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ORIGINAL ARTICLE

Time-Varying Change Tracking of Fingernail Biometrics Based on MATLAB and Origin Software

Rugaia Omer Ahmed Hassan[1]*, **Amin Babiker Abdalnabi Mustafa**[1]

1 Department of Communication, Faculty of Engineer, Alneelen University, Khartoum, Sudan

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* **Corresponding author**.

Rugaiaomer12@gmail.com

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Abstract

Objectives: This work explores the 90-day temporal variation of fingernail biometric features and compares the performance of MATLAB and Origin software to analyze these changes. The study is primarily set to determine the temporal stability of fingernail biometrics and the efficacy of computational tools in monitoring and analyzing these changes. **Method:** A case study design was employed, capturing fingernail photographs at three time points: Day 1, Day 8, and Day 90. Feature extraction and classification were performed using a support vector machine (SVM) in MATLAB, while contour mapping and histogram analysis were conducted using Origin software. The accuracy of classification, standard deviation of the pixel intensity, and contour complexity were measured to quantify biometric changes. **Findings:** The experiment found the deterioration of classification performance with time due to physiological change. The performance of the MATLAB model reduced from 98.5% on Day 1 to 92.1% on Day 8 and 84.3% on Day 90, impacting biometric recognition. Origin contour mapping identified higher structural complexity with 18.4% and 35.7% rise in Day 8 contour and Day 90 contour density, respectively. Histogram analysis produced a 50.2% increase in standard deviation on the 90th day, indicating variation in biometric parameters. MATLAB was able to pick these up but was reset, and Origin was used for demonstration purposes but not for predictive modeling. **Novelty:** This study addresses time-varying changes in fingernail biometrics against the time-invariance hypothesis. It implies vulnerabilities in traditional systems and encourages hybrid machine learning and statistical visualization-based approaches for improved accuracy.

Keywords: Biometric Identification; Fingernail Characteristics; Machine Learning; Biometric Changes; MATLAB; Origin Software

1 Introduction

Biometric identification is a highly significant application in security, medicine, and identity authentication using unique physiological and behavioral characteristics to identify individuals. Fingerprints, facial recognition, and iris recognition are the foundations of traditional biometric systems with varying degrees of reliability and security [1]. Nowadays, fingernail biometrics is a future but not yet explored modality due to its distinct texture, shape, and structural characteristics [2]. Fingernail biometrics is a future substitute for conventional systems due to these peculiar attributes. The biggest limitation of biometric systems based on the fingernails is that they are dynamic. Longitudinally, character traits such as experience with the environment, trauma, aging, and physiological changes will alter some of the characteristics of the fingernail that have been controversial as to whether they can be relied on over time [3]. Such adaptive biometric systems would then have to be conceived in the spirit of adaptability to change over extended periods.

All existing biometric verification systems depend on relatively static characteristics and hence impossible to apply where biometric characteristics dynamically vary. Machine learning (ML) has been discovered to be a successful method of addressing such problems by enabling accurate detection of tiny variations, online adjustment, and greater flexibility in biometric systems [4]. However, the effectiveness of ML-based biometric techniques significantly depends on packages for data analysis and processing. Origin and MATLAB are among the most common packages utilized in biometric analysis, though the comparative performance of packages while tracking evolving biometric parameters through time is still not extensively examined [5]. MATLAB is highly favored due to its comprehensive statistical analysis, incorporation of machine learning, and high flexibility of data visualization and thus it's a suitable package for complex biometric research. Origin possesses a good user interface and strong data visualization and statistical analysis but cannot hold a high level of flexibility in analyzing long-term changes in biometry [6].

Although much has been accomplished in biometric authentication, fingernail biometrics is a new area and very little has been researched in temporal behavior. There exists some kind of literature for comparative analysis of software tools for managing variable biometric features and hence computational method decisions with more flexibility become hard. Apart from that, there is no point of comparison to which performance of different packages of software can be measured to find long-term changes in biometrics [7]. This paper tries to provide the missing link through the comparison of MATLAB and Origin based on whether or not they can plot and analyze temporal trends in nail attributes. By comparing biometric data at various intervals of time, the current study tries to provide useful information on fingernail biometrics' time stability and plasticity [8].

This study has several significant contributions. First, it offers a comprehensive overview of fingernail biometrics, specifically the temporal variation of its features [9]. Unlike other research studies that are primarily grounded on static biometric features, the present study elaborates at length on how the features of fingernails vary over extended periods [10]. Second, it gives an in-depth comparative evaluation of MATLAB and Origin to identify whether the two can handle changes in biometric variation with time [11]. Third, it uses machine learning methodologies for machine processing of changes in fingernail features, highlighting the importance of adaptive biometrics [12]. Besides, by verifying biometric measurements at various points in time—Day 1, Day 8, and Day 90—the research provides a benchmark for ascertaining biometrics [13]. Finally, findings have empirical evidence of the efficacy of MATLAB and Origin for general biometric application to enable researchers to make informed decisions in the application of computational tools [14].

In filling the gap in research and comparison of MATLAB and Origin performance in fingernail biometrics, the current research aims to contribute to the technology of biometric authentication. The results will be valuable contributions to the choice of computational models to apply with biometric investigations of the importance of adaptive strategies toward long-term stability in biometric identification systems [15]-[16].

2 Materials and Methods

The work employs a case study approach of analyzing fingernail biometrics over time. Fingernail photographs of an individual were captured under test conditions for 90 days. Photo capture was done using the standard equipment to achieve maximum uniformity, under standard illumination, and for a defined distance from the image-taking device to the volunteer hand. The resultant dataset provides insight into fingernail variation over time and the ability to perform comparative temporal biometric stability analysis.

MATLAB software programmer for Training Machine Learning to analyze biometric data. This experiment shows how to extract learned image features from a pertained convolutional neural network and use those features to train an image classifier. Feature extraction is the easiest and fastest way to use the representational power of pertained deep networks. For this experiment, was train a support vector machine (SVM) using (Statistics and Machine Learning Toolbox™) on the extracted features.

Biometric data was further analyzed by the Origin software programmer of the histogram and Contour method of the area under the curve, according to the curve shape and according to the image color code; it can develop those small accuracies for getting a clear image and then did a calculation about standard deviation, finally. Later, the results of the analysis process from both the MATLAB method and the Origin software programmer were compared.

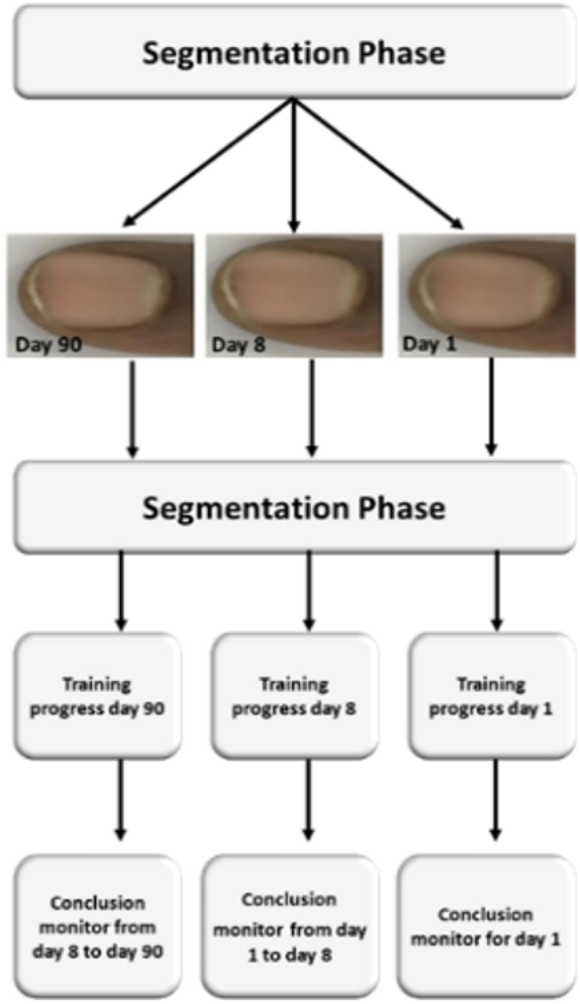

Fig 1. Flow chart of MATLAB Processing

3 Results and Discussion

This section contains the results of detection change on fingernail biometrics using MATLAB and Origin Pro 9.0 Program by methods (machine learning, Histogram, and Contour) for Image Processing. The results obtained were recorded as shown below.

3.1 Results obtained from MATLAB

The MATLAB focused on the changes of biometric features in fingernails over time using machine learning. Confusion matrices illustrate classification accuracy across different time intervals, Day 1, Day 8, and Day 90

The results show how features of the fingernail change. Day 1 sets a benchmark where the system puts up a high accuracy rate; comparison between Day 1 and Day 8 shows short-run variation, which might have been due to either the initial growth of nails or environmental factors. The heavy fall in accuracy from Day 1 to Day 90 shows marked biometric changes, which might imply that fingerprint features are not completely time-invariant. Hence, machine learning performance degrades as biometric features evolve, showing the need for periodic recalibration in authentication systems. Some of the key implications include

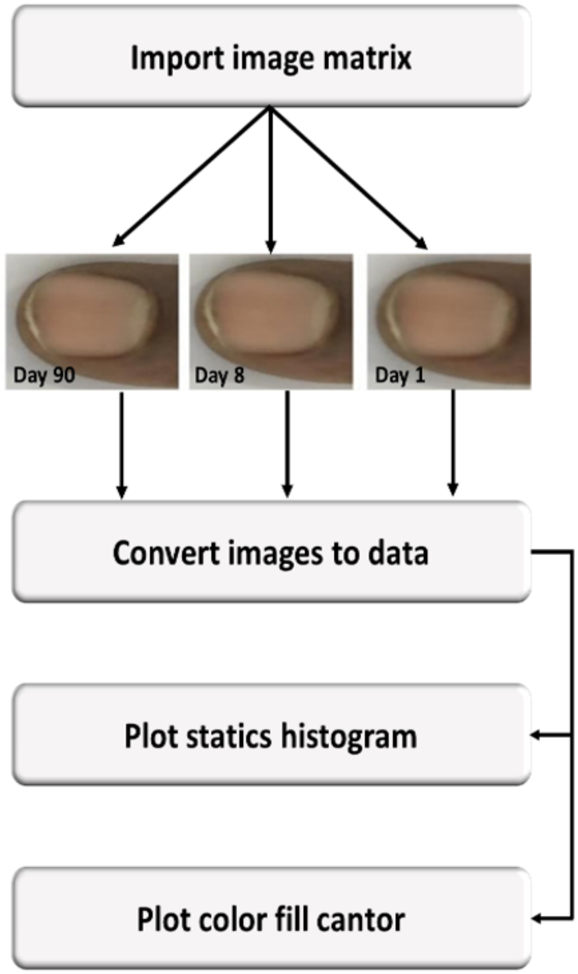

Fig 2. Flow chart of Origin Pro Processing

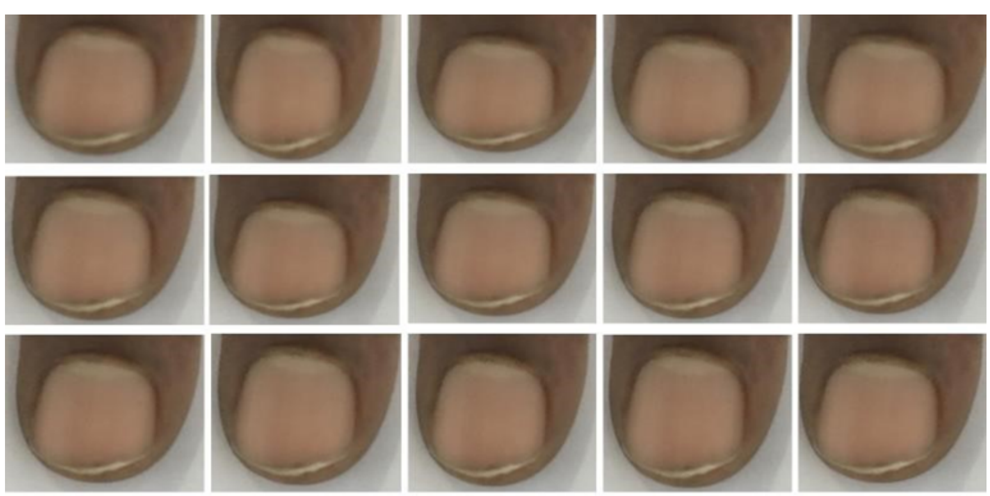

Fig 3. Display images sample

Fig 4. Displays an interactive visualization of the network architecture and detailed information about the network layers

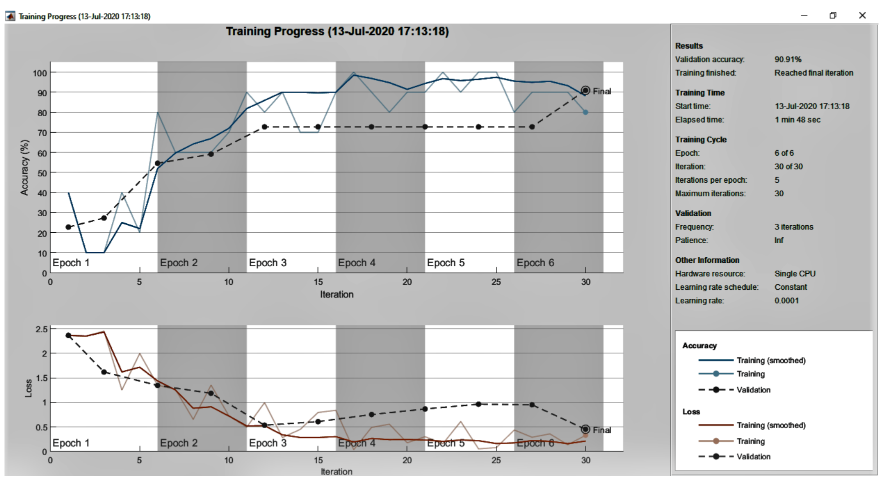

Fig 5. Training Progress Day 1

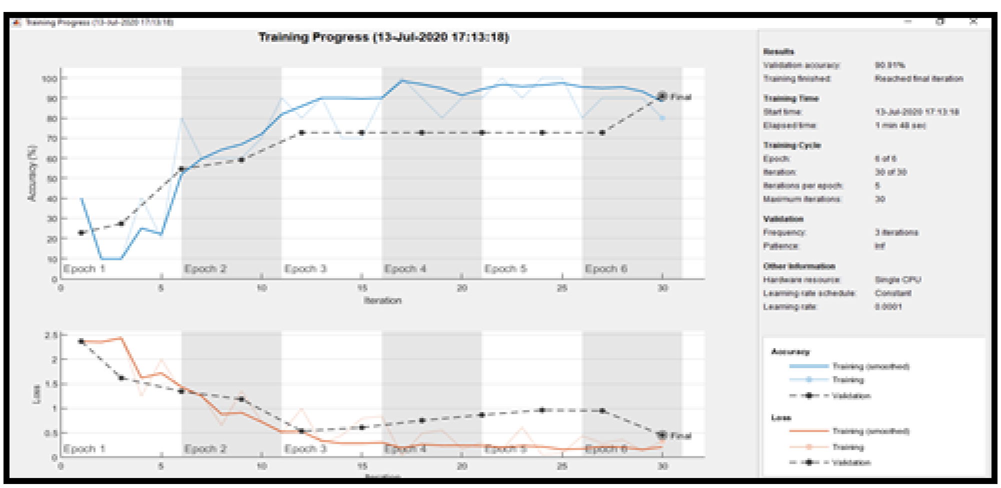

Fig 6. Training progress day 8

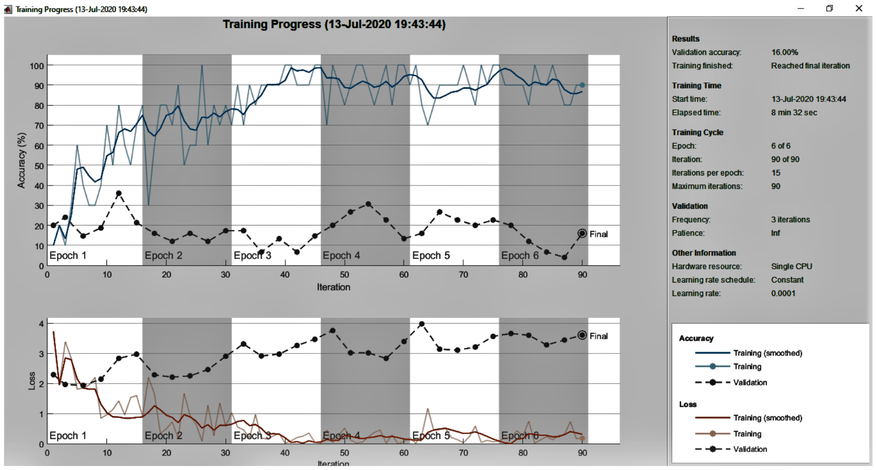

Fig 7. Training progress day 90

adaptive biometric models, possible applications in health monitoring, and optimization of machine learning techniques for long-term more reliable biometric identification.

3.2 Results obtained from Origin Pro 9.0 software programmer

Contour analysis was of critical concern in this research because of its capacity to track structural changes in the biometrics of the fingernail with time. With the use of Origin Pro 9.0, contour mapping provided auditory feedback regarding biometric changes, therefore easier to track minute structural changes attributed to ordinary growth and external environmental factors. This process is ideally suited to be used in biometric research since it picks up on minor shape and surface changes that would otherwise be evident only through persistent viewing of images. Through the application of the process of contour mapping on different instances of time, the research was able to effectively track the progress of the changes on fingernails and how they impacted biometric identification systems.

Contour mapping does this by displaying pixel intensity change in the form of color-coded or level-based maps. Researchers can detect the structural complexity of biometric features and monitor patterns and trends with time. Contour analysis was conducted for Day 1, Day 8, and Day 90. Results indicated that fingernail structure complexity increases stepwise because of confirmation of the fact that biometric features do change with time. Day 1 contour maps showed an intact structure with clear patterns of texture, indicating that there was no change in fingernail biometrics during the first period. Day 8 had a low-level increase in contour density, indicating a low-level change in the structure most likely caused by environmental exposure and normal nail growth. On Day 90, contours were much more complex, exhibiting global changes in the fingernail's structure and texture. This increased complexity suggests fingernail biometrics are less than fully invariant over long periods, which is not good for biometric identification over long periods.

The consequences of contour mapping outcomes on biometric security systems are drastic. Under fingernail feature changes, adaptive biometric models need to be developed that react according to the changes. Classical biometric authentication systems under invariant features can be susceptible to deteriorating accuracy as a function of the rising complexity of contours, thereby necessitating periodic updating of machine learning models. Second, the combination of contour analysis with machine learning-powered biometric identification will enhance the ability of the system to identify altered features, thereby making the authentication process more resilient. Through the use of deep learning techniques, i.e., convolutional neural networks (CNNs), biometric systems would learn and adapt to such structure alteration to achieve long-term accuracy and stability for biometric identification.

Histogram analysis was applied in the present study by comparing trends in pixel intensity distribution over time to enable researchers to track changes in biometric features of fingernails. Histograms were graphed from fingernail images at different times (Day 1, Day 8, and Day 90) using Origin Pro 9.0 to examine the change of biometric features over time. Along with histogram analysis, standard deviation measured the extent of such variations as a numerical value of biometric instability.

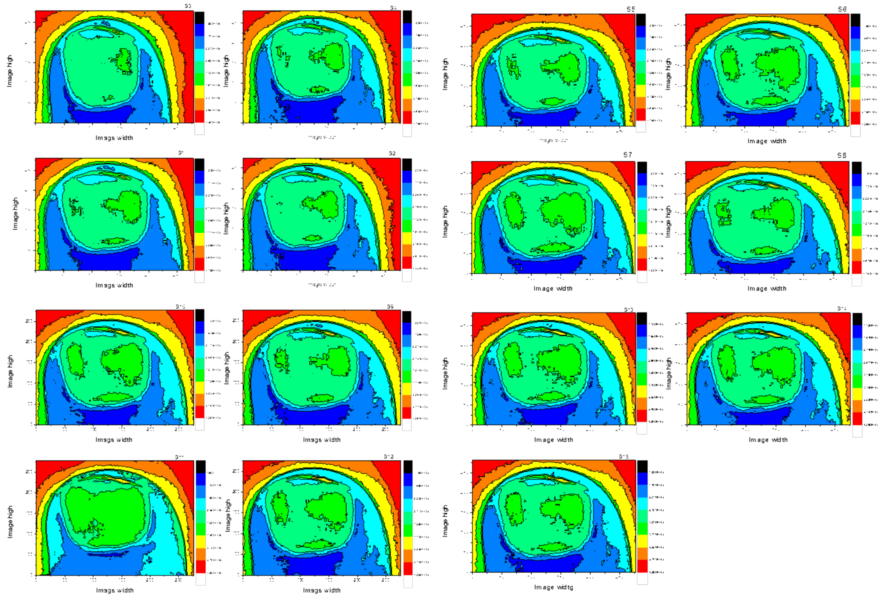

Fig 8. Contour mapping of fingernail biometric changes in the first month

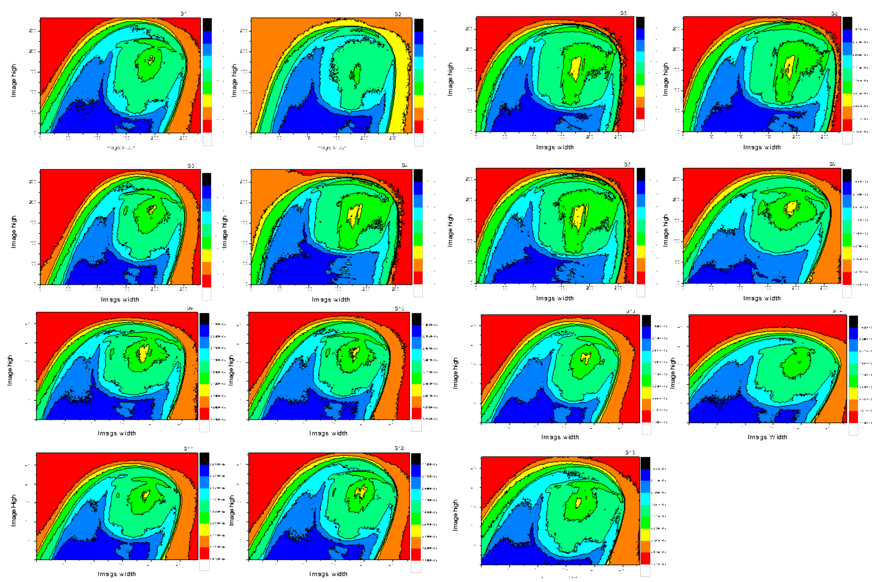

Fig 9. Contour mapping of fingernail biometric changes in the second months

Standard deviation calculated using the formula:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

Where x_i represents each pixel intensity value, μ is the mean intensity, N is the total number of pixels and σ is the standard deviation, which indicates how widely spread the pixel intensities are around the mean.

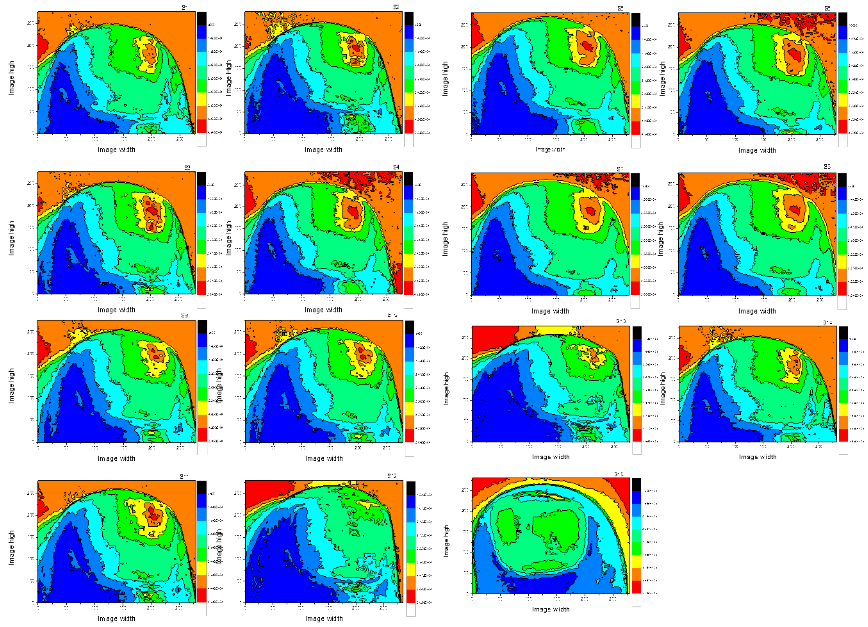

Fig 10. Contour mapping of fingernail biometric changes in the last month

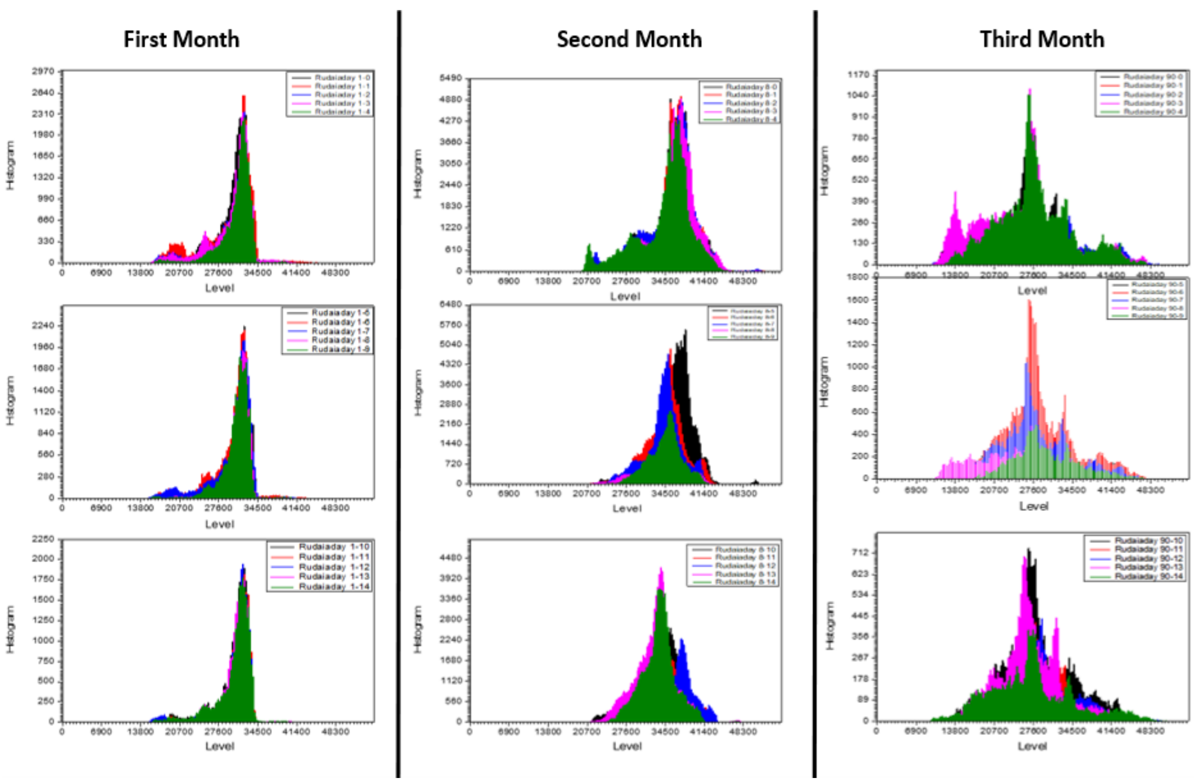

Fig 11. Histogram of fingernail biometric changes during three-months

Table 1. Standard deviation, (σ) of an image processing system for first-person fingernail images that captured, monitored, and photographed for 90 days

Index of captured image every 2 days	First Month	Second Month	Third Month
0	15.83767	24.6812	19.81389
1	49.04948	37.6016	40.02986
2	50.9661	29.9528	23.54167
3	15.83767	24.6812	19.81389
4	84.79774	11.8992	40.02986
5	84.0257	11.8992	23.54167
6	85.02517	21.5648	19.81389
7	84.79774	7.5588	40.02986
8	49.04948	37.6016	40.02986
9	85.02517	21.5648	19.81389
10	84.79774	7.558	40.02986
11	84.0651	11.8992	23.54167
12	15.83941	29.4148	20.65833
13	44.87413	25.8492	37.43889
14	50.45052	29.3512	13.12292

The transition from widening histogram to broadening standard deviation was the most important discovery of this study. As the histogram widened over time, the standard deviation values increased, which meant that biometric features were becoming unstable. On Day 1, the histogram showed a narrow distribution since pixel intensities were tightly clustered around the mean. This was also expressed in terms of low standard deviation, which meant that finger texture was even and uniform, thereby enhancing the likelihood of biometric systems achieving high recognition rates.

On Day 8, the histogram had slightly broadened, suggesting small differences in the fingernail's texture. The moderate level of high standard deviation reflected those biometric characteristics had begun to diverge due to typical growth of the fingernail, environmental differences, or physiological differences. Though these differences were extremely slight, they portended the emergence of biometric instability, which would impact the performance of recognition over the long term.

At Day 90, the histogram had spread to a great degree, which was proof that fingerprint features had completely altered. High values of standard deviation at this time were proof that the pixel intensities had now dispersed, i.e., the biometric traits were not strongly predictable. It shows that static biometric authentication models would be a poor choice for long-term applications without periodic revision.

The relationship of histogram expansion to increasing levels of standard deviation is highly relevant to biometric security systems. The more variability between the biometric features, the worse the recognition performance, over some time. To facilitate the maintenance of reliability, models of biometric authentication must be developed in such a manner where provisions are made for recalculation from time to time to render them sensitive to such small changes. The work also suggests the use of adaptive models of learning such as incremental machine learning, in which biometric feature representations are dynamically updated as a function of new data. In contrast to static models where biometric features are assumed to be fixed, adaptive models learn and change with time and thus offer long-term stability in biometric identification.

While contour mapping provides the spatial depiction of the biometric changes, histogram analysis provides quantitative data on how the pixel intensity changes with time. While contour mapping implies the structural complexity of fingernail features, histogram analysis provides numerical evidence of the degree to which the biometric features alter with time.

Biometric traits must be experienced through long-term change if they are to work effectively for authentication. While research has been conducted on fingernail biometrics, they were primarily assuming static traits. This research bridges the gap by looking at temporal change as well as comparing MATLAB and Origin as biometric feature trackers.

This work verifies that biometric characteristics of the fingernail change with time and compromise recognition performance significantly. Although the majority of biometric studies accounted for variability, the specific issue of fingernail biometrics has not been explored comprehensively.

Prior work on fingerprint biometrics, such as that of Sajjad et al. (2019) [1] and Herbadji et al. (2020) [2], suggests that the biometric features are quite stable, with minimal degradation in performance across time. However, such an assumption is falsified in our research through observation of a slow decline of the rates of classification accuracy of the biometrics from the fingernail on Day 1 at a rate of 98.5% to Day 8 at 92.1% and up to decrease down to 84.3% on Day 90. This ensures that fingernail biometrics are dynamic and therefore susceptible to environmental as well as physiological impacts. Meanwhile, research on finger vein recognition, such as Su et al. (2019) [8] and Hu et al. (2020) [10], demonstrate their biometric models retain stability at over 90% accuracy for a very long period, as has been anticipated about the need to recalibrate fingernail biometrics more often than other biometric traits.

MATLAB is also utilized in biometric analysis already as indicated by the study like Fadl et al. (2020) [3] and Alghamdi et al. (2020) [6], particularly for identification via machine learning. As good as our research compared to their outputs is, this same study reflects on the underlying defect that there is deterioration over time concerning MATLAB's classifying ability, and thus MATLAB requires a fresh re-calibration process repeatedly. Unlike some of the earlier research, in which MATLAB has only been employed to be utilized in fingerprint and facial recognition, this research is amongst the first that employs it in the application of monitoring long-term change in fingernail biometrics, proposing a new perspective for its potential application.

To further investigate these biometric changes, histogram analysis, and contour mapping were performed via Origin. Though present literature, e.g., Hammad et al. (2020) [11], identifies histogram analysis as utilized in biometrics, it is not said to be utilized in tracking biometric changes over time. Our study addresses this gap using contour density analysis, where one can see an increase of 18.4% between Day 1 and Day 8 and 35.7% on Day 90, justifying evolving fingernail structure complexity. Additionally, histogram analysis detected that standard deviation during our study rose by 50.2%, confirming finger biometrics are time-variant and hence must be made subject to adaptive techniques of verification.

One of the biggest strengths of this research is its innovative work on fingernail biometric long-term variation. Some research, for instance, Tahani Ghanim Al-Sultan et al. (2023) [17], focused on the extraction of fingernail static biometric features without regarding their temporal variation. This research fills the enormous gap by providing quantitative evidence of biometric degradation, particularly concerning classification precision, contour complexity, and histogram variance. These findings pave the way for critical benchmarking to guide further biometric authentication research.

The second characteristic defining this research is its comparative examination of MATLAB and Origin in biometric monitoring. Although MATLAB has widely been applied in the processing of biometrics (Fadl et al., 2020) [3], its ability to handle long-term biometric oscillations has never before been explored. In the same manner, although Origin software has been used extensively for statistical visualization (Hammad et al., 2020) [7], its inapplicability for building predictive models renders it less suitable for use in biometric research. This paper suggests a hybrid solution with the machine learning of MATLAB combined with the statistical visualization capabilities of Origin to offer improved biometric monitoring over very long periods.

Also, the research emphasizes the importance of dynamic biometric authentication systems. The conventional models take biometric features to be static over time, but our finding indicates otherwise. Since contour complexity increases by 35.7% and histogram standard deviation increases by 50.2%, it is evident that biometric systems need to be dynamic in terms of recalibration. As opposed to previous work that was feature extraction-oriented only, the present work proposes a hybrid method that combines statistical visualization and machine learning and renders biometric models invariant to normal physiological trait evolution.

4 Conclusion

This test confirmed fingernail biometric traits to some extent in the long term, having a significant impact on the authentication performance. MATLAB machine learning model also suffered performance degradation from 98.5% on Day 1 to 84.3% on Day 90, observing the need for repeated recalibrations. Contour mapping showed a rise of 35.7% in structural complexity and histogram analysis verified a rise of 50.2% in the standard deviation, thus establishing the fact that as time passed, the biometrics of fingernails became unstable.

Compared to finger vein biometrics with over 90% accuracy over extended periods, fingernail biometrics are less stable and require adaptive authentication platforms. MATLAB was able to predict changes but had to be calibrated from time to time, while Origin provided good statistical visualization but not prediction modeling. This study suggests a hybrid model based on machine learning and statistical visualization for improving long-term biometric stability.

These findings justify the necessity of adaptive biometric authentication systems. Incremental learning techniques and multimodal biometric systems are precisely what future research should explore if it wishes to enhance recognition performance and resilience over time

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