

A Comprehensive Review of Bio-inspired and Artificial Intelligence Algorithms for Various Lung Diseases Detection

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Abstract:

In the world, millions of people are affected by lung disease. Some lung-related diseases include Pneumonia, tumors, Cancer, Asthma, Tuberculosis, and Pulmonary Emphysema. Various diagnostic techniques are employed to identify such diseases, including CXR, CT, MRI, PET scan, biopsy, and pulmonary function tests. It causes symptoms such as cough, fever, chest pain, breathing difficulties, weight loss, and fatigue. This research is mainly focused on Pneumonia, tumors, and Pulmonary Emphysema. Bacteria, Viruses, and Fungi mainly cause pneumonia. It is an inflammatory disease that primarily affects the lungs' air sacs. A lung tumor is an abnormal cell growth in the lung. It may be benign (Non-cancerous) or Malignant (Cancerous). Chronic Obstructive Pulmonary Disease is a form of Pulmonary Emphysema. It damages the alveoli, resulting in reduced lung elasticity and reduced ability to exhale. These illnesses are identified through Bio-inspired and Artificial Intelligence algorithms. The limited set of Bio-inspired algorithms comprises Swarm Intelligence-Based, Evolutionary, and Swarm-Based Metaheuristics, as well as Population-Based Stochastic Optimization Algorithms. Some of the Artificial Intelligence Algorithms are Deep Learning (DL), Machine Learning (ML), Clustering Algorithm, and Image Enhancement Algorithm. Early diagnosis of these diseases helps people save lives.

Keywords — Lung Diseases, Pneumonia, Tumor, Pulmonary Emphysema, Bio-inspired algorithm, Artificial Intelligence Algorithm.

I. INTRODUCTION

Traditional intelligent systems are built on Artificial Intelligence (AI) algorithms. It is intended for human intellect, which encompasses learning, thinking, problem-solving, perception, and decision-making. AI algorithms have been classified as Natural Language Processing, Machine Learning, Deep Learning, Robotics, and

Bio-inspired Algorithms. AI applications are involved in education, banking, healthcare, finance, transportation, agriculture, business, and cybersecurity.

In the world, millions of people are affected by Pneumonia, Pulmonary Emphysema, and Lung Tumors. 2.5 million people died from pneumonia. 1.8 million People have died from lung tumors, and

3 million people have died due to Pulmonary Emphysema disease. These disorders are identified using a few tests, including (CXR) Chest X-ray, (CT) Computed Tomography, Pulmonary Function Tests, Biopsy, and Computer-Aided Diagnosis (CAD). Common symptoms of these diseases include persistent cough, Weight loss, Shortness of breath, chest pain, fever, fatigue, and signs of infection.

Devi et al (2025). In this study, lung tumors were initially collected using CT scans. The gathered images undergo preprocessing to enhance image quality and improve diagnostic precision. For instance, Fast-Flexible Denoising Networks (FFDNets) are applied to reduce noise in CT images. Subsequently, an enhanced Reformed Histogram Equalization (RHE) technique is implemented to augment image contrast, with the optimal parameter selection facilitated by the Tasmanian Devil Optimization (TDO) algorithm. Tumor delineation is achieved through a Reliable MultiView Segmentation Network (TMS Net), enabling precise localization of tumor regions [3].

Rajput et al (2023). This work proposes a Bio-Inspired Optimization-based Long Short-Term Memory (Bio-LSTM) algorithm, a new technique for detecting pneumonia disease from Chest X-ray (CXR) images. CXR images from both normal and pneumonia cases are collected and compiled into a large dataset on Kaggle. The dataset preprocessing using a Sparse Auto-Encoder (SAE) to improve image quality. Gabor filters are employed to extract features from medical images. They are effective in capturing texture and spatial details. The LSTM networks are employed as a basis for a classification system. To improve model performance, bio-inspired optimization techniques were incorporated, particularly the Stud Genetic Algorithm (SGA). The optimized BIO-LSTM model was trained and tested using CXR images containing both healthy and pneumonia patients [4].

The study by Isaac et al. (2022) introduces a sophisticated Computer-Aided Diagnosis (CAD) framework for identifying pulmonary emphysema in computed tomography (CT) scans of the lungs. A critical stage in this diagnostic pipeline involves the isolation of Regions of Interest (ROI) from the lung CT data. This segmentation is achieved using the

Spatial Fuzzy C-Means (SFCM) clustering method. The methodology prioritizes extracting three distinct feature categories: morphological shape characteristics, textural attributes, and run-length patterns. To optimize diagnostic accuracy, the research integrates two distinct bio-inspired, wrapper-based computational strategies. Specifically, Spider Monkey Optimization (SMO) and the Paddy Field Algorithm (PFA) were utilized to construct a robust, competitive coevolutionary feature selection (FS) architecture. This integrated model was rigorously benchmarked against independent applications of the SMO and PFA algorithms to validate its superior performance in feature subset selection. Following the identification of the most salient features, a Support Vector Machine (SVM) classification model was engineered to categorize the lung conditions. The efficacy and reliability of this proposed system were scrutinized using a ten-fold cross-validation protocol. This evaluative process was conducted across two comprehensive datasets, comprising standard CT imagery and verified real-time clinical cases of emphysema. The integration of SFCM for segmentation alongside the coevolutionary optimization of SMO and PFA represents a significant advancement in automated respiratory diagnostics. By refining the feature space before classification, the SVM model achieves greater sensitivity in detecting emphysematous tissue. This dual-algorithmic approach to feature selection mitigates the dimensionality challenges typically encountered in high-resolution medical imaging, ensuring that only the most informative descriptors influence the final diagnostic outcome. Furthermore, the reliance on both historical and real-time clinical data ensures the model's generalizability across diverse patient populations and imaging hardware [8].

This review mainly focuses on Pulmonary Emphysema, Pneumonia, and Tumor, which of these diseases affects the lung area. Within the broader clinical context, Figure 1 delineates the various classifications of pulmonary pathologies relevant to this study.

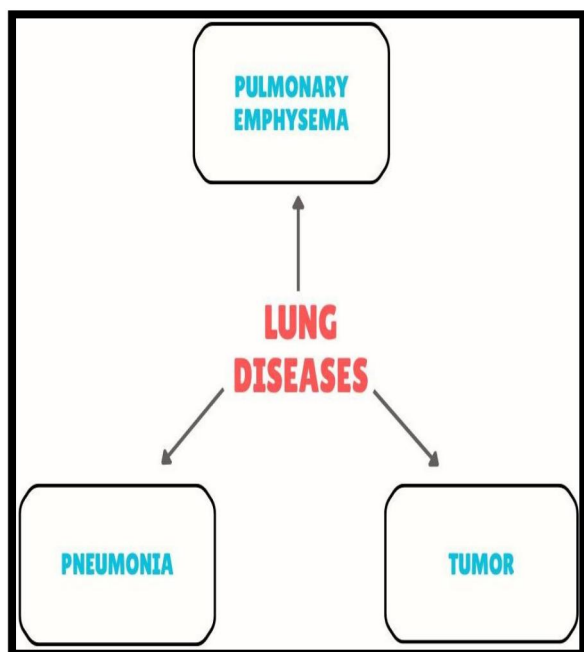


Fig. 1 Various types of Lung Diseases

II. LITERATURE SURVEY

The investigation by Alkhonaini et al. (2022) introduces a sophisticated computational framework for identifying malignancies in pulmonary computed tomography (CT) scans. This methodology integrates the Whale Optimization Algorithm (WOA) with an architectural variant of the U-Net, yielding the Atrous Spatial Pyramid Pooling Unified Network (ASPP-UNet-WOA). By using the WOA for hyperparameter tuning and architectural optimization, the researchers addressed common limitations in standard segmentation models, particularly in capturing multi-scale contextual information. In the broader context of the study's experimental phase, various optimization and classification strategies were evaluated against public datasets. For instance, the Firefly Optimization (FFO) algorithm demonstrated significant efficacy when paired with the Binary Grasshopper Optimization Algorithm (BGOA) for feature selection. This specific combination yielded a peak accuracy of 89.19%. Such results highlight the critical role of feature dimensionality reduction and selection in enhancing the performance of meta-heuristic search patterns within medical imaging environments. A rigorous performance assessment reveals a hierarchy of diagnostic precision across

several deep learning architectures. Standard implementations of the Convolutional Neural Network (CNN) and the Deep Convolutional Neural Network (DCNN) achieved accuracies of 91.67% and 93.45%, respectively. While these models provide robust baselines, the specialized U-Net architecture demonstrated superior spatial feature extraction, achieving a higher accuracy of 95.75%. The pinnacle of the reported experimental results was observed in the proposed ASPP-UNet-WOA model. By leveraging atrous convolutions to expand the receptive field without losing spatial resolution, this unified network achieved a remarkable accuracy of 98.68%. This performance metric indicates that the fusion of the Whale Optimization Algorithm with the Atrous Spatial Pyramid Pooling mechanism significantly outperforms traditional deep learning configurations. Consequently, this study establishes a high benchmark for automated malignancy detection systems in clinical radiology [2].

The research conducted by Khosla et al. (2023) introduces a sophisticated hybrid framework designed to refine image segmentation processes. This methodology synthesizes the foundational strengths of Opposition-Based Learning (OBL), the Chameleon Swarm Algorithm (CSA), and Particle Swarm Optimization (PSO). By merging these distinct computational strategies, the authors aimed to overcome the inherent limitations of singular optimization techniques, such as premature convergence and the entrapment of local optima. This convergence of algorithms facilitates a more robust search mechanism, balancing exploration and exploitation within complex feature spaces. To validate the efficacy of this tripartite model, designated as the Opposition-based Chameleon Swarm Algorithm augmented by Particle Swarm Optimization (CSAPSO), a rigorous empirical study was conducted. The experimental dataset comprised twelve distinct Chest X-ray (CXR) images sourced from clinical subjects. This diagnostic focus centered specifically on the automated identification of pneumonia, a critical task in modern radiological informatics. The implementation of OBL within this structure broadens the initial search horizons. At the same

time, the PSO component enhances the swarm's velocity and accuracy as it converges toward optimal segmentation thresholds. The evaluative phase of this study employed a comprehensive suite of quantitative performance metrics. Accuracy and reconstructive quality were scrutinized through Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR), and the Structural Similarity Index (SSI). Furthermore, the broader diagnostic utility of the Deep Learning architectures was assessed using model performance metrics and Area Under the Curve (AUC) values. These metrics collectively provide a multidimensional view of the algorithm's capability to preserve spatial integrity while maximizing classification accuracy. Statistical rigor was maintained through the application of the Friedman rank-sum test. This non-parametric analysis was used to assess the significance of the observed performance improvements relative to traditional benchmarks. The results indicated that the CSAPSO strategy consistently outperformed extant state-of-the-art methodologies. Most notably, the proposed technique attained superior global-optimal outcomes, reaching a benchmark of 99.98%. Such high-precision results suggest that the synergistic application of OBL, CSA, and PSO offers a transformative approach to medical image processing, significantly enhancing the reliability of computer-aided diagnostic systems in pulmonary medicine [5].

The research conducted by Isaac et al. (2020) focuses on the automated identification of pulmonary emphysema utilizing computed tomography (CT) scans within a Computer-Aided Diagnosis (CAD) infrastructure. The initial stage of this framework involves isolating lung tissues and subsequently identifying Regions of Interest (ROIs). This segmentation is achieved using a Spatial Intuitionistic Fuzzy C-Means clustering technique, which enhances the precision of tissue delineation. To refine the diagnostic process, an optimal subset of features is determined through a wrapper-based selection methodology. In this specific configuration, the fitness function is anchored to the classification efficacy of a Support Vector Machine (SVM). The study explores the

integration of four distinct bio-inspired metaheuristic algorithms to facilitate this selection: Moth-Flame Optimization (MFO), Firefly Optimization (FFO), Artificial Bee Colony Optimization (ABCO), and Ant Colony Optimization (ACO). Each optimization strategy yields a unique feature set, which is subsequently processed using an Extreme Learning Machine (ELM) classifier. The robustness of the classification results is validated using 10-fold cross-validation. The evaluation of this diagnostic framework involved binary classification tasks, distinguishing emphysema-affected lung CT images from healthy control samples. These tests utilized both publicly available and real-time datasets. Comparative analysis of the bio-inspired methodologies revealed that the MFO algorithm achieved the best results on the real-time dataset. The reported metrics for MFO included an accuracy of 91.89%, a recall rate of 96.15%, a specificity of 81.82%, and a precision of 92.59%. In contrast, the FFO algorithm achieved a peak accuracy of 89.19% on the public dataset [7]. The superiority of the MFO-ELM configuration suggests that metaheuristic feature selection has a significant impact on the performance of CAD systems in respiratory pathology. Furthermore, integrating fuzzy clustering with bio-inspired search strategies offers a viable pathway to improve the diagnostic reliability of automated CT scan analysis. These findings underscore the potential for hybrid computational models to assist radiologists in the early detection and monitoring of chronic obstructive pulmonary disease [7].

III. METHODOLOGY

Lung Tumor

Vijh et al. (2020) delineate an innovative bio-inspired methodology for medical diagnostics. This research synthesizes the operational strengths of the Whale Optimization Algorithm (WOA) with the mechanisms of Adaptive Particle Swarm Optimization (APSO). The resulting hybrid WOA_APSO framework represents a robust evolutionary strategy designed for complex computational environments. Such an amalgamation aims to mitigate the limitations

inherent in individual metaheuristic approaches. The architecture specifically targets the intricacies of pulmonary health assessment. A Convolutional Neural Network (CNN) model serves as the primary engine for classification within this proposed system. The research employs a dataset comprising 120 lung computed tomography (CT) images for empirical validation. Extensive preprocessing and segmentation protocols are executed before the core analysis. These preliminary stages are vital for ensuring the integrity of the visual data. The subsequent analytical phase identifies and categorizes nodules as either tumorous or non-tumorous. Such precision is essential for effective clinical decision-making. A sophisticated feature selection protocol is central to the hybrid system's efficacy. This mechanism leverages the dual advantages of the Whale Optimization Algorithm and Adaptive Particle Swarm Optimization. By combining these two paradigms, the researchers introduce an advanced technique to isolate the most relevant diagnostic features. This optimization reduces dimensionality while preserving critical information. Consequently, the hybrid feature selection process enhances the overall efficiency of the deep learning model. The investigation subjects the WOA_APSO model to a comprehensive performance evaluation. The algorithm is benchmarked against established classification paradigms. These comparative methods include standard Convolutional Neural Networks (CNNs), Artificial Neural Networks (ANNs), and Support Vector Machines (SVMs). Each model is assessed based on its ability to handle the specificities of lung CT data. Furthermore, the study examines the computational overhead associated with the hybrid approach. This expenditure is contrasted with the performance of conventional WOA and standalone APSO methods. The empirical results validate the superiority of the suggested hybrid algorithm. The system achieves a remarkable classification accuracy of 97.18%. Additionally, the model's sensitivity is recorded at 97%. The specificity reaches a high threshold of 98.66% during testing. These statistical outcomes demonstrate that the algorithm surpasses other sophisticated contemporary approaches. The integration of these

techniques enables automated, reliable detection of lung malignancies. In conclusion, the research provides a transformative contribution to the field of automated oncology. The synergy between metaheuristic optimization and deep learning creates a highly resilient diagnostic tool. The reported accuracy and specificity metrics underscore its potential for clinical application. This hybrid model offers a scalable and precise solution for early-stage lung cancer intervention. The findings suggest that bio-inspired hybridization is a viable path for improving medical image classification [1].

Pneumonia

The investigation conducted by Sabaawi et al. (2024) introduces a sophisticated diagnostic framework centered on a transfer-learning architecture. This methodology utilizes MobileNet V1 as its primary structural foundation. Although newer iterations exist, this specific framework is rooted in a Convolutional Neural Network (CNN) design that reportedly outperforms contemporary techniques. The selection of MobileNet V1 facilitates a balance between computational efficiency and high-level feature extraction. Such an approach proves critical for medical imaging tasks where model depth and accuracy must be meticulously synchronized. A significant contribution of this research involves the integration of a hybrid optimization strategy. This system synergizes the strengths of the Fick's Law Algorithm (FLA) and the Dung Beetle Optimizer (DBO). The FLA component functions by steering candidate solutions toward globally optimal regions within the search space. This ensures a focused convergence during the training phase. Simultaneously, the DBO enhances the model's exploration capabilities. It achieves this by emulating the unique navigation behaviors observed in dung beetles. This dual-optimizer setup prevents the model from stagnating in local optima, thereby refining the network's overall weight distribution.

The empirical validation of this framework involved a substantial dataset comprising 7750 chest X-ray pictures. These images provided the

necessary diversity for the model to learn complex patterns associated with pulmonary pathologies. The primary objective was the binary classification between pneumonia-affected lungs and healthy respiratory states. By processing 7750 distinct samples, the system attained a high degree of generalizability. The training process focused on maximizing the CNN's sensitivity to subtle radiographic abnormalities. The performance metrics reported by the authors underscore the efficacy of the proposed system. The framework achieved an impressive accuracy of $98.19 \pm 0.94\%$. Furthermore, the recorded sensitivity reached $98 \pm 0.99\%$. These statistical outcomes demonstrate a high level of reliability in identifying true positive cases. The precision of $98.19 \pm 0.94\%$ suggests that the hybrid optimization method significantly improves classification boundaries. Consequently, this innovative framework offers a robust solution for early medical intervention. In conclusion, the findings highlight a promising advancement in clinical technology. The combination of MobileNet V1 and metaheuristic optimization provides a cost-effective tool for diagnostic imaging. High sensitivity rates of $98 \pm 0.99\%$ indicate a minimal risk of overlooked infections. This precise early detection capability is essential for improving patient outcomes in various healthcare settings. The study successfully validates that classical architectures, when enhanced with modern hybrid optimizers, remain highly competitive in the field of medical AI [6].

Pulmonary Emphysema

The investigation by Ananthajothi et al. (2023) presents a sophisticated methodology for detecting and assessing pulmonary emphysema using deep learning-based segmentation and classification. This research introduces a multi-stage computational pipeline designed to enhance diagnostic precision. Initial image refinement begins with applying average filtering and Contrast-Limited Adaptive Histogram Equalization (CLAHE). These preprocessing techniques function to suppress noise and optimize the dynamic range of medical imagery. Such enhancement is vital for the detection model to distinguish subtle pathological variations within

lung tissue. A fundamental prerequisite for accurate diagnosis involves the isolation of the pulmonary region from surrounding anatomical structures. Consequently, the researchers implemented an Enhanced U-Net (E-UNet) architecture specifically for lung segmentation. This model undergoes rigorous optimization via a multi-objective function. This mathematical approach ensures that the segmentation boundaries are both anatomically correct and computationally efficient. The precision of this stage determines the reliability of all subsequent diagnostic interpretations. Following successful segmentation, the framework executes detailed feature extraction. This process utilizes local tri-directional Weber pattern descriptors and local directional pattern descriptors. These mathematical tools quantify the complex textures and structural irregularities characteristic of emphysematous tissue. By capturing multidirectional spatial information, the system identifies the progressive degradation of alveolar walls. These descriptors provide a robust numerical representation of the physiological changes occurring within the respiratory system. The final phase of the diagnostic system involves a Heuristic-Improved Deep Neural Network (HI-DNN). This model leverages a novel architectural approach to stratify extracted features into distinct severity levels. The classification performance is significantly improved by integrating an Electric Fish-based Grey Wolf Optimization (EF-GWO) algorithm. This hybrid meta-heuristic optimizer fine-tunes the parameters of both the segmentation and classification modules. As a result, the EF-GWO-based HI-DNN achieves a notable classification accuracy of 97%. This integrated methodology surpasses existing benchmarks and offers a superior alternative for the automated clinical assessment of pulmonary emphysema [9].

IV. ANALYSIS AND DISCUSSION

Bio-inspired algorithms are used in various Healthcare areas, such as lung diseases, Pulmonary Emphysema, and pneumonia. This study focuses primarily on algorithms such as Artificial Intelligence-based Learning and Optimization Algorithms. Compared to other Hybrid Artificial Intelligence algorithms, Bio-inspired algorithms

achieve higher diagnostic accuracy. Table 1 shows the various algorithms used for lung disease

Algorithms	Accuracy	Sensitivity
WOA_APSO	97.18%	97%
MobileNet V1	98.19%	98%
EF-GWO-HI-DNN	97.10%	98%

prediction. Figure 4.1 shows the classification of various lung diseases using different algorithms.

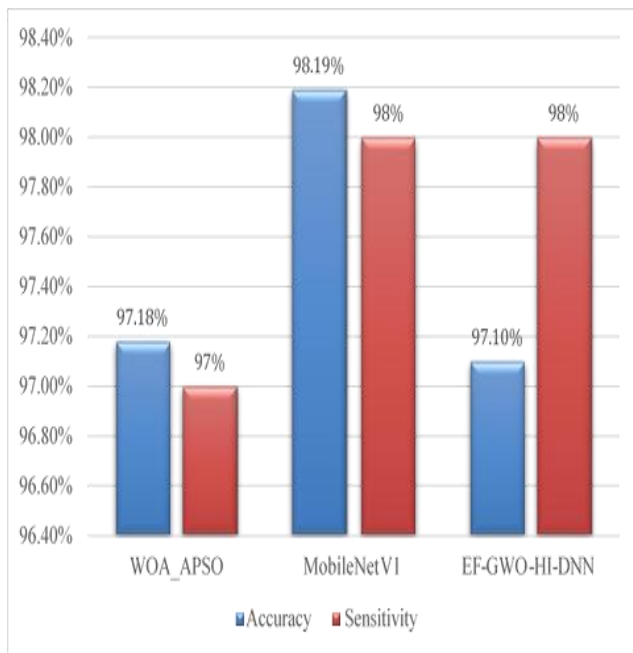
TABLE 1

VARIOUS ALGORITHMS USED FOR LUNG DISEASE PREDICTION

Fig.4.1 Diagnosis of Various Lung Diseases

V. CONCLUSIONS

This study shows that the application of Bio-inspired and Artificial Intelligence (AI) algorithms



for the diagnosis of major lung diseases, including pneumonia, Lung Tumors, and Pulmonary Emphysema. From this study, the results indicate that Hybrid Bio-inspired Meta-heuristics and

Genetic algorithms have enhanced diagnostic accuracy, sensitivity, and specificity compared with Machine Learning algorithms for classification. Therefore, integrating bio-inspired algorithms and AI methods provides an effective framework for early detection of lung disease, helping reduce mortality rates and supporting clinical decision-making.

VI. FUTURE ENHANCEMENT

In the future, the research will focus on Computer-Aided Diagnosis (CAD) to implement Hybrid AI models for hospital use, ensuring faster and more accurate clinical decisions. Integrating CT, Chest X-ray, and MRI data can improve diagnosis precision. The upcoming research system should incorporate explainable AI models to improve the transparency of healthcare professionals. Future models can focus on predicting disease severity, progression, and treatment outcomes.

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