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A Comparative Study on Colorectal Cancer Detection Using Deep Learning Approaches

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ABSTRACT

Colorectal cancer (CRC) is among the primary reasons for most cancer-associated deaths worldwide, requiring early detection for progressive survival rates. Traditional diagnostic strategies, including colonoscopy and histopathological analysis, are powerful but may be time-in-depth and vulnerable to variability among practitioners. Deep Learning (DL) approaches have emerged as transformative in clinical imaging and diagnostics, providing automated, precise, and practical solutions for CRC detection. This study explores the applications of DL strategies, including convolutional neural networks (CNNs) and hybrid models, to analyze imaging modalities with histopathology, CT scans, and colonoscopy tests. These models show remarkable accuracy, sensitivity, and specificity in identifying malignant and precancerous lesions with the help of massive datasets and sophisticated feature extraction techniques. Transfer learning, augmentation, and explainable AI frameworks are employed to overcome obstacles such as class imbalance, data scarcity, and the necessity for clinical integration. The outcomes emphasize the possibility of using DL-based methods through the development of more reliable, trustworthy, non-invasive diagnostic techniques to transform CRC screening and diagnosis.

Keywords: Colorectal cancer (CRC), deep learning (DL) methods, evaluation metrics, medical imaging, transformer-based methods

INTRODUCTION

In terms of cancer incidence, colorectal cancer (CRC) is the third most common type of cancer worldwide and remains a significant cause of death (Muneer et al., 2023). Obesity and eating practices are closely linked to its rising prevalence, especially in Western nations. Proinflammatory cytokine production, caused by elevated visceral

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adipose tissue, leads to inflammatory reactions in the colon. Endoscopy and other traditional diagnostic techniques are essential for diagnosing CRC, especially endoscopy because they allow tumor localization and histological analysis through biopsies (Muneer et al., 2023). Endoscopy has been a key factor in lowering CRC morbidity and mortality, with sensitivity and specificity surpassing 90%.

Deep Learning DL-based systems are essential in the prognosis of most colorectal cancers because they can evaluate complicated medical images, extract features, and operate without human intervention. The primary purpose of this study was to thoroughly assess the recent developments in DL techniques for CRC detection and underscore how they could revolutionize diagnostic procedures.

RECENT ADVANCEMENTS

Deep Learning (DL) models are appropriate for large-scale datasets because each layer gradually extracts task-specific characteristics. This feature has made DL highly effective in several fields, including digital pathology's cancer prognosis and detection.

Figure 1 depicts the mechanism of a DL-based Computer-Assisted Diagnosis (CAD) system for CRC detection. The workflow begins with input data then processed through convolutional and pooling layers to extract important features. Following their transmission to ultimately connected layers, these characteristics allow for classification as benign or malignant categories. Deep Learning (DL) models simplify the diagnostic process by extracting and classifying features simultaneously, which depend on manually constructed feature extraction before classification.

The comparative study of recent research in Table 1 in CRC detection reveals trends in dataset usage, DL models, and image types. The LC25000 dataset is frequently employed by Khan et al. (2024) and Sakr et al. (2022), alongside other datasets like NCT-CRC-HE-100K employed by Sharkas and Attallah (2024), CT colonography images used by Hicham et al. (2024), and self-prepared histopathological images utilised by Haq et al. (2024). Most studies focus on histopathology images for CRC detection, though 3D CT images used by Hicham et al. (2024) and pathological images are also explored by Muneer et al. (2023).

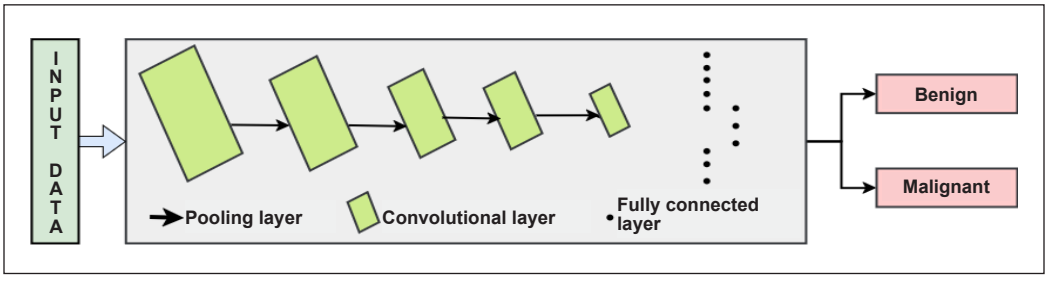

Figure 1. An overview of a DL-based approach for colorectal cancer detection

Standard DL models used include ResNet (ResNet-18, ResNet-50) across multiple studies Haq et al. (2024), Haq et al. (2023), Muneer et al. (2023), Swin Transformer by Khan et al. (2024), CNN models by Sakr et al. (2022), Azar et al. (2023), and 3D CNN by Hicham et al. (2024). Models like Inception V3, utilized by Xu et al. (2020), and YOLOv2, by Haq et al. (2024), are also utilized for enhanced CRC classification and detection. These findings highlight the frequent use of histopathological images and ResNet-based models in CRC diagnosis.

Table 1
Recent advancements in the CRC

Reference	Dataset	Image Types	Methods	Key Findings
Khan et al. (2024)	LC25000	Histopathology	Swin Transformer	The modified Swin Transformer showcases its robustness in colon cancer detection compared to other models.
Sharkas and Attallah (2024)	NCT-CRC-HE-100 K	Histological	ResNet + DesnseNet + AlexNet + DCT + SVM	Effective feature reduction with DCT and ANOVA, improving classification performance.
Hicham et al. (2024)	CT colonography	3D CT	3DCNN-BN	3D CNN-BN effectively improves early detection in CT colonography, aiding colorectal cancer prevention.
Haq et al.(2024)	Medical Image	Histopathology	YOLOv2, ResNet-50, ResNet-18	Integration of YOLOv2 with ResNet-18 and ResNet-50 efficiently detects and quantifies overlapping colorectal cancer cells.
Xu et al. (2020)	Medical Image	Histopathology	Inception V3	The DL method for CRC detection can assist pathologists by reducing workload and improving diagnostic efficiency.
Sakr et al. (2022)	LC25000	Histopathology	Lightweight CNN	The proposed model for colon cancer detection presents high accuracy, efficiency, and robustness, outperforming existing methods.
Haq et al. (2023)	Self-prepared	Histopathology	ResNet50	ResNet-50 detects and accurately counts HT-29 colorectal cancer cells, advancing colon cancer diagnosis.
Azar et al. (2023)	Colon, Colonoscopy, Warwick-QU, and CRC-VAL HE-7K	Histopathological	CNN	The study explores DL techniques for colon cancer classification using various optimizers like CNN-Adam, CNN-RMSprop, and CNN-Adadelta.
Muneer et al. (2023)	Pathological data	Pathological	ResNet-18	The use of DL for classifying colorectal cancer cells demonstrates its potential to improve diagnosis and treatment planning.

Recent advancements in CRC detection through deep learning models have demonstrated remarkable efficacy, as depicted in Figure 2. According to Khan et al. (2024), unique results were obtained with Swin Transformer and reported an accuracy of 99.64% with marked precision, recall, and F-score. Moreover, Sakr et al. (2022) used Lightweight CNN to perform with a fantastic accuracy of 99.50% combined with 100% recall. Sharkas and Attallah (2024) introduced a hybrid model with an impressive accuracy of 99.30 % In addition, Haq et al. (2024) used YOLOv2, ResNet-50, and ResNet-18 to detect and quantify CRC cells in challenging situations and achieved an accuracy of 98.70% with a precision and recall score of 97%. Haq et al. (2023) and Muneer et al. (2023) demonstrated the feasibility of ResNet-50 and ResNet-18 with a reliability level of 95.50% and 95%, respectively. Recently, Hicham et al. (2024) demonstrated the potential of a 3D CNN-BN model in detecting early CRC through tomography data and had accuracy of 92%. Xu et al. (2020) used Inception V3 to improve diagnostic results, with an accuracy of 99.90%. These results reinforce the power of DL, with models such as ResNet and Swin Transformer being very effective tools for accurate CRC classification.

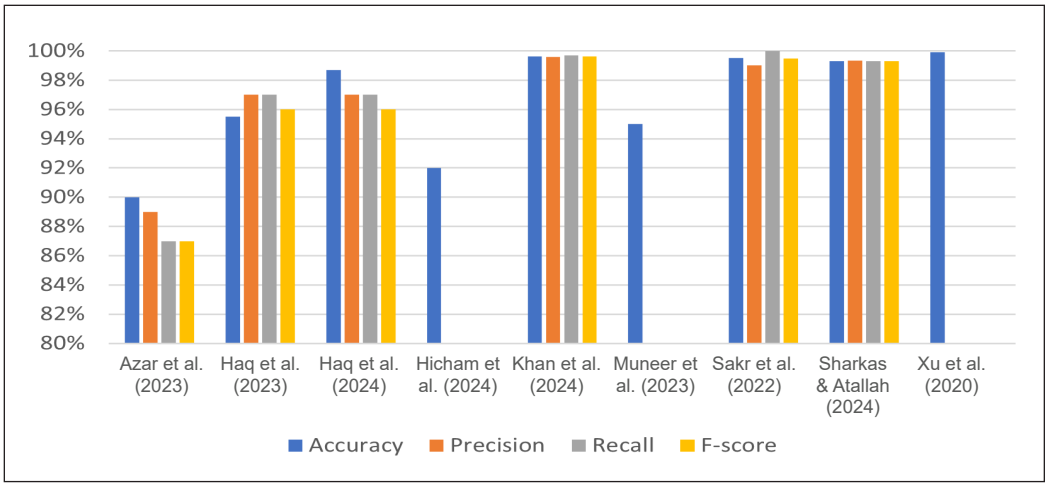

Figure 2. Performance analysis of existing models

CONCLUSION

Deep Learning (DL) approaches for CRC detection greatly enhanced medical diagnosis and became evident as we examined several DL models and methodologies that transformed the identification, categorization, and treatment of colorectal cancer. ResNet, Swin Transformer, and 3D CNN models presented significant advancements in enhancing the accuracy and effectiveness of CRC detection. These DL techniques reduced the workload of DL pathologists while improving diagnostic accuracy. DL was positioned to play a

key role in the early detection of CRC by providing a better future for both diagnosis and treatment of the ongoing development of these models and their capacity to handle complicated medical data.

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