Biometric Recognition of Infants Using Fingerprints

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Can the infant fingerprint be used for secure authentication?

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***Abstract* - One of the first recognised and commonly used biometric modalities for men is the fingerprint, which is frequently used to register adults at home and in traffic centres. Fingerprint biometrics for babies, in particular, are not commonly used or approved. The infant recognition system discussed in this article is tested in infants as early as six weeks of age using a prototype infant fingerprint capture device. To compare and contrast the identification performance of the prototype fingerprint scanner with the traditional fingerprint scanner, the same error rates, standard deviations, and Failure to Acquire were calculated. The results of this investigation point to the possibility of registering newborns as early as six weeks using a baby's fingerprint.**

Keywords—Infant Fingerprint; Infant Biometric; Fingerprint Biometric, Authentication.

I. INTRODUCTION

Infant biometric recognition is becoming ubiquitous due to advances in technology and the high rate of crimes committed on and through infants and young children. This is motivated by the high rate of rising crimes being committed against children, ranging from child theft, child trafficking, fraudulent distribution of child grants, etc. This problem has grown out of proportion worldwide and infant biometric technology that can be used to enrol babies as young as birth is a dire need[1]. This paper presents a fingerprint solution for infant recognition.

Various biometric modalities are being studied for infant recognition purposes, ranging from palmprint, fingerprint, ear, finger veins, footprint, face, and voice [2]– [25]. The big question of which biometric modality to use remains unanswered. Some of the information required before picking the biometric is detailed in Fig. 1 which depicts the process of analysing biometric modalities and determining whether they are appropriate for use in an automated biometric recognition system. An acceptable biometric modality should be universal even though some small percentage of the human population may give birth to newborns without limbs, but that is highly unlikely. The infant fingerprint is also not easily damaged compared to the adult fingerprint, which can be destroyed by the nature of the work that is done. The most important concepts to consider when choosing a biometric modality are universality which implies that everyone should possess that biometric, then uniqueness which means that the chosen biometric must be distinctive from one individual to another, including monozygotic children, the next important concept relates to the permanents of the biometric; it is important to consider if the chosen biometric will be stable and available for the duration of a lifetime. Collectability is a major concern, especially concerning the infant population; however, this problem will not age as technology advances and infant biometrics is attracting more attention. Acceptability can be another bottleneck if people cannot accept the use of a certain biometric. During Covid-19, it was difficult to collect data because no parents or guardians would accept the collection of their children's biometrics using touchable devices. Expected performance varies depending on where and how the biometric technology will be used, and resistance against circumvention is important as this will determine the level at which a biometric technology can be spoofed.

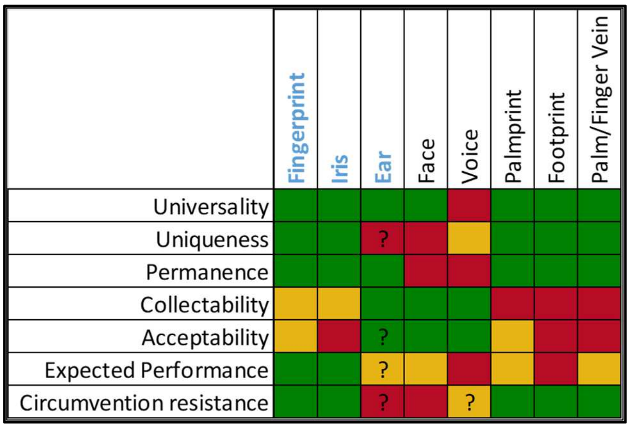

Fig. 1: An example of analysing biometric modalities and determining whether they are appropriate for use in an automated biometric recognition system [26].

II. BACKGROUND OF FINGERPRINT RECOGNITION.

A. Infant Fingerprint Biometric

Several research institutions have been working on the development of infant fingerprint recognition technology. The important principle is to ensure that a fingerprint can be acquired using a to-be-processed fingerprint acquisition device. Aronoff-Spencer *et al.* [27], developed a non-contact fingerprint technology with adjustable fingertip sizes for the recognition of newborns. The resolution of the acquired images was very high and the recognition performance was very impressive. However, the technology developed is not cost-effective. Jain *et al,*[28] used the USB-connected touch-based DigitalPersona 4500 optical fingerprint reader to capture images. The images were of poor quality and also used a touch-based reader, which most users are not willing to adopt anymore. Engelsma *et al.* [2], and [29], experimented with both the conventional fingerprint scanner and the noncontact scanner and found that the noncontact produces more high-resolution images as compared to conventional touch-based scanners. Regardless of the data collection procedures reported in the literature, it is evident that touch-based fingerprint scanners do not perform well on infants' fingers. For this reason, this paper presents a lightweight and cost-effective microscopic prototype fingerprint scanner with numerous caps to accommodate various fingertip sizes. Fig. 2, shows the prototype scanners and some fingerprint images of infants. This prototype has a resolution capacity of 2500 dpi fingerprint camera (this device was developed to assist in the capture of infant fingerprint data and was tested during the collection of data presented in this work and also in [26]).

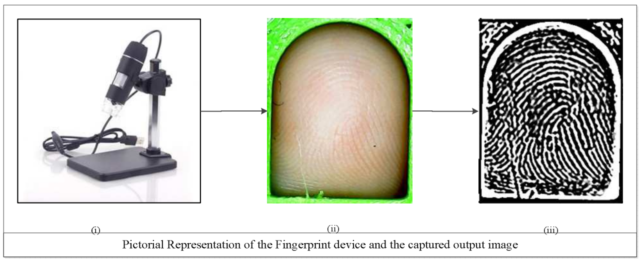

Fig. 2: The contactless infant fingerprint acquisition device (i), with the captured output image (ii) and the enhanced infant finger image (iii).

B. *Acquisition of biometric data from the infant fingerprint*

The process of acquiring a fingerprint image from a fingertip evolved from the use of inks to conventional scanners that capture multiple fingers at once or a single finger at once. All methods had their advantages and disadvantages, of which the disadvantages outweighed the advantages, especially after the dawn of the Covid-19 pandemic. The prototype fingerprint acquisition tool used in this work, shown in Fig. 2, was created, tested and shown to be more effective than a traditional touch-based scanner in capturing more high-quality fingerprint images.

TABLE I: TABLE OF FINGERPRINT IMAGES COLLECTED

Age Group	Age Group Class	Proposed Prototype Scanner
Group A	0 < Weeks < 18	225
Group B	18 < Weeks < 24	273
Group C	Weeks >	696

Data acquisition using the prototype scanner is more user-friendly than using the conventional scanner. The approach uses the same principle as optical coherence tomography (OCT) technology, which is also being used to capture the inner fingerprint features. This prototype device can capture fingerprint images with 2500 dpi resolution and can cover a maximum capture surface area of *(12MM X 16MM),* using its built-in light-emitting diode (LED) illumination in a colour image space.

III. PROPOSED APPROACH

In this work, the main purpose was to develop a touchless (non-contact) prototype fingerprint-capturing device that has the capability to capture high-resolution fingerprint RGB images and then develop a novel fingerprint processing approach as depicted in Fig. 3.

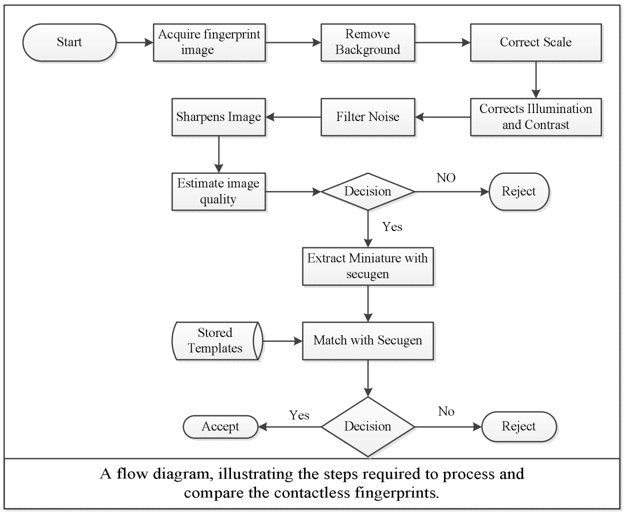

Fig. 3: An illustration of the proposed fingerprint processing approach

A. *Infant Fingerprint Data Processing and Analysis.*

In Fig. 3, it is demonstrated that the acquired fingerprint colour images should be converted first into a compatible greyscale image using the steps described below:

i. **Fingerprint background removal:** This is done by applying multiple colour channel histograms with a predefined threshold that would effectively separate the foreground pixels from the background image pixels. The morphological operations are then applied to the output image to close the holes in the images. The output of this process will be the fingerprint image.

ii. **Fingerprint Scale Correction:**

In any imaging technology device, the acquired images will have different image resolutions due to the possible acquisition distance and acquisition angles. This discrepancy needs to be corrected so that the images will be of the same pixels. This is done to ensure that the output image will meet the necessary comparison conditions for the commercially available fingerprint-matching software for fingerprint-matching testing purposes.

iii. **Fingerprint Image Enhancements:** The captured fingerprint images will probably have some noise. To solve this, the acquired image should be enhanced to correct the image contrasts and image-varying illuminations and filter the fingerprint image noise using image filtering algorithms and image sharpening techniques.

iv. **Image Quality Estimation:** Infants' participants will probably be uncooperative subjects in their nature, making capturing quality fingerprint images a daunting exercise that requires patience. When evaluating the quality of an acquired fingerprint impression to determine if it can be used for comparability, the National Institute of Standards and Technology (NIST) Fingerprint Image Quality (NFIQ2) scoring system is used ordinarily [30]. NFIQ2 requires that the usable fingerprint have a quality score value that ranges from one (1) to four (4), the value of five (5) is generally considered a poor-quality scare, and it is not considered for use in a fingerprint biometric recognition system.

IV. RESULTS AND DISCUSSIONS OF THE EXPERIMENTS

In this experiment, the following performance analysis tools were used to analyze the results.

i. Standard Error Rates

ii. Equal error rates

iii. Failure to acquire a fingerprint image.

Fig. 4 shows the comparison of the NFIQ2 quality NFIQ2 scores to measure the performance between the proposed prototype and the conventional system in the age groups. From the figure, it can be deduced that the proposed prototype fingerprint scanner performs better than the conventional fingerprint scanner.

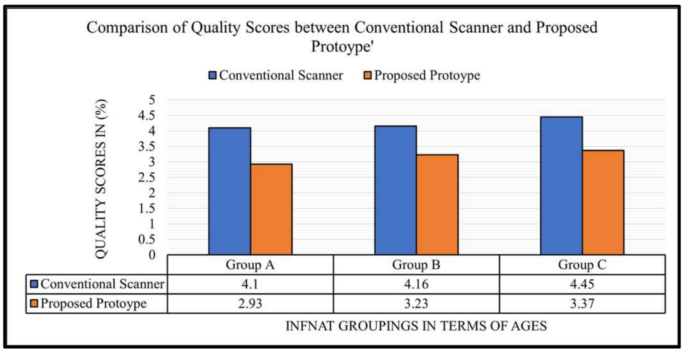

Fig. 4: Comparison of scores between the proposed prototype and the conventional touch-based fingerprint scanner.

Performance was also carried out on the demo system using the images collected. The output of the demo system is shown in Fig. 5, where

1) The photographic image is an input image from the proposed prototype fingerprint acquisition device.

2) The image marked enhanced is the processed image with extracted minutiae points marked in blue.

The result of the comparison is a match that implies that the device can capture high-quality fingerprints that can be used for identification or verification.

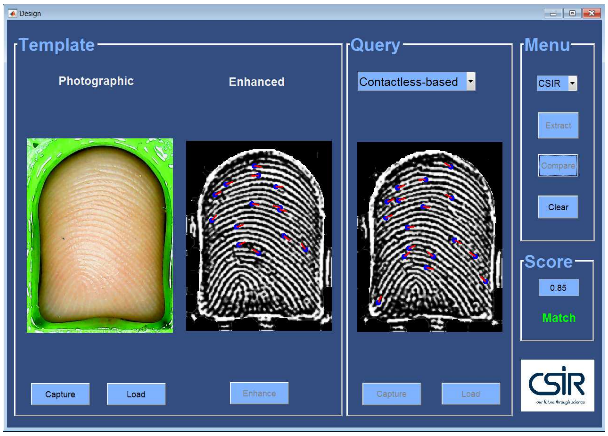

Fig. 5. Matching of the fingerprint images acquired using the prototype fingerprint scanner.

The performance between images acquired from both devices was also tested as shown in Fig. 6. Marked photographic images were captured using the proposed prototype device, and the other image that is being compared was captured using the conventional contact-based fingerprint acquisition device. From the figure, it can be deduced that the proposed fingerprint acquisition device produced images with a visible fingerprint surface area while the contact-based produced smaller unclear fingerprint images. For this reason, the two fingerprints image from the same infant results in a no-match due to variations in fingerprint acquisition devices. This result implies that contact-based scanners are not good for use in children's identification purposes.

Fig. 6: Matching a fingerprint from a proposed prototype with the fingerprint acquired from the conventional scanner.

In Fig. 7, it is demonstrated that the developed acquisition prototype device only failed to acquire 25% of the fingerprint images. However, the conventional touch-based fingerprint reader failed to acquire almost 60% of the images. These findings indicate that the proposed and developed fingerprint device performed significantly better than the touch-based fingerprint reader. However, it was also discovered that the prototype did not perform well on older children. This may be due to replacement caps that did not fit on some of the children's fingers.

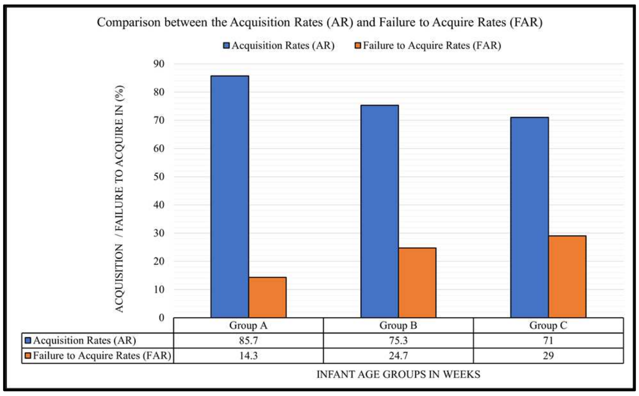

Fig. 7: Comparison of acquisition rates and failure to acquire across all groups.

The analysis of results from this experiment was evaluated using two factors, namely error rates and standard deviations between the two fingerprint-capturing devices. In Fig. 8, it is clear that touch-based fingerprints have influenced the low error rates due to low-quality captured images. The lack of a sufficient quantity of quality fingerprint images from the normal conventional scanner also influenced the comparison, leading to the high rate of failure to acquire quality fingerprint images. It was also discovered that the proposed prototype fingerprint acquisition device produced better performance across all ages under 12 (12) months old.

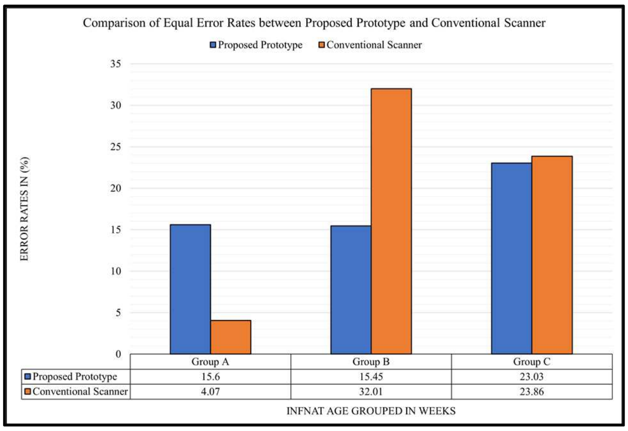

Fig. 8: Comparison of error rates between prototype and Conventional scanners for each age group.

V. CONCLUSION AND FUTURE WORK

We have presented an infant biometric recognition system using infant fingerprints collected from a non-contact prototype fingerprint acquisition device. The prototype device has shown that it can acquire high-quality RGB images of infant fingerprints. The youngest subject captured was only six (6) weeks old. The captured fingerprint image was also shown to be converted into a format that makes it easily comparable to other captured fingerprints using commercial-grade fingerprint-matching software.

In the future, the researchers aim to improve and equip the prototype fingerprint capture camera and replacement caps so that it can capture the full fingertip correctly. As more longitudinal data are available in the database, research will continue to study the stability of fingerprint patterns as the child grows.

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