# Principles of Pathology

In anemia diagnosis, the color characteristics of the eyelid, particularly the degree of pallor, are key indicators. In healthy individuals, the eyelid appears reddish, reflecting sufficient levels of hemoglobin in the blood. However, when anemia occurs, hemoglobin levels drop, and the color of the eyelid tends to become pale, as the blood's oxygen-carrying capacity decreases, affecting oxygen supply to tissues.

Technically, changes in eyelid color can be captured using image processing methods. Specifically, the image processing system can decompose the eyelid image into red, green, and blue channels, and compare the value of the red channel against other color channels. Studies have shown that anemic patients often exhibit lower red channel values, with RGB channel values being similar, causing the eyelid to appear pale or pinkish. This phenomenon serves as a potential indicator for quantifying hemoglobin levels, providing a non-invasive approach for evaluating anemia.
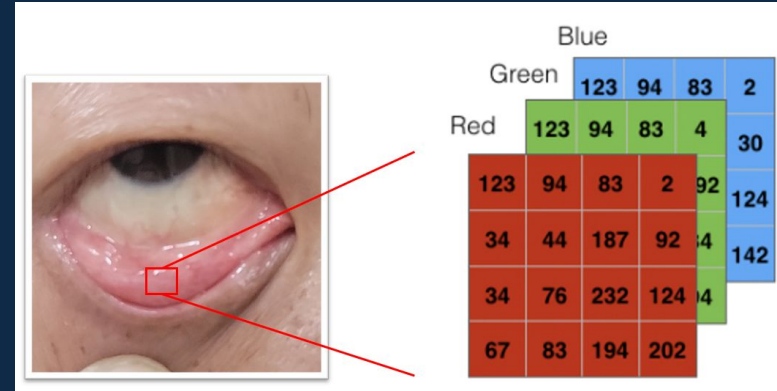
Application Principles

Data Preprocessing

To address the issue of glare in the images, we implemented two methods. First, we used the HSV color space to filter out glare points with excessively high brightness or low saturation. The second method involved converting the image to grayscale and using threshold operations to detect and correct over-bright areas.

During the image segmentation stage, the UNet model was employed to automatically segment the eyelid region, allowing for precise extraction of anemia-related features. The UNet architecture consists of an encoder and a decoder: the encoder progressively captures critical features within the image to locate the eyelid, while the decoder restores these features to accurately mark the eyelid area.

Deep Learning Classification

In deep learning classification, a deep learning model is employed to classify anemia images, using a hemoglobin (Hb) concentration threshold of 12 g/dL to determine anemia presence. The model leverages multi-level feature extraction to automatically identify anemia-related features, such as color variations in the eyelid area. To improve the model's generalization, data augmentation techniques are applied during training to diversify the dataset, enhancing the model's performance on new data and strengthening the stability and accuracy of the classification results.The model achieved an accuracy of 85% to 90% on the test set, demonstrating its reliability in anemia detection.

Regression Analysis

Regression analysis is used to quantify the severity of a patient's anemia by examining trends in hemoglobin levels. This analysis selects features closely related to eyelid color—such as hue, saturation, brightness, the R channel, the difference between R and GB channels, and grayscale—to estimate hemoglobin levels. Linear and polynomial regression models are employed to precisely predict hemoglobin fluctuations, while mean squared error (MSE) and the coefficient of determination (R^2) are used to assess model performance, ensuring both predictive accuracy and interpretability.

Preliminary results

Our team, having received approval from the Institutional Review Board (IRB), has initiated human trials at Shuang Ho Hospital and the Hemodialysis Center of New Civil Hospital. To date, we have successfully enrolled over 350 participants, and recruitment is actively ongoing.

Technology support

Our team has been supported by the National Science and Technology Council (NSTC) under Project Nos. 113-2221-E-027-039, 112-2221-E-027-099, and 111-2221-E-027-042, underscoring the study's academic significance and practical potential.

To further secure the legitimacy and commercial applicability of our findings, we have filed multiple patents for the relevant technologies, ensuring legal protection of the intellectual property.