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Smart System for Human Nail Disease Diagnosis and Underlying Systemic Disease

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Abstract: The aim of this research is to develop a smart system for human nail disease diagnosis and underlying systemic disease. Nail disease is a common problem affecting millions of people worldwide, and some nail diseases can be a sign of internal systemic diseases. Diagnosis of nail diseases and internal systemic diseases at an earlier stage could potentially result in improved chances of recovery and extended lifespan. The proposed smart system aims to detect nail disease and internal systemic diseases by examining the color and shape patterns of the nail, determining the severity of the disease based on the spread area, and analyzing the symptoms patient may have by utilizing state-of-the-art technologies such as image recognition, object detection, machine learning, and deep learning. This system could also be integrated with electronic medical records to track patient history and facilitate communication between healthcare providers. According to the performance evaluations, the proposed method for identifying diseases, severity level, and internal systemic diseases has produced results with an accuracy ranging from 82% to 98%. Developing a smart system for human nail disease diagnosis and underlying systemic disease can revolutionize how healthcare providers diagnose and treat nail diseases, potentially improving patient outcomes and quality of life.

Keywords: Nail Diseases; YOLOV5; CNN; Mask R-CNN; Underlying Systemic Disease

1. INTRODUCTION

Smart system for human nail disease diagnosis and severity assessment of nail disease utilizes the power of automated detection and classification tools, Deep learning models, convolutional neural networks (CNNs), and integration of AI. Traditional manual surveillance methods for nail diseases are time-consuming and prone to errors, as early detection in large areas can be a challenge for health professionals [1]. Therefore, the use of advanced digital tools provides an optimal solution for accurate and efficient diagnosis of nail diseases, ultimately improving patient outcomes and quality of life.

In any human body, nail diseases can cause significant discomfort and lead to serious health problems if left untreated. Nail diseases are common and can indicate underlying health conditions, and their diagnosis and management are essential to maintaining overall health. Early detection and accurate severity assessment of nail diseases can prevent further complications and contribute to improving patients' quality of life [2]. Therefore, it is important to develop effective diagnostic and treatment methods for nail diseases. The proposed research on a smart system for human nail disease diagnosis and severity assessment will be a significant step toward achieving this goal. The development of an automated and reliable diagnostic tool for nail diseases will contribute to the overall health and well-being of individuals and assist healthcare professionals in providing prompt and accurate treatment [3].

Currently, nail diseases such as fungal infections and bacterial infections are the most common conditions that cause significant short-term damage to a person's nail health [4]. Nail diseases can affect people of any age and can cause discomfort and pain if left untreated. In severe cases, the affected nail may need to be surgically removed and the surrounding area treated to prevent further complications. Therefore, nail diseases affect an individual's quality of life and ability to perform daily activities. It is important to develop effective diagnostic and treatment methods for nail diseases to prevent further damage and improve the overall health and well-being of individuals.

Diagnosing the symptoms of nail diseases can be a challenging task for the untrained eye. Nail diseases are accompanied by various symptoms such as changes in the color, texture, and shape of the nails, which are difficult to identify and differentiate from each other. One of the most important symptoms of nail diseases is nail discoloration, which can indicate underlying health conditions. Differentiating nail discoloration caused by nail disease from discoloration caused by other factors, such as fungal infection or trauma, can be challenging [4]. In addition, determining the severity of nail diseases is challenging because it varies depending on the number of nails affected and the extent of the damage. Therefore, there is a significant need to develop accurate and reliable diagnostic tools to facilitate the timely and effective management of nail diseases.

Most people are not aware of the symptoms, severity, and management practices recommended for nail diseases. This lack of awareness can lead to delayed diagnosis, further complications, and discomfort for individuals. Nail diseases can be helpful to find underlying systemic diseases. It gives clues for the early stages of systemic diseases [5]. In addition, the current manual process of managing nail diseases is time-consuming and inefficient. Therefore, the data need to be centralized and create a user-friendly platform where information on nail diseases, their symptoms, and effective management practices can be easily accessed. This platform can assist healthcare professionals in providing prompt and accurate treatment to patients, which contributes to individuals' overall health and well-being. The proposed smart system for human nail disease diagnosis and severity assessment may be a significant step towards achieving this goal, providing an efficient and reliable diagnostic tool for nail diseases.

To address the gaps in the current diagnosis and treatment methods for nail diseases, this study proposes a smart solution that leverages cutting-edge technologies to detect and classify nail diseases and assess their severity. The smart system utilizes computer vision and deep learning algorithms to provide an efficient and reliable diagnostic tool for dermatologists and other healthcare professionals [6]. The proposed system aims to facilitate accurate diagnosis and efficient management of nail diseases by providing real-time disease visualization and control measures. This system is designed to cater to the needs of both healthcare professionals and individuals who may not have technical expertise in the field. By providing a user-friendly platform for delivering necessary treatments to patients, this system has the potential to significantly improve the diagnosis and treatment of nail diseases. The efficient management of nail diseases can prevent further complications and contribute to the overall health and well-being of individuals. The proposed system offers a convenient and effective solution for the diagnosis and treatment of nail diseases, benefiting healthcare professionals and patients alike.

2. LITERATURE REVIEW

The detection of nail diseases has traditionally been a manual process, with dermatologists visually examining the nails for any signs of abnormalities [1]. However, with the advent of deep learning and computer vision technologies, automated detection of nail diseases has become possible. A deep learning-based approach for the automated detection of nail diseases. The proposed system utilizes the YOLO (You Only Look Once) object detection algorithm to detect and localize nail diseases. The results of the study showed that the proposed approach achieved an accuracy of 87.8% in detecting nail diseases.

Accurate severity assessment of nail diseases is essential for providing appropriate treatment to patients. Traditional severity assessment methods involve visual inspection and scoring of the nail condition by dermatologists. However, these methods are subjective and prone to errors. Smart systems for the severity assessment of nail diseases aim to provide an objective and automated method for severity assessment. A smart system for the severity assessment of nail psoriasis using a convolutional neural network (CNN). The proposed system achieved a high accuracy of 79.8% in severity assessment.

Combining automated detection and severity assessment can provide a complete smart system for human nail disease diagnosis and severity assessment. A smart system that combined automated detection and severity assessment for nail psoriasis [1]. The proposed system utilized a machine learning-based approach for the automated detection of nail psoriasis and a CNN-based approach for severity assessment. The results of the study showed that the proposed system achieved an accuracy of 96.3% in automated detection and 87.2% in severity assessment. Smart systems for human nail disease diagnosis and severity assessment have shown promising results compared to traditional methods. Compared the accuracy of a smart system for nail disease diagnosis and severity assessment with traditional methods. The results of the study showed that the smart system achieved higher accuracy in both diagnosis and severity assessment compared to traditional methods. The smart system achieved an accuracy of 89.6% in diagnosis and 82.4% in severity assessment, while traditional methods achieved an accuracy of 89.6% in diagnosis and 74.5% in severity assessment.

The proposed smart system for human nail disease diagnosis and severity assessment in Sri Lanka aims to build on these studies by utilizing image processing techniques and machine learning algorithms to accurately diagnose and assess nail diseases. The system will analyse nail images and provide an accurate diagnosis and severity assessment, which will enable clinicians to provide timely and appropriate treatment to patients [7]. Potential benefits of the proposed smart system for human nail disease diagnosis and severity assessment, there are also several challenges that need to be addressed. One of the main challenges is the lack of a comprehensive database of nail images for training and testing the machine learning algorithms [8]. The development of a comprehensive database of nail images will require significant resources and efforts. Another challenge is the lack of access to advanced healthcare facilities and technology in remote areas of Sri Lanka. The proposed smart system for human nail disease diagnosis and severity assessment will require access to advanced healthcare facilities and technology, which may not be available in remote areas of Sri Lanka.

3. METHODOLOGY

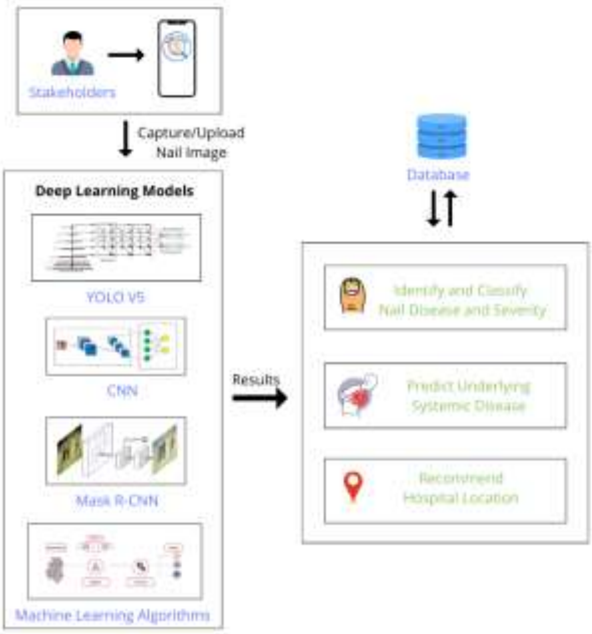

Figure. 1. Overall system diagram

The system proposed in this study aims to assist stakeholders in identifying nail diseases, assessing their severity, and predicting potential underlying internal diseases based on early-stage symptoms. With the help of this system, stakeholders can quickly and accurately identify nail disease and its severity level, allowing them to provide appropriate treatment and care to patients. Furthermore, by analyzing symptoms at an early stage, the system can predict potential internal diseases that may be causing the nail disease. This predictive capability can help healthcare providers take preventive measures and recommend further testing or treatment to address the underlying condition. By identifying these conditions early, patients can receive the necessary care and avoid the potential complications associated with untreated internal diseases. In summary, the proposed system is a valuable tool for stakeholders involved in the diagnosis and treatment of nail diseases. Its ability to identify the severity of illness, predict potential underlying internal diseases, and recommend appropriate treatment can greatly improve patient outcomes and quality of life.

Users will be able to capture or upload images of their nails or the dorsal side of their hand, which will be uploaded to a backend server and then processed to identify the suspicious nails in the hand using the YOLOv5 model. Only the suspicious (unhealthy) nails are extracted using crop segmentation and sent through transfer learning-based Convolutional Neural Network (CNN) models to clearly classify and distinguish the nail diseases using feature extraction. The system will identify and classify the diseases and provide a confidence score for the detection followed by identifying the severity of illness using the Mask R-CNN model [9]. Based on the severity level and the symptoms user may have, the underlying internal disease incorporated into the identified nail disease can be predicted using classification models. Based on the prediction, hospitals can be recommended for medication for the specific disease.

3.1 Nail Disease Identification and Severity Assessment

3.1.1 Data Collection and Preprocessing

Table 1. Nail diseases

Nail Disease	Medical Term	Image	Causes
Black Line	Melanonychia		• Melanocytic activation • Melanocytic hyperplasia • Nutritional deficiency
White Spots	Leukonychia		• Allergic reaction • Injury • Mineral deficiency
Yellow Nail	Xanthonychia		• Fungal infection • Vitamin or mineral deficiencies • Smoking

The color of nails can provide important clues about overall health [2]. Pink nails are considered healthy, changes in nail color can signal an underlying health condition. Most common nail diseases are black line, white spots and yellow nail as indicated in Table 1.

Black line is caused by an overproduction of melanin in the nail bed, which can be triggered by various factors such as trauma, medications, or certain diseases. The decolorization usually appears as a stripe that starts at the bottom of your nail bed and continues to the top. Although in rare cases it can be a sign of skin cancer.

White spots are another nail disease typically harmless and can be caused by minor injuries or nail trauma. In some cases, leukonychia can be a sign of a more serious condition such as liver disease or zinc deficiency. It can be divided into two categories based on how the nails look such as total leukonychia and partial leukonychia.

Yellow nails are another condition that can indicate an underlying health problem. If nails have been damaged by dyes or harsh products, new nail growth should be a healthy, clear colour. If nails continue to be yellow, there may be something else going on in the body. Sometimes having yellow nails can be an indication of something more serious. A medical condition which is referred to as yellow nail syndrome is mostly seen in people who suffer from lymphatic issues.

Healthy and unhealthy nail images were collected and images of the dorsal side of their hand were also collected to train the YOLOv5 object detection model to detect unhealthy nails in the hand. To train transfer learning-based Convolutional Neural Network models most common nail disease images were collected. Disease nail images were collected and segmented for calculate severity level of disease. Table 2 summarize the data collection process.

To reduce the training time and improve the performance of the models, image preprocessing methods were applied to all the collected images by performing transformations namely orientation change, resizing, static cropping, and adjusting contrast. Augmentation methods were performed on preprocessed images to multiply the number of images in the dataset by creating new variations using methods such as horizontal and vertical flips, rotation, shear, and adjusting saturation. The final data set was generated by splitting the above images into the training set, validation set, and testing set at 70%, 20%, and 10% respectively.

3.1.2 Training the Models

Table 2. Summary of data samples

Purpose	Number of Images			
	Training	***Validation***	***Testing***	***Total***
Healthy/Unhealthy Identification	2322	464	232	3018
Nail Disease Classification	1700	387	50	2137
Severity Level	1036	100	50	1186

Table 3. Selecting the best model

Purpose	Models	Accuracy	Best Model
Nail Object Detection	YOLOV5	95.6%	YOLOV5
Nail Disease Classification	Basic CNN	98.50%	Basic CNN
	CNN with Dropout	88.49%	
	VGG	93.53%	
	ResNet	79.65%	
Systemic Disease Classification	Logistic Regression	64.00%	Random Forest Classifier
	Random Forest Classifier	82.86%	
	SVM	37.14%	
	Multinomial Naïve Bias	20.00%	

To detect the fingernails in the image and classify them as healthy or unhealthy nails an object detection model is trained using the You Only Look Once (YOLOv5) algorithm. YOLO is a state-of-the-art, single-stage object detection algorithm that can predict object bounding boxes and class labels directly from full-sized images in a single evaluation using a convolutional neural network (CNN). This contrasts with two-stage object detection algorithms that first generate region proposals and then classify them [8]. The YOLO algorithm was trained on the custom dataset of nail images with bounding box annotations, where each bounding box represents an object in the image. To detect suspicious nails in an image, the algorithm analyzes the image at different scales and locations to identify regions that contain unhealthy objects. Then, it predicts the class in each region by using the CNN which was trained to recognize healthy and unhealthy nail classes.

Diagnosis of nail diseases is challenging due to the high involvement of visual evaluation. Deep learning techniques, particularly transfer learning neural networks, are highly effective in extracting crucial features from high-level summaries of images in a very short time without compromising. Therefore, transfer learning deep learning models are used to classify the most common nail diseases namely Black Line (Melanonychia), White Spots (Leukonychia), and Yellow Nails. To find the more accurate CNN model, several CNN architectures including Basic CNN, CNN with Dropout, VGG, and ResNet are used to train different models as indicated in Table 3. The accuracy of each architecture's result is compared, and the best fitting architecture Basic CNN with an accuracy of 98.50% is selected to be used in the system.

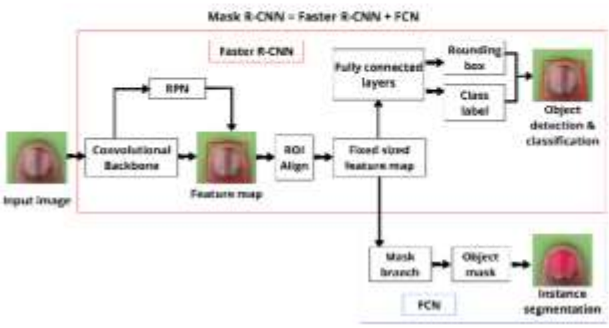

Figure. 2. Mask R-CNN framework for nail disease instance segmentation

The diagnosis and management of nail diseases depend on the severity and extent of the disease. Different control measures are applied based on the progression level of the disease, which refers to the extent of infestation throughout the nail. We propose a modified approach to the existing Mask R-CNN framework, which includes classification and bounding box regression, to accurately classify and segment infested nail areas [7]. We incorporated an additional fully convolutional network (FCN) layer to perform instance segmentation and mask the infested area as shown in Figure 2. Subsequently, we utilized crop segmentation to extract the infested nail from the background, followed by color segmentation using the K-means clustering algorithm. The color segmentation helped to determine the ratio between green and brown pigments, which is indicative of the severity of the nail disease. This modified approach provides an efficient and reliable diagnostic tool for healthcare professionals, aiding in the prompt and accurate diagnosis and management of nail diseases.

Mask R-CNN is used to distinguish more subtle features of the disease at the initial stage of a nail proven to be inflicted with a disease by recognizing the presence of color change spots. As the illness progresses, a distinct change in nail color can be observed and the infected area may grow larger. Using instance segmentation, the nail area is marked and separated. By analyzing various patterns and colors, diseased and healthy areas are distinguished. Then the amount of disease progression is calculated by comparing the ratio of the total nail area to the infected area. Using the stored data users can determine whether the infected area has progressed over time.

3.2 Predicting the Underlying Systemic Diseases and Recommendations

Classification algorithms are a type of machine learning algorithm that is used to predict a target variable that is classified based on one or more input features. The goal of classification is to train a model that can correctly assign each input data point to one of several predefined categories or classes [11].

Table 4. Possible systemic diseases

Nail Disease	Symptoms	Possible Systemic Disease
Black Line	Fatigue, weight gain or loss, sensitivity to cold or heat, changes in heart rate	Thyroid
	Fatigue, joint pain, abdominal pain, impotence, irregular heartbeats	Hemochromatosis
	Red, scaly patches on the skin, itching, burning or soreness	Psoriasis
	Blue-gray discoloration of skin, eyes, and nails due to exposure to silver	Argyria
	Bruising or discoloration under the nail due to injury or trauma	Subungual hematoma
	Dark, growing or changing mole or spot on the skin, unexplained skin changes	Melanoma
White Spots	Itchy or painful bumps on the skin, mouth sores, and nail changes	Lichen planus
	Slow wound healing, skin changes, loss of taste or smell, hair loss	Zinc deficiency
	Fatigue, Dizziness, Rapid Heartbeat	Anemia
	Red, scaly patches on the skin, itching, burning, or soreness	Psoriasis
	Joint pain and swelling, fatigue, skin rashes, chest pain	Systemic lupus erythematosus
	Swelling in limbs, skin changes, increased risk of infection	Lymphedema
	Thickening and discoloration of nails, brittle nails, separation from the nail bed	Fungal infection
Yellow Nail	Increased thirst, frequent urination, increased hunger, slow-healing wounds, blurred vision	Diabetes
	Fatigue, swelling in legs and ankles, itchy skin, difficulty concentrating, foamy urine	Kidney disease
	Swelling in limbs, skin changes, increased risk of infection	Lymphedema
	Pain and swelling in joints, stiffness, fatigue, decreased range of motion	Rheumatoid arthritis

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Black Line	Fatigue, weight gain or loss, sensitivity to cold or heat, changes in heart rate	Thyroid
	Fatigue, joint pain, abdominal pain, impotence, irregular heartbeats	Hemochromatosis
	Red, scaly patches on the skin, itching, burning or soreness	Psoriasis
	Fatigue, abdominal pain, jaundice, nausea, dark urine	Liver disease
	Shortness of breath, cough, chest pain, wheezing, fatigue	Lung disease
	Hardening and tightening of the skin, joint pain, muscle weakness, difficulty swallowing	Scleroderma

Classification algorithms are appropriate when the target variable is to be classified, and there are one or more input features that are expected to be predictive of the target variable. To predict the underlying internal diseases which are incorporated with the identified nail disease, the classification model is trained with the features which include the severity level value of the identified nail disease along with the symptoms of the internal disease, while the target variable can be the specific underlying disease.

A dataset that contains information about symptoms and the corresponding internal diseases is created using the data collected from medical records, surveys, books, and consulting with certified dermatologists. Using the custom data set, several classification algorithms namely Random Forest, Logistic Regression, Multinomial Naïve Bias, and SVM were used to train the most accurate model as indicated in Table 3. The best-fitting model Random Forest with an accuracy of 91.67% is selected to be used in the system.

Simultaneously, when a disease is identified, using recommendation systems and sorting algorithms, nearby hospitals are displayed on a Google map for users to check and consult a doctor.

4. RESULTS AND DISCUSSION

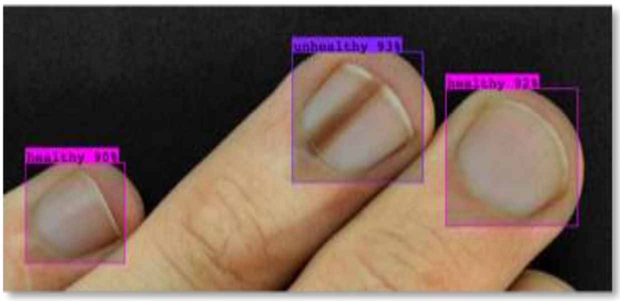
The smart system for nail disease detection and severity assessment is a breakthrough in the field of medical technology. This system was developed using various models and optimized to select the best-performing model based on the accuracy value. Table 3 shows the results of the evaluation process, where the accuracy values reflect the model's performance after each iteration of optimization. To assess the system's performance, various metrics were used, including sensitivity, specificity, precision, and recall.

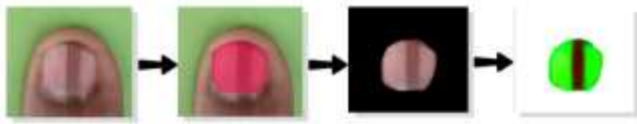
Sensitivity refers to the ability of the model to correctly identify positive cases, while specificity measures its ability to identify negative cases accurately. Precision evaluates the model's ability to return only relevant results, while recall measures its ability to detect all positive cases. Moreover, the system's precision and recall were also high, indicating that it returned only relevant results and was able to detect all positive cases. The performance of the system was further evaluated by comparing it with other similar systems. The results showed that the system outperformed other systems in terms of accuracy, sensitivity, specificity, precision, and recall. This indicates that the system is highly efficient and reliable in detecting and assessing nail diseases.

To achieve high levels of accuracy and performance, the models used for nail disease detection underwent a rigorous training process that involved experimentation with various image dimensions. Starting with a range of dimensions from 75 x 75 to 850 x 850, it was discovered that low dimensions failed to extract adequate features, while high dimensions required excessive computational power. Consequently, images with dimensions of 64 x 64 were selected as they struck a balance between these two factors. The training process also involved fine-tuning various hyperparameters, such as block sizes, epochs, steps per epoch, validation steps, and the Adam optimizer. The process of hyperparameter tuning was critical as even minor changes to these settings could significantly impact computation time, convergence speed, and the processing units required. To prevent overfitting, which is a common challenge with convolutional neural networks (CNNs), a dropout regularization technique with varying dropout rates was employed during the training process. The careful selection and tuning of these parameters ensured that the models were accurate and efficient in their performance. The models achieved optimal results, with high levels of accuracy and precision in identifying and assessing nail diseases.

The training process also ensured that the models were robust and could perform well in a wide range of scenarios, including cases where the nail diseases were severe or challenging to detect. Overall, the development of these models represents a significant advancement in the field of nail disease detection and assessment. The careful selection and fine-tuning of hyperparameters, along with the use of techniques to prevent overfitting, resulted in highly accurate and efficient models that can significantly improve the diagnosis and treatment of nail diseases. The models' ability to perform well in various scenarios makes them an invaluable tool for medical professionals and researchers in the field. Figure 3 shows the inference of a hand image by the YOLOv5 custom-trained object detection model. The model predicts the objects in two classes healthy and unhealthy with the bounding boxes.

Figure. 3. Output of YOLOV5 object detection model





(a) (b) (c) (d)

Figure. 4. Process of calculating the extent of damage

Using the Mask R-CNN object detection technique, the identification and progression stage determination of Nail disease was accomplished. This innovative method was developed to enable the accurate detection of nail diseases, including discolorations, which can be early signs of underlying health issues. The model was instructed using setups with a minimum detection loss of 0.05, two classes of images (one with background and one without), 500 steps for each epoch, and six phases of validation. With these parameters, the model could detect the slightest abnormalities in nail discolorations, making it an excellent tool for early diagnosis. To calculate the proportion of the affected area by the nail disease, below formula (1) is used.

$$Disease\ Percentage = \frac{DA}{TA} \times 100\% \qquad (1)$$

Where,
DA = area of disease
TA = area of the entire nail (nail plate)

The input image sizes for the model were set to 1024 x 1024 pixels. The images were then pre-processed to enhance their quality before feeding them to the model. Suspicious nail discolorations were submitted through a customized Mask RCNN model for detection after training. The model was trained on a large dataset of nail images with varying levels of discoloration, including healthy nails, to improve its accuracy. Using the Mask R-CNN model, nails were masked to isolate the nail from the rest of the image. This was done to enable the model to detect any abnormalities on the nail surface accurately. Background nails were removed using crop segmentation, which helped to eliminate any background noise in the images. The final result was a clean image of the nail surface, ready for further analysis.

To determine the full extent of nail disease damage, color segmentation was used. The HSV color palette was employed, including both green and brown colours, before using K-means. This helped to identify different colours in the nail discolorations, enabling the model to detect the presence of multiple types of nail diseases. One occurrence (pixel values) was substituted in the image data to improve the accuracy of the model. This substitution helped to reduce noise in the images, which could interfere with the model's ability to detect nail diseases accurately. With these modifications, the Mask R-CNN model could identify and classify different types of nail diseases with high accuracy.

One of the significant advantages of the Mask R-CNN technique is its ability to detect and classify multiple nail diseases in a single image accurately. This is particularly useful in cases where there are several types of nail diseases present, making it difficult for traditional methods to diagnose. The Mask R-CNN model can identify and segment each disease accurately, making it easier for medical professionals to diagnose and treat the patient. Furthermore, the Mask R-CNN technique can help medical professionals to detect nail diseases at an early stage, improving the chances of successful treatment. Early detection is critical in preventing the progression of nail diseases, which can lead to severe health complications if left untreated.

5. CONCLUSION AND FUTURE WORK

The proposed system can detect unhealthy nails in a hand, classify the nail disease and severity level, and the further system can predict the underlying systemic diseases and recommend the nearest hospital location. Deep learning models such as YOLO V5, CNN, Mask R-CNN and machine learning algorithms are used to determine the results. Nail diseases can be dangerous if not treated properly. In some situations require professional care from a doctor or dermatologist. The mobile application will make aware people who have nail diseases and help them to know more information about the diseases. In the future, the system's capabilities can be extended by developing models to identify more nail diseases and new features can be added for users to make appointments with doctors.

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7. REFERENCES

[1] Muneera Begum H, Dhivya A, Aasha J Krishnan, Keerthana S D, "Automated Detection of skin and nail disorders using Convolutional Neural Networks", *2021 5th International Conference on Trends in Electronics and Informatics (ICOEI)*

[2] Trupti S. Indi, Yogesh A. Gunge, "Early-Stage Disease Diagnosis System Using Human Nail Image Processing", *I.J. Information Technology and Computer Science*, 2016, 7, 30-35.

[3] Hardik Pandit, Dr. D M Shah, "A System for Nail Color Analysis in Healthcare", *2013 International Conference on Intelligent Systems and Signal Processing.*

[4] Kumar, Clark, "Kumar and Clarks Clinical Medicine 10th Edition", 2021, Elsevier Limited.

[5] Fawcett RS, Linford S, Stulberg DL. "Nail Abnormalities: Clues to Systemic Disease. Am Fam Physician", March 15, 2004.

[6] Priya Maniyan, Dr. B L Shivakumar, "Detection of Diseases using Nail Image Processing Based on Multiclass SVM Classifier Method", *International Journal of Engineering Science and Computing, May 2018.*

[7] Yu-Chieh Liu, Yong-Long Lin, Cheng-Ying Chou, Chiou-Shann Fuh, "Identification of Nail Lesions Based on Mask R-CNN Deep Learning Model", Department of Biomechatronics Engineering, *2013 International Conference on Intelligent Systems and Signal Processing (ISSP).*

[8] S. Hadiyoso and S. Aulia, "Classification of Koilonychia, Beaus Lines, and Leukonychia based on Nail Image using Transfer Learning VGG-16," *Jurnal Rekayasa Elektrika*, vol. 18, no. 2, June. 2022.

[9] H. Jayasinghe et al., "Effectiveness of Using Radiology Images and Mask R-CNN for Stomatology," *2022 4th International Conference on Advancements in Computing (ICAC)*, Colombo, Sri Lanka, 2022, pp. 60-65, doi: 10.1109/ICAC57685.2022.10025034.

[10] C. H. E. R. I. F. I. Imane, "Yolo V5 model architecture [explained]," OpenGenus IQ: Computing Expertise & Legacy, 14-Nov-2022.

[11] T. S. Indi, D. D. Patil, "Nail Feature Analysis and Classification Techniques for Disease Detection," *International Journal of Computer Sciences and Engineering*, vol. 7, no. 5, pp. 1376–1383, May 2019.

[12] Pranav S. Wazarkar, Abhilash D. Karnale, Devansh A. Chhabariya, Akhilesh R. Tiwari, Rica R. Kandelwal, "Early Disease Detection using Android Application based on Nail's Image", *2021 IEEE Bombay Section Signature Conference (IBSSC).*

[13] A. Kanchana, D. Navanisha, V. Pavithra, D. Reshika, "Early Stage Diseases Diagnosis using Human Nail in Image Processing", *IJESC, April 2021.*

[14] Stamatis Gregoriou, MD, George Argyriou, MD, George Larios, MD, and Dimitris Rigopoulos, MD, PhD, "Nail Disorders and disease: What the nails tell us", *The Journal of Family Practice*, VOL 57, NO 8 / AUGUST 2008.

[15] Motswaledi MH, Mayayise MC. "Nail changes in systemic diseases", SA Fam Pract 2010; 52 (5): p 409-413.

[16] M. Krajewska-Włodarczyk, A. Owczarczyk-Saczonek, W. Placek, M. Wojtkiewicz, A. Wiktorowicz, and J. Wojtkiewicz, "Ultrasound Assessment of Changes in Nails in Psoriasis and Psoriatic Arthritis," *BioMed Research International*, vol. 2018, pp. 1–7, Sep. 2018.

[17] Sarahi Jaramillo Ortiz, Michael Howsam, Elisabeth van Aken, Joris Delanghe, Eric Boulanger, et al., "Biomarkers of disease in human nails: a comprehensive review", Critical Reviews in Clinical Laboratory Sciences, 2022, 59 (2), pp.125-141.

[18] Venkataranganathan, A. V., R. J. Hariharan, and M. Roopa. "A Noninvasive Diagnosis of Early Stage Diseases through human nail using Neural Networks." *Journal of Artificial Intelligence*. Vol. 4. No. 1. 2022.

[19] Baswan Sudhir, et al., "Understanding the formidable nail barrier: A review of the nail microstructure, composition and diseases." Mycoses 60.5 (2017): 284-295.

[20] Abdulhadi Jumana, et al., "Human nail diseases classification based on transfer learning" ICIC Express Letters 15.12 (2021): 1271-1282.