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Efficient Descriptor of Histogram of Ridges Orientation Delineate for Fingernail

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***Abstract.** Orientation, ridges, and edges are prominent features of fingernail structure. This paper proposes a local descriptor based on ridges orientation, called histogram of ridges orientation delineate (HROD), based on Edge Histogram Descriptor (EHDD). As humans perceive images by looking at edge features, Finger HROD utilizes this sensitivity. Prior to performing features extraction, HROD algorithm performs a range of pre-processing steps, including resizing, filtering, enhanced and segmented images. After this, ridges orientation delineate maps are obtained by selecting an orientation with the maximum edge magnitude for each pixel based on predefined orientations. This study utilized five oriented edge maps to generate and detect the maximum edge orientations of each block: vertically, horizontally, diagonally 45°, diagonally 135°, and isotropically (non-orientation specific). The results of experiments conducted on fingernail images demonstrate that the performance of HROD is similar to that of advanced orientation-based methods such as the Gabor filter, histogram of oriented gradients, and local directional code. Additionally, the HROD algorithm being suggested offers the benefits of minimal feature complexity and quick execution, making it ideal for a real-time system designed to recognize fingernail orientations.*

***Keywords:** Edge Histogram Descriptor (EHD), Histogram of Ridges Orientation Delineate (HROD), Edge Orientation; Bit-Point (BP); Vertical Edge Orientation; Horizontal Edge Orientation; Diagonal Edge; Non-Edge Orientation (İsotropic).*

I. INTRODUCTİON

The nail tissues are a complicated structure found on the surface and edges of the hands (fingertips) and feet (toes). The primary purposes of these nails are to provide protection and sense touch. In order to comprehend the causes of nail diseases and related health issues, it is essential to have a basic knowledge of the anatomy of the nail structure [1]. In general, the nail is made up of the nail matrix, lunula (half-moon-shaped area), nail fold, nail plate, and nail bed [2]. Figure 1 shows the complete structure of a nail.

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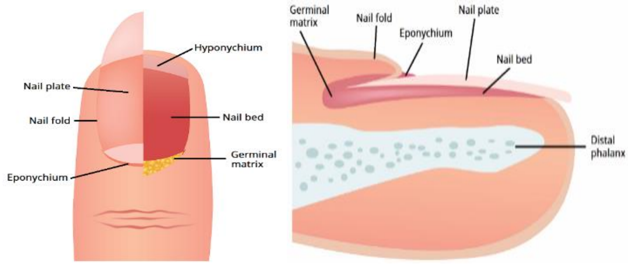

Fig. 1. Illustrated Diagram of Nail Anatomy [3]

The nails reflect the overall health and conditions and could be an obvious sign of serious case. Therefore, knowledge of the basic structure of nails and being able to recognize various types of nail colors, lines, and formations allows healthcare professionals such as general practitioners, clinicians, and hospitals to effectively diagnose and treat nail disorders, as well as identify potential underlying systemic illnesses. [1]. The authors of a 2015 study [4] emphasized the significance of nail condition, stating that dermatologists should make it a practice to carefully inspect the nails during each routine visit as even minor abnormalities can be indicative of underlying systemic diseases. As a nail tech, it is common to encounter nails that are fragile and prone to breakage, with the presence of white spots, lines, or ridges. The white horizontal lines on the nails may be Beau's lines, which show up as horizontal indentations in the nail surfaces [5]. These lines typically indicate underlying problems in the body, such as long-term health issues, injuries, or a response to medication, and could indicate the presence of toxins [6]. It is common for patients (44%) undergoing chemotherapy to experience changes in the color of their nails [6-8]. Nevertheless, in a population without a past of major drug-related harm, these lesions could serve as important indicators in identifying systemic illness [9]. Some patterns and nail lines are clearly visible in figures 2 (A) and (B), while others are less noticeable in figure 2 (C).

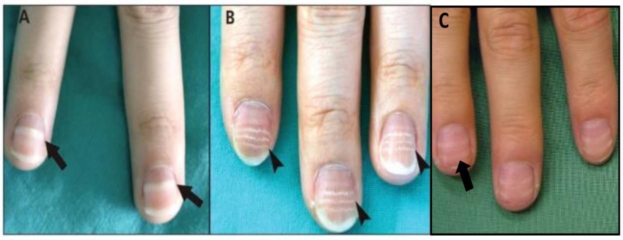

Fig. 2 (A) 27-Year-Old Woman has Lines (Arrows) in her Fingernails. (B) There are Arrow-Shaped Beau Lines Present on the Fingernails of a 41-Year-Old Woman and (C) There are Beau Lines Present in the Fingernails of a Man [5]

Beau lines and onychomadesis can be caused by trauma, s urgery, infection, Raynaud disease, pemphigus, or chemothe rapy (such as toxoids) [6-8].

In contrast, Mees lines (also known as true leukonychia) are characterized by a distinct change in color of the nail without any lines running from the lunula to the tip of the nail, and without any noticeable ridges [6]. Mees lines have connections to arsenic poisoning, Hodgkin lymphoma, carcinoid tumors, and certain types of chemotherapy such as cyclophosphamide, vincristine, and doxorubicin. Muehrcke lines can be distinguished from Mees lines by the fact that Muehrcke lines fade when pressure is applied to the nail and do not shift as the nail grows.

Meandering lines (also known as Mees lines) can be linked to arsenic poisoning, Hodgkin lymphoma, carcinoid tumors, and the use of certain chemotherapeutic drugs such as cyclophosphamide, vincristine, and doxorubicin. Muehrcke lines are caused by liver disease, nephrotic syndrome, malnutrition, and severe hypoalbuminemia [6-8]. However, in the case of genuine leukonychia, the white discoloration is not influenced by pressure and instead progresses towards the tip of the nail as it grows, a progression that can be documented through sequential photographs taken during follow-up appointments [10]. Mees lines are linked to various systemic stresses, including acute renal failure, heart failure, ulcerative colitis, breast cancer, infections like measles and tuberculosis, and diseases such as systemic lupus erythematosus. They can also be caused by exposure to toxic metals like thallium [11]. Another form of white stripes on the nails (Onychomycosis) can also occur as a fungal infection, which is responsible for around 50% of all nail disease cases. This infection can appear as white or yellowish lines running along the nail, along with thickening of the skin around it, which is known as a dermatophytoma. Figure 3 depicts the white-yellow lines [1].

Fig. 3. Fungal Infection in the Big Toenail Causing A Dermatophytoma, Which Can Be Seen As A White-Yellow Stripe Running Lengthwise [1]

One way to stain subungual debris with potassium hydroxide can be used to look for signs of a fungal infection when examined under direct microscopy [12]. Instead, you can send a piece of nail clipping in a container with 10% buffered formalin and request a fungal stain like periodic acid-Schiff [12]. Under the microscope, a dermatophytoma reveals a concentrated cluster of dermatophyte hyphae, also known as a fungal abscess. The detective's role in diagnosis is crucial, as clinical findings that indicate dermatophytoma are linked to a lack of improvement with antifungal treatment [14]. However, these techniques and observations highly require skills stuffs and professional clinical practice as well as an expensive tool and equipment i.e Microscope.

Various health conditions can lead to alterations in the nails and nail bed, such as the formation of ridges on the nails. The most common type of ridges found in fingernails are vertical ones, and they are typically harmless. This type of ridge on the fingernail is typically a result of getting older. To be more precise, due to the aging of the nail matrix. As the cells in the nail bed deteriorate over time, they produce a fingernail with uneven vertical ridges. Nonetheless, horizontal ridges and lines frequently indicate an underlying health issue that needs to be identified and treated. Therefore, examining the fingernails, toenails, and their structure should be included in both a comprehensive physical exam and a regular check-up. As a result, this study offers a straightforward method for monitoring and examining the structure of fingernails, which can enhance and expedite the overall inspection process. Furthermore, the micro-lens on the mobile phone can identify fine lines and small structures that are not visible to the naked eye, allowing for the collection of precise data and the generation of traditional outcomes.

II. METHOD

A. Experimental Setup

The experimental setup was constructed as hardware setup and image processing technique (IPT). The IPT, computer vision and artificial intelligence AI have enabled manufacturers and researchers to automate a wide range of tasks. This study has developed a special effort that required to make such complex technology robust and mature, to meet the high demands required by modern general clinical practice. The method is easier to apply in our system, it is simply used a cheap consumer micro-lens that attached to the phone to get high-resolution images of nails and to quantify symptoms that may attacks the nails itself and to develop an automated nails monitoring system of possible illness finding. Figure 4 shows experimental setup. The system includes micro-lens, phone, adjustable phone handle, USB cable, piece of clothing or paper (for background enhancement) and MATLAB algorithm script.

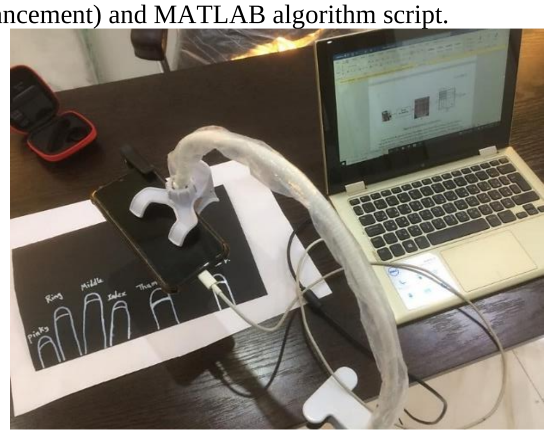

Fig. 4. The Overall System Design and Experimental Setup

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B. Examining Algorithm

Image pre-processing techniques are primarily utilized to enhance obscured details or emphasize specific features of interest in an image. These are primarily procedures created to utilize an image search in order to capitalize on the human visual system's strengths. The Content Base Image Retrieval (CBIR) and Histogram of Ridges Orientation Delineate (HROD) equalization techniques were used with proposed method algorithm to enhance the detection. [17]

The CBIR is also known as query by image content, which refer to a process of retrieving expected image from image database according to the content of the query image. The image's content primarily consists of its color, texture, and shape characteristics, which can be automatically obtained from the images through a variety of feature extraction techniques.

The CBIR differs from traditional methods that rely solely on metadata like keywords, tags, or descriptions that are linked to the image. The keyword in the traditional technique is also limit the scope of queries because of the set of predetermine criteria. While the CBIR technique provides the flexibility to search and focusing on the content of the image with no predefine criteria. Figure 5 shows the CBIR technique that implemented on this study.

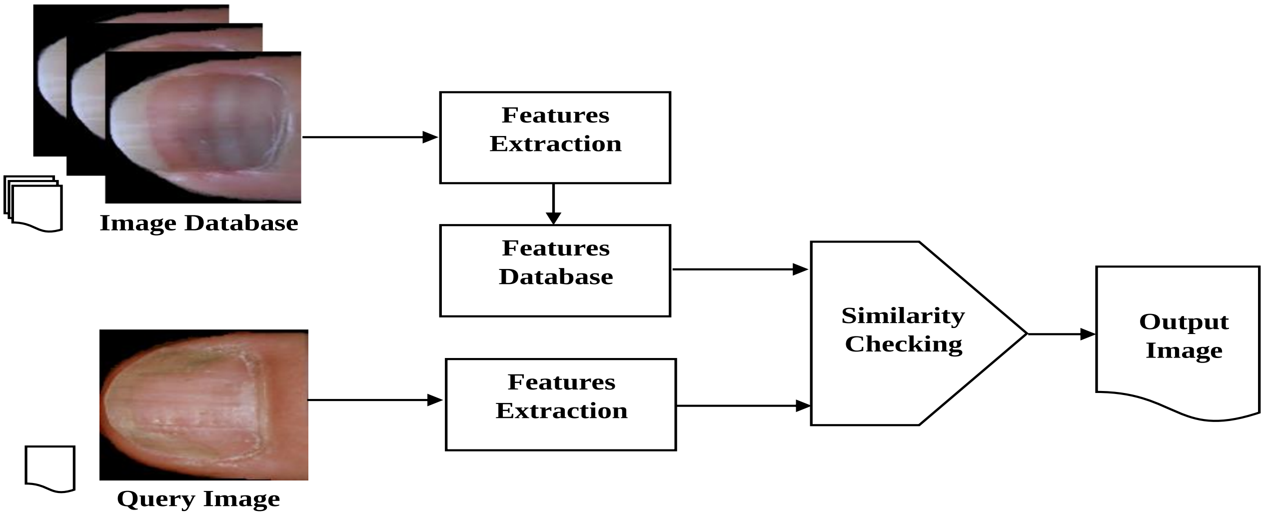

Fig. 5. The CBIR Technique Algorithm

Figure 5 shows the overall extraction processing of Find the closest match between the query image and the images in the database based on minimal distance features between these images. On the base of the minimum and smallest distance, the features can be extracted easily, thus, the output can be obtained with most similarity features. More details will be explained in the following section.

C. Algorithm Data Processing

There are many descriptors methods that can be used to extract the interest features, similarity, and differences of the images such as color, texture, shape, motion descriptor and localization. In this study, the edge histogram descriptor (EHD) is being utilized as a type of texture descriptor[15][16]. The EDH is a strong descriptor used for image search and retrieval at a basic level. Therefore, the arrangement of edges serves as an effective texture signature utilized in the process of matching images. The use of the EDH is beneficial when the underlying area does not have uniform texture properties. The EDH represents the spatial distortion of edges, which can be classified into five main categories: vertical, horizontal, diagonal at 45 degrees, diagonal at 135 degrees, and isotropic (not specific to orientation). Figure 6 displays the intricate block diagram of the proposed methodology.

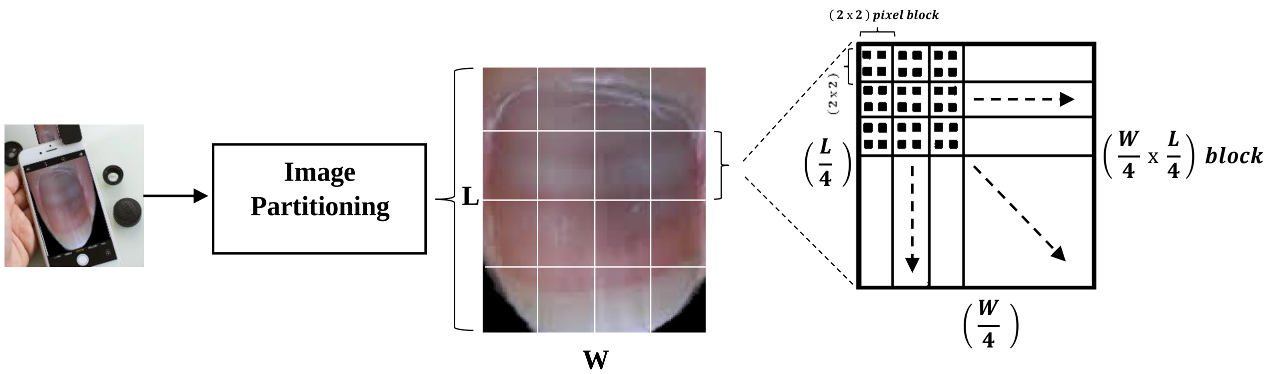

Fig. 6. Image Partitioning Implementation

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Figure 6 shows the process of image partitioning which divided the raw image into the length *(L)* and width *(W)* of *4×4* (*16* sections) non-overlapping block. Each extracted block of *16* section is further divided into *2×2* small pixel block for capturing the local edge orientation. The capturing edge orientation for each extracted block $\left(\frac{W}{4} \text{ x } \frac{L}{4}\right)$ (1) is then initialized by *5* Bit-Point (*5BP*) as following; *BP = [V, H, D45, D135, NON] = [0, 0, 0, 0, 0]* (2)

Where *BP* is Bit-Point, *V* represents Vertical edge orientation, *H* is Horizontal edge orientation, *D45* is Diagonal edge at *45°* orientation, *D135* is Diagonal edge at *135°* orientation and *NON* is non-edge orientation (isotropic) [19].

Therefore, the partition image has *16-BP[N]* for all *16* blocks as overall and each of these blocks comprises of *5-BP*, thus if the *BPs* are kept side-by-side, it makes *EHD* vector of total length of *80-BP*.

$$EHD = \begin{pmatrix} BP[1] & BP[2] & BP[3] & BP[4] \\ BP[5] & BP[6] & BP[7] & BP[8] \\ BP[9] & BP[10] & BP[11] & BP[12] \\ BP[13] & BP[14] & BP[15] & BP[16] \end{pmatrix} \quad BP[8] \rightarrow [V, H, D45, D135, NON] \quad (3)$$

Now for the capturing the local edge orientation from each *2×2*-pixel sub block, it will apply an operator of *2×2* as shown in the following table 1.

Table 1. Five types of Edges in EHD

Edge Type	Visual Representation	Operator Mask
Vertical edge (*V*)		$\begin{bmatrix} 1 & -1 \\ 1 & -1 \end{bmatrix}$
Horizontal edge (*H*)		$\begin{bmatrix} 1 & 1 \\ -1 & -1 \end{bmatrix}$
Diagonal edge (*45°*)		$\begin{bmatrix} \sqrt{2} & 0 \\ 0 & -\sqrt{2} \end{bmatrix}$
Diagonal edge (*135°*)		$\begin{bmatrix} 0 & \sqrt{2} \\ -\sqrt{2} & 0 \end{bmatrix}$
Non-edge orientation		$\begin{bmatrix} 2 & -2 \\ -2 & 2 \end{bmatrix}$

Each operator mask is applied on *2×2* sub block by the following formula;

$$ET = \left| \sum_{i=0}^{3} p_i \cdot m_i \right| \quad (4)$$

Where *ET* represents the Edge Type;

$p_i = \begin{bmatrix} p_0 & p_1 \\ p_2 & p_3 \end{bmatrix}$ represents *2×2*-pixel sub block;

$m_i = \begin{bmatrix} m_0 & m_1 \\ m_2 & m_3 \end{bmatrix}$ represents *2×2* operator mask.

After applying all operators mask on a single *2x2* image sub block, the five corresponding of edge types (*ET*) will be obtained such as ET_v, ET_h, ET_{45}, ET_{135} and ET_{non}. The maximum of these values is compared with a threshold value (*T*) to fin the dominant edge type as following;

$ET_{dominant} = max(ET_v, ET_h, ET_{45}, ET_{135}, ET_{non}) > T$ (5)

After finding the maximum value among these values, the dominant edge type ($ET_{dominant}$) will be equal to that maximum number. Next, the Bit-Point (BP) count corresponding to each 2x2 sub block is raised by one, and this process is repeated for all sub blocks within the larger block [18].

One$\left(\frac{W}{4} \text{ x } \frac{L}{4}\right)$ image block.

Thus, for one $\left(\frac{W}{4} \text{ x } \frac{L}{4}\right)$ image block, we obtained the complete Bit-Point *BP* and can be expressed as following;

BP[1] = $[b_0, b_1, b_2, b_3, b_4]$ (6)

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The operations are repeated for all sixteen- $\left(\frac{W}{4} \times \frac{L}{4}\right)$ image block to acquire all *16 BP*. After getting *BP* for all sixteen$\left(\frac{W}{4} \times \frac{L}{4}\right)$ -image block, these *16 BP* can be re-arranging as following;

$$All_{BP} = \begin{pmatrix} b_0 & b_1 & b_2 & b_3 & b_4 \\ b_5 & b_6 & b_7 & b_8 & b_9 \\ . & . & . & . & . \\ . & . & . & . & . \\ b_{75} & b_{76} & b_{77} & b_{78} & b_{79} \end{pmatrix} \begin{matrix} \rightarrow BP\ [1] \\ \rightarrow BP\ [2] \\ \vdots \\ \rightarrow BP\ [16] \end{matrix} \quad (7)$$

For accurate result, the global BP_g can be calculated by taking the mean of each column and then combined all extracted *BP* with global BP_g to make the *EHD* vector of *85 PB* in total.

$$EHD = [\underbrace{BP\ [1], BP\ [2], BP\ [3], \ldots\ldots BP\ [16]}_{80\text{-}BP}, \underbrace{BP_g}_{5\text{-}BP}] \quad (8)$$

D. Nail Examination Essentials (Protocol)

A complete examination includes all 10 nails (individually or unit) of the hand. Subjects should be instructed to remove all nail polish or any barrier on their nails prior to carry the examination. Photo shoots and careful measurement help document the status of the nails as well as the overall of a health condition that might detected. A set of images in database are stored for further processing, comparison and similarity detection. This examination and processing are executed by using MATLAB image processing toolbox such as image acquisition, background subtraction, segmentation, edge detection, filtering, enhancement, feature extraction, normalization and classification. In addition, the main CBIR and EHD proposed method were implemented for accurate extraction result. In this examination, a twenty (20) participances in the experimental protocol with approval of the Taif University Ethics Committee (No. 44-283).

The committee for Bioethic with No. (HAO-02-T-105) and the committee considered that the proposal fulfils the requirements of Taif University and accordingly ethical approval was granted (from March 23rd). The participants ask to place their hand and/or fingertip on the defined position as showing in Figure 7, however, take a photo of the whole unit (hand) require more time and processing such as resizing, disregarding the palm and fingers and detect area of interest (nails). Thus, this study only considers taking individual finger at a time.

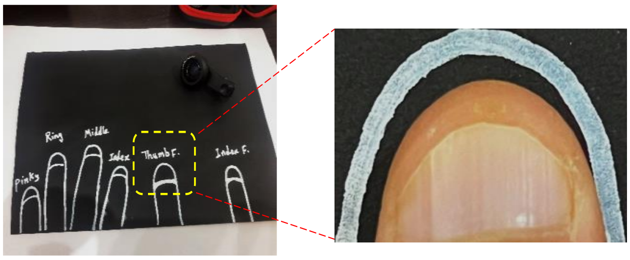

Fig. 7. (a). The Area of Interest (nails), (b). The Nail on Place

In addition, two photos are taken in a row for the same finger where the user asks to place his/her finger with no pushing down toward the table as a first shoot (normal placing), and the second photo is taken with a little pressure applied toward the table as shown in Figure 8. The idea is to keep tracking all possibilities of fine lines that could appear. However, on occasion we cannot tell the difference with naked eyes, but by pre-processing and algorithm implementation.

Fig. 8. Capture Two Photos, (a) with no Pressed, (b) with Little Push Toward the Table

III. RESULTS AND DİSCUSSİON

A. Analyzing Detection Data

Initial signal processing of the recorded data was conducted using MATLAB (The MathWorks, Inc., Natick, MA, USA) software to assess the effectiveness of the suggested algorithm alongside a visual examination. Figure 9 shows nails of different participants that captured during the examinations.

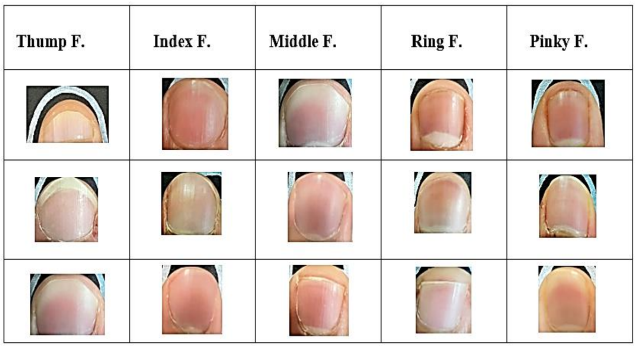

Fig. 9. Fingers (Nails) of Different Subjects

The edge histogram descriptor (EHD) can be extracted easily by implementing the algorithm and can be compared with database photos for further inspection.

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The algorithm operates by analyzing each sample and recording the local edge orientation to determine if the samples are similar or match the photos in the database. The point where the edge is found is identified by locating the smallest value within a 2x2 pixel sub block using a 2x2 operator mask.

The running algorithm on the sample detects the maximum magnitude values in each sub block and scan through the entire target (nail photo) and comparing them. Figure 10 shows outcome of pre-processing and enhanced the data, the time of processing is small < 7s. The outcomes from the initial detection processing of maximum orientation values are better than a physical inspection method and not comparable due to the present of fine lines that cannot be detected with naked eyes.

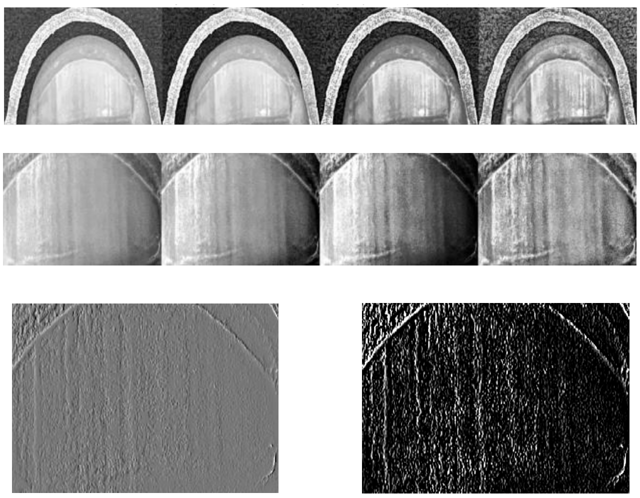


Fig. 10. Outcome Pre-Processing and Enhancement

Figure 11 shows the graph of EHD of both images and comparing the factors of how they are difference from each other.

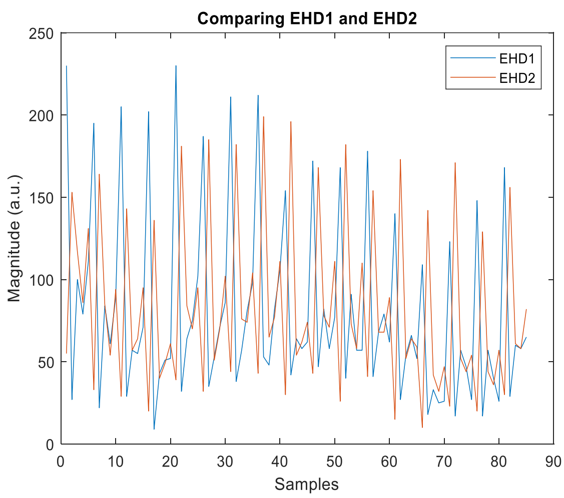


Fig. 11. Comparing of EHD1 and EHD2

Figure 12 show that the global bin of both images. Each bar represents edge orientation, the first bar from the left is a vertical, then horizontal, diagonal 45°, diagonal 135° and isotropic (non-orientation specific) at bar number 5.

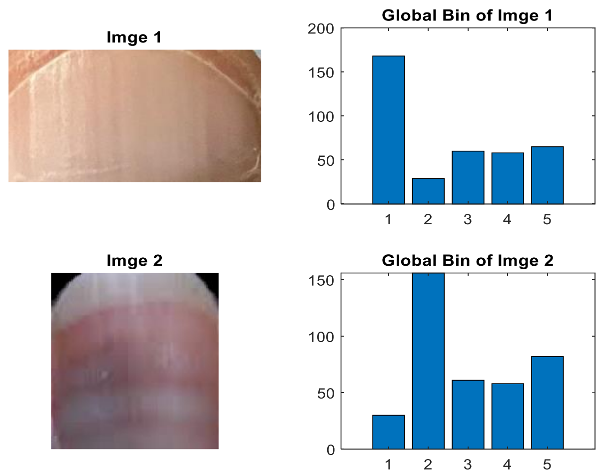
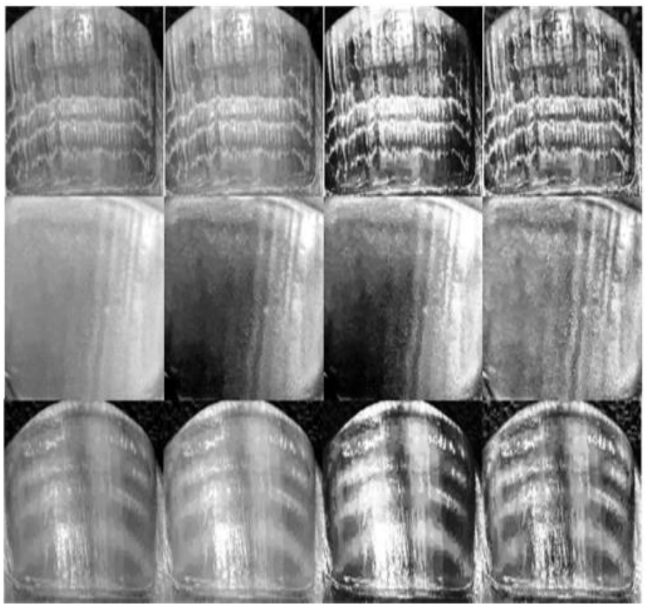


Fig. 12. Edge Orientation Detection of Different Images

It can be seen from Figure 12 that the dominant edge value of the first image is the vertical orientation, which represent the maximum vertical edges. Similarly, the highest value orientation is a horizontal bin on the second image.

It can also be seen that both graphs have smaller values on other orientations. Occasionally, it is difficult to tell from the image itself by naked eyes, but by implementing the Edge Histogram Descriptor (EHD) algorithm, the outcome is obvious and clear on the graph.

Figure 13 show the comparison that have been taken between the same image. It can be clearly seen that the graphs of figure 13 (b) are identical, there is no difference as it used the same image of comparison. Both EHD1 and EHD2 are matching thus the blue line legend (EH1) is not appear in the graph since it is located exactly underneath the red line (EH2).



(a)

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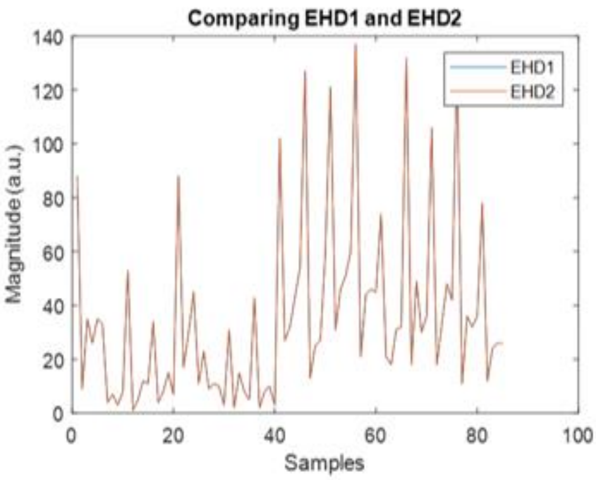

(b)

Fig.13. (a) Enhancement Images, (b) Comparison of Edge Histogram Descriptor

Figure 14 shows the dominant edge orientation of each image. It is clear that figure 14 (a) and (b) has the highest horizontal values bin orientation, while the dominant values on figure 14 (c) are vertical bins.

The idea of comparison two identical image is to prove the concept of algorithm and its implementation.

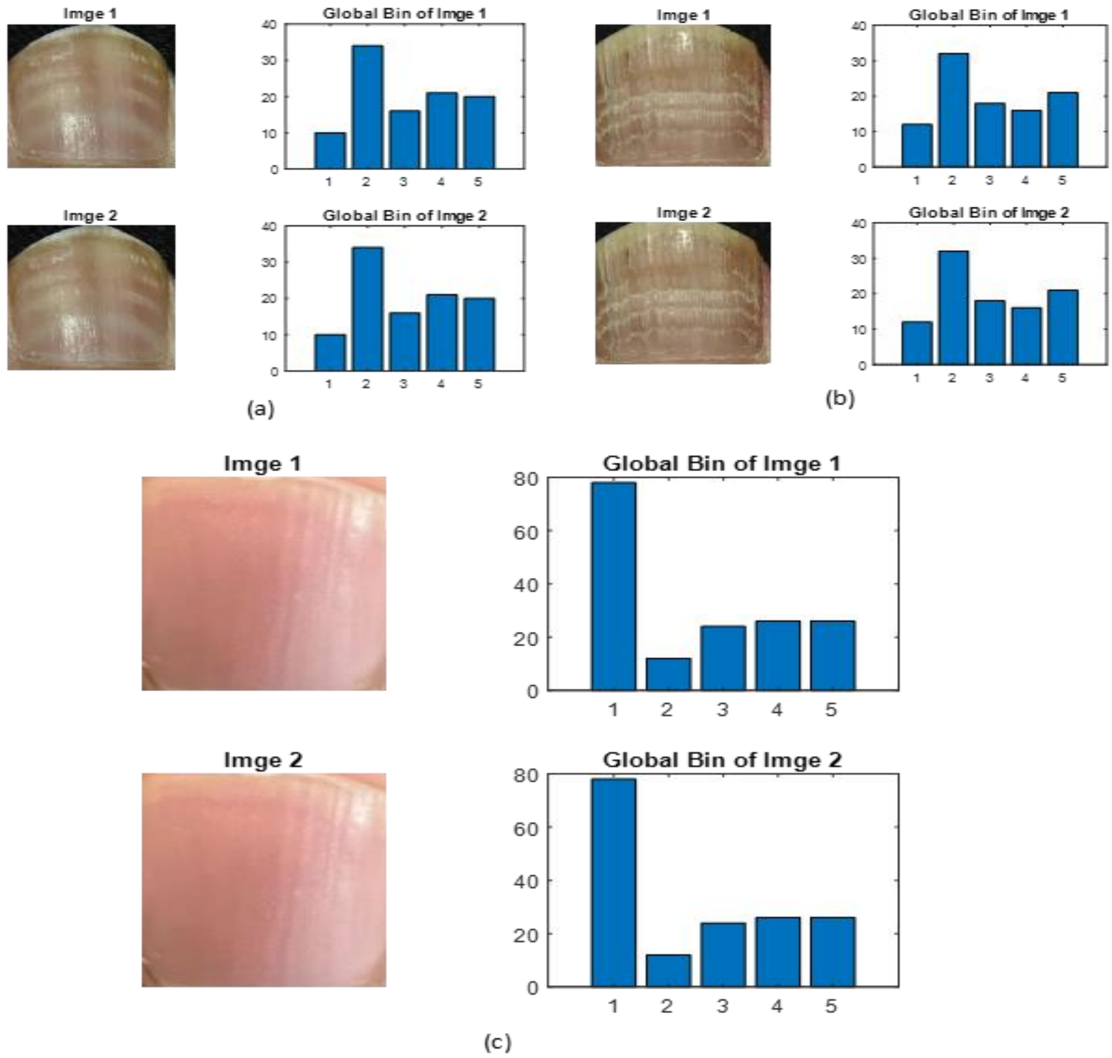

Fig.14. Edge Orientation Detection of Similar Images

IV. CONCLUSİONS

This work introduced descriptors method together with help of phone for capturing the data. The edge histogram descriptor (EHD) is used in this study as one type of texture descriptor of the target (nail). A micro-lens is also used to enhance the quality of photo and make texture even more visible. The proposed algorithm is a low-level descriptor for image search and retrieval which then provides a good agreement and comparability with database photos.

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Thus, the distribution of edges is used to investigate the texture signature that is used for images matching. The EDH is useful when the underline region is not homogenous in texture properties. The captures of spatial disruption of edges which are grouped to different categories (vertical, horizontal...) to determine the orientation on a small region which then result into accurate result as overall.

Nevertheless, certain invalid data errors may occur as a result of finger misalignment. This issue can be resolved by ensuring the finger is properly positioned, adjusting the holder height, and using the zoom functions on the phone when capturing data. Moreover, the scarcity of photos in the database could lead to decreased agreement during the comparison stage. Furthermore, the camera quality is substantial. The outcome from the proposed work indicates that a new paradigm of nail monitoring could be used instead of using physical and naked eyes inspection to detect and compare ridges and lines in fingernails thus, this method can be incorporated into clinical for further assessment and does not require for highly staff training to operate.

List of Abbreviations

- EHD: Edge Histogram Descriptor,
- HROD: Histogram of Ridges Orientation Delineate,
- BP: Bit-Point,
- IPT: image processing technique,
- CBIR: Content Base Image Retrieval and
- HROD: Histogram of Ridges Orientation Delineate.

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DECLARATION STATEMENT

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Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	Yes, The experimental protocol with approval of the Taif University Ethics Committee (No. 44-283). The committee for Bioethic with No. (HAO-02-T-105) and the committee considered that the proposal fulfils the requirements of Taif University and accordingly ethical approval was granted (from March 23rd).
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	As the only author, I have approved the final version of the manuscript and agree to be accountable for all aspects of this work.

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