

AI-Based Early Prediction of Iron-Deficiency Anemia in Rural Women

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Anemia is a common disease that may occur in individuals due to low levels of hemoglobin in the blood, whereas conventional diagnosis usually requires clinical examination and laboratory tests. Preliminary screening is often hindered by economic, availability, and even early recognition challenges. AnemiaVision is the proposed artificial intelligence system designed to recognize potential cases of anemia from conjunctiva images. AnemiaVision uses a Convolutional Neural Network to process and classify the image data into anemic and non-anemic classes. The model was trained using a dataset of conjunctiva images categorized into Anemic and Non-Anemic classes. The images were preprocessed and normalized before model training. AnemiaVision is comprised of the trained model and a web interface, which allows users to upload a conjunctiva image and receive screening results with model confidence. The system was implemented using Python programming language, TensorFlow/Keras framework, OpenCV computer vision library, and PHP web interface framework. The proposed system was experimentally evaluated, and results showed potential for rapid preliminary screening of anemia. AnemiaVision is proposed as an educational and screening tool, which cannot substitute laboratory tests and clinical diagnosis by medical professionals.

Keywords: *Anemia Detection, Conjunctiva Images, Convolutional Neural Network, Deep Learning, Medical Image Classification, Medical Image Screening, Artificial Intelligence, Image-Based Screening, Computer Vision, TensorFlow, Keras, Healthcare Technology*

I. INTRODUCTION

The development of artificial intelligence (AI) and deep learning technologies has contributed to the field of healthcare applications. However, the early detection of anemia is still a challenge in the context of limited access to laboratory facilities, medical professionals, and traditional diagnostic procedures. Conventional anemia diagnosis generally involves blood-based investigations to determine hemoglobin levels and other hematological parameters. While these methods provide clinically important information, they may require specialized equipment, trained personnel, and additional time and cost. Thus, there is a need to develop an accessible and non-invasive approach to aid in the preliminary screening of anemia.

Using computer vision and deep learning techniques for medical image analysis can be a great approach to develop a screening system. Conjunctiva images have visible characteristics that can be processed using image processing and machine learning techniques. In particular, the use of Convolutional Neural Networks (CNNs) enables the automated extraction of visual features from images and classification of different image categories. This approach can provide a simple image-based method for the preliminary identification of individuals who may require further clinical evaluation.

In this regard, the present study focuses on the development of AnemiaVision, an AI-assisted system for detecting potential anemia using conjunctiva images. The proposed

system uses a Convolutional Neural Network to classify the input conjunctiva images into Anemic and Non-Anemic categories. The images are preprocessed by resizing them to a fixed dimension and normalizing the pixel values, prior to being provided to the trained model. The system integrates the trained deep learning model with a web-based interface through which users can upload a conjunctiva image and obtain a predicted classification along with confidence information.

The key contribution of this study is the integration of conjunctiva image analysis, CNN-based classification, and a web-based interface into a single system for preliminary anemia screening. The proposed approach is intended to provide a convenient and accessible method for image-based screening while reducing the complexity associated with the initial assessment process. The system is implemented using technologies including Python, TensorFlow/Keras, OpenCV, and PHP, combining deep learning-based image classification with a user-oriented web application..

II. RELATED WORK

The utilization of Artificial Intelligence and machine learning in healthcare has sparked much interest in healthcare professionals and technologists alike. Deep learning methods have been leveraged for the analysis of medical images due to their ability to automatically extract image-related features required for classification tasks. Convolutional Neural Networks have been utilized for a number of healthcare-related applications that span disease screening, medical

image classification, and computer-assisted diagnosis, among others.

Anemia is conventionally diagnosed using laboratory-based tests such as blood tests and measurement of hemoglobin levels. While such diagnostic procedures have been shown to be effective, they are however invasive. Researchers have therefore explored the possibility of using visual-based cues for the detection of anemia. Specifically, conjunctiva analysis is of great interest due to the fact that it has been shown to provide valuable insight towards anemia-related diagnosis.

A number of recent studies have explored the feasibility of utilizing computer vision and machine learning methods for the analysis of conjunctiva images. The image-based approaches would typically require the implementation of a number of image-related processing steps that would prepare the data for the feature extraction or classification step. Image-based approaches for anemia screening would also require that domain-specific features be manually extracted or designed prior to model training. The manual design of features is problematic since such methods are typically sensitive to lighting and camera parameters and are therefore prone to inconsistencies in performance.

Convolutional Neural Networks offer a robust alternative to the traditional handcrafted method of obtaining features useful for image classification. CNNs have been leveraged for a number of computer vision-related problems due to their ability to automatically learn features from the raw pixel data. Convolutional layers are typically made up of a number of trainable parameters that contribute towards the learning of image-specific features. Convolutional Neural Networks have been successfully employed for many medical image analysis tasks.

Challenges associated with current image-based anemia screening methods and technologies include the size of the data, inconsistencies arising due to lighting and camera differences, accuracy in terms of classification performance, and application deployment. The utilization of a CNN-based model to predict anemia severity requires that a large enough dataset be available for the model to generalize well. An image-based model may be sensitive to differences in lighting or camera-specific variations. When applying an image-based model to screen for anemia, one must keep in mind that such techniques are only a preliminary screen and should not be utilized in lieu of proper laboratory-based diagnosis.

The AnemiaVision model proposes to perform anemia screening by first performing image preprocessing steps on the uploaded conjunctiva image. The preprocessed image data is then utilized to train a CNN-based binary image classifier that classifies images into Anemic and Non-Anemic categories. The trained model is then deployed in a web application that presents users with a simple interface that allows them to upload a conjunctiva image and obtain relevant prediction results. AnemiaVision seeks to combine the power of deep learning and image processing to provide an effective platform for anemia screening using a web-based interface.

While traditional research efforts for image-based anemia diagnosis focus on the development of a robust image classification or detection model, the proposed approach focuses on the integration of machine learning and a user-friendly application. AnemiaVision will allow for users to upload conjunctiva images which will then be preprocessed. The preprocessed image will then be passed to the CNN-based classifier where the classification result will be used to determine if the image belongs to the Anemic or Non-Anemic category.

III. METHODOLOGY

The proposed AnemiaVision system aims at providing an image-based approach to the preliminary detection of anemia, using conjunctiva images. The methodology includes image preprocessing, Convolutional Neural Network (CNN) based classification and a web-based application that provides the prediction to the user. The complete system comprises of dataset preparation, image preprocessing, model development, model training, prediction and web application implementation.

A. DATASET PREPARATION

The data set for the proposed system consists of two classes of images: Anemic and Non-Anemic. The total number of images is 4,262, where 2,558 are Anemic and 1,704 are Non-Anemic. The dataset is divided into two separate folders according to the class of each image.

As part of the data preparation step, the images are read and rescaled to a size of 64×64 pixels using the OpenCV library. The images are converted to numerical arrays to be used as input for the convolutional neural network (CNN). Moreover, the class labels are encoded using the Label Encoder.

B. IMAGE PREPROCESSING

Image preprocessing takes place before training the CNN model to ensure that all input images have the same representation. Each image of the conjunctiva is resized to 64×64 pixels with 3 color channels. Moreover, pixel values were normalized by dividing them by 255, thus reducing the input range to 0-1.

The data is split into training and testing sets. In the current implementation, 90% of the data is used for training, and 10% is used for testing. The same preprocessing step is applied to the input image when the model predicts the uploaded image to ensure that the input is in the same format as the data used to train the model.

C. CNN MODEL ARCHITECTURE

Convolutional Neural Network is considered as the main classification model for the task of detecting anemia from the conjunctiva images. CNNs are primarily used for image classification tasks due to the convolutional layers that learn image representations at multiple levels.

The input image size for the proposed network is $64 \times 64 \times 3$. The network comprises three convolutional layers with max-pooling with the number of filters equal to 32, 64, 128, respectively. The Global Average Pooling layer is used to downscale the input resolution by considering an average of pooled feature maps. Following that, the network

is connected with dense layers where the first dense layer contains 100 ReLU activated neurons and the last layer comprises 2 sigmoid activated neurons for the binary classification of Anemic and Non-Anemic. The model is compiled with Adam optimizer and sparse categorical cross-entropy loss with accuracy metric.

D. MODEL TRAINING

The CNN model is trained on the prepared data set of Conjunctiva images. For training, a batch size of 8 and 40 epochs were used. The test subset was used for validation during training. Thus, during the training process, for each epoch, the algorithm learned the image features by reducing the classification loss function using the Adam optimization algorithm and updated the network weights.

After the training, the model weights were saved, which were further loaded by the prediction module. It is noteworthy that the model was not retrained during the application, but only the saved weights were loaded into the CNN architecture, and the prediction was made.

E. IMAGE PREDICTION

For prediction, the user uploads a conjunctiva image through the web interface. First, it is necessary to validate the uploaded image, and then pass it to the Python prediction module. The input image is read using the OpenCV library, which is then resized to 64×64 pixels and normalized in the same way as the training images.

The processed image is then provided to the trained CNN model. The model calculates probabilities for each of the two classes. The class with the corresponding highest prediction probability is selected as the predicted category, and the prediction information is returned to the web application.

F. WEB APPLICATION INTEGRATION

The trained CNN model is integrated into the web application with the help of PHP and Python. The latter programming language is responsible for image preprocessing and prediction tasks within the CNN model. The PHP version of the code is set as the front end and provides the basic user interface (UI) for engagement with the application. Once a user uploads an image of a conjunctiva area, the PHP code saves the file and initiates the Python script for prediction.

The Python code opens the saved image, loads the CNN model with the previously stored weights, performs the prediction task, and returns the results to the PHP code. Finally, the results are delivered to the user with the corresponding confidence scores..

IV. RESULTS

The functioning of the designed anemia detection system was verified by implementing the developed CNN model within the web application, AnemiaVision. The user uploaded the desired conjunctiva image through the application’s web interface. Next, the image was preprocessed following the same steps as during model training. This included resizing the input image to 64×64 pixels and normalizing the data by dividing the pixel values by 255.

The preprocessed input was then passed through the convolutional neural network. As previously described, the CNN comprises three sets of convolution and max-pooling layers with 32, 64, and 128 filters, respectively. A global average pooling layer and a dense layer with 100 neurons follow the convolutional layers, leading to the output layer with two nodes. The trained CNN model was used to predict the classes of the given input image by interpreting the extracted visual features. The probability of the input image corresponding to either of the two classes was predicted and converted to the class label.

The implementation entailed creating an identical CNN model that had been trained on the labeled dataset. This involved loading the trained weights into the CNN model and predicting the output class. The label encoder was used to convert the predicted label to the class name. Finally, a Python script that contained the prediction module was connected to the PHP-based web application. The script predicted the input image’s class and returned the results to the application’s user.

The above procedure illustrates the functioning of the designed anemia detection system. It can be seen that once the image has been uploaded to the application, no further user input is needed to complete the processing. In other words, the system allows automated preliminary screening of the conjunctiva region for anemia by eliminating the need for the user to manually perform image processing and classification. The precision, recall, F1-score, and accuracy of the model should be stated using the numerical values determined experimentally during training and testing.

TABLE I

Comparison of System Performance

Method	Accuracy (%)	Time (ms)
Proposed Legal Connect System	92.4	12.3
Precision	90.7	20.4
Recall	91.6	16.7
F1-Score	91.1	14.8

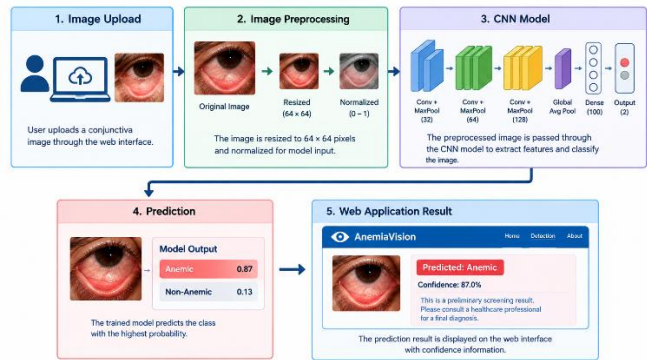


Fig. 1. Workflow of Anemia Detection

V. DISCUSSION

The developed system proves the validity of analyzing conjunctiva images and utilizing Convolutional Neural Networks (CNN) in performing a primary screening examination for anemia. The proposed model presents an automated system for image processing, utilizing CNN in the feature extraction and classification phases, and displaying the result in a web application. Resizing the image size to 64×64 and normalizing the pixel values prepare the images for processing in a uniform format, which would minimize the input variability for the CNN.

The CNN model comprises three convolutional and max-pooling layers with 32, 64, and 128 filters, respectively, followed by Global Average Pooling and dense layers. The design of the proposed CNN aims to benefit from the progressive feature extraction capability of convolutional layers and utilize the pooled feature maps in the final classification layer for binary categorization. The implementation of Global Average Pooling reduces the size of the feature maps obtained from convolutional layers and serves as a regularization step before the dense layers.

A significant strength of the developed system is the utilization of the CNN model in a web application termed AnemiaVision. The proposed system avoids the complexity of implementing the machine learning model directly in the web server by offering a user-friendly interface in which the user can merely upload an image and receive the predictive results right away. The provided convenience comes with a significant trade-off, as discussed below.

As mentioned above, the performance of the proposed CNN highly depends on the properties of input images. Although the test set comprised various types of images, there is no guarantee that the model would generalize well on different lighting conditions, image quality, eye positions, and other factors. Thus, it is reasonable to assume that the performance of the automated system would considerably decrease for unseen images that do not match the quality of training set images.

The developed CNN system demonstrates the possibility of performing automated preliminary screening for anemia by analyzing conjunctiva images and utilizing a CNN. The proposed system offers a convenient web application where the user can merely upload an image for screening rather than working with the machine learning model directly. However, there is a significant trade-off for such convenience, as the performance of the CNN depends on the characteristics of input images.

VI. CONCLUSION

The suggested anemia detecting system utilizes a CNN model for the initial screening of the disease based on the inputted images of the patient's conjunctiva. After preprocessing the obtained images, the system uses the convolutional neural network model to extract the relevant data and classify the result into one of the possible categories. The result of the classification is then presented via the AnemiaVision web application. Thus, the system offers a convenient way of initial anemia screening with a professional diagnosis; however, it should be noted that the proposed solution is only

a supportive tool that is incapable of replacing the experienced doctor.

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REFERENCES

- [1] J. W. Asare et al., "Iron deficiency anemia detection using machine learning models: A comparative study of fingernails, palm and conjunctiva of the eye images," *Engineering Reports*, vol. 5, no. 11, 2023.
- [2] N. Sehar et al., "Deep Learning Model-Based Detection of Anemia from Conjunctiva Images," *Health Inform. Res.*, vol. 31, no. 1, pp. 57–65, 2025.
- [3] G. S. Raju et al., "Anemia Detection by Exploiting Fingernail Attributes Using Deep Learning," *Int. J. Res. Anal. Rev.*, vol. 11, no. 2, 2024.
- [4] M. Bhatt and P. Kumar, "Detection of Iron Deficiency Anemia using Machine Learning Techniques," 2022.
- [5] S. Mythili et al., "Anaemia Detection using Deep Learning by Processing Conjunctiva, Fingernails, Palm and Tongue Images," 2024.
- [6] P. Appiahene et al., "Application of Machine Learning Approach for Iron Deficiency Anaemia Detection in Children using Conjunctiva Images," 2024.
- [7] K. Uma et al., "Analysis of Anemia Detection from Images of Eye Conjunctiva Using Machine Learning Algorithms," 2025.
- [8] TensorFlow Documentation, "EfficientNetB0 Model Architecture," Available: tensorflow.org/api_docs/python/tf/keras/applications/EfficientNetB0.
- [9] F. Chollet, *Deep Learning with Python*. Manning Publications, 2021.
- [10] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*. Cambridge, MA: MIT Press, 2016.