Implementation of Biometric Identification System Utilizing Fingernail Feature Points

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The biometric system has to differentiate each person's biometric data precisely. This study suggested the use of nail information in a biometric authentication system. We researched the makeup of human nails in order to develop a state-of-the-art biometric identification system that utilizes the finger lunula with a nail bed. It was established through analysis of the gathered nail photos that each person's nail differed in terms of length, breadth, and semicircle. Our choice for the study nail among the fingernails was the thumbnail. The thumb has the biggest nail, which accounts for the great image accuracy. The analytical methods employed in the system were SIFT, haar wavelet, independent component analysis, and principal component analysis. The support vector machine and the Naive Bayes approach were used to examine the algorithm's performance. It is possible to use genuine human nail data in experiments to create a nail-based biometric identification system.

Keywords: Biometric Identification, Nail, Lunula, Nail bed, Feature Point.

1 INTRODUCTION

For the most adaptable and effective means of identifying or authenticating people, a biometric identification system is employed. One of the primary benefits of this kind of system is that it can be used quickly and at a lower cost of password management because the user does not need to carry an OTP card or remember the password (Wahid et al., 2023; Fan et al., 2022; Bauspieß et al., 2023; Uwaechia & Ramli, 2021).

Many biometric technologies, including voice, iris, hand, ear, and fingerprint recognition, are being utilized to identify and verify individuals. However, to lessen issues with previously used technologies or to expedite the functioning of contemporary systems, the necessity for alternative biometric authentication technologies—such as lip shape, joint, or fingerprint—is being highlighted (Galbally et al., 2014; Moolla et al., 2016). Recently, numerous studies are...
currently utilizing measurement techniques and integrating it with artificial intelligence to identify diseases in plants and animals, improve cryptographic systems, and enhance security and forensic systems (AlZubi, 2023; Cho, 2024). Combining these methods has led to better performance (Knezović et al., 2023). These techniques can also benefit businesses by securing employee personal information (Tiwari et al., 2023). All these reflects the development of non-contact systems meant for secure management.

Researchers are focusing more on developing non-contact systems to prevent attacks by fraudulent users. Research like this focused on measuring the unique biometric characteristics that distinguish people from other people without coming into contact with the device. In particular, human joint engineering, fingernails, and hand engineering were studied (Genovese et al., 2019). In this study, fingernails were selected among various features of the human body and research related to authentication was conducted.

The following are the nail's anatomical features. The plate of a nail is the only one which regenerates with the creation of new cells during the nail development cycle since the spacing between nail grooves remains generally constant. The human nail's nail grooves are an essential component. For instance, identical twins' nails on the same hand may be differentiated with accuracy (Munteanu et al., 2021; Yin et al., 2021). The nail bed was the primary approach used in this investigation to measure changes in biometrics. The human nail's anatomy is seen in Figure 1. The size and form of a person's face and ears vary as they age, while the average person's nail plate size essentially stays the same (Nigam et al., 2022). The development of nail-based biometric identification systems can benefit greatly from this particular feature of nails.

![Fig. 1: Fingernail and nail anatomy of human](image)

This study is structured as follows. Chapter 2 introduces related research. Chapter 3 describes the system structure proposed in this study. Next, the experimental results are described in Chapter 4. Finally, in Chapter 5, the research is summarized and future research contents are explained.

**2 RESEARCH METHODOLOGY**

2.1 Characteristics of Nails

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At the base of the nail, the lunula is a white, half-moon-shaped structure that extends upward from the proximal nail fold's border (Munteanu et al., 2021). Determining the nail plate's form is the crescent's primary purpose. In essence, the translucent, rectangular keratin components that makeup nails. Trilobate (dorsal, ventral, and medial) fibers in the nail cover the nail bed transversely and longitudinally. The nail is more resilient to mechanical stress thanks to this curve. Transversely situated constitute the dorsal along with ventral fibers, whereas longitudinally located are the central fibers. This particular kind makes the nail more resilient to rips and fractures.

2.2 Biometric Identification

A lot of research on biometrics has been conducted, but fingernail-based biometrics is a field in which research has recently begun. Barbosa's study proposed transient biometrics as a concept different from existing biometrics (Barbosa et al., 2008). Existing biometric recognition systems provide recognition accuracy by using a property that does not change in a living body, such as the retina. Temporary biometrics proposed in the paper utilized the characteristics of biometrics that change over time. Utilizing this feature, it was applied to temporary recognition within a lifetime. The authors employed fingernails and concentrated on well-established biometric characteristics. Using a variety of textural cues, they were able to extract pictures of nails. Due to variations in the tissue that was used when the sample was collected, the study showed that the images were accurate for a month after the date of acquisition.

Garg et al. (2012) presented research that suggested an automated biometric identification method that utilizes the fingernail, palm, and the ring, index, and middle fingertips of the hand. For this study, the transplanted nail plate, nail bed, and nail skin color gradation values were used to remove the nail bed region, leaving the nail plate out. In comparison to the nail bed, the skin's gray tone value was determined to be lower. According to Ganguly et al. (2022), the Haar wavelet feature extraction approach is used to separate the nail bed from the nail surface. Complex region-of-interest (ROI) extraction methods do not need to be used with this method.

3 BIOMETRIC FINGERPRINT SYSTEM

3.1 System Architecture

In this study, information on the nail bed and crescent of the right thumb was used for biometric recognition. The use of this information for biometrics is because nail beds and crescents are unique. The feature extraction system proposed in this study is designed to operate based on the nail bed and crescent moon. And the system does not refer to nail plates that change all the time.

In the proposed system, 5 feature points are displayed on the nail bed and 5 feature points on the half-moon, and 2 regions are extracted using these points. Figure 2 shows a summary of the proposed system.
3.2 Semantic Points

With current technology, the nail bed cannot be divided precisely. The reason is that the edge of the nail image is not continuous. To solve this problem, semantic point mediation techniques were used (Easwaramoorthy et al., 2016). In this study, the task of obtaining a nail bed was divided into stages.

The first step is to adjust the semantic points to find the desired area as shown in Figure 3. The circumference of the crescent moon located below the nail was calculated as a square as shown in Figure 3(a), and the property of the midpoint was used for this purpose (Su et al., 2022). By repeating the previous procedure again, the nail bed is calculated as shown in Figure 3(b). And mark common points on the nail bed.

In the second step, the nail plate is processed. Next, the image is rotated 180 degrees to perform the anterior process. This removes the background of the image and makes the color of the growing nail plate the same as the background color. In the third step, draw a line between the two points on the nail bed. Do this so that all five points can be connected. Finally, draw the hyperplane. A line between the bottom two points and the topmost point of the five meaning points is connected vertically to form the hyperplane. Next, the parameters for each of the meaning points were computed until they reached the pixels of the binary image's edge area, based on the intersection of the pixel of the hyperplane's left and right regions and its center node area. The nail picture is shown in Fig. 3(a) as a consequence of using the semantic point mediation approach.

![Fig. 2: Architecture of biometric finger print system](image)

![Fig. 3: Results of semantic point mediation technique](image)
3.3 Processing of Nail Image

The photos underwent the subsequent image processing methods to get the best possible image: Our initial approach consisted of employing a 50 median filter masks to remove random noise that was brought about by the uneven lighting in the image. Because the Gabor filter provides an extremely high combined resolution in the spatial frequency field, it was used for the second stage of edge identification in the image. In order to create both the picture and texture of a product or model, researchers have frequently used this filter. In the subsequent step, the graph was applied to every image in order to get the maximum contrast value. First, each captured picture is optimized using a predefined threshold value. Finally, the background's clutter has been eliminated, the gaps in the foreground form are filled in, and the edges of the finger picture are joined. The next step is enhancing the finger picture's essential features using the Canny edge detection approach.

Feature Extraction

As a result, the identification approach proposed in this study mostly relies on describing the nail tissue. The nail plate is primarily due to the individual nail's roughness. Several methods were employed to extract reliable characteristics from the outermost layer of different nail plates so that biometrics could be applied in this work. Discrete Haar functions are defined as those obtained by sampling the Haar functions at 2n locations. Representing these functions in a matrix is a practical approach. Given the row ordering of the Haar matrices H(n), consideration is given to the natural and sequence orderings, which vary. The discrete Haar function (or, alternatively, the discrete Haar sequence) is present in each row of the matrix H(n). Mathematical procedures known as independent component analysis (AIC) are used to separate mixed signals into subcomponent signals that are then added to non-Gaussian signals. The images obtained from the input source are represented by AIC as $x_d(j)$, where $j=1, 2, ..., n$.

3.4 Haar Wavelet

By generating the Haar-waveform pyramid, this waveform type reliably and satisfactorily delivers information about the picture under examination, making it one of the most direct waveform types when compared to others. These waveforms help identify the variations between tissue layers. This approach has the benefit of being a non-continuous step, which aids in the analysis of images with spatial discontinuities. Equation 1 can be used to calculate and identify the main wave of the Haar wave (Wolter et al, 2022).

$$\varphi(t) = \begin{cases} 1 & 0 \leq t < \frac{1}{2} \\ -1 & \frac{1}{2} \leq t < 1 \\ 0 & \text{otherwise} \end{cases}$$ (1)

The scale function can be state as Equation 2

$$\varphi(t) = \begin{cases} 1 & 0 \leq t < 1 \\ 0 & \text{otherwise} \end{cases}$$ (2)

Using an iterative approach to low-frequency transformation application and nail image
surface estimation, we build a Haar Wavelet pyramid that produces a collection of specific parameters at each level. Nearly equal horizontal, vertical, and diagonal components made up the 230 by 310 image of the nail surface. The greatest accuracy that the five-level Haare waves offer means that the beginning and end levels cannot be distinguished from one another, even though they produce good outcomes. We chose to employ the final three levels and ignore the first and last to obtain the values for the radial, vertical, and horizontal coefficients—which were subsequently used to construct the attribute vectors.

4 RESULTS

In this study, nail biometric data were acquired by two methods. First, 11,000 hand images were downloaded from Kaggle, which provides a big data dataset. Among these images, subjects that can be used as data were selected. Eighty subjects were selected in a 50:50 ratio of male and female adults. In addition, 20 actual adult volunteers were received to obtain actual data.

Also, for biometrics, the information of the nail bed and crescent of the right thumb was used. The nail bed and crescent moon were used in this study because these two pieces of information are unique to the nail. For this reason, the nail-meaning point-based security system proposed in the study was designed to operate based on the nail bed and crescent moon.

In order to select accurate data, studies on how to measure nail length and width were referred. In the study, the distance of the nail groove is defined as the width (W) of the nail as shown in Figure 4(a). In Figure 4(b), the distance from the nail fold to the tip of the nail is defined as the length of the nail (L). The last Figure 4(c) shows the width and length of the nail when viewed from above.

![Fig. 4: Measurement variables of fingernail](image)

We separated the data into three major groups and used the identical acquisition procedure on each group to evaluate the impact of nail plate growth on the measurements. Photos of volunteer nails from the first acquisition day make up the first Group (GR1). The second group (GR2), which was created at the same time, included images of volunteer nails that were obtained seven days after the original capture. Thirty people that were a part of the initial group (GR1) made up this group. Twenty-five photos from the same participants as the second group (GR2) were included in the third group (GR3) but sixty days after the first acquisition. We used the nail bed data to calculate the return on investment because the results showed that nail plate growth had no impact on the measurements made or the validation method.

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According to age group, the experiment's nail data is displayed in Table 1. Arranging the experiment participants' data revealed that human age variation did not affect the nail bed or the ratio of nail length to breadth (W/L). Nails flattened as a result of a reduction in the radius of curvature with advancing age. Age's influence on the variables employed in the study is examined in Table 1, which also serves as a statistical summary of the investigation.

<table>
<thead>
<tr>
<th>Age</th>
<th>W/L ratio</th>
<th>Transverse nail curvature (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>20</td>
<td>1.05±0.06</td>
<td>0.90±0.07</td>
</tr>
<tr>
<td>30</td>
<td>1.03±0.09</td>
<td>0.91±0.08</td>
</tr>
<tr>
<td>40</td>
<td>1.03±0.01</td>
<td>0.91±0.09</td>
</tr>
<tr>
<td>50</td>
<td>1.05±0.06</td>
<td>0.91±0.05</td>
</tr>
<tr>
<td>60</td>
<td>1.03±0.06</td>
<td>0.92±0.04</td>
</tr>
</tbody>
</table>

To verify the accuracy of the system proposed in this study, image feature extraction was performed using different algorithms. In Table 2, the accuracy of all algorithms used was compared and summarized using a Naive Bayes classifier and a Support Vector Machine (SVM) (Szymkowski et al., 2020; Basheer et al., 2021).

Experiments on the nail bed are shown in Figure 5(a), and findings on the crescent moon are shown in Figure 5(b). Scale-invariant characteristic accuracy was higher than that of the other techniques when the data were examined using the Support Vector Machine (SVM) methodology. Furthermore, compared to other methods, the SIFT approach demonstrated greater accuracy. An 8% improvement over the Naive Bayes classifier was seen when the SVM classifier was used with the SIFT technique.

<table>
<thead>
<tr>
<th>Feature extraction</th>
<th>Navie Bayes (%)</th>
<th>SVM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nail Bed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal component analysis (PCA)</td>
<td>67.83</td>
<td>78.81</td>
</tr>
<tr>
<td>Analysis of independent components (AIC)</td>
<td>72.06</td>
<td>72.04</td>
</tr>
<tr>
<td>Haar wavelet</td>
<td>73.67</td>
<td>78.53</td>
</tr>
<tr>
<td>PCA+Haar</td>
<td>75.78</td>
<td>83.69</td>
</tr>
<tr>
<td>AIC+Haar</td>
<td>83.75</td>
<td>91.03</td>
</tr>
<tr>
<td>Feature transformation of scale-invariant (SIFT)</td>
<td>86.56</td>
<td>94.64</td>
</tr>
<tr>
<td>Lunula</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal component analysis (PCA)</td>
<td>13.58</td>
<td>15.90</td>
</tr>
<tr>
<td>Analysis of independent components (AIC)</td>
<td>14.27</td>
<td>14.26</td>
</tr>
<tr>
<td>Haar wavelet</td>
<td>14.81</td>
<td>15.91</td>
</tr>
<tr>
<td>PCA+Haar</td>
<td>15.36</td>
<td>16.96</td>
</tr>
<tr>
<td>AIC+Haar</td>
<td>16.78</td>
<td>18.13</td>
</tr>
<tr>
<td>Feature transformation of scale-invariant (SIFT)</td>
<td>17.46</td>
<td>19.14</td>
</tr>
</tbody>
</table>
5 CONCLUSIONS

The study reported here uses data collected from the outermost layer of nails for biometric identification. The recommended approach, in particular, may detect important markers by using the crescent moon within the nail and the nail bed. Some of the basic information that was obtained to build the system model were the nail's length (l), width (w), and l/w ratio. Excessive precision was achieved by integrating the various methodologies, and several algorithms were employed to extract all of the crucial essential information. Comparing the
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results was done using both the svm and naïve bayes classification techniques. All classifiers yielded favorable outcomes for the sift approach, according to the trial.

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References

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