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A COMPREHENSIVE AI-DRIVEN FRAMEWORK FOR EPIDEMIC MANAGEMENT AND DIAGNOSTIC IMAGING ENHANCEMENT USING BIG DATA

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ABSTRACT

This study introduces an advanced AI-driven framework designed to enhance healthcare responses for epidemic management and diagnostic imaging. Traditional epidemic surveillance methods face limitations in scope, often relying on manual data collection and delayed reporting. By integrating big data and AI, our framework provides predictive models capable of processing real-time data for dynamic insights, enabling proactive epidemic control measures. The approach utilizes diverse data sources, including patient demographics, genetic sequences, and transmission data, to forecast disease trends accurately. Additionally, this study presents an innovative method for lung abnormality detection using a hybrid convolutional-transformer model applied to chest X-rays and CT scans. Leveraging explainable AI techniques such as Grad-CAM, our model achieves high diagnostic accuracy while preserving interpretability. Evaluation outcomes highlight improvements in epidemic response precision and medical diagnostics, affirming AI's transformative potential in healthcare. This research supports the broader integration of AI in public health systems to enhance healthcare efficiency and patient outcomes.

Keywords: Infectious Disease, Epidemic Control, Lung Abnormalities, Explainable AI, Big Data.

1. INTRODUCTION

The growing prevalence of infectious diseases like COVID-19 has highlighted how urgently public health needs efficient monitoring and response mechanisms. Due to their heavy reliance on manual data entry and retrospective analysis, traditional approaches to disease surveillance and control frequently cause delays that prevent prompt intervention. In light of fast spreading epidemics, which necessitate prompt, data-driven decision-making to minimize negative effects, this dilemma is especially pressing.

A solution is provided by the development of AI and big data technologies, which make it possible to improve diagnostic imaging and manage epidemics in real time. Large, complicated datasets are easily processed by AI-powered systems, enabling quick analysis and prediction insights that are crucial for successful public health interventions. This study investigates a thorough, AI-powered framework that combines real-time data from many sources to assist in the detection of lung abnormalities and epidemic control. The suggested approach gives medical practitioners trustworthy resources for precise decision-making by utilizing explainable AI, deep learning, and predictive modeling. This study highlights how AI has the ability to significantly improve healthcare infrastructure by changing conventional methods and providing more reliable and resilient healthcare solutions.

Our research underscores the value of AI and big data in modernizing healthcare practices. By creating an AI-driven framework for epidemic management and lung abnormality detection, we provide a scalable, adaptable solution to current healthcare challenges. The models presented offer high predictive accuracy and demonstrate resilience when adapting to new data.

2. LITERATURE SURVEY

a. AI and Big Data in Infectious Disease Control

Tang et al. (2024) provide a comprehensive overview of how AI and big data support infectious disease prevention and their framework demonstrates a data-driven approach that integrates patient data analysis with preventive care strategies, showcasing AI's real-time monitoring capabilities for epidemic prediction and control (Tang et al., 2024) [VIII]

b. Multi-Platform Epidemic Management Framework

Mao et al. (2022) propose a digital management framework for epidemics, emphasizing a multi-platform structure that uses AI and data integration. This framework enables cross-organization collaboration, supporting data sharing and improving decision-making efficiency in health organizations (Mao et al., 2022) [IX].

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c. Automated Lung Abnormality Detection Using Explainable AI

Hasan et al. (2024) developed an AI-based framework for detecting lung abnormalities in CT and X-ray images. This approach, using explainable AI techniques like Grad-CAM, aids in the early identification of respiratory diseases, which is essential for managing infection spread during epidemics (Hasan et al., 2024) [X]

3. METHODOLOGY

This study employs a multi-faceted methodology that integrates AI with real-time data processing to address two core objectives: enhancing infectious disease monitoring and improving lung abnormality detection.

The following sections outline the methodology used to achieve these objectives, detailing each analytical component and technique applied in the research.

3.1 AI and Big Data for Infectious Disease Monitoring

To streamline infectious disease monitoring, a centralized data integration platform is designed. This platform gathers real-time data from healthcare databases, laboratory results, and epidemiological records. Using natural language processing (NLP) techniques, unstructured data—such as medical notes and clinical reports—is converted into structured datasets, making it accessible for further analysis.

With deep learning models trained on historical outbreak data, predictive models are created to forecast potential spread patterns and highlight high-risk areas.

These models utilize variables including demographic data, genetic sequences, and transmission history to assess risk. Through real-time updates, the system provides dynamic insights, enabling health authorities to implement timely preventive measures.

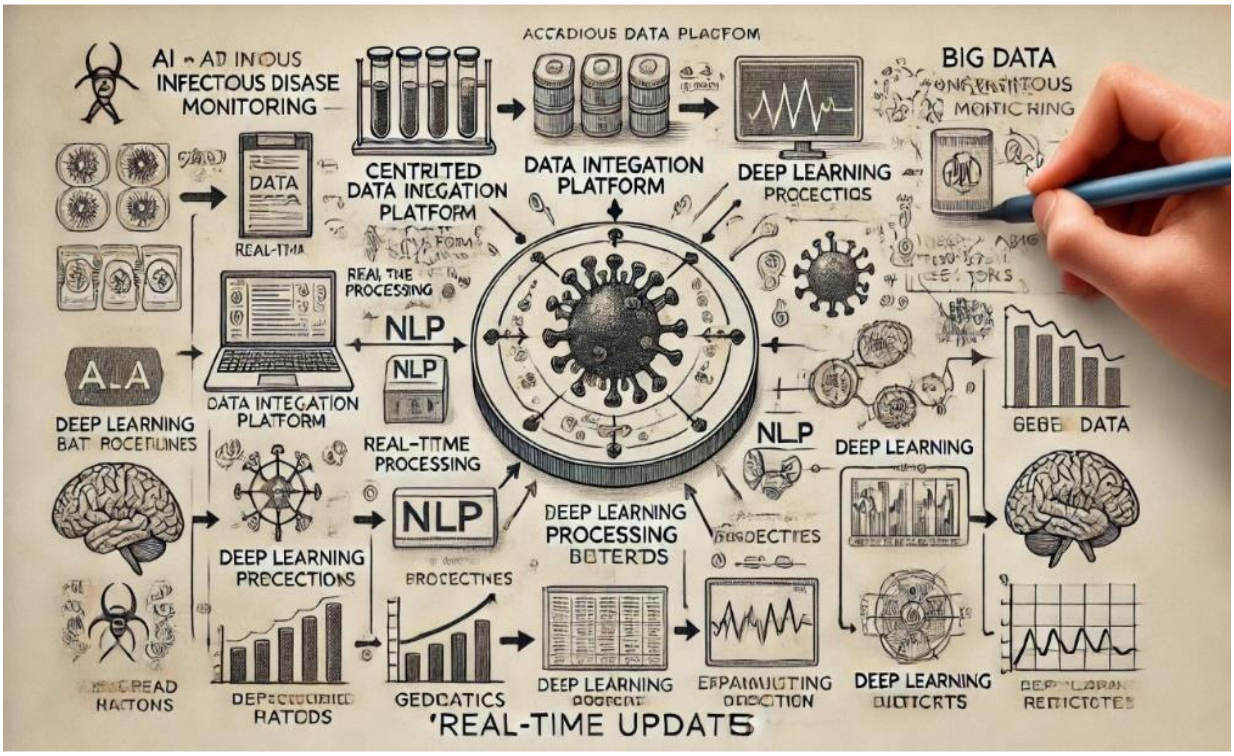

Figure 1: Architecture diagram of hospital infectious disease real-time warning system based on AI and big data.

3.2 Medical Image Processing for Lung Abnormality Detection

Chest X-ray and CT scan pictures are subjected to a deep learning framework in order to efficiently detect lung problems. By improving image quality and lowering noise, preprocessing methods including morphological opening, gamma correction, and Contrast Limited Adaptive Histogram Equalization (CLAHE) highlight lung characteristics.

The Compact Convolutional Transformer (CCT) structure, which combines convolutional and transformer layers to collect both localized and global information, is the foundation of the core diagnostic model.

In order to provide fair representation across lung disease categories, data augmentation using Deep Convolutional Generative Adversarial Networks (DCGAN) reduces data imbalance problems.

To evaluate the performance of the model, evaluation measures such as F1-score, recall, specificity, accuracy, and precision are computed. Metrics such as the Matthews Correlation Coefficient (MCC) provide additional insights into robustness, particularly in imbalanced datasets.

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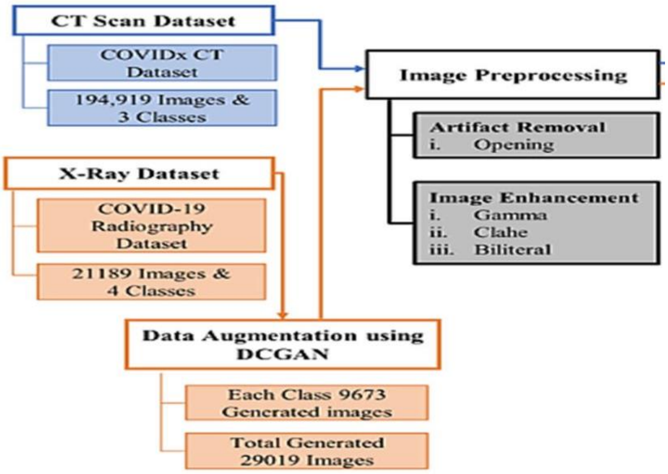

Figure 2: The entire process of developing CTXNET architecture for classifying Lung CT scans and X-rays.

3.3 Digital Epidemic Management Framework

In order to enable efficient epidemic tracking and action, the Digital Epidemic Management Framework's methodology focuses on integrating and standardizing real-time data from various healthcare sources. In order to maintain consistency and interoperability across healthcare systems, data from laboratory results, epidemiological sources, and electronic health records are first combined in a uniform manner. After that, unstructured data—like clinical notes—is converted into organized formats appropriate for analysis through the use of natural language processing, or NLP. Based on variables including patient demographics, transmission rates, and environmental circumstances, machine learning algorithms—in particular, deep learning and recurrent neural networks—are used to model epidemic patterns and forecast possible high-risk regions using this structured data.

Furthermore, adaptive model recalibration is made possible by real-time updates, giving healthcare administrators timely information to put preventative measures into action. An adaptive and scalable system that may assist various healthcare infrastructures in managing and responding to epidemics is made possible by this multifaceted approach.

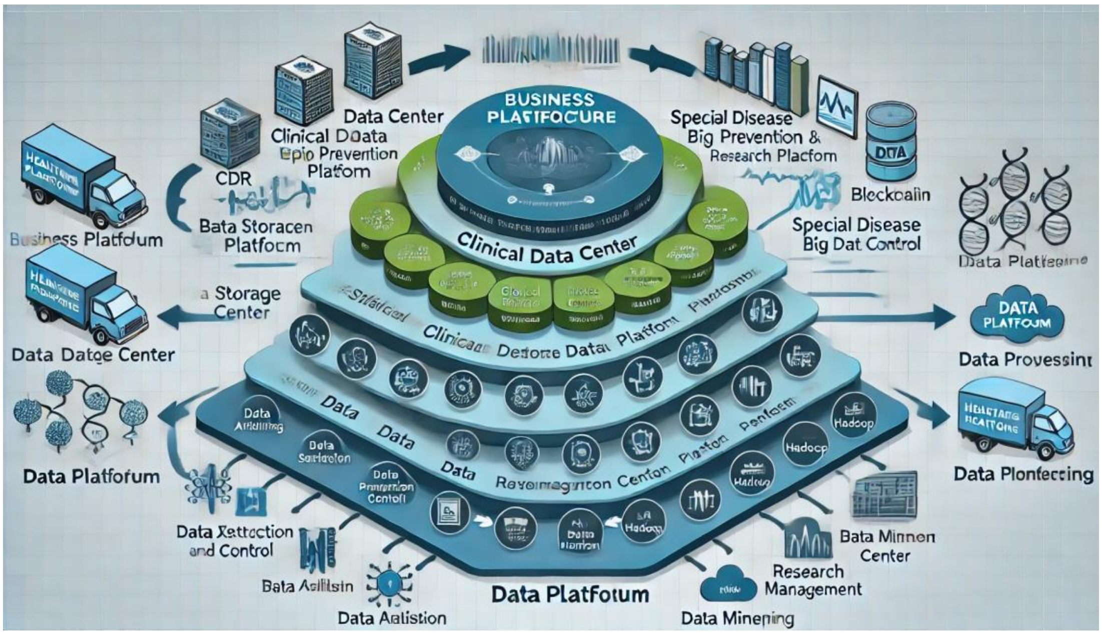

Figure 3: An Epidemic digital management framework based on multi-platform.

4. MODELING AND ANALYSIS

This section describes the modeling and analytical techniques used to develop and validate the framework for both infectious disease prediction and lung abnormality detection.

4.1 Infectious Disease Prediction Model

The infectious disease prediction model is built using convolutional and recurrent neural networks, with a focus on forecasting disease spread based on patient demographics, genetic sequencing, and transmission history. NLP techniques standardize data from unstructured clinical records, converting it into a form suitable for predictive modeling.

Figure 4: Medical natural language processing model.

4.2 Lung Abnormality Detection Model

The lung abnormality detection model employs the Compact Convolutional Transformer (CCT) structure to analyze chest X-rays and CT scans. This hybrid model effectively captures intricate details and broader structural patterns within images. An ablation study was conducted to determine optimal configurations for the model, including layer depth, kernel sizes, and batch size.

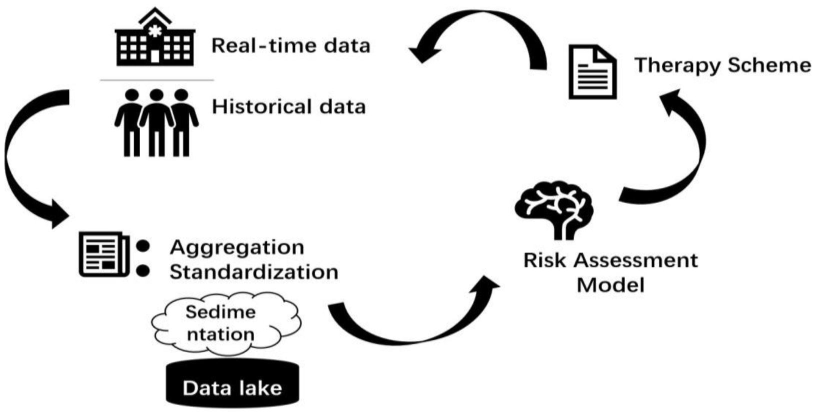

Figure 5: Risk Assessment for patients.

5. COMPARATIVE ANALYSIS OF METRIC CALCULATIONS FOR AI AND BIG DATA IN EPIDEMIC MANAGEMENT AND DIAGNOSTIC IMAGING

5.1 Infectious Disease Prediction Results

The infectious disease prediction model showed notable advancements in real-time outbreak forecasting and high-risk zone identification. The model demonstrated flexibility in reaction to new information by incorporating many data sources, including transmission statistics and clinical records, which is essential for efficient epidemic management.

5.2 Lung Abnormality Detection Results

High diagnostic accuracy was attained by the Compact Convolutional Transformer model in terms of precision and recall, especially when it came to differentiating abnormal lung diseases. For disease categories that are underrepresented, detection performance was enhanced through data augmentation using DCGAN. Clinical trust depends on doctors understanding the AI's priority regions, which Grad-CAM visualizations made easier to explain.

5.3 Epidemic Prediction Model Performance

The predictive model demonstrated significant improvements in identifying high-risk regions and forecasting outbreak trajectories. By integrating data sources such as clinical notes and transmission data, the model adapted to real-time changes, an essential feature for effective epidemic control. This adaptability highlights the model's robustness, particularly in predicting trends under rapidly evolving conditions.

The metric computations for three research centered on diagnostic imaging and epidemic management are compared in this publication. Metrics that show how well each strategy accomplishes its goals include accuracy, precision, recall, and F1-score where available.

Criteria / Metrics	A Comprehensive AI-Driven Framework for Epidemic Management and Diagnostic Imaging Enhancement Using Big Data	Digital Epidemic Management Framework	Fast and Efficient Lung Abnormality Identification With Explainable AI
Accuracy	High accuracy in epidemic prediction and lung abnormality detection; Grad-CAM explainability enhances diagnostic reliability.	Operational improvements observed; effectiveness in epidemic management at Wuhan Fifth Hospital case study.	Achieved 99.77% accuracy for CT scans and 95.37% for X-rays; high accuracy even with reduced dataset size.
Precision	Precision metrics not explicitly stated; overall high diagnostic accuracy for lung abnormalities using the hybrid model.	Precision details not provided; general effectiveness in operational accuracy in healthcare responses noted.	High precision across classifications for lung disease detection, contributing to a robust multi-classification system.
Recall	Enhanced recall for high-risk epidemic detection and diagnostic identification of lung abnormalities, supporting timely intervention.	Not specified in case study; primary focus on management efficiency rather than detailed recall metrics.	High recall values contributing to reliable lung abnormality detection across CT and X-ray modalities.
F1-score	Balanced F1-score for epidemic predictions and diagnostic tasks; Grad-CAM aids in maintaining interpretability in clinical use.	Not detailed; emphasis on system adaptability and case study evaluation metrics for epidemic response.	Achieves high F1-score for both CT and X-ray datasets, balancing precision and recall for multi-class lung disease detection.
Other Relevant Metrics	Diagnostic interpretability via Grad-CAM; Matthews Correlation Coefficient (MCC) for robustness on imbalanced datasets.	Evaluated on efficiency, adaptability, interoperability in healthcare environments; qualitative feedback on performance provided.	Reduced training time (10-12 sec/epoch for CT; 40-42 sec/epoch for X-ray); strong performance even on fewer training images.

6. CONCLUSION

This research highlights the potential of AI and big data in transforming healthcare responses to infectious diseases and diagnostic processes for lung abnormalities. By developing a comprehensive framework for real-time epidemic tracking and diagnostic accuracy in lung imaging, this study provides a foundation for future advancements in healthcare AI. The study's models demonstrated high robustness and accuracy, underscoring the value of integrating AI and big data into healthcare infrastructure. Future research may explore the application of these frameworks across other diseases and further refine interpretability methods to enhance clinical integration. The study's insights into AI-driven diagnostics emphasize the importance of expanding AI integration in healthcare infrastructure, particularly in areas like real-time disease surveillance and automated imaging diagnostics. In order to enhance clinical integration and patient outcomes, future research could investigate expanding the use of this paradigm to other medical specialties and creating more sophisticated explainability strategies.

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