Onyxray: A Mobile-Based Nail Diseases Detection Using Custom Vision Machine Learning

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***Abstract*—Nails serves as a great way to discover several underlying systemic diseases of a person. There are different nail abnormalities that are associated with systemic diseases. The objective of the study is to utilize mobile camera that will allow users to capture of nail. Through this, the application will suggest several systemic diseases found based on the uploaded nail image by the user. The methods applied in this study includes the use of Custom Vision API that process images to analyze certain nail abnormalities. This study concludes that systemic diseases can be identify through nail abnormalities, so that the proponents developed an application that will analyze a fingernail image and will provide systemic diseases suggestions.**

***Index Terms*—Custom vision, mobile application, nail abnormalities, systemic diseases.**

I. Introduction

Looking at the nail plate and the nail unit of someone can be a puzzle to confirm their systemic disease [1], [2]. In the fifth century, Hippocrates – a Greek physician and the Father of Western Medicine, described clubbing as an important clue to countless systemic manifestation [3]. Nail clubbing can be identified when the finger has increased its longitudinal nail bed [4]. The method used for analyzing fingernail clubbing is Schamroth sign test. The Schamroth sign test was named after Leo Schamroth – a world-renowned electrocardiologist, when he experienced 3 attacks of infective endocarditis in the year 1975 [5]. Infective endocarditis is an infection in the heart's surface [6]. Other unhealthy nails which are associated with systemic manifestations can be also described by looking at the nail. Nail abnormalities can arise in conjunction with a result health issue [7], [8].

This study intends to utilize mobile camera that will allow user to capture images of nail and upload it to be analyzed using Microsoft Cognitive – Custom Vision Service. Custom Vision Service is part of Azure Cognitive Services that lets people to build custom image identifiers [9]. This service allows developers to classify certain images by feeding or uploading images on it. With these, proponents will upload enough images of each nail abnormalities and will be trained automatically by the service to make a feedback. Uploaded images can also be used as part of the feedback loop to keep improving the system.

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II. Related Studies

A. Leukonchia

It is the most common nail abnormalities that is observable with the whitening of the nail plate as shown in Fig. 1. There is an explanation in leukonychia that is related to Newton's Theorem which is about the reflection of the light. In year 1919, Leukonychia was first described by Mees as a "Arsenic Intoxication" while Bara described it as True Leukonychia where the engagement of pathology begins in the matrix then combined with the nail plate, Apparent Leukonychia, in which the nail plate is where the pathology rest, Pseudo Leukonychia in which the pathology in the nail plate is exogenous [4], [10]–[13].

Fig. 1. Nails with Leukonychia. [14], [15].

B. Mees' Lines

Mees' Lines so called as Aldrich-Mees' Lines, it was described first by E.S. Reynolds in year 1901, and it was described again by C.J, Aldrich in 1904 then the credit was got by R.A. Mees in the year 1919. The findings were due to arsenic poisoning and it was described by all the three physicians [16]. The description about the Mees' Lines are two white lines across the nail bed that caused by a "vascular congestion" [17] as shown in Fig. 2.

Fig. 2. Nails with Mees' Lines [17], [18].

C. Muehrcke's Lines

Apparent Leukonychia which is the result of pathology in the nail bed and there three variation that are present. One of the presents in Apparent Leukonychia is the Muehrcke's Lines was first described by Dr. Robert Muehrcke in his

clinical finding novel that was published in year 1956 [19]. The description of the nail abnormality was a narrow "double white transverse lines" as shown in Fig. 3. This means that vascular bed of the nails is abnormal which is due to the decrease of protein (hypalbuminaemia), nephrotic syndrome or kidney disease, cirrhosis or liver disease, or chemotherapy, human immunodeficiency virus or acquired immunodeficiency syndrome commonly known as HIV/AIDS [20], [21].

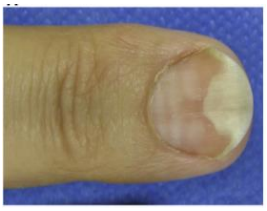

Fig. 3. A nail with Muehrcke's Lines [4], [22].

D. Half and Half Nails

The half and half nails is commonly called as "Lindsay's nails". Bean first described the half and half nails for the first time in the year 1963, but Lindsay's description is one that publicize in the medical circles in year 1967 [23]. The nail abnormality is a present discoloration and half reddish in the distal nail as shown in Fig. 4. This nail abnormality is associated with several diseases like hepatic cirrhosis, peripheral vascular disease, chronic renal failure, malnutrition, HIV infection, tuberculosis, congestive cardiac failure, pellagra zinc deficiency, Behcet disease, Kawasaki disease [4], [22].

Fig. 4. A nail with Half and Half Nails [4], [24].

E. Terry's Nail

Terry's nails who was described by Richard Terry a British physician, who examined the patient's nail-bed abnormality. There are 82 of 100 patients were diagnosed with hepatic cirrhosis and 90% of the patient were due to too much alcohol. The nail has a discoloration, which suddenly stops at 1-2 mm from the distal edge and it leaves a brownish transverse and the band is around 0.5 to 3 mm width and it corresponds to the onychodermal transition [25], [26] as shown in Fig. 5.

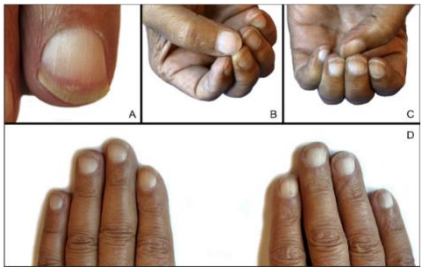

Fig. 5. Nails with Terry's Nails [26], [27].

F. Clubbing

In the 5th century B.C., the clubbing was one of the first indicator of the health status of a person it was recognized by Hippocrates and described it as a symptom of a disease [21]. This abnormality related to cretinism and it is caused by iodine deficiency [20]. The formation of this nail abnormality is a visible deformation in the base of the nail that results to a swollen and curved distal phalanx as shown in Fig. 6. It is categorized in three important parts which are idiopathic, hereditary-congenital, and acquired [3], [4], [28].

Fig. 6. Nails with Clubbing [14].

G. Splinter Hemorrhages

The Splinter Hemorrhages which is a form of a vertical blood the nails that is more common in the fingernails rather than the toenails. It also said that the Splinter Hemorrhages are common in men rather than women and common in dark complexion than in white [29] as shown in Fig. 7. The nutritional reason behind this nail abnormality is the lack of Vitamin C [20].

Fig. 7. A nail with Splinter Hemorrhages [24], [29].

H. Beau's Lines

Beau's Lines which is another nail abnormality that is first described by a French Physician in year 1846 and his name is Joseph Honore Simon Beau it is described that this abnormality was a sign of febrile sickness [16]. The formation of this nail abnormality is consists of transverse pressure on back part of the nail plates and Onychomadesis is the separation of scaling of the nail plate that describe a stiff form of Beau's Lines [2] as shown in Fig. 8.

Fig. 8. A nail with Beau's Lines [14], [24].

I. Koilonychia

Koilonychia which is also a nail abnormality and it is a "spoon-shaped nail" caused by iron deficiency and it can be genetic, gained and it is also occurred due to the changes of

blood flow in the nail matrix [30] as shown in Fig. 9.

The most common causes of this nail abnormality are iron deficiency, coronary artery disease, chronic renal failure, hypothyroidism, hemochromatosis, polycythemia vera, and traumatic injury [4].

Fig. 9. A nail with Koilonychia [24].

J. Nail Pitting

Nail pitting which is another nail abnormality and it is a depression where the nail plate has a defect at the upper layer of the nail plate, which appears from the proximal nail matrix as shown in Fig. 10. It is common when associated with alopecia and psoriasis [22].

This nail abnormality is associated with diseases such as Psoriasis, Alopecia Areata, Psoriatic Arthritis, Reiter's Syndrome, Sarcoidosis, Incontinentia Pigmenti, Systemic Lupus Erythematosus, Dermatomyositis, Syphilis, and Pemphigus Vulgarist [4], [12].

Fig. 10. A nail with Nail Pitting [12], [24].

K. Melanonychiahe

Melanonychia is another type of nail disorder and it is characterized as "nail plate pigmentation" and it is a rare kind of nail disorder that caused by a fungal infection as shown in Fig. 11. There are several causes of Melanonychia it includes exogenous materials and nail matrix nevus (NMN), and if it is untreated there is a chance that it will spread and can be crucial [31].

Fig. 11. A nail with Melanonychia [4].

L. Pterygium

Pterygium is a rare nail abnormality where the condition can be acquired or can be present at birth as shown in Fig. 12. These conditions can be associated with several connective tissue disorder like systemic lupus erythematous and progressive systemic sclerosis [28].

This nail abnormality may also be associated with several diseases which seen in Chronic Renal Failure, Raynaud's Disease, Neurofibromatosis, Leprosy, and Subungual Exostosis [4].

Fig. 12. A nail with Pterygium [15].

M. Probability Threshold

The threshold is set to 0.5 or 50% to get a fifty-fifty result from precision and recall, and this is for the model to achieve the right precision versus recall balance. The probability threshold is the minimum probability score for a prediction to be valid when calculating precision and recall of Custom Vision. Precision is the calculated number on how likely the iteration should be right. In other words, the precision is the ability of a classification model to identify only the relevant data points. The recall is the calculated number on what percentage did the model correctly find in all the tags. In other words, the recall is the process of finding the same image in the dataset.

Based on William Koehrsen's formula, the recall is defined with the formula as shown in Fig. 13 [29]. Number of true positives divided by the number of true positives plus the number of false negatives is the recall. The true positives are the correct data, and the false negatives are the incorrect data.

$$recall = \frac{true\ positives}{true\ positives\ + false\ negatives}$$

Fig. 1. Recall Formula [29].

William Koehrsen defined the precision as true positives divided by the true positives plus false negatives which is shown on the Fig. 14 [29]. False positives are the data that are marked as positive but identified as negative by the model. Recall is the capability for the system to find all relevant data in the dataset, while precision indicate the proportion of the data in the model that are relevant.

$$precision = \frac{true\ positives}{true\ positives + false\ positives}$$

Fig. 2. Precision Formula [29].

N. F1 Score

F1 Score is used to get the harmonic mean of precision and recall giving both metrics equal weights which is shown on the Fig. 15. Its goal of F1 score is to minimize both false positive and false negative of a good model.

$$F_1 = 2 * \frac{precision * recall}{precision + recall}$$

Fig. 3. F1 Score Formula [29].

O. Image Processing Using Custom Vision Service

Fig. 13 shows the flowchart of the Custom Vision Service. Custom Vision is a service under Cognitive Services of

Microsoft Azure. Custom Vision is used to build own image classifiers to classify item if prominent to the image. Image classifier is running under deep learning where it requires huge number of data or images to recognize patterns well. Item passes to a neural network where it performs some operations and passes the output to the following neuron.

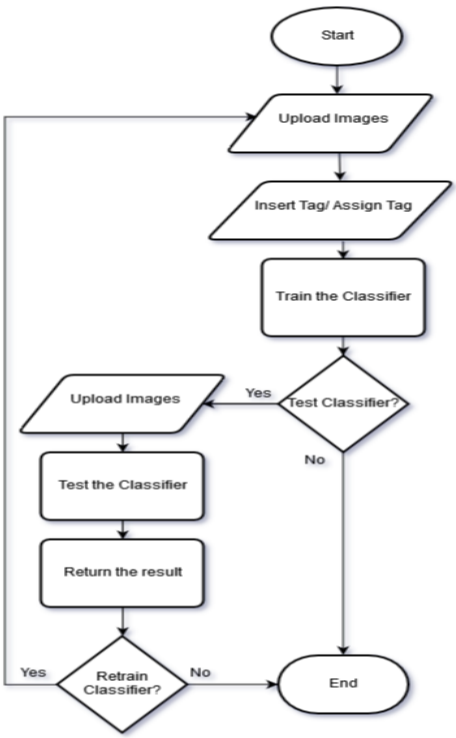

Fig. 13. Precision Formula [29].

III. Methodology

A. Conceptual Framework

The conceptual framework to organize data and to easily execute the captured ideas of the proponents. Fig. 14 shows that from the user, the application will directly authenticate the user under the Firebase service which is offered by Google. Next, the gathered data which is the nail image will be processed and trained under Microsoft Azure service which is Custom Vision. Last, the processed data will be sent to the user's device.

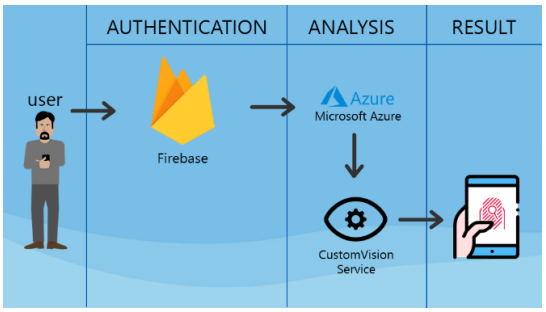

Fig. 14. Conceptual Framework.

B. System Architecture

Fig. 15 shows how the system works and communicate with the Custom Vision and Firebase. The user needs to authenticate by logging in using Google email. Firebase will be used for the authentication of user. After being authenticated, the user can now use the application. When predicting images captured by the user, it will use Custom Vision. All captured image will be automatically uploaded to Firebase Storage that will be used to re-train the system.

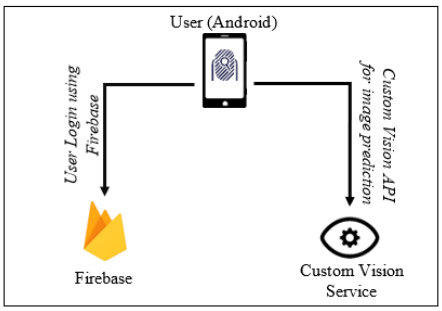

Fig. 15. System Architecture

IV. Results and Discussion

A. Dataset

The proponents used 445 images in the model. 70% of the images which is 24 were used to train the model. 20% of the images were used as a test set, and the remaining 10% are used to validate the results.

TABLE I: Dataset

Nail Abnormalities	Trained Images	Test Images	Validation	Total
Beau's Lines	24	7	4	35
Clubbing	24	7	4	35
Koilonychia	24	7	4	35
Lindsay's Nail	24	7	4	35
Mees` Lines	24	7	4	35
Melanonychia	24	7	4	35
Muehrckes Lines	24	7	4	35
Nail Pitting	24	7	4	35
Pterygium	24	7	4	35
Splinter Hemorrhages	24	7	4	35
Terry's Nail	24	7	4	35
Normal Nail (Negative)	42	12	6	60
Total	**306**	**89**	**50**	**445**

Table I shows the dataset used. Overall, it consists of 445 images of different nail abnormalities.

B. Classified Data

The proponents fed several images to the model that are not included in the training set.

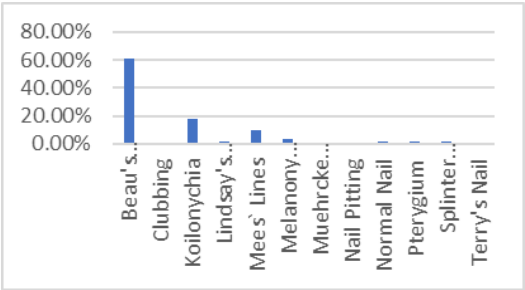

Fig. 16. Overall result in Beau's Lines.

Beau's Lines images that are not included in the training set were uploaded and resulted 61.10% on accuracy as shown in Fig. 16.

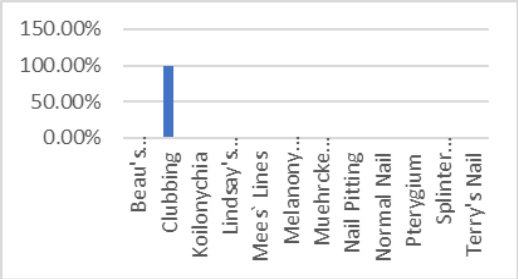

Fig. 17. Overall result in clubbing.

Clubbing images that are not included in the training set were uploaded and resulted 98.60% on accuracy as shown in Fig. 17.

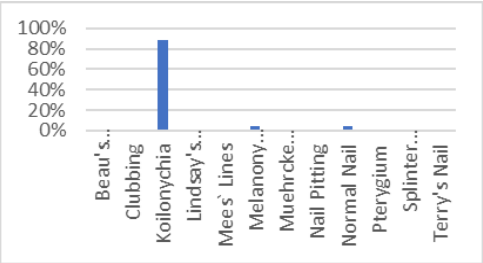

Fig. 18. Overall result in koilonychia

Koilonychia images that are not included in the training set were uploaded and resulted 88% on accuracy as shown in Fig. 18.

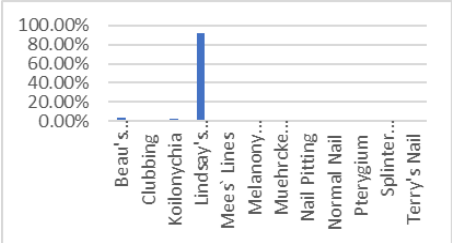

Fig. 19. Overall result in Lindsay's nails

Lindsay's Nails images that are not included in the training set were uploaded and resulted 91.80% on accuracy as shown in Fig. 19.

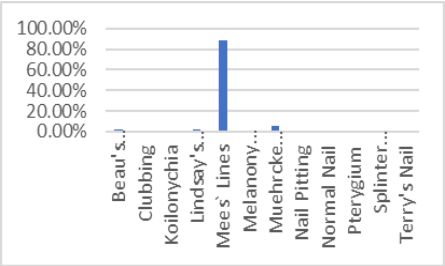

Fig. 20. Overall result in Mees' lines.

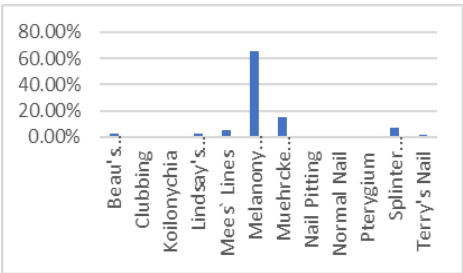

Fig. 21. Overall result in melanonychiahe.

Mees' Lines images that are not included in the training set were uploaded and resulted 89.90% on accuracy as shown in Fig. 20.

Melanonychiahe images that are not included in the training set were uploaded and resulted 65.20% on accuracy as shown in Fig. 21.

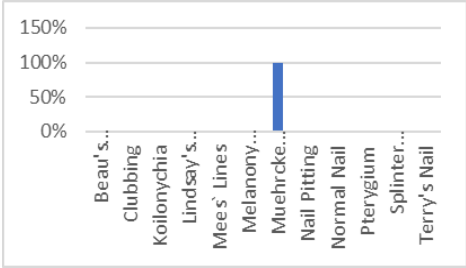

Fig. 22. Overall result in Muehrcke's lines

Muehrcke's Lines images that are not included in the training set were uploaded and resulted 99% on accuracy as shown in Fig. 22.

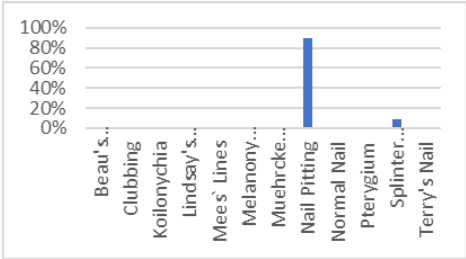

Fig. 23. Overall result in nail pitting.

Nail pitting images that are not included in the training set were uploaded and resulted 90% on accuracy as shown in Fig. 23.

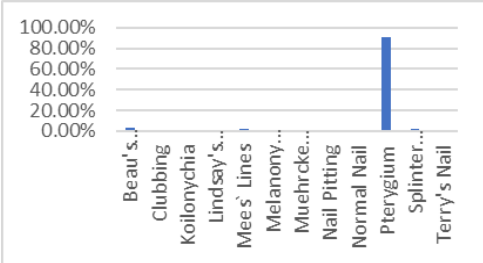

Fig. 24. Overall result in pterygium.

Pterygium images that are not included in the training set were uploaded and resulted 90.80% on accuracy as shown in Fig. 24.

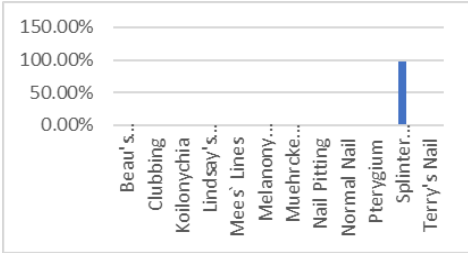

Fig. 25. Overall result in splinter hemorrhages.

Splinter Hemorrhages images that are not included in the training set were uploaded and resulted 97.80% on accuracy as shown in Fig. 25.

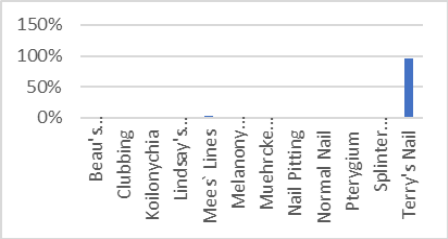

Fig. 26. Overall result in Terry's nail.

Terry's Nail images that are not included in the training set were uploaded and resulted 97% on accuracy as shown in Fig. 26.

C. F1 Score

Table II shows the confusion matrix of the model. Confusion Matrix is a table that contains data about the actual and predicted classifications that are done by the model [30], [31]. The proponents used F1 score to compute the accuracy of the model. Also, the proponents tested each tag with 7 images to come up with the data that will be used in confusion matrix. Overall, there are 89 images used to test the model.

TABLE II: CONFUSION MATRIX

CONFUSION MATRIX		PREDICTED											
		Beau's Lines	Clubbing	Koilonychia	Lindsay's Nail	Mees` Lines	Melanonychia	Muehrcke's Lines	Nail Pitting	Normal Nail	Pterygium	Splinter Hemorrhages	Terry's Nail
ACTUAL	Beau's Lines	4	-	-	-	-	-	1	2	-	-	-	-
	Clubbing	-	6	-	1	-	-	-	-	-	-	-	-
	Koilonychia	1	-	6	-	-	-	-	-	-	-	-	-
	Lindsay's Nail	-	-	-	4	1	-	-	2	-	-	-	-
	Mees` Lines	-	-	1	-	4	-	2	-	-	-	-	-
	Melanonychia	-	-	-	-	1	5	1	-	-	-	-	-
	Muehrcke's Lines	-	-	1	-	-	-	5	-	-	-	1	-
	Nail Pitting	-	-	-	-	-	-	-	7	-	-	-	-
	Normal Nail	-	-	-	-	-	-	-	-	7	-	-	-
	Pterygium	-	-	-	-	-	-	-	1	-	6	-	-
	Splinter Hemorrhages	-	-	-	1	-	-	1	-	-	-	5	-
	Terry's Nail	-	-	-	-	-	-	-	-	-	-	-	7

Table III shows the computation of precision and recall. Gathered data from confusion matrix was used to get the precision and recall of each tag. The precision is the positives divided by the sum of true positives and false positives, while the recall is the true positives divided by the sum of true positives and false negatives. In the last column is the F1 score which is calculated using the given precision and recall from the confusion matrix.

Table IV shows the overall evaluation of the mobile application. In relation to ISO 25010 standards, the application can function well as the functionality sustainability is rated as excellent, and also the mobile application can maintain its service provision it means to say that it can continue to run properly, can sustain its high level of performance for a long period of time as the usability, reliability, maintainability, and portability were rated as excellent. Also, the application is safe for the users as the security were rated as excellent. This demonstrates that the mobile application may have a very high chance of success.

TABLE III: PRECISION, RECALL, AND F1 SCORE

TAG	Precision	Recall	F1 Score
Beau's Lines	0.8	0.57	0.67
Clubbing	1	0.86	0.92
Koilonychia	0.75	0.86	0.8
Lindsay's Nail	0.66	0.57	0.61
Mees` Lines	0.66	0.57	0.61
Melanonychia	1	0.71	0.83
Muehrcke's Lines	0.56	0.71	0.63
Nail Pitting	0.58	1	0.73
Normal Nail	1	1	1
Pterygium	1	0.86	0.92
Splinter Hemorrhages	0.83	0.71	0.77
Terry's Nail	1	1	1
TOTAL	0.82	0.785	0.8

TABLE IV: OVERALL EVALUATION WEIGHTED MEAN

CRITERIA	RESULTS	INTERPRETATION
Functionality Sustainability	4.58	Excellent
Performance Efficiency	4.66	Excellent
Compatibility	4.63	Excellent
Usability	4.575	Excellent
Reliability	4.66	Excellent
Security	4.62	Excellent
Maintainability	4.72	Excellent
Portability	4.76	Excellent
TOTAL	**4.65**	**EXCELLENT**

V. CONCLUSION

This paper presents that Custom Vision API has a capability in identifying nail abnormalities that are associated with Systemic Diseases with high precision based on F1 score testing method. Through the use of publicly available images which served as training data for the system, Result showed that the developed system integrated with Custom Vision API has a 80% precision rate; thus, supporting the functional and reliability performance of the system. That being said, the mobile application is of excellent capacity in being utilized as a tool for supporting the medical field.

CONFLICT OF INTEREST

There is no conflict of interest in this paper, our results point to a broader picture when it comes to disclosure of COIs in research papers. As part from financial interests, personal, intellectual, and other kinds of competing interests have also been noted as a concern in research papers.

AUTHOR CONTRIBUTIONS

Sholomon Pinoliad and Duanne Austin Dichoso conducted the research and developed the software as well as the testing and enhancement of the software; Arlene Caballero and Erlito Albina, verified and analyzed the data as well as the editors of this paper.

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