2025 3rd International Conference on Advancement in Computation & Computer Technologies (InCACCT) | 979-8-3315-4389-1/25/$31.00 ©2025 IEEE | DOI: 10.1109/InCACCT65424.2025.11011403

A Systematic Review of Deep Learning Techniques in Colon Cancer Screening

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***Abstract*— Deep Learning is nowadays one of the powerful approaches of the Artificial Intelligence field in object detection and recognition. It also has gained reputation for improvement in the analysis of medical images. Early diagnosis and accuracy in prediction can be obtained by finding various normal and abnormal patterns in complex datasets by using different deep learning algorithms. Once deep learning models have undergone extensive training on enormous datasets, it can learn distinguishing between tissues that are either cancerous or not. Moreover, it improves precision in diagnosis and also enables better results in the outcomes of patients. This paper elaborates various deep learning architectures employed in investigating the state of the colon in diagnosing cancer. Deep learning algorithms which detect colon cancer help to identify various significant performance parameters to measure their effectiveness. The metrics include accuracy which helps to make the correct predictions, sensitivity metric to correctly identify the patients suffering from the disease and specificity metric to identify the people without the disease accurately. This paper will present reviews of different research papers that outline the overall framework. This paper will be beneficial for those researchers who are keen to know about different deep learning techniques for diagnosing the cancer in colon.**

Keywords*— Colon Cancer, Dataset, Neural Networks, Explainable Artificial Intelligence, Machine Learning

I. INTRODUCTION

Colorectal cancer also called colon cancer is a critical global public health problem. World-wide, colorectal cancer is the third most common malignancy, representing approximately 10% of all cancers. It starts in the colon or rectum, and is one of the primary causes of the ailment and demise from cancer. It typically begins as polyps, small growths on the inside lining of the colon that, over time, may develop into cancer. Anyone can get this kind of cancer, however, people who are over 50, people having family history related to this and those who are suffering from obesity, high-fat diet and sedentary lifestyle are more likely to get this type of cancer. Pain in stomach, bleeding in the stool, changes in bowel habits, fatigue and inexplicable loss in weight are some symptoms of colon cancer which are presented in Figure 1 [1]. To enhance the survival rates of patients and to improve the treatment outcomes, diagnosing the colon cancer is crucial at a primary stage for which colonoscopies and other screening techniques are required [2].

Detecting the colon cancer at primary stage will make it more easy to manage the situations and also reduces the chances of spreading more. Although, it has an advantage to diagnose the colon cancer at an early stage but it has some disadvantages also. Sometimes, it creates some false positives which cause anxiety among people and people need to go for treatments like colonoscopies which are not even required. Moreover, there is an issue of low accuracy in the screening tests which results in the wrong results during early detection of colon cancer. For example, although fecal tests are extremely useful, sometimes false-positives might indicate subsequent colonoscopies that need not have been required and which could put a patient through unnecessary stress or an invasive operation [3].

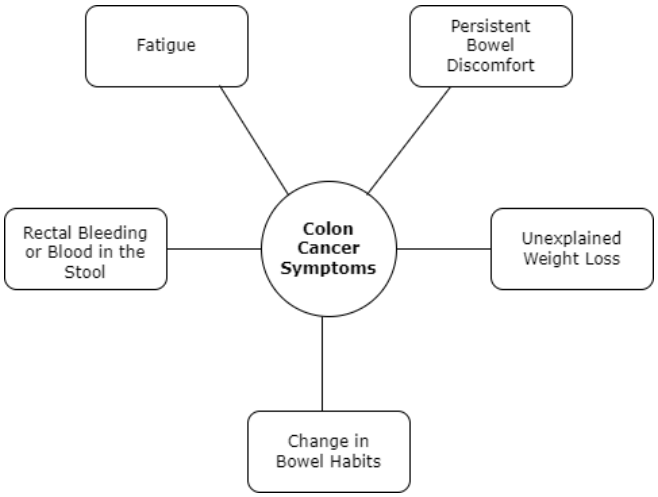

Fig. 1. Colon Cancer Symptoms

From the beginning, machine learning (ML) has been utilized for cancer diagnosis, which has significantly increased the speed and competence of the diagnosis. To help radiologists in more effectively detecting tumors, machine learning methods primarily focused on pattern recognition in X-rays and CT images. As electronic health records became more common, ML models began sifting through vast amounts of data for predictive modeling, finding patients who may be at clinical risk based on their demographics and clinical background. Machine learning techniques applied in histopathology for the first time involved analysis of tissue slides to observe tumorigenic cells from normal cells, which paved way for different deep learning techniques [4] .

Nowadays, large volume of data is evaluated by neural networks which are used by deep learning (DL) which becomes a significant rule in the diagnosis of cancer and other diseases. Various algorithms are used for cancer diagnosis to find various complex patterns from the datasets which are labeled. It allows the diagnosing of the cancer accurately and finds the variances in medical imaging such as CT Scans, MRI Imaging, and Histopathological images [5]. When it comes to accurately differentiating between benign and malignant tumors, these algorithms often do better than traditional

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methods. Beyond the diagnosis of cancer, deep learning may be used to forecast illness outcomes, analyze electronic health records for risk stratification, and interpret genetic data to identify variants linked to other conditions. Deep learning's ability to gather and analyze unstructured data, such as text and photos, makes it extremely helpful in the healthcare sector. By facilitating earlier and more accurate diagnoses, this capacity advances customized medicine and improves patient care. As technology advances, deep learning might further alter the world of medical diagnosis [6].

The analysis of the paper is described as follows. Section 2 represents a thorough analysis of various machine learning and deep learning approaches or techniques that have been applied to different colon cancer datasets. Moreover, literature review summary is presented in tabular form which represents the best algorithm on the basis of accuracy. Also, it shows the different charts visualizing the Accuracy, Precision and Recall comparison. Section 3 recapitulates the paper with brief conclusions. Researchers studying deep learning and colon cancer are expected to find this paper useful.

II. LITERARURE REVIEW

Akshay M Godkhindi et al. presented that when malignant cells grow on the rectum or colon's inner lining in the large intestine, colon cancer results. The interior view of the colon is obtained by the use of Computed Tomography (CT) scanning. The lungs and small intestine are among the noises present in the CT colonography image [7] . Separating the colon from the noise is the crucial challenge. Additionally, to separate the original polyps from the images of polyp-like structures is also a tough task and to recognize the polyps from the interior perspective. In this paper, author has identified the accuracy of CNN to detect the polyp which is 88% and for colon segmentation is 87%. This is better than the accuracy of RF and KNN which are conventional methods [8].

Ishak Pacal et al. reviewed that deep learning algorithms are having great impact in medical image analysis. It has been reviewed that CNN is the one of the most preferred method for the recognition of colon cancer at primary stage [9]. Here, the investigation of colon cancer is completed and is categorized into 5 different categories such as discovery, classification, separation of data, existence forecast and inflammatory bowel diseases. Moreover, the analysis on various imaging techniques and the datasets of colon cancer has been done which is helpful to do further studies [10].

An advanced computer-based system for diagnosing colon cancer has been created using various deep learning techniques. Early identification of colon tumors is crucial for effective treatment and accurate diagnosis. Deep learning algorithms are very effective for early identification of colon cancer. Neural networks, essential elements of deep learning, are crafted to replicate the problem-solving abilities of the human brain which is quite helpful in detecting Colon cancer [11].

It has been reviewed by Mohammad Amin Fahami et al. that among all cancers, colon cancer ranks third and second in the globe in terms of mortality rates for both men and women. Various machine learning algorithms such as Decision tree based, K-Nearest Neighbor (KNN), Decision trees and Neural Networks (NN) are used to identify the most suitable genes to find the condition of colon cancer patients [12]. Principle-Component-Analysis (PCA) is used to decrease the features of the dataset and on the basis of PCA results clustering of patients is done. Moreover, the best 20 extracted genes were identified and analysis of genes was done to diagnose the colon cancer among patients [13].

In this paper, Ammar Ahmad Khan et al. have used Histopathological imageries to discover the colon cancer disease. A deep learning based novel approach has been used which includes Vision Transformer and Swin transformer. Splitting of dataset is done to divide it into Training and Testing set. Moreover, accuracy of testing dataset is calculated and compared in which Swin transformer is showing more accuracy as compared to Vision Transformer [14].

Hussein Akar et al. have reviewed that due to human cognitive limits, the changeableness of diseases, the difficulty in medical decision making and errors in prediction creates a serious safety concern in the healthcare industry [15]. In this paper, data is in the form of Histopathological images and is used to categorize lung, colon and breast cancer. In this paper, the baseline model is created by using CNN architecture and is contrasted with a number of pre-trained models, including VCG-16, VCG-19, ResNet-50, and ResNet-101. Out of all the models, ResNet-50 is the most effective [16].

Vanishka Kadian et al. have analyzed that the gold standard for identifying practically every kind of cancer, including colon cancer, is histopathology. Deep Learning models such as MobileNet, ResNet-34, XCit, SqueezeNet are used to predict their performance by calculating the accuracy and other parameters. Out of all the models, MobileNet is showing the highest accuracy and is considered the best model [17].

Sameh Hany Emile et al. reviewed that the degree of similarity between the clinical assessment of colon cancer in stages T & N and the final pathologic stage was moderate, indicating good diagnostic accuracy. Compared to previous stages, advanced T and N stages had a higher likelihood of being successfully staged. The clinical assessment demonstrated a low sensitivity, particularly in detecting nodal involvement, but a high specificity of less than 3% of patients being over-staged [18].

Ahmed S. Sakr et al. mentioned that the identification of colon cancer at an early stage helps to lower the infection and mortality rates. The detection of colon cancer is done by the CNN which is one of the DL approaches [19]. The data is used in the form of Histopathological imageries where normalization is performed before inputting the data in the CNN model. The CNN model is predicting the maximum accuracy of around 99.5% which is considered as the best as compared to other existing deep learning models [20].

Subash Kavitha et al. have implemented deep learning models to diagnose the colon cancer at an early stage. However, in the medical field transparency is required which cannot be obtained only by the deep learning techniques. Explainable deep learning models are preferred as it helps to provide the more transparent results. Moreover, it reduces the load on the medical practitioners and enhances the accuracy of diagnosis[21].

In this paper, Noshin Tabassum Arthi et al. have used CNN based model to diagnose the colon cancer at primary stage to save time and to reduce the load on doctors. Federated learning (FL) based model is used to determine the accuracy of detecting the colon cancer. FL is performed on large datasets which puts a significant effect on the accuracy [22]. Moreover,

Explainable AI approach is applied to bring the transparency and to visualize the super pixels on the images. The CNN approach ResNext50 is integrated with FL which brings the more accuracy (96.04%) as compared to other CNN models [23].

Omneya Attallah et al. have reviewed that Deep learning techniques help to identify the cancer patients in short period of time. Multiple lightweight deep learning techniques are used to create a framework to detect lung and colon cancer [24]. The various imageries which are Histopathological based are added into various models like MobileNet, ShuffleNet and SqueezeNet. Moreover, PCA and FWHT (fast Walsh–Hadamard transform) techniques are used to diminish the features of the image dataset. Then the reduced features are fused with the help of Discrete Wavelet Transform (DWT). Transformation methods to reduce the features are helpful for accurate diagnosis and interpretation of data [25]. Moreover, Table 1 represents the complete summary of different papers with their performance metrics and research outcomes.

TABLE I. LITERATURE REVIEW SUMMARY

Author Name (year)	Paper Title	Source of Dataset	Algorithms used	Performance Metrics	Research Outcome
Mohammad Amin Fahami et al. (2021) [10]	"Detection of the effective genes in colon cancer: A Machine Learning Approach"	The Cancer Genome Atlas Colon Adenocarcinoma (TCGA-COAD) [26]	Naïve Bayes	Accuracy:83.26% Precision:89.91% Recall:75.29%	Decision tree performance outperforms the other algorithms
			Quadratic Discriminant Analysis	Accuracy:90.00% Precision:89.76% Recall:92.88%	
			SVM	Accuracy:94.77% Precision:95.89% Recall:93.71%	
			Linear Discriminant Analysis	Accuracy:94.97% Precision:96.20% Recall:93.70%	
			KNN	Accuracy:97.49% Precision:100% Recall:95%	
Ammar Ahmad Khan et al. (2024)[11]	"Classification Of Colon Cancer Using Deep Learning Techniques On Histopathological Images"	LC25000 dataset [27]	ResNet-101	Accuracy:98.97% Precision:89.91% Recall:75.29%	RestNet-101 outperforms the other algorithms
			Vision Transformer	Accuracy:90.00% Precision:89.76% Recall:92.88%	
			Swin Transformer	Accuracy:94.77% Precision:95.89% Recall:93.71%	
			Swin Transformer Modified Last Layer	Accuracy:94.97% Precision:96.20% Recall:93.70%	
Hussein Akar et al. (2023)[12]	"A Comparative Study for lung, colon and breast cancer diagnosis using different convolutional neural networks"	Kaggle [28]	Baseline CNN Model	Validation Accuracy: 74.6% Precision:83.1% Recall:74.6%	RestNet50 is the best performer among all.
			ResNet50	Validation Accuracy: 98.3% Precision:98.33% Recall:98.33%	
			ResNet101	Validation Accuracy: 95.8% Precision:95.8% Recall:95.8%	
Vanishka Kadian et al. (2023)[13]	"A Robust Colon Cancer Detection Model Using Deep-Learning"	Chaoyang dataset from Chaoyang hospital, China [13]	ResNet-34	Accuracy: 83.4% Precision:78.33% Recall:75.45%	MobileNet outperforms all other models.
			XCiT	Accuracy: 80.83% Precision:75.82% Recall:75.01%	
			SqueezeNet	Accuracy:78.07% Precision:74.42% Recall:73.01%	
			MobileNet	Accuracy: 84.39% Precision:81.79% Recall:79.67%	
Ahmed S. Sakr et al. (2022)[15]	"An Efficient Deep Learning Approach for Colon Cancer Detection"	LC25000 Dataset [27]	CNN	Accuracy:99.5%	CNN with Layer 12 is having with max. accuracy.

Noshin Tabassum Arthi et al. (2022)[17]	"The Decentralized Federated Learning and Deep Learning Leveraging XAI-Based Approach to Classify Colorectal Cancer"	Zenodo [29]	VGG16	Accuracy: 98.68% F1 Score: 98.66%	ResNeXt50 bears the highest accuracy
			Inception V3	Accuracy: 98.97% F1 Score: 98.96%	
			ResNet50	Accuracy:99.24% F1 Score: 99.23%	
			ResNeXt50	Accuracy: 99.53% F1 Score: 99.53%	
Omneya Attallah et al. (2022)[18]	"A Framework for Lung and Colon Cancer Diagnosis via Lightweight Deep Learning Models and Transformation Methods"	LC25000 Dataset [27]	LDA (Linear Discriminant Analysis)	Sensitivity:99.3% Specificity:99.8% Precision:99.3%	Linear SVM performance is better than the other models.
			QDA (Quadratic Discriminant Analysis)	Sensitivity:99.3% Specificity:99.8% Precision:99.3%	
			Linear SVM	Sensitivity:99.6% Specificity:99.9% Precision:99.6%	

III. Proposed Methodology

The methodology which is proposed for the discovery of colon cancer using DL algorithms aims to use the cutting-edge computational methods to escalate the performance metrics such as Speed, Accuracy, and accessibility of colon cancer diagnosis, especially in early detection [30]. Figure 2 discussed about the proposed methodology for Colon cancer detection

A. *Data Collection and Preprocessing:* Colon cancer detection data collection usually entails collecting clinical records and data which is medical based (such as CT scans and colonoscopies). In addition to converting clinical data into organized forms, preprocessing include picture normalization, noise reduction, and tumor region labeling.

B. *Model Selection and Architecture:* Selecting a model for colon cancer diagnosis frequently entails deciding between machine learning models like Random Forests or SVM for clinical data and deep learning models like CNNs for image analysis of the images.

C. *Model Training:* The preprocessed dataset is fed into the chosen model during model training for colon cancer detection in order to identify patterns associated with malignant growths. Optimization techniques like backpropagation (for deep learning) and cross-validation are used to fine-tune model parameters and improve accuracy.

D. *Model Evaluation and Performance Metrics:* In colon cancer detection, model assessment entails evaluating performance using measures such as F1-score, sensitivity, specificity, and accuracy to gauge how well the model detects malignant cases.

E. *Model Interpretation and Explainability:* Understanding how the model produces predictions and making sure its judgments are clear and justified are the main goals of model interpretation and explainability in colon cancer diagnosis. Methods such as Grad-CAM or SHAP values make it easier to see which areas or characteristics in medical pictures influence the model's choice.

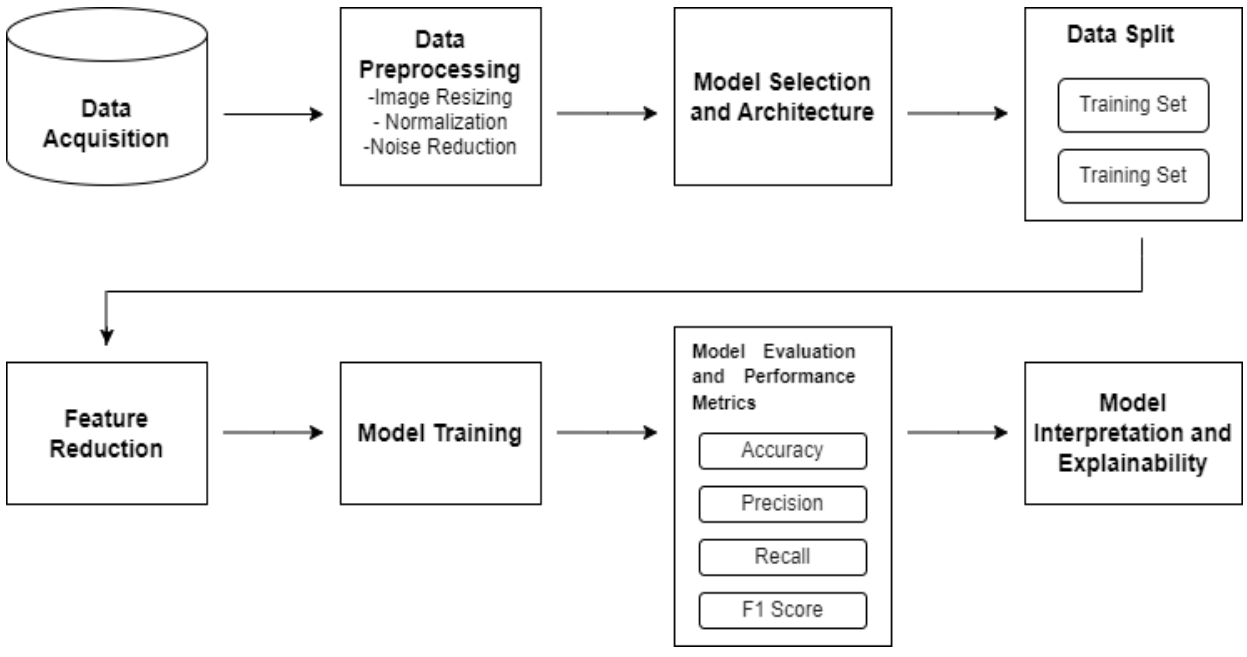

Fig. II. Proposed Methodology for colon cancer detection

IV. Results and Analysis

The advancements in colon cancer diagnosis by deep learning techniques as documented in the reviewed literature are examined in this comparative analysis. Important elements are looked at, including model designs, datasets used, performance indicators (such accuracy, sensitivity, and specificity), and real-world deployment difficulties. This analysis attempts to uncover prevailing trends, identify limitations, and suggest directions for improving the robustness and generalizability of deep learning models in colon cancer detection by highlighting the similarities and differences among CNNs, hybrid models, and transfer learning techniques.

Figure 3 representing the comparison of different accuracy values achieved by different ML and DL models in which Inception V3 and ResNet-101 architectures shows the maximum accuracy i.e. 98.97%.

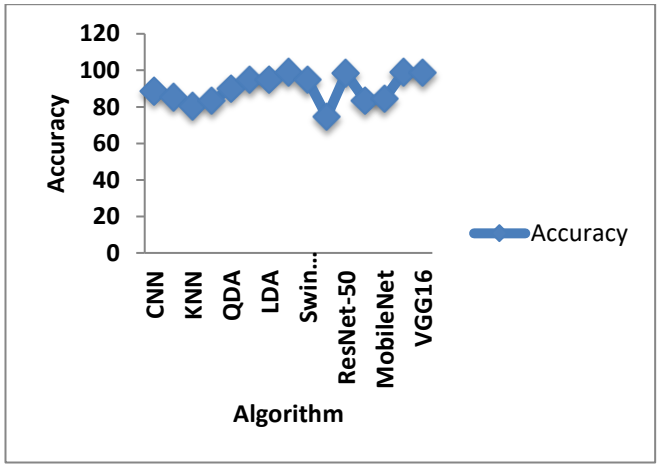

Fig. 3. Comparison chart of Accuracy values

In another Figure 4, precision values of different models are compared to measure the proportion of correctly predicted positive instances out of all instances predicted as positive. Linear SVM shows maximum precision value which is 99.6% and Squeeze net has 74.42% precision value which is lowest of all compared models.

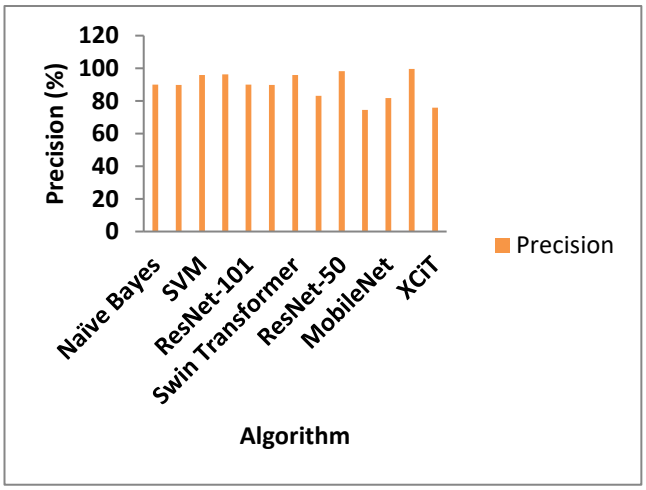

Fig. 4. Comparison chart of Precision values

Figure 5 illustrates the comparison of different recall values to measure how good a model is at identifying all the relevant positive instances. Out of all models, ResNet-50 shows the maximum recall value with 98.3%.

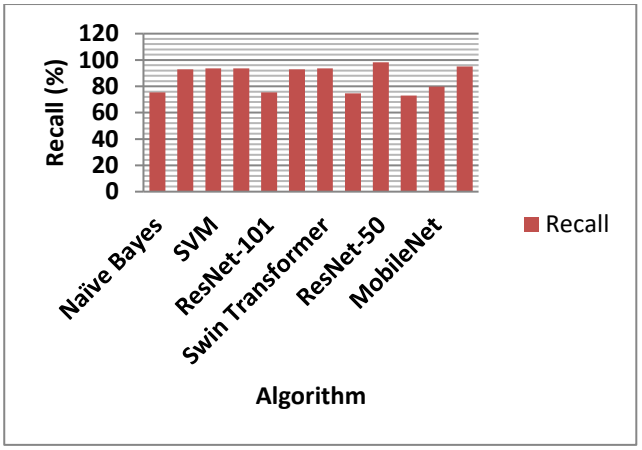

Fig. 5. Chart comparing the Recall values in percentage

V. Conclusion

Colon cancer is one of the most lethal and dangerous cancers in the globe. Early detection is the most crucial phase of any malignancy. Deep learning applications have recently received a lot of momentum in the field of medical image analysis due to their achievements in primary identification of a malignant organ. In this article, the current studies on the application of deep learning methods only for the diagnosis and detection of colon cancer has been discussed. All of the insights are collected in one place to make the review easier to understand. To provide a more thorough comparison, the research summary in table is also included. The table includes methods, datasets, study outcomes and parameters to evaluate the performance. Despite the promising advancements, various challenges still exist which includes datasets of high quality, big datasets and interpretability of the outcomes. While continuing to innovate in algorithm design and training methods, future research should concentrate on resolving these issues. In the end, the continued advancement and use of deep learning in colon cancer research has enormous potential for early identification and individualized treatment plans, opening the door to better healthcare provision.

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