Jaundice detection by deep convolutional neural network using smartphone images

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① Introduction

Jaundice usually indicates severe hepatic or biliary diseases and prompt management is needed to reduce disease complications. The degree of jaundice correlates with the severity of illness, and jaundice is easily confirmed by checking serum total bilirubin (T-Bil) level. Practically, self-identification of jaundice is the key for its early detection, because a careful inspection may detect jaundice with a T-Bil > 2 - 3 mg/dL. However, self-monitoring of jaundice is not easy for people without training, so a correct diagnosis is usually delayed. In our work, we propose a method to determine whether a person has jaundice based on facial images taken by a smartphone, a non-invasive, simple and fast test.

② Jaundice Dataset

We conducted a prospective study to enroll healthy volunteers and patients with jaundice. They all have recent data of T-Bil level as the reference standard. All facial images were taken indoors using the same Samsung Galaxy S20 smartphone and has a resolution of 12000 x 9000 pixels. To control the environmental light, we use the X-Rite ColorChecker and a ring light when taking the photos.

A total of 108 patients had been enrolled with 146 facial images being collected. There were 105, 10, and 31 scleral images with a T-Bil level <2, 2-3, and ≥3 mg/dL, respectively. Serial images were collected from the same jaundiced patients with different T-bil levels.

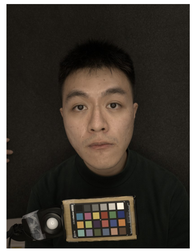

Figure 1: *Example of collected face image*

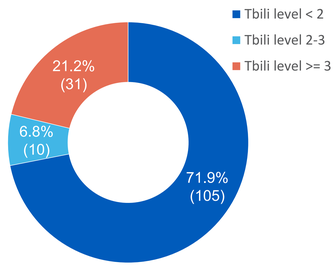

Figure 2: *Data proportion of T-Bil level*

④ Machine Learning Method

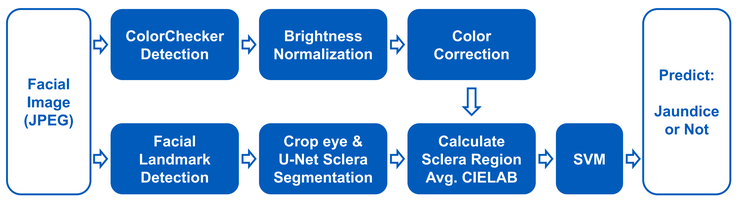

Figure 3: *Overview of the proposed scleral classification framework*

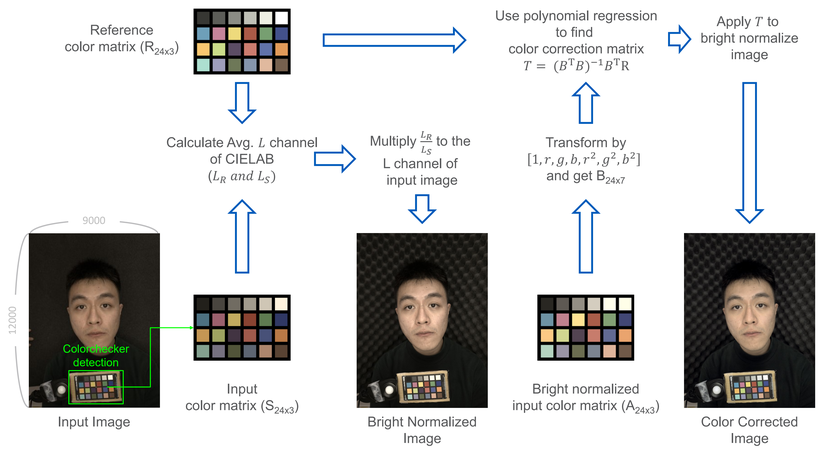

Figure 4: *Bright normalization and color correction pipeline*

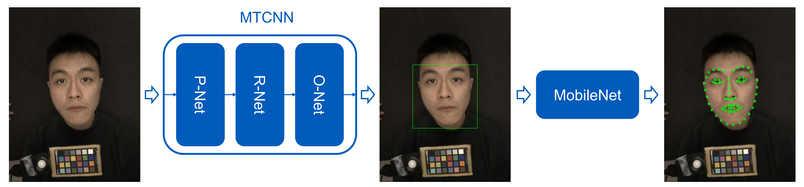

Figure 5: *Facial landmarks detection process*

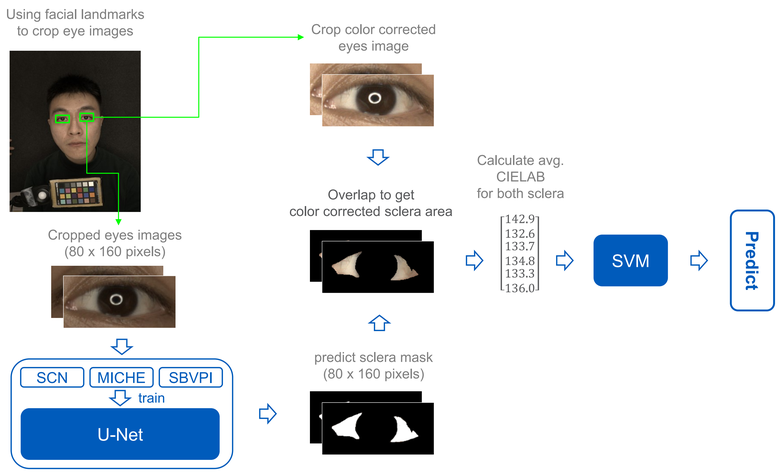

Figure 6: *Data flow of the cropped eye image*

④ Results

The average B-channel value of the sclera in the color-corrected image is highly correlated with the actual T-Bil level. For our collected data, the Pearson correlation is 0.84.

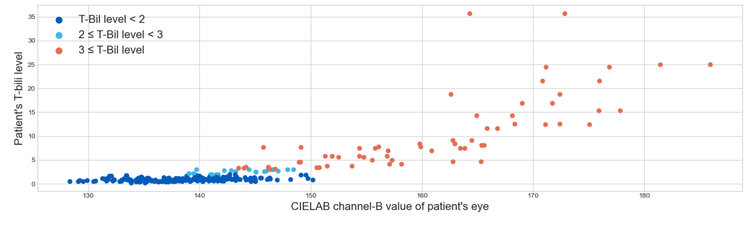

Figure 7: *T-Bil level and corresponding average B-channel value of all data*

To evaluate our jaundice prediction method, we use two T-Bil level (2 mg/dL and 3 mg/dL) as thresholds respectively to determine whether a person has jaundice, and train two SVM models separately for these two threshold. We use the following criteria to determine the quality of our model: area under receiver operating characteristic curve (AUROC), sensitivity, specificity, positive predict value (PPV) and negative predict value (NPV). We divide 80% of the data into training set and 20% of the data into testing set. The percentage of categories between training and testing sets is balanced. In order to ensure the generalization ability of the method, 10-fold cross-validation is also applied.

SVM Prediction Result					
	AUROC	Sensitivity	Specificity	PPV	NPV
10-Fold Validation (T-Bil threshold=2)	0.988	0.867	0.965	0.925	0.959
10-Fold Validation (T-Bil threshold=3)	0.983	0.883	0.978	0.933	0.968
Testing Set (T-Bil threshold=2)	0.986	0.909	0.947	0.909	0.947
Testing Set (T-Bil threshold=3)	0.979	0.833	0.958	0.833	0.958

Table 1: *SVM prediction results of the validation set and the testing set on two different T-Bil thresholds*

⑤ Conclusions & Future Work

Our data demonstrates the capability of jaundice detection by smartphone captured images with good performance. This platform may be applied in the scenario of self-monitoring or telemedicine.

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