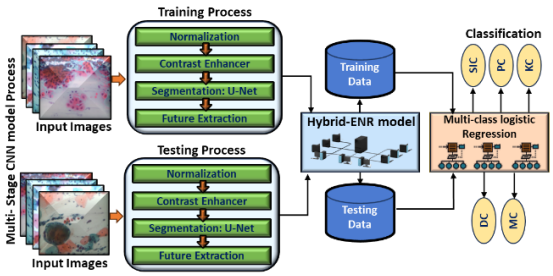

Fig. 3. Hybrid ENR model Architecture

A. Multi-Stage CNN

The Multi-Stage CNN architecture comprises multiple convolutional layers, each followed by Rectified Linear Unit (ReLU) activation and max-pooling layers, designed to extract hierarchical features from input images. The final stage produces feature maps that are flattened and fed into a regression model. Pre-trained models like AlexNet, ResNet-101, ResNet-152, and GoogleNet were fine-tuned for feature extraction, leveraging their robust feature learning capabilities to enhance the model's performance.

B. Hybrid Elastic Net Regression

Equation 1 represents the loss function for Elastic Net, incorporating both Lasso (L1) and Ridge (L2) penalties through the regularization parameter λ. This formulation is adept at managing high-dimensional data while mitigating the risk of overfitting.

$$ENR = \frac{1}{2n}\|y - x\beta\|_2^2 + \lambda_1\|\beta\|_1 + \lambda_1\|\beta\|_2^2 \quad (1)$$

IV. Results

Evaluation with existing models such as VGG19, ResNet, GoogleNet, etc. shows that the proposed model achieved an accuracy of 97.7% on the SIPaKMeD dataset and 98.18% on the Herlev dataset.

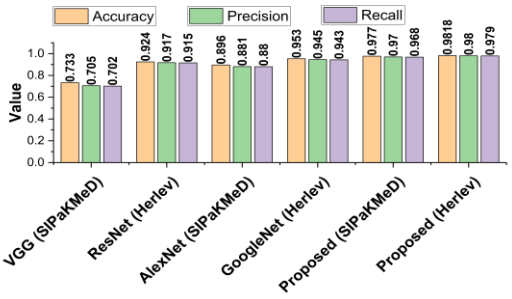

Fig. 4. Performance comparison of existing model's vs Proposed model

V. Conclusion

This study presents a novel approach to cervical cancer detection, combining the strengths of CNN and Elastic Net Regression. The proposed model demonstrates high accuracy and efficiency, making it a promising tool for early diagnosis. Future work will focus on further improving the model's performance and validating it on larger dataset.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A4A5034130 & RS-2024-00359450), and also by the MSIT(Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support program(IITP-2024-RS-2022-00156353) supervised by the IITP(Institute for Information & Communications Technology Planning & Evaluation

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