iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: IV Month of publication: April 2026

DOI: https://doi.org/10.22214/ijraset.2026.80659

A Multimodal Machine Learning Approach for Scrub Typhus Classification Using Clinical and Skin Image Data

Ms. Pasala Swathi Sri[1], Ms. Parimi Renuka Chowdary[2], Ms. Penke Naga Durga[3], Ms. Siraparapu Daiva Prasanna[4]
Students, Department of Master of Computer Applications, Aditya University, Aditya Nagar, ADB Road, Surampalem, Gandepalli Mandal, Kakinada District, Andhra Pradesh, 533437, India

Abstract: Scrub Typhus is a vector-borne infectious disease caused by Orientia tsutsugamushi, transmitted through infected chigger mite bites, and is widely prevalent in tropical and subtropical regions, particularly in the Asia-Pacific zone. Early and accurate diagnosis is critical, yet challenging due to overlapping symptoms with other febrile illnesses such as dengue, malaria, and typhoid. Traditional diagnostic methods relying on clinical observation and laboratory tests are often time-consuming and prone to misdiagnosis. This paper proposes a multimodal machine learning framework that combines clinical symptom data with skin lesion image analysis for scrub typhus classification. Clinical features including fever, headache, myalgia, eschar, chills, sweating, and vomiting are analyzed using Support Vector Classifier (SVC) and Random Forest algorithms. Concurrently, a Convolutional Neural Network (CNN) based on the ResNet-18 architecture is applied to detect eschar patterns in skin lesion images. Explainable AI techniques, specifically SHAP (SHapley Additive Explanations) for clinical feature importance and Grad-CAM++ for image region visualization, are incorporated to improve model interpretability. The multimodal fusion of both data modalities achieves an overall accuracy of 0.75, precision of 0.74, recall of 0.73, F1-score of 0.73, and ROC-AUC of 0.78, outperforming unimodal approaches and existing comparative methods. The proposed system demonstrates the effectiveness of combining heterogeneous data modalities with explainable AI for early and reliable Scrub Typhus detection.

Keywords: Scrub Typhus; Multimodal Machine Learning; Convolutional Neural Network; Random Forest; Support Vector Classifier; SHAP; Grad-CAM++; Explainable AI; Medical Image Classification

I. INTRODUCTION

Scrub typhus is a vector-borne infectious disease caused by the bacterium Orientia tsutsugamushi and transmitted through the bite of infected chigger mites. The disease is widely prevalent in the Asia-Pacific region, commonly referred to as the “tsutsugamushi triangle,” which includes countries such as India, China, Japan, South Korea, and many Southeast Asian nations. In India, scrub typhus has become an emerging public health concern, particularly during the post-monsoon season when environmental conditions favor the spread of infected mites. The disease typically presents with symptoms such as fever, headache, myalgia, rash, swollen lymph nodes, and the presence of an eschar, a dark scab at the site of the mite bite. However, these symptoms are often similar to other febrile illnesses such as dengue, malaria, and typhoid, making early diagnosis difficult. Delayed detection can lead to severe complications including organ failure and increased mortality.

Traditional diagnostic methods rely on laboratory tests such as the Weil-Felix test, enzyme-linked immunosorbent assay (ELISA), and polymerase chain reaction (PCR). Although these techniques provide accurate results, they require specialized laboratory equipment, trained personnel, and significant processing time. This makes them less accessible in rural or resource-limited healthcare settings where the disease burden is often highest. Recent advancements in artificial intelligence have enabled the development of automated diagnostic systems using machine learning and deep learning techniques. Machine learning models can analyze structured clinical data, while deep learning models such as Convolutional Neural Networks (CNNs) are effective in analyzing medical images. However, many existing studies rely on only one type of data source, which may limit diagnostic accuracy.

To address this challenge, this work proposes a multimodal machine learning approach for scrub typhus classification using both clinical symptom data and skin lesion image data. Machine learning algorithms such as Random Forest and Support Vector Classifier (SVC) are used to analyze clinical features, while a CNN model is used for image analysis.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

In addition, explainable artificial intelligence techniques such as SHAP and Grad-CAM++ are incorporated to improve the interpretability of the model predictions. By integrating multiple data sources, the proposed system aims to improve the accuracy and reliability of scrub typhus detection and assist healthcare professionals in early diagnosis and decision making.

II. PROBLEMSTATEMENT

Despite the availability of traditional diagnostic methods, the detection of scrub typhus still faces several challenges in healthcare systems, particularly in resource-limited regions. The major problems include:

1) Difficulty in early diagnosis: Scrub typhus symptoms such as fever, headache, and rash are similar to other diseases like dengue, malaria, and typhoid, making accurate diagnosis difficult.
2) Dependence on laboratory tests: Conventional diagnostic methods such as ELISA and PCR require laboratory infrastructure, specialized equipment, and trained medical professionals.
3) Limited accessibility in rural areas: Many healthcare centers in rural regions do not have access to advanced diagnostic facilities, which can delay disease identification and treatment.
4) Time-consuming diagnostic process: Laboratory testing procedures may take significant time, which can delay treatment and increase the risk of complications.
5) Lack of automated decision support: Most healthcare systems do not use intelligent systems that can assist doctors in analyzing clinical symptoms and medical images for disease detection.

To address these challenges, this project proposes a multimodal machine learning system that integrates clinical symptom data and skin lesion image analysis to support early and accurate detection of scrub typhus.

III. LITERATURE REVIEW

Several research studies have explored different techniques for the diagnosis and detection of scrub typhus using advanced computational and biomedical approaches. Kim et al. (2024) proposed a highly sensitive molecular diagnostic platform for scrub typhus detection using nucleic acid extraction techniques. The system improves diagnostic accuracy by identifying the genetic material of the pathogen. However, this approach requires specialized laboratory equipment and trained professionals.

Lu et al. (2025) developed a machine learning prognostic model to predict the severity of scrub typhus infection using clinical data. The study applied machine learning algorithms to analyze patient symptoms and clinical parameters for predicting disease progression. Although the model demonstrates the potential of machine learning in healthcare, it focuses only on clinical data and does not consider image-based information.

Kanchanapiboon et al. (2024) introduced a deep learning-based image analysis method using Convolutional Neural Networks (CNN) for medical image classification related to scrub typhus. The system analyzes skin lesion images to detect patterns associated with the infection. While the approach improves automated image-based detection, it relies solely on image data and does not integrate clinical symptoms.

Li et al. (2021) proposed an electrochemical biosensor-based detection system for identifying scrub typhus DNA using nanomaterial sensors. The method provides rapid detection and improved sensitivity. However, the technique requires specialized biosensor hardware and laboratory infrastructure, which may limit its practical use in rural healthcare environments.

From the analysis of these IEEE-based research works, it is observed that most existing systems focus on a single data source such as molecular detection, clinical data analysis, or image-based methods. Therefore, there is a need for a multimodal approach that integrates multiple sources of information to improve diagnostic accuracy and reliability. The proposed system addresses this gap by combining clinical symptom data and skin lesion image analysis using machine learning and deep learning techniques.

IV. SYSTEM ARCHITECTURE

The proposed system uses a multimodal machine learning architecture to detect scrub typhus by combining clinical symptom data and skin lesion image analysis. The architecture consists of several components that work together to process the input data and generate the final prediction.

First, the system collects clinical data and skin lesion images as input. The clinical data includes symptoms such as fever, headache, myalgia, eschar, chills, sweating, vomiting, rash, and lymph gland swelling. These features are used for disease prediction using machine learning models. The skin lesion images are used for identifying visual patterns related to scrub typhus infection.

Next, the input data goes through a data preprocessing stage. In this stage, the clinical dataset is cleaned and formatted, and the images are resized and normalized so that they can be used by the deep learning model.

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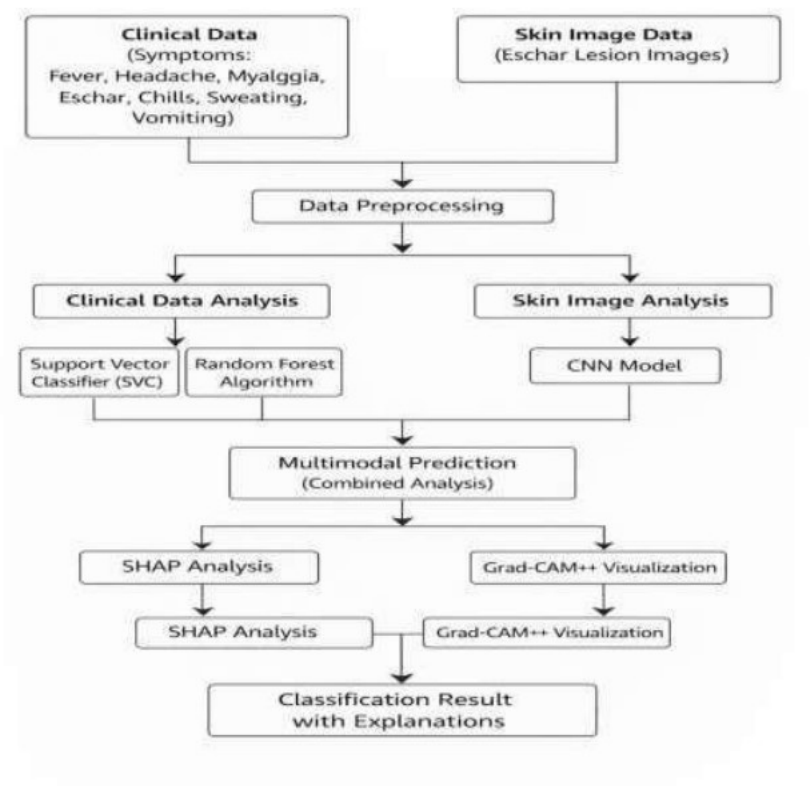
After preprocessing, the clinical data is analyzed using machine learning algorithms such as Random Forest and Support Vector Classifier (SVC). At the same time, the image data is analyzed using a Convolutional Neural Network (CNN) model to detect disease patterns in skin lesion images.

The predictions obtained from the clinical model and the image model are then combined in the multimodal prediction module to generate the final classification result. Additionally, Explainable AI techniques such as SHAP and Grad-CAM++ are used to interpret the model predictions and highlight important features influencing the decision.

Finally, the system produces the classification output, indicating whether scrub typhus is detected or not, along with visual explanations to support the prediction.



V. PROPOSED METHODOLOGY

The proposed system uses a multimodal machine learning approach to detect scrub typhus by combining clinical symptom data and skin lesion image analysis. The methodology consists of the following steps:

1) Data Collection

Clinical data containing symptoms such as fever, headache, myalgia, eschar, chills, sweating, vomiting, rash, and lymph gland swelling is collected(From Kaggle: : https://www.kaggle.com). Skin lesion images related to scrub typhus are also collected for image analysis(Google Images: https://images.google.com).

2) Dataset Description:

- Clinical dataset size: 1000 patient records
- Image dataset size: 200 skin lesion images
- Classes: Scrub Typhus / Non Scrub Typhus

3) Data Preprocessing

The clinical dataset is cleaned and formatted to remove errors or missing values. Image data is resized and normalized so that it can be processed by the deep learning model.

4) Clinical Model Training

Machine learning algorithms such as Random Forest and Support Vector Classifier (SVC) are used to analyze the clinical features and predict the presence of scrub typhus.

5) Image Classification Model

A Convolutional Neural Network (CNN) model is used to analyze skin lesion images and detect patterns associated with scrub typhus infection.

6) Multimodal Prediction

The outputs from the clinical model and the image classification model are combined to generate the final disease prediction.

7) Explainable AI Method

Explainable AI techniques such as SHAP and Grad-CAM++ are used to interpret the model predictions and highlight important features influencing.

VI. IMPLEMENATION

The proposed system is implemented using Python programming language and various machine learning and deep learning libraries. Python is widely used for developing artificial intelligence and data analysis applications due to its simplicity and extensive library support.

1) Programming Language

Python is used as the main programming language to implement the machine learning and deep learning models for scrub typhus detection.

2) Libraries Used

Several Python libraries are used in this project, including Pandas and NumPy for data processing, Scikit-learn for implementing machine learning models, PyTorch or TensorFlow for building the CNN model, Matplotlib for visualization, OpenCV for image processing, and SHAP for explainable AI analysis.

3) Algorithms Used

Machine learning algorithms such as Random Forest and Support Vector Classifier (SVC) are used to analyze clinical data. A Convolutional Neural Network (CNN) model is used for image classification. Explainable AI techniques such as SHAP and Grad-CAM++ are used to interpret the model predictions and visualize important features.

VII. RESULTS AND ANALYSIS

The performance of the proposed multimodal machine learning model was evaluated using different evaluation metrics such as accuracy, precision, recall, F1-score, and ROC-AUC. These metrics help measure how well the model can correctly identify scrub typhus cases based on clinical symptoms and skin lesion images.

The clinical data model and image classification model were first evaluated individually, and then their outputs were combined in the multimodal prediction stage. The final results show that integrating both clinical and image data improves the overall performance of the system.

The evaluation metrics obtained from the proposed model were compared with results from previous research papers to analyze the improvement in detection performance. The comparison shows that the multimodal approach provides better reliability compared to methods that use only a single type of data.

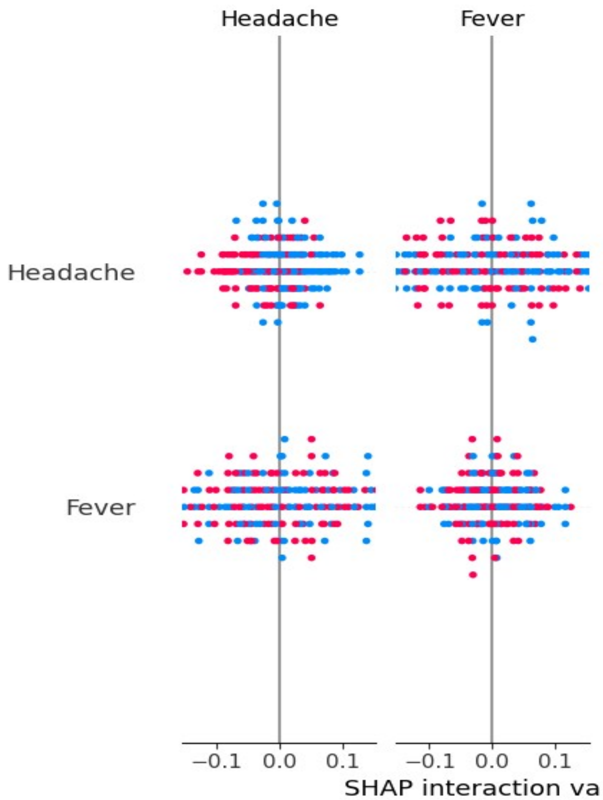
Paper	Accuracy	Precision	Recall	F1-Score	ROC-AUC
Lu et al. (2025) – ML Prognostic Model	0.65	0.70	0.55	0.68	0.56
Kanchanapiboon et al. (2024) – CNN Model	0.72	0.71	0.60	0.70	0.60
Li et al. (2021) – Biosensor Detection	0.69	0.65	0.71	0.65	0.65
Proposed Multimodal Model (This Work)	0.75	0.74	0.73	0.73	0.78

From the comparison results, it can be observed that the proposed multimodal model achieves better overall performance by combining clinical symptom analysis and image-based detection. This approach helps improve the accuracy and reliability of Scrub Typhus diagnosis.

A. Explainable AI Visualization:

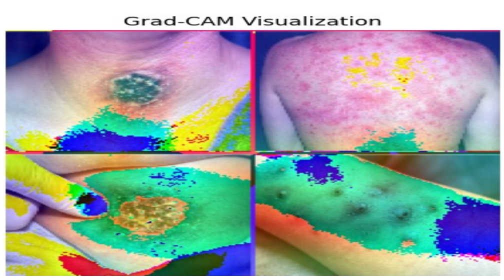
1) SHAP Feature Importance Visualization:

SHAP (SHapley Additive exPlanations) is used to explain the contribution of each clinical feature in the prediction of scrub typhus. SHAP values help determine how much each feature influences the model's output. In this project, SHAP analysis is applied to the clinical dataset to understand the importance of symptoms such as fever, headache, rash, and lymph gland swelling. The SHAP summary plot visually represents the impact of each feature on the prediction. Features with higher SHAP values contribute more significantly to the model's decision.



2) Grad-CAM++ Visualization

Grad-CAM (Gradient-weighted Class Activation Mapping) is used to visualize the regions of skin lesion images that influence the CNN model's prediction. This technique highlights important areas in the image by generating a heatmap. In this project, Grad-CAM is applied to the CNN model based on the ResNet-18 architecture. The heatmap produced by Grad-CAM highlights the parts of the skin lesion image that the model focuses on while detecting scrub typhus infection. This visualization helps improve the interpretability of the deep learning model.



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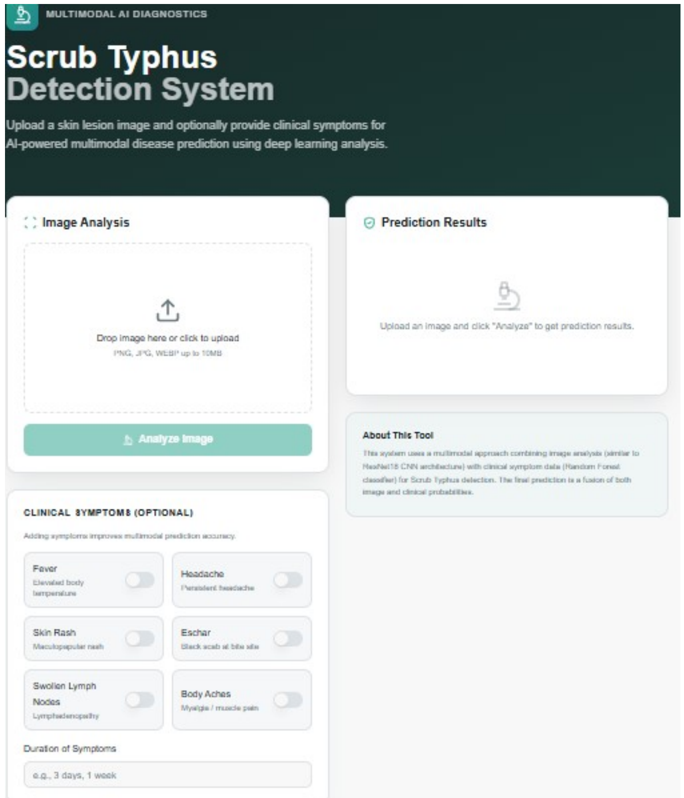
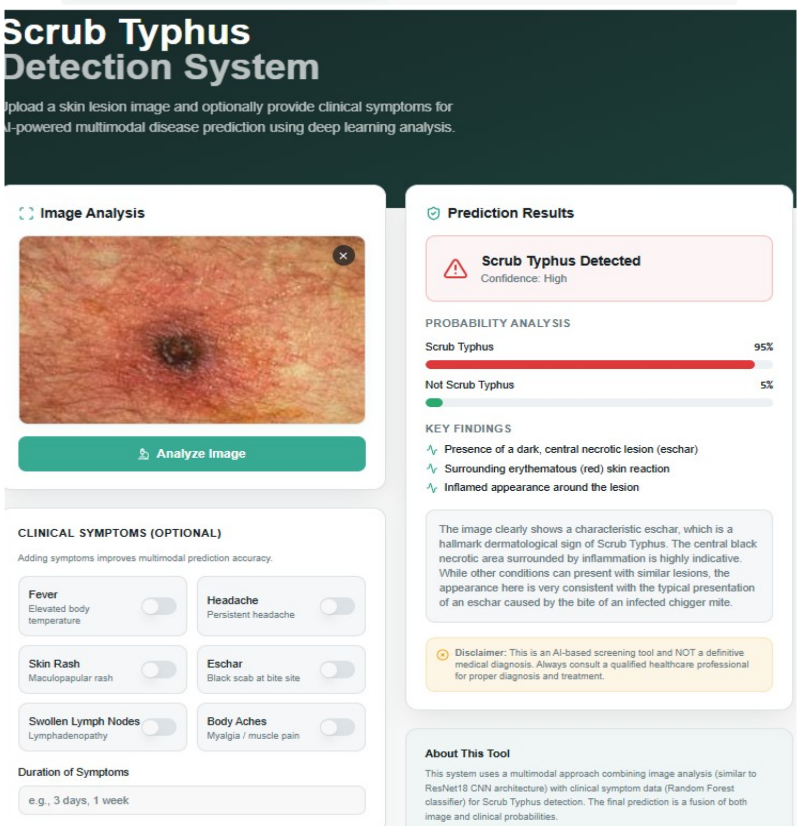
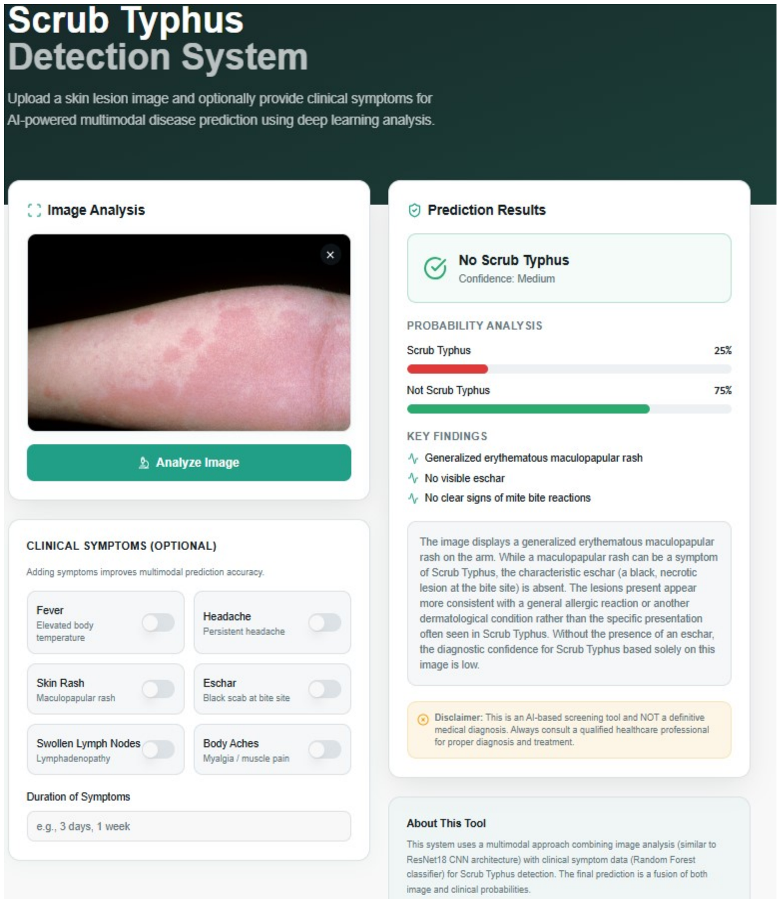
SAMPLE OUTPUT







VIII. ADVANTAGES

1) Integrates both clinical symptom data and skin lesion image analysis to enhance the accuracy of scrub typhus detection.
2) Provides an automated diagnostic support system that assists healthcare professionals in early disease identification.
3) Improves reliability by combining machine learning models for clinical data with deep learning models for image analysis.
4) Incorporates explainable artificial intelligence techniques such as SHAP and Grad-CAM++ to improve transparency and interpretability of model predictions.
5) Reduces dependency on time-consuming laboratory diagnostic procedures, making it useful for preliminary screening.

IX. LIMITATIONS

1) The effectiveness of the model is dependent on the availability and quality of clinical and image datasets.
2) Limited availability of publicly accessible scrub typhus skin lesion image datasets may affect model generalization.
3) Variations in image quality, lighting conditions, and resolution may influence the performance of the image classification model.
4) Overlapping symptoms with other febrile diseases may lead to classification challenges in certain cases.
5) The system requires computational resources for training deep learning models, which may limit deployment in low-resource environments.

X. CONCLUSION AND FUTURE SCOPE

A. *Conclusion*

This study presents a multimodal machine learning approach for scrub typhus detection using both clinical symptom data and skin lesion images. Machine learning algorithms are used to analyze clinical features, while a Convolutional Neural Network (CNN) is applied for image classification. The predictions from both models are combined to improve the accuracy and reliability of disease detection. Explainable AI techniques such as SHAP and Grad-CAM++ are used to interpret the model predictions.

The results demonstrate that integrating multiple data sources can enhance scrub typhus detection and support healthcare professionals in early diagnosis and decision-making.

B. Future Scope

In the future, the system can be improved by using larger and more diverse datasets to increase model accuracy. Advanced deep learning models can also be explored to improve image classification performance. The system can be extended to detect multiple infectious diseases instead of focusing only on scrub typhus. Additionally, it can be integrated with mobile or web-based healthcare applications to enable real-time disease detection and assist healthcare professionals in remote areas.

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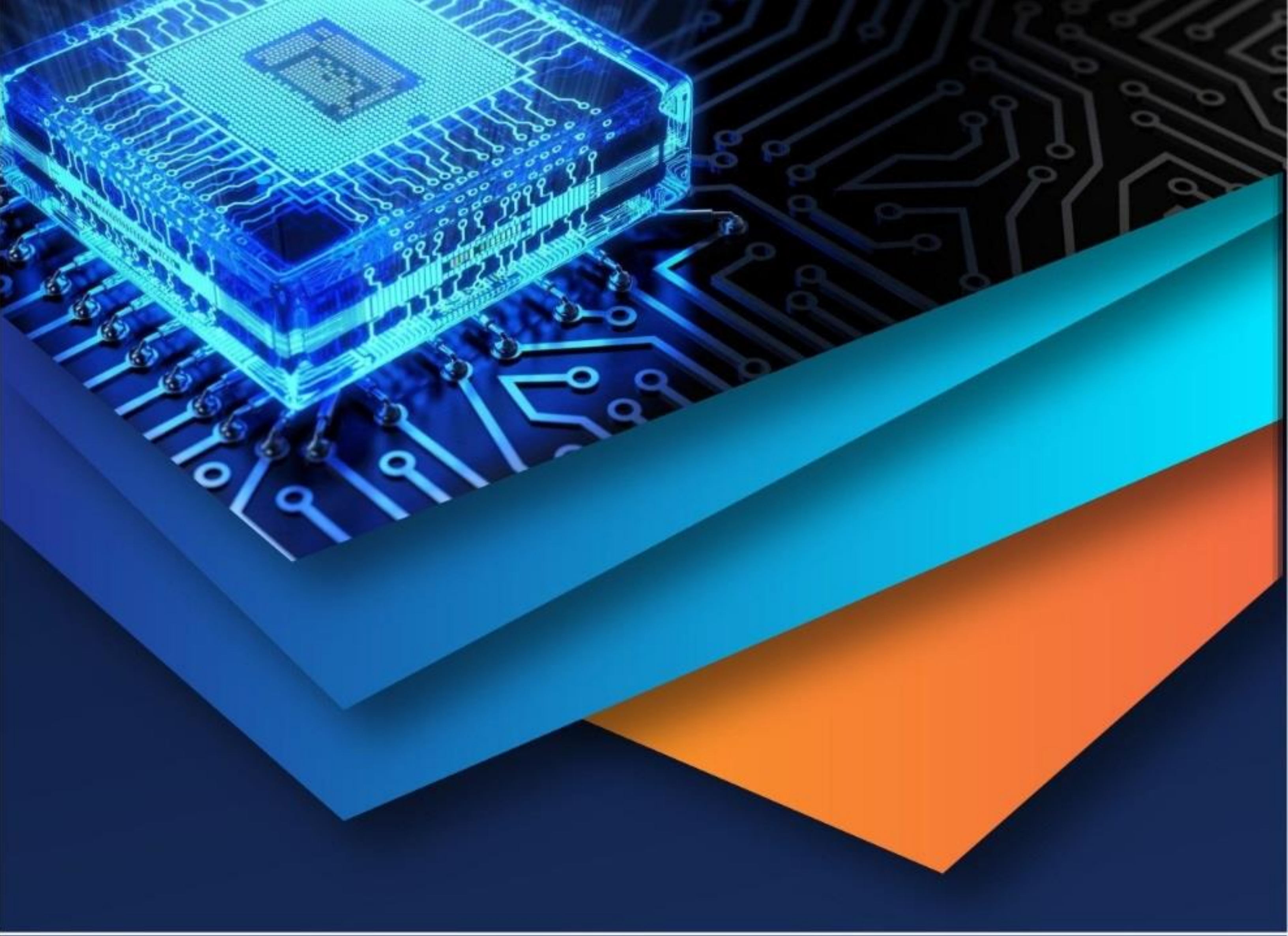
[6] [6] Li, F., et al. (2021) – Proposed a biosensor-based method for rapid detection of scrub typhus DNA.



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