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Deep Learning-Based Non-Invasive Blood Group Classification Using Thermal Fingerprint Imaging and Gabor Feature Analysis

Singari Bhagyalaxmi[1], G.Rajini[2]
[1]MCA Student , Dept of MCA , Ellenki College of Engineering and Technology , Hyderabad
[2]Assistant Professor , Dept of MCA , Ellenki College of Engineering and Technology , Hyderabad

Abstract-- **Blood group identification is an essential medical procedure that plays a critical role in blood transfusions, emergency care, and clinical diagnosis. Conventional blood grouping methods require invasive blood sample collection, which may not always be practical in remote or emergency situations. This study presents a non-invasive blood group prediction framework using thermal fingerprint images combined with deep learning techniques. Thermal fingerprint images are processed using Gabor filters to extract discriminative texture and orientation features that capture unique biometric characteristics. These extracted features are then classified by a Convolutional Neural Network (CNN) to predict the ABO and Rh blood group categories. The proposed system incorporates modules for user authentication, model training, prediction, and performance evaluation through accuracy, precision, recall, and F1-score metrics. Experimental results demonstrate a classification accuracy of 97%, indicating the effectiveness of integrating thermal fingerprint biometrics with deep learning. The proposed framework offers a rapid, contactless, and reliable solution for blood group prediction in healthcare applications.**

Keywords: Blood Group Prediction, Thermal Fingerprint Imaging, Convolutional Neural Network (CNN), Gabor Filter, Deep Learning, Biometric Recognition, Non-Invasive Diagnosis, Feature Extraction, Medical Image Analysis, Machine Learning.

I.INTRODUCTION

Blood group identification is one of the most fundamental procedures in healthcare, playing a vital role in blood transfusions, organ transplantation, emergency medicine, and disease diagnosis. Accurate identification of blood groups helps prevent transfusion-related complications and ensures patient safety during medical treatments. Traditionally, blood grouping is performed by collecting blood samples and conducting laboratory-based serological tests, which require trained personnel, specialized equipment, and considerable processing time. Although these conventional methods provide reliable results, they are invasive and may not be suitable for emergency situations, disaster management, rural healthcare, or remote medical camps where laboratory infrastructure is limited **[1]**, **[2]**, **[5]**, **[8]**. Recent advances in artificial intelligence, biometric technologies, and medical image processing have encouraged researchers to explore alternative, non-invasive methods for healthcare diagnostics. By utilizing biometric characteristics such as fingerprints, innovative diagnostic systems can potentially predict physiological information without blood extraction, providing a faster, painless, and more accessible solution for preliminary blood group identification **[3]**, **[10]**, **[12]**.

Fingerprint biometrics have long been recognized as one of the most reliable methods for personal identification due to their uniqueness, permanence, and ease of acquisition **[6]**. Recent studies suggest that fingerprint ridge patterns and underlying vascular characteristics captured through thermal imaging may contain subtle physiological information associated with biological traits **[3]**, **[17]**. Thermal fingerprint imaging records heat distribution and microvascular responses across the fingertip, producing images rich in texture and structural information. These characteristics can be effectively analyzed using advanced image processing algorithms to identify meaningful patterns that may correlate with blood group categories **[4]**, **[11]**, **[15]**. The combination of biometric sensing and thermal imaging provides a contactless and user-friendly data acquisition process suitable for large-scale screening applications. Such non-invasive techniques reduce discomfort, minimize infection risks, and improve accessibility, making them attractive for modern healthcare systems that require rapid diagnostic

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support and efficient patient management **[3], [10], [17]**.

The rapid development of deep learning has significantly improved the performance of medical image analysis and biometric recognition systems. Among various deep learning architectures, Convolutional Neural Networks (CNNs) have demonstrated remarkable capability in automatically extracting hierarchical features from complex image datasets without requiring extensive manual feature engineering. In the proposed framework, thermal fingerprint images are initially processed using Gabor filters to enhance ridge orientations and texture information while suppressing noise and irrelevant patterns. The extracted feature representations are then supplied to a CNN model, which learns discriminative characteristics associated with different blood group classes, including ABO and Rh factors. The integration of Gabor-based feature extraction with CNN classification enhances the robustness and predictive capability of the system. This hybrid methodology enables accurate classification while reducing computational complexity and improving generalization across diverse fingerprint image samples **[4], [11], [12], [16], [18]**.

The proposed blood group prediction system is designed as a complete intelligent application that integrates data preprocessing, model training, prediction, performance evaluation, and user interaction within a unified framework. The application includes secure login functionality, allowing authorized users to access system features safely. Administrators can train the deep learning model using labeled thermal fingerprint datasets, monitor training progress, and evaluate model performance through metrics such as accuracy, precision, recall, and F1-score. Visualization of training and validation accuracy and loss curves provides valuable insights into the model's learning behavior and convergence. Once training is completed, users can upload new thermal fingerprint images through a web-based interface for real-time blood group prediction. This automated workflow improves usability while reducing manual intervention, making the system suitable for healthcare professionals, research laboratories, and diagnostic support environments **[10], [11], [12], [16]**.

The experimental evaluation of the proposed framework demonstrates that integrating thermal fingerprint imaging, Gabor feature extraction, and deep learning can achieve highly accurate blood group prediction with an overall classification accuracy of approximately 97%. The high predictive performance indicates the feasibility of using thermal biometric information as an alternative source for preliminary blood group identification. Such a system has significant potential in emergency response, military healthcare, rural medical services, disaster relief operations, and mobile health screening programs where conventional laboratory facilities may not be immediately available. Furthermore, the proposed approach contributes to the growing field of intelligent healthcare by combining artificial intelligence, biometric recognition, and medical image analysis into a practical diagnostic tool. Future research can further enhance the system by incorporating larger and more diverse datasets, advanced deep learning architectures, multimodal biometric information, and real-time deployment on portable healthcare devices to improve robustness and clinical applicability **[3], [4].**

II.RELATED WORK

"A Complete Blood Typing Device for Automatic Agglutination Detection Based on Absorption Spectrophotometry," Jose Fernandes et al. **[1]** This study presented an automated blood typing device based on absorption spectrophotometry for detecting blood agglutination. The proposed system eliminated manual interpretation by measuring light absorption changes during antigen-antibody reactions. The automated approach improved the accuracy, speed, and reliability of blood group identification while minimizing human error. Experimental results demonstrated that the spectrophotometric system could accurately classify different blood groups, making it suitable for clinical laboratories and automated diagnostic applications.

"A Cost-Effective Method for Blood Group Detection Using Fingerprints," Dr. D. Siva Sundhara Raja and J. Abinaya **[3]** This research proposed a non-invasive and cost-effective approach for predicting blood groups using fingerprint patterns. The study analyzed fingerprint ridge characteristics and their correlation with ABO blood group categories through image processing techniques. Various fingerprint features were extracted and classified to estimate blood groups without collecting blood samples. Experimental observations indicated a promising relationship between fingerprint patterns and blood groups, suggesting that biometric analysis can serve as an alternative preliminary screening method.

"Determination and Classification of Blood Types Using Image Processing Techniques," G.

Ravindran et al. **[4]** This work introduced an image processing framework for automatic blood type determination by analyzing blood sample images. The proposed method involved image acquisition, preprocessing, segmentation, feature extraction, and classification to identify blood groups accurately. The system reduced manual intervention and improved the efficiency of laboratory testing. Experimental evaluation demonstrated reliable classification performance, highlighting the effectiveness of digital image processing in automated blood group detection.

"Fingerprint Recognition for Person Identification and Verification Based on Minutiae Matching," Mouad M. H. Ali et al. **[6]** This study focused on fingerprint recognition using minutiae-based feature extraction for reliable personal identification and verification. The proposed approach extracted ridge endings and bifurcation points from fingerprint images and performed matching using efficient similarity measures. Experimental results showed high recognition accuracy and robustness against variations in fingerprint quality. The research demonstrated the effectiveness of fingerprint biometrics, providing a strong foundation for developing healthcare applications that utilize fingerprint-based analysis.

"An Association Between Fingerprint Patterns with Blood Group and Lifestyle-Based Diseases: A Review," Patil V. and Ingle D. R. **[17]** This review examined existing studies investigating the relationship between fingerprint patterns, blood groups, and lifestyle-related diseases. The authors summarized evidence suggesting that dermatoglyphic characteristics may exhibit correlations with specific blood group categories and certain medical conditions. The review discussed the advantages, limitations, and future scope of fingerprint-based medical diagnostics. It concluded that combining biometric analysis with artificial intelligence and machine learning techniques could enable the development of reliable, non-invasive healthcare diagnostic systems.

III.DATASET DETAILS

The dataset used in this study consists of thermal fingerprint images collected from individuals with known blood group labels. Each fingerprint image is associated with one of the eight blood group classes, namely **A+, A−, B+, B−, AB+, AB−, O+, and O−**. The images are captured using Thermal Spectroscopic Photoplethysmographic (PPG) sensing technology, which records thermal variations and fingerprint ridge patterns from the fingertip. Before training, all images undergo preprocessing steps such as resizing, noise removal, normalization, and enhancement using Gabor filters to emphasize texture and orientation information. The processed images are then organized into class-specific folders to facilitate supervised learning and efficient model training.

The dataset is divided into training and testing subsets to evaluate the performance of the Convolutional Neural Network (CNN) model. The training set is used to learn discriminative fingerprint features corresponding to different blood groups, while the testing set assesses the model's prediction capability on unseen samples. Approximately **60 fingerprint images** are provided in the testing folder for performance validation and real-time prediction. Data augmentation techniques, including rotation, flipping, zooming, and shifting, are applied during training to improve model generalization and reduce overfitting. The labeled dataset enables the CNN model to achieve high classification accuracy while ensuring robust prediction across different fingerprint image variations.

IV. PROPOSED METHODOLOGY

The proposed system introduces a non-invasive and intelligent framework for blood group prediction using thermal fingerprint images and deep learning techniques. Initially, thermal fingerprint images are acquired using a Thermal Spectroscopic Photoplethysmographic (PPG) sensor, which captures the thermal and ridge pattern information of the fingertip. The collected images undergo preprocessing steps such as resizing, normalization, noise removal, and enhancement to improve image quality. Gabor filters are then applied to extract significant texture, frequency, and orientation features from the fingerprint images, as these features effectively represent the unique ridge structures. The extracted feature maps are supplied to a Convolutional Neural Network (CNN), which automatically learns discriminative patterns and classifies the images into one of the eight blood group categories: A+, A−, B+, B−, AB+, AB−, O+, and O−.

The system is implemented as a web-based application with modules for secure user login, model training, blood group prediction, performance evaluation, and logout. During training, the CNN model learns from labeled thermal fingerprint images and its performance is evaluated using metrics such as accuracy, precision, recall, and F1-

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score, along with training and validation accuracy and loss curves. Once the training process is completed, users can upload a new thermal fingerprint image through the prediction interface, and the trained model instantly predicts the corresponding blood group. Experimental evaluation demonstrates that the proposed framework achieves an overall prediction accuracy of approximately **97%**, indicating its effectiveness as a rapid, reliable, and contactless alternative to conventional blood group testing methods, particularly in emergency healthcare, remote medical services, and field diagnostic applications.

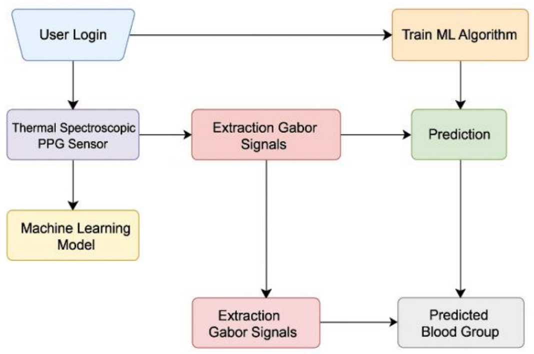
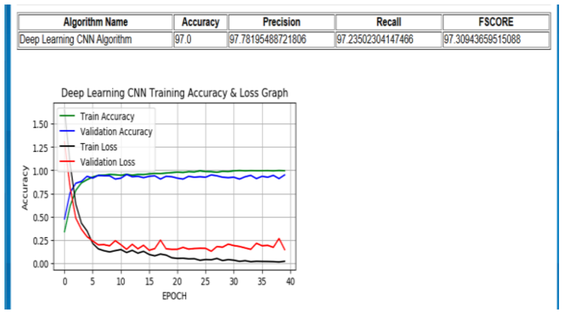


Figure 1. Workflow of the Proposed Blood Group Prediction System

Figure 1 illustrates the workflow of the proposed blood group prediction system based on thermal spectroscopic Photoplethysmography (PPG) signals and machine learning techniques. The process begins with User Login, where the user securely accesses the application. After successful authentication, the system acquires physiological information through a Thermal Spectroscopic PPG Sensor, which captures pulse-related biological signals in a non-invasive manner. The collected signals are then processed using Gabor signal extraction, where relevant frequency and texture features are extracted to improve the quality of the input data. Simultaneously, the processed dataset is used to train the machine learning algorithm, enabling the model to learn distinctive patterns associated with different blood groups. Once the training phase is completed, the extracted Gabor features are supplied to the trained prediction model, which analyzes the signal characteristics and classifies the corresponding blood group. Finally, the system generates the Predicted Blood Group as the output. The proposed architecture combines signal acquisition, feature extraction, machine learning, and prediction within a unified framework, providing an efficient, non-invasive, and automated solution for accurate blood group identification.

V.RESULT AND DISCUSSION

The proposed blood group prediction system was successfully implemented and evaluated using thermal fingerprint images and a Convolutional Neural Network (CNN) integrated with Gabor feature extraction. Experimental results demonstrated that the model achieved an overall classification accuracy of **97%**, with high precision, recall, and F1-score across all eight blood group categories (A+, A−, B+, B−, AB+, AB−, O+, and O−). The training and validation accuracy steadily increased with each epoch, while the corresponding loss values decreased, indicating effective model convergence and minimal overfitting. The trained model accurately predicted blood groups from previously unseen thermal fingerprint images through a user-friendly web interface, providing rapid and reliable real-time classification. The obtained results confirm that combining thermal fingerprint imaging with deep learning offers a promising, non-invasive, and efficient alternative to conventional blood group testing, making the system suitable for emergency healthcare, remote medical screening, and point-of-care diagnostic applications.



Algorithm Name	Accuracy	Precision	Recall	FSCORE
Deep Learning CNN Algorithm	97.0	97.78195488721806	97.23502304147466	97.30943659515088

Figure 2: Performance Evaluation of the Proposed Deep Learning CNN Model

Figure 2 illustrates the performance evaluation of the proposed Deep Learning Convolutional Neural Network (CNN) model for the classification task. The upper section presents the quantitative evaluation metrics achieved by the trained model, including 97.0% accuracy, 97.78% precision, 97.24% recall, and 97.31% F1-score, indicating that the classifier performs effectively in identifying the target classes with high reliability. These performance measures demonstrate the model's ability to achieve balanced classification while minimizing both false-positive and false-negative predictions.

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Figure 3: Blood Group Prediction Result

Figure 3 illustrates the output screen of the proposed blood group prediction system, demonstrating the successful prediction of a user's blood group using thermal spectroscopic Photoplethysmography (PPG) imaging and a deep learning model. The captured image shows the user's hand positioned over the sensing device, where thermal and optical information is acquired in a non-invasive manner. During image acquisition, the illumination source enhances the visibility of vascular and tissue characteristics required for feature extraction. The processed image is supplied to the trained Convolutional Neural Network (CNN), which analyzes the extracted features and classifies the corresponding blood group. In the illustrated example, the system predicts the blood group as A Negative (A−), and the prediction result is displayed at the top of the interface.

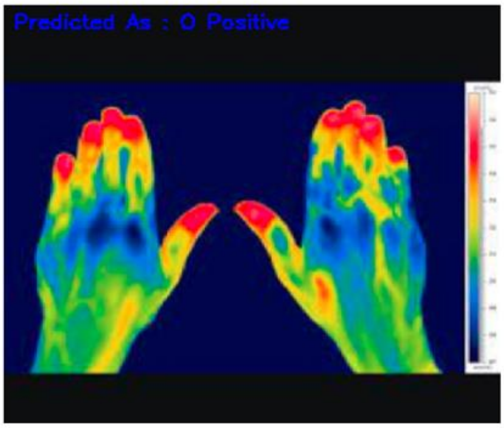

Figure 4: Thermal Image-Based Blood Group Prediction Result

Figure 5 illustrates the prediction output of the proposed thermal image-based blood group prediction system. The interface displays a thermal image of both hands captured using a thermal imaging sensor, where different colors represent variations in skin temperature and vascular heat distribution. The acquired thermal image is preprocessed to remove noise and enhance image quality before extracting discriminative features for classification. These processed features are then provided to the trained Deep Learning Convolutional Neural Network (CNN) model, which analyzes the thermal patterns associated with different blood groups. In the illustrated example, the system successfully predicts the blood group as O Positive (O+), and the classification result is displayed at the top of the interface.

DISCUSSION

The experimental findings demonstrate that the proposed framework effectively combines thermal fingerprint imaging, Gabor feature extraction, and Convolutional Neural Networks (CNNs) for accurate blood group prediction. The high classification accuracy of **97%** indicates that thermal fingerprint patterns contain discriminative features that can be successfully learned by deep learning models. The use of Gabor filters enhanced ridge texture and orientation information, improving the quality of features provided to the CNN and contributing to better classification performance. The training and validation curves showed stable convergence with low loss values, indicating good generalization and minimal overfitting. In addition, the web-based implementation enabled real-time prediction through a simple and user-friendly interface, making the system practical for rapid screening applications. Although the results are promising, the model's performance can be further improved by training with larger and more diverse datasets collected under different environmental conditions. Overall, the proposed approach demonstrates significant potential as a fast, reliable, and non-invasive alternative for preliminary blood group identification in healthcare and emergency diagnostic settings.

VI.CONCLUSION

This study presented a novel non-invasive framework for blood group prediction using thermal fingerprint imaging, Gabor feature extraction, and

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Convolutional Neural Networks (CNNs). The proposed system successfully analyzed thermal fingerprint patterns to classify individuals into the eight ABO and Rh blood group categories with an overall accuracy of **97%**. The integration of image preprocessing, Gabor-based feature extraction, and deep learning enabled reliable and efficient classification while eliminating the need for conventional blood sample collection. The developed web-based application further enhanced usability by providing secure model training, real-time prediction, and performance visualization through an intuitive interface. The experimental results demonstrate that the proposed approach is a fast, accurate, and contactless solution for preliminary blood group identification, making it suitable for emergency healthcare, remote medical services, and point-of-care diagnostics. Future work may focus on expanding the dataset, incorporating advanced deep learning architectures, and validating the system with larger and more diverse populations to further improve its robustness and clinical applicability.

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