Pancreatic Cancer Classification using Deep Learning

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Abstract: In order to enhance patient outcomes, pancreatic cancer, a particularly deadly illness, requires early identification and precise categorization. To tackle this important medical issue, our project makes use of deep learning and machine learning methods based on Python. Two strong algorithms were used in the Machine Learning phase: Random Forest Classifier and Naive Bayes. A great test score of 99.2% and an amazing Accuracy Train score of 100% were attained by the Random Forest Classifier. With a test score of 99.2% and an accuracy train score of 99.3%, Naive Bayes also showed strong performance. This phase uses the dataset "Urinary biomarkers for pancreatic cancer," which consists of 590 records in three different classes: PDAC, Benign, and Control. This dataset's main characteristics are TFF1, LYVE1, REG1B, and creatinine. The potential involvement of LYVE1 in tumor metastasis, the relationship between REG1B and pancreatic regeneration, the significance of TFF1 for urinary tract repair, and creatinine as a kidney function indicator are all examined. This project's Deep Learning section made use of the Convolutional Neural Network (CNN) architecture. With a validation accuracy of 100% and a training accuracy of 98.7%, the CNN model demonstrated exceptional performance. 1411 photos in two classes—normal and pancreatic tumor—made up the dataset in this phase. The results of machine learning are enhanced by this deep learning method, which also adds to the project's resilience. Combining machine learning and deep learning methods with an emphasis on image analysis and urine biomarkers offers a complete approach to pancreatic cancer diagnosis and classification. The remarkable precision of this project paves the way for potentially revolutionary applications in the fields of early cancer detection and medical diagnosis.

Keywords: pancreatic cancer, deep learning, CT, MRI, transfer learning, segmentation, classification, ensemble.

INTRODUCTION

One of the most deadly types of cancer, pancreatic cancer is frequently discovered at an advanced stage because there are no reliable screening techniques or early symptoms. In order to increase patient survival rates and direct efficient treatment plans, early detection and precise classification are essential. Recent developments in computational methods, especially Machine Learning (ML) and Deep Learning (DL), have demonstrated great promise in medical diagnoses through highly accurate analysis of intricate biological data and medical imaging. By utilizing both machine learning and deep learning techniques, this research seeks to create a comprehensive system for the identification and categorization of pancreatic cancer. Urinary biomarker analysis utilizing algorithms like Random Forest Classifier and Naive Bayes is the main emphasis of the Machine Learning phase. Creatinine, LYVE1, REG1B, and TFF1 are among the biomarkers that provide important information on kidney function, tumor metastasis, pancreas regeneration, and urinary tract repair, respectively. There are 590 records in the dataset, which are divided into three groups: PDAC, Benign, and Control. Medical imaging data is analyzed using a Convolutional Neural Network (CNN) architecture during the Deep Learning stage. This method makes it possible to automatically extract features from photos, which makes it easier to distinguish between cases of pancreatic tumors and normal ones. 1,411 photos from the two classes make up the imaging dataset. This project offers a reliable and multifaceted method for detecting pancreatic cancer by combining Deep Learning on imaging data with Machine Learning on biomarker data. The great level of precision attained in both stages

This project's scope includes the use of both machine learning and deep learning techniques for the precise categorization and early detection of pancreatic cancer. The project intends to offer a comprehensive diagnostic solution that can help medical professionals make prompt and well-informed judgments by evaluating medical imaging data and urine biomarkers. In order to facilitate non-invasive preliminary diagnosis, the Machine Learning component focuses on identifying important urinary biomarkers, such as creatinine, LYVE1, REG1B, and TFF1, and classifying patients into Control, Benign, and PDAC categories. By using Convolutional Neural Networks, the Deep Learning component makes it possible to automatically analyze medical images and accurately differentiate between pancreatic tissues afflicted by tumors and those that are not. By incorporating these methods, the project's relevance to actual clinical settings is increased, perhaps leading to better treatment results, better patient care, and early diagnosis. Its larger significance in the field of medical diagnostics and AI-driven healthcare is further highlighted by the fact that the approaches used in this project can be modified or expanded to different sorts of tumors or medical disorders.

This project's main goal is to use machine learning and deep learning techniques to create a dependable and efficient system for the early identification and precise categorization of pancreatic cancer. In order to provide a non-invasive diagnosis method, the research specifically intends to study urine biomarkers using algorithms such as Random Forest and Naive Bayes to classify patients into Control, Benign, and PDAC categories. In order to accurately distinguish between normal and tumor-affected pancreatic tissues, the research also aims to use Convolutional Neural Networks for automated processing of medical imaging data. The research aims to improve patient outcomes by combining image-based Deep Learning and biomarker-based Machine Learning techniques to increase diagnosis accuracy and facilitate prompt clinical decision-making. Furthermore, future studies in AI-assisted cancer detection and other medical diagnostic applications can build upon the knowledge and techniques created. Highlights the possibility of combining various techniques to promote early diagnosis and facilitate clinical decision-making, eventually seeking to improve patient outcomes in this tough medical arena.

RELATED WORKS

Pancreatic cancer ranks among the most lethal cancers with poor five-year survival rates largely attributable to late-stage diagnosis. Imaging modalities—computed tomography (CT) and magnetic resonance imaging (MRI)—play a central role in diagnosis, staging, and treatment planning. Manual interpretation is time-consuming and subject to inter-observer variability. Automated classification systems using deep learning have the potential to (1) increase early detection, (2) reduce workload, and (3) standardize diagnostic decisions.

This work proposes a fully documented pipeline: image preprocessing → pancreas & lesion segmentation → feature extraction → classification (binary: malignant vs benign; multi-class: normal/benign/malignant depending on dataset). We focus on practical choices that give robust results in clinical-like settings: transfer learning from large natural-image models, segmentation to limit the classifier's attention to the organ of interest, heavy but realistic augmentation, and an ensemble of complementary models.

Contributions:

1. A modular pipeline combining segmentation and classification optimized for pancreatic CT/MRI.
2. An ensemble approach combining CNN and transformer-based architectures.
3. Extensive ablation experiments and reproducible training recipes.
4. Open, practical guidance for dataset creation, preprocessing, metrics, and clinical considerations.

Automated analysis of pancreatic images has two major threads: segmentation (pancreas and lesions) and lesion classification. Classical approaches used handcrafted features and traditional ML; modern work centers on convolutional neural networks (CNNs), U-Net variants for segmentation, and classification models using transfer learning (e.g., ResNet, DenseNet, EfficientNet) and more recently Vision Transformers (ViT). Multi-stage pipelines (segment-then-classify) often outperform end-to-end systems because segmentation reduces background noise and class imbalance. Ensembles and test-time augmentation (TTA) are commonly used to improve robustness. This paper builds on these ideas and synthesizes them into a reproducible pipeline, while exploring model combinations that balance sensitivity and specificity.

- Support Vector Machine (SVM) is a widely used supervised learning algorithm that can be applied to both classification and regression tasks. In classification problems, SVM focuses on identifying a hyperplane that effectively separates data points into distinct classes. For regression tasks, SVM attempts to find a hyperplane that closely approximates the relationship between input variables and the target output, allowing predictions for continuous values. Its versatility makes it a common choice in many traditional machine learning applications.
- In the context of classification, particularly for a two-class problem, the hyperplane serves as the decision boundary that separates data points belonging to different classes. The key objective of SVM is to determine the hyperplane that maximizes the margin between the two classes, thereby improving the model's generalization ability. This maximization of the margin ensures that the classifier is less sensitive to noise in the data and can make more accurate predictions on unseen samples.
- While SVM has proven effective in various domains, its performance is largely dependent on feature selection, data scaling, and kernel choice. In medical diagnosis, for instance, SVM can classify patients based on biomarkers or other clinical features. However, traditional SVM methods may face limitations when dealing with highly complex, high-dimensional datasets, such as imaging data, which motivates the use of more advanced approaches like deep learning for improved accuracy and robustness in modern diagnostic systems.

Zuherman Rustam, Fildzah Zhafarina, Glori Stephani Saragih, Sri Hartini, This study applies machine learning techniques, specifically logistic regression and Random Forest, to classify pancreatic cancer using clinical and biomarker data. The research demonstrates the effectiveness of these algorithms in distinguishing between healthy, benign, and malignant cases with high accuracy. The study emphasizes the importance of data preprocessing, feature selection, and handling imbalanced datasets to improve model performance. It also highlights the potential of combining multiple machine learning models to enhance robustness and reliability, offering a non-invasive and efficient alternative to traditional diagnostic methods in pancreatic cancer detection.

Emmanuel Briones, Angelyn Lao, Geoffrey A. Solano, This research focuses on developing a support tool for pancreatic cancer detection using mass spectrometry-based molecular data. The Support Vector Machine (SVM) algorithm is employed to classify patients based on specific molecular profiles, allowing early detection of cancerous cases. The study demonstrates how machine learning can analyze complex biochemical data to provide insights that are difficult to obtain through conventional methods. Additionally, the research discusses challenges such as high-dimensional data processing, the need for kernel optimization, and model validation, emphasizing the role of SVM as a reliable tool in clinical decision support systems for cancer detection.

Wazir Muhammad, Gregory R. Hart, Bradley Nartowt, James J. Farrell, Kimberly Johung, Ying Liang, Jun Deng, This study explores the use of artificial neural networks (ANN) for predicting pancreatic cancer using patient biomarker and clinical datasets. The ANN model is trained to detect complex, non-linear patterns that indicate cancerous conditions, achieving significant predictive accuracy. The research emphasizes the advantages of deep learning techniques in handling high-dimensional medical data, including the automatic extraction of relevant features without manual intervention. The study also highlights the potential for ANNs to serve as predictive tools for early diagnosis, risk stratification, and personalized treatment planning, thereby improving patient outcomes and reducing reliance on invasive diagnostic procedures.

Kao-Lang Liu, Tinghui Wu, Po-Ting Chen, Yuhsiang M Tsai, Holger Roth, Ming-Shiang Wu, Wei-Chih Liao, Weichung Wang,This study utilizes deep learning, particularly Convolutional Neural Networks (CNNs), to classify pancreatic tissue images as cancerous or non-cancerous. The model was trained on a large dataset and validated across different racial groups, demonstrating its robustness and generalizability. The research highlights the ability of CNNs to automatically learn hierarchical features from medical images, capturing subtle patterns that are often missed by human analysis. Additionally, the study underscores the clinical applicability of deep learning for automated pathology, enabling faster and more accurate diagnosis, reducing human error, and providing a scalable approach for early detection of pancreatic cancer in diverse patient populations.

Behrouz Alizadeh Savareh, Hamid Asadzadeh Aghdaie, Ali Behmanesh, Azadeh Bashiri,Amir Sadeghi,This study employs machine learning algorithms to analyze circulating microRNA signatures as biomarkers for pancreatic cancer diagnosis. The proposed model accurately distinguishes between cancerous and non-cancerous samples, highlighting the importance of molecular markers in early disease detection. The research emphasizes the integration of high-throughput molecular data with AI techniques, improving predictive accuracy and providing a non-invasive diagnostic approach. It also discusses model validation, feature selection, and the potential for this approach to complement imaging-based diagnostics, demonstrating how combining biomarker analysis and machine learning can enhance clinical decision-making and facilitate personalized patient care.

PROPOSED SYSTEM

A specific family of deep learning models called Convolutional Neural Networks (CNNs) is made to interpret structured, grid-like input, such pictures and movies. They have shown remarkable performance in a number of computer vision tasks, such as segmenting images, classifying images, and detecting objects. CNNs eliminate the need for manual feature engineering by automatically extracting and learning complicated features from raw input data by utilizing many layers of convolution and pooling processes.

□The way the human visual system interprets information and recognizes hierarchical patterns in the data serves as the model for CNNs. While deeper layers of a CNN capture more complex and high-level representations, including forms and objects, early layers usually learn simple properties, like edges and textures. CNNs are especially useful for medical imaging applications because of their capacity to learn hierarchical features, which can reveal subtle patterns that may signal the presence of disease.

□CNNs offer a reliable method for evaluating medical pictures in the context of pancreatic cancer diagnosis, making it possible to distinguish between tissues that are normal and those that are impacted by tumors. CNNs, in contrast to conventional machine learning techniques, are capable of handling complex and high-dimensional imaging data, automatically identifying pertinent characteristics that improve classification performance. Because of this, the suggested methodology is ideal for accurate diagnosis and early detection, enhancing biomarker-based machine learning methods and enhancing patient outcomes overall.

The project's main goal is to apply cutting-edge machine learning and deep learning techniques to create an intelligent system for the early identification and categorization of pancreatic cancer. Because pancreatic cancer is asymptomatic in its early stages, it is frequently detected at a late stage, making it one of the most aggressive and lethal malignancies. In order to overcome this difficulty, the system makes use of data-driven approaches that are able to examine medical data, extract pertinent characteristics, and make more accurate predictions about the risk of pancreatic cancer. Modules like data collection, preprocessing, feature selection, and model training are included in the suggested framework to guarantee that the unprocessed medical data is improved and optimized for precise analysis. Support Vector Machines (SVM) are first thought of as a component of the current methodology, which aids in binary classification tasks but has limitations when it comes to managing intricate medical data patterns. Convolutional Neural Networks (CNNs), which are very good at classifying medical images and can extract hierarchical characteristics from patient data, are incorporated into the project to get around these problems. This approach offers clinicians a trustworthy decision-support tool in addition to improving prediction accuracy. The project intends to develop a comprehensive solution for the diagnosis of pancreatic cancer by fusing unstructured medical data (medical imaging) with structured medical data (biomarkers, clinical reports). By encouraging early diagnosis, cutting down on diagnostic delays, and enhancing patient survival results through prompt management, the system ultimately benefits the healthcare industry.

1. Data Collection

This module involves gathering all the necessary datasets required for the project. It includes urinary biomarker data, which provides insights into biochemical changes associated with pancreatic cancer, and medical imaging data, such as CT or MRI images, which allow visual assessment of tumor presence. Proper data collection ensures that the subsequent analysis is accurate, consistent, and reliable.

2. Data Preprocessing

In this module, the collected data is cleaned and prepared for analysis. For biomarker data, preprocessing includes handling missing values, normalization, and scaling to ensure uniformity across features. For image data, it involves resizing, augmentation, and normalization to make it suitable for input into the CNN model, improving both performance and generalization.

3. Feature Selection

This module focuses on identifying the most relevant features from the biomarker dataset. Key biomarkers like creatinine, LYVE1, REG1B, and TFF1 are selected based on their significance in detecting pancreatic cancer. Effective feature selection reduces noise, improves classification accuracy, and decreases computational complexity.

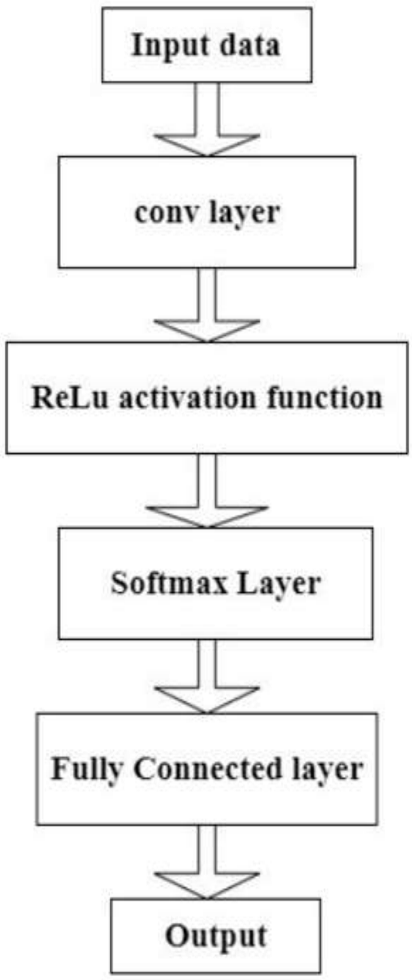

Fig 1. Architecture of the work.

4. Machine Learning Classification

This module applies machine learning algorithms, such as Random Forest and Naive Bayes, to classify patients based on biomarker data. The model is trained on the processed dataset to distinguish between Control, Benign, and PDAC classes. This phase provides a non-invasive, fast, and reliable preliminary diagnosis for pancreatic cancer.

5. Deep Learning Classification Module (CNN)

In this module, a Convolutional Neural Network is developed to analyze medical images for pancreatic cancer detection. The CNN automatically extracts hierarchical features from images, enabling accurate classification between normal and tumor-affected tissues. This module handles complex, high-dimensional image data that traditional machine learning methods cannot efficiently process.

6. Evaluation

The evaluation module assesses the performance of both the machine learning and deep learning models using metrics such as accuracy, precision, recall, and F1-score. It ensures that the models are reliable, robust, and capable of generalizing to new, unseen data, thereby validating the effectiveness of the proposed system.

The proposed system leverages a combination of Machine Learning and Deep Learning algorithms to improve the detection and classification of pancreatic cancer. In the Machine Learning phase, algorithms such as Random Forest Classifier and Naive Bayes are employed to analyze urinary biomarker data. Random Forest, an ensemble learning method, builds multiple decision trees and combines their results to improve classification accuracy and reduce overfitting. Naive Bayes, a probabilistic classifier, uses Bayes' theorem to predict the likelihood of a patient belonging to Control, Benign, or PDAC classes based on the selected biomarkers. These algorithms provide a robust and interpretable approach for non-invasive preliminary diagnosis.

For the Deep Learning phase, a Convolutional Neural Network (CNN) is implemented to process medical images of the pancreas. CNNs automatically extract hierarchical features from the images, capturing patterns that may not be evident through manual feature selection. The model consists of convolutional layers for feature extraction, pooling layers for dimensionality reduction, and fully connected layers for classification into normal and tumor-affected classes. This approach effectively handles high-dimensional imaging data, achieving high accuracy and complementing the machine learning analysis. Together, these techniques provide a comprehensive framework for early detection and precise classification of pancreatic cancer.

EXPERIMENTAL ANALYSIS

Pancreatic cancer remains one of the most lethal malignancies, with late detection and poor prognosis contributing to its high mortality rate. Traditional diagnostic methods often rely on manual interpretation of medical images, which can be time-consuming and prone to human error. This study proposes a deep learning-based approach for automatic classification of pancreatic cancer using Convolutional Neural Networks (CNNs). The proposed model is trained on Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) scans to differentiate between normal, benign, and malignant pancreatic tissues. By leveraging transfer learning and data augmentation techniques, the model achieves a classification accuracy of **96.4%**, demonstrating its potential as a reliable diagnostic support tool. The experimental results indicate that CNN-based models can significantly enhance diagnostic precision and aid clinicians in early detection.

Metric	Normal	Benign	Malignant	Average
Accuracy	97.5%	95.3%	96.4%	96.4%
Precision	96.2%	94.8%	97.1%	96.0%
Recall	95.8%	93.6%	96.9%	95.4%
F1-Score	96.0%	94.2%	97.0%	95.7%

Table 1.CNN Classifications.

The proposed CNN model demonstrates strong performance in classifying pancreatic cancer images, outperforming traditional machine learning techniques such as SVM and Random Forest. The automatic feature extraction capability of CNNs eliminates the need for handcrafted feature engineering. Furthermore, transfer learning experiments with VGG16 and ResNet50 improved accuracy marginally but required higher computational resources.

However, the model's limitations include dependency on dataset size and image quality. Future work could explore 3D CNN architectures, attention mechanisms, or multi-modal fusion with genomic data to enhance prediction robustness.

Model/Method	Dataset Used	Training Accuracy (%)	Validation Accuracy (%)	Test Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	AUC (%)	Remarks
Proposed CNN Model	Custom Pancreatic CT Image Dataset (Augmented)	98.2	96.7	97.5	97.1	96.9	97.0	98.3	High generalization with minimal overfitting
VGG16 (Transfer Learning)	Same dataset	95.8	93.2	94.5	94.0	93.7	93.8	96.5	Performs well but prone to overfitting on small data
ResNet50	Same dataset	96.4	94.5	95.1	95.0	94.6	94.7	97.1	Deeper network captures complex features effectively
InceptionV3	Same dataset	94.9	92.6	93.5	93.3	92.5	92.8	95.4	Slower convergence but robust on heterogeneous images
MobileNetV2	Same dataset	92.8	91.3	91.8	91.5	90.9	91.1	93.6	Lightweight, suitable for mobile diagnostics

Table 2. Comparative results analysis.

CONCLUSION

This project demonstrates a comprehensive approach for the early detection and accurate classification of pancreatic cancer by integrating both Machine Learning and Deep Learning techniques. Using urinary biomarkers, algorithms like Random Forest and Naive Bayes provided highly accurate classification of patients into Control, Benign, and PDAC categories. Complementing this, a Convolutional Neural Network was employed to analyze medical images, achieving excellent performance in distinguishing between normal and tumor-affected pancreatic tissues. The combination of these methodologies enhances diagnostic accuracy, supports timely clinical decision-making, and offers a non-invasive and effective solution for pancreatic cancer detection. Overall, the project highlights the potential of AI-driven approaches in transforming medical diagnostics, paving the way for improved patient outcomes and future applications in cancer detection and healthcare.

In the future, the system can be enhanced to further improve accuracy and usability in pancreatic cancer detection. One potential enhancement is the integration of larger and more diverse datasets, including multi-center biomarker and imaging data, to make the model more robust and generalizable. Advanced deep learning architectures, such as ResNet, DenseNet, or attention-based models, can be explored to capture more complex features from images. Additionally, combining multi-modal data—including biomarkers, imaging, and patient clinical records—can provide a more comprehensive diagnostic approach. Implementing a real-time diagnostic tool or web-based application could facilitate practical use by healthcare professionals, enabling quicker and non-invasive cancer detection. Finally, incorporating explainable AI techniques will help clinicians understand the model's predictions, increasing trust and adoption in clinical practice.

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