Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7766329

FINGERPRINT RECOGNITION OF NEWBORNS AND TODDLERS USING PRE-TRAINED MODEL UNDER CONVOLUTION NEURAL NETWORKS

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Abstract—Newborns kidnapping, switching, disappearance and illegal adoption are becoming problems at hospitals, birthing centers and other places where several births take place simultaneously. Eliminating the occurrence of childhood illnesses that may be prevented by vaccination (e.g., Polio, Tuberculosis, and Tetanus) is also one of the main objectives of most national, international, and non-governmental health organizations. To enhance vaccine coverage, access to healthcare, and receipt of nutritional supplements, an efficient immunization programmer must keep track of toddlers who have been inoculated and those who have gotten the necessary booster injections during the first three years of life.

On the other hand, the fingerprint recognition system is effective at authenticating and identifying adults, but when it comes to newborns and solving toddler problems like immunizations against diseases and nutritional care, it encounters difficulties like poor fingerprint image quality and incorrect registration, reducing the recognition accuracy.

To solve this problem, we are going to use Pre- trained model that falls under Convolution Neural Networks and we train our dataset on it, the trained model tested have been on data NITG for 154 newborns and toddlers. The experimental results show that the trained model gave better results than before reaching an accuracy of 100% on the training set and 82.47% on validation.

Keywords—Biometrics, Fingerprint recognition, Newborns, Toddlers, Pre- trained model, Convolution Neural Networks

1. INTRODUCTION

Worldwide, it is anticipated that more than 600 million children will live between the ages of 0 and 5 [1], translating into 4.3 births every second and around 259 births per minute [2]. In the poorest regions of the globe, the majority of these births occur. It is incredibly difficult to give medical treatment, administer vaccinations, and effectively provide food supplies while preventing fraud, and neither children nor their parents will probably have access to official identification documents especially when the newborn is (0–1 year old) at the most vulnerable level in growth. Goal 16.9 of the Sustainable Development Goals of the United Nations states that by 2030 every person must have a legal identity that includes birth registration [3]. Nearly half of the world's population of over 1 billion people now lack this legal status [4]. By developing national identity programmers that generate digital ID systems using biometrics

like face, eye, and fingerprint scanning, an increasing number of nations have bridged this gap [5]. Aadhaar, the largest of them, has been operational in India since 2019 and has enrolled more than 1.1 billion persons [6]. This initiative has generated some criticism as well [7,8], and one of its most noticeable flaws is the exclusion of children under the age of five since adult biometric technologies have not satisfied requirements for usage in a legal manner [9]. Since the use of current biometric technology for children under five, and notably those under one year of age, has failed, there are still many unfulfilled demands. The most difficult age range, according to research on age and aging in fingerprints, was 0–4 years old [10]. This group's fingerprint research revealed very low fingerprint picture quality, poor device accuracy, and a noticeable aging impact [11,12], which suggests the presence of babies' fingerprint difficulties [13].

Although the DNA test is well recognized to be successful at identifying specific persons, it is expensive and requires specialist laboratory procedures, so it cannot be used in real-time applications.

In a long-term study supported by the Global Innovation Fund and the UK Department for International Development (DFID), analyses revealed that the use of biometrics to specifically identify expectant mothers in Bangladesh increased prenatal visits by 38% and the number of newborns receiving essential care by 19%. [14].

Creating a system for fingerprint recognition is important for newborn and toddler authentication to ensure that there is no exchange within birthing centers, for example, and to follow up on vaccination, health care, and nutritional supplements for them, using principles of artificial intelligence to authenticate easily and reliably, identifying newborns and toddlers through their fingerprints, and we work toward obtaining Integrated system (Secure over time), uniqueness (Different for each individual), cheap cost (Easily accessable to all), lifetime usage, portability, and acceptability of easy applicability and wide acceptance.

Any biometric system typically consists of five modules: data collection, pre-processing, feature extraction, matching, and decision. Figure 1 illustrates how the enrollment and authentication/verification stages of a biometric system [15].

When a person enrollment, a sensor is used to capture biometric pictures of them, such as their fingerprints, faces, iris, etc. These images are then preprocessed to extract the necessary characteristics using various feature generation/extraction techniques. These qualities are then filtered to create and save distinct templates.

When authentication or verification, which is then pre-processed similarly in the registration step to extract the necessary characteristics before template construction. Using various matching techniques, the created template is compared to the stored templates.

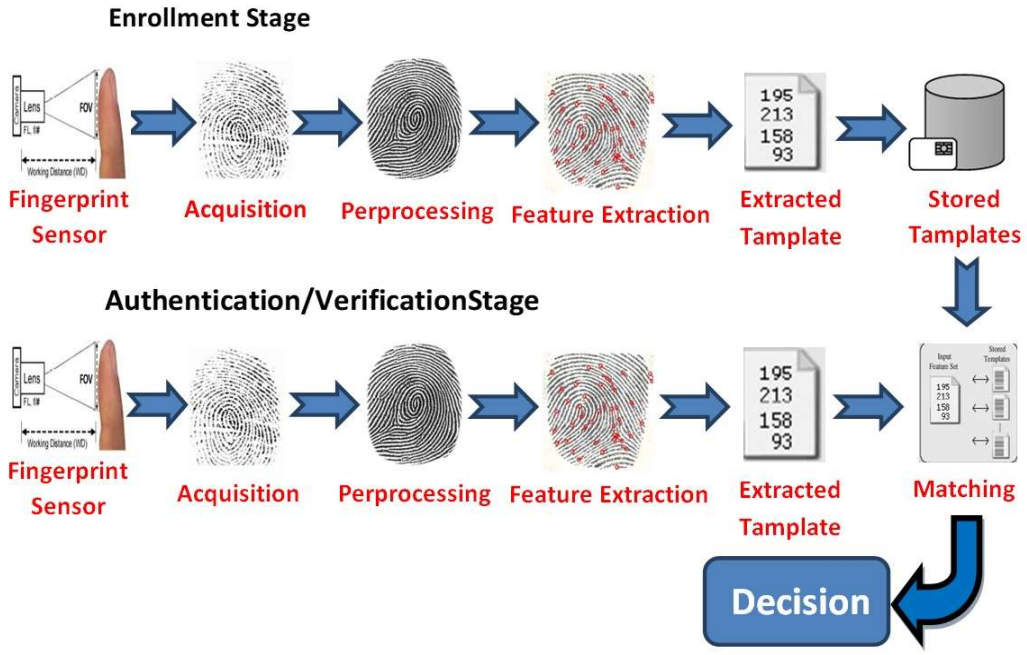

Figure1. Enrollment and Recognition stages of a biometrics system

In this work, we use Pre- trained model that falls under Convolution Neural Networks. This paper arranged as follow, Section I contains the Introduction and significance of fingerprint recognition of newborns and toddlers. In Section II elaborates the Related Work on fingerprint recognition systems for newborns and toddlers. While present section III the Methodology. In Section IV Experimental Results and Discussion that obtained from applying the proposed method with compare it with previous study. While section V Concludes our research work, then Referenced at the end.

2. RELATED WORK

In this section, we review previous works on the fingerprints of newborns and toddlers. For example, Anil k et al.[16] used a 500 PPI commercial sensor to capture fingerprint images of 90 Subjects for age(0 - 4 years) and got promising results. While Kai Cao et al.[17] used a 500 PPI too commercial sensor to capture fingerprint images of 206 Subjects for age(0 - 4 years) with a time interval of 3 months, based on preliminary results appears promising, they want to collect statistical data from the same participants three times over the course of a year. Bhatnagar et al.[18] used a 1,270 PPI commercial sensor to capture fingerprint images of 309 Subjects for age(0 - 5 years) with a time interval of 1 year, It was Recognition of children over 6 months. While Vanina Camacho et al.[19] used a 500 PPI commercial sensor to capture fingerprint images of 45000 Fingerprints for ages (0 - 10 years)they found Recognition of children over 1 year. In addition, Francesco Franzoni et al.[20] used a 500 PPI commercial sensor to capture fingerprint images of 16865 Fingerprints for ages (0 - 18 years) It was good

accuracy from ages beginning at 1 year of age, the standard obtained after pre-processing for five years of age is higher than that obtained for adult fingerprints. As for Amol D et al.[21] used Real Scan G10 commercial sensor to capture fingerprint images of Subjects 119 + 154 for age(0 - before school), they used the Euclidean distance method for matching the fingerprint datasets was very encouraging. Tom Kalisky et al.[22] used a 3,400 PPI commercial sensor to capture fingerprint images of Subjects 142 for age(month) with a time interval of 2 years, They obtained outstanding results. As for Prem S et al.[23] used a 1900 PPI commercial sensor to capture fingerprint images of Subjects 315 for age(0 - 3 months) with a time interval of 1 year, It was very encouraging. While Yaseen Moolla et al. [24] have suggested fingerprint modality and used a 2500 PPI for the acquisition of contact-less fingerprint in RGB color space, fingerprint images of Subjects 142 for age(16 weeks - 1 year), It has been demonstrated that it is feasible to develop a machine to collect fingerprints from newborns, with participants as child as 6 weeks of age, and record newborns' fingerprint data in a format that is compatible with pre-existing software for fingerprint comparison. We analysed the benefits and drawbacks of utilising each of these techniques over the first year of life. In addition, Tom Kalisky et al. [25] used a monochrome CMOS sensor with an internal blue LED illumination commercial sensor to capture fingerprint images of 494 Subjects for age(0-329 days) It was good accuracy from ages for newborns enrolled at ≤ 3 days and for age ≥ 4 days and Based on results appears promising.

3. METHODOLOGY

In this study, using Pre-trained model is proposed based on the convolutional neural network in order to quickly and precisely authenticates and identify newborns and toddlers using their fingerprints. The convolutional neural network is used as a backbone network for deep features generation, while the Pre-trained model used for based on the transfer learning principle.

The proposed deep learning model involves a few steps to be fulfilled in order to improve the accuracy of fingerprints recognition of newborns and toddlers, as shown in Figure 2.

Firstly, the collected images were in BMP format; for simplicity, such images were converted to PNG by using PYTHON code. After that, preprocessing step was by cropping based on location the fingerprint in the Image because fingerprints of newborns and toddlers a small, then doing enhancement for it all these by using PYTHON code too. After that the dataset was then splitting into training and testing. Finally, the proposed AI model was trained and tested

then is showing prediction (Recognizing them). The following is an explanation of how each phase in the proposed method functions:

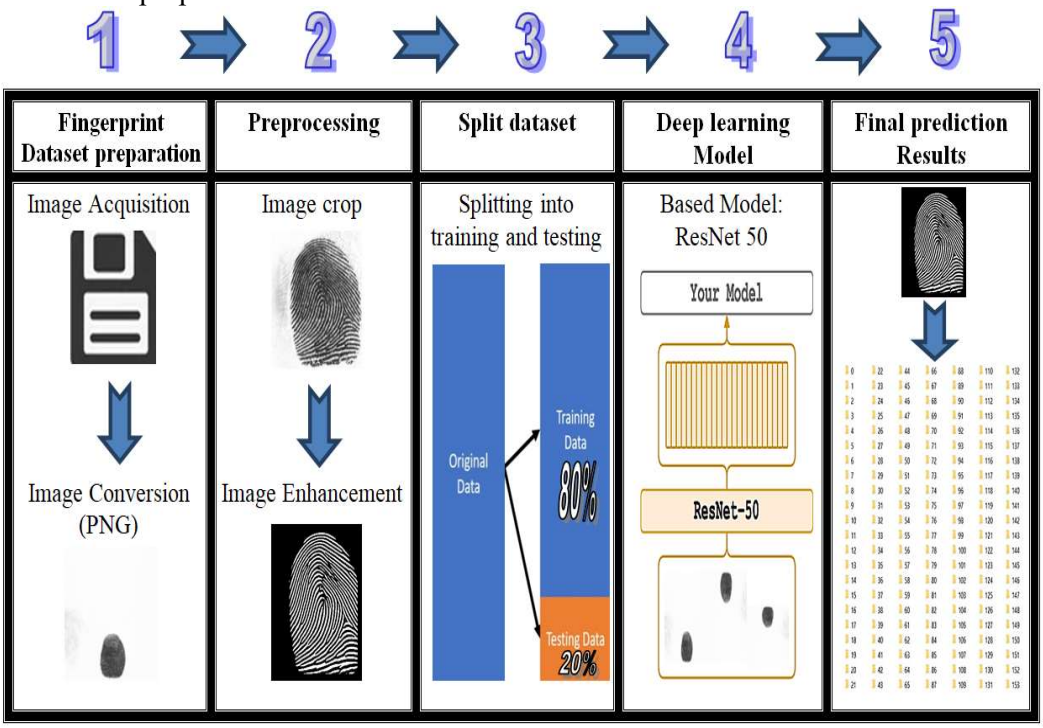

Figure2. The design of our proposed method fingerprints of newborns and toddlers based Model: ResNet 50

3.1 DATA ACQUISITION

In this paper is used dataset named as NITG-FDCv1[21] Provided by the institute NATIONAL INSTITUTE OF TECHNOLOGY GOA, India 2019 and I had taken permission from NITG. Taken fingerprints using machine Real Scan G10 Multi Fingerprint Scanner (Suprema), It was in BMP type and then we converted it to PNG type because of the advantages this type has. They had collected this dataset over the span of 2 years and in it different types of Fingerprints newborns and toddlers (Good, Bad, Dry, Half, Wet, pressure, Scars). as in Figure 3.

Figure3. Different types used in the dataset

We took 154 subjects from newborns and toddlers, five images per of the left thumb prints of them (age range: 0-5 years). Table 1 shows the details of the dataset.

Table1. Fingerprints dataset in detail.

Dataset	NITG-FDCv1
Subjects	154
Fingerprint per subject	1
Images per Fingerprint	5

Total images	770
Image type	bitmap (PNG)

3.2 Fingerprint Image Crop

In this step, we used the process of cropping the fingerprints, because fingerprints from newborns and toddlers a small on the fingerprint scanner, and for the image to be analyzed to the fullest, we must crop only the location of the fingerprint and remove everything around it As shown in Figure 4.

Figure 4. Process of cropping the fingerprint

3.3 Fingerprint Image Enhancement

According to NFIQ 2.0, the baby's fingerprint presents problems for the fingerprint identification system since the pictures are blurry [1]. Therefore, improving the children's fingerprints is necessary for accurate feature extraction and matching. We adopted the Gabor filter for picture enhancement because it has essential characteristics such as being frequency- and orientation-selective [26] and being appropriate for frequency and spatial domain. The primary goal of this is to provide an input fingerprint picture using Gabor filtering methods; the image is processed through a few essential stages before being filtered using Gabor filtering methods, which results in a clean output image [27]. Gabor filter is employed here to detect edges. The Gabor filter, which is mostly utilized for fingerprint applications globally, is designed here using Python. Gabor filters are essentially band pass filters utilized mostly in image processing and fingerprint applications for the extraction of distinctive features, When a Gabor filter is applied to an input picture, it responds strongly in the corners and precisely where the texture shifts. As demonstrated in Figure 5, the Gabor filter may reduce noise, preserve ridge and valley patterns, and provide orientation-specific information through the convolution of its impulse response, which is typically produced by a Fourier transform and a Gaussian factor.

Complex Portion: $g(x,y,\lambda,\theta,\psi,\sigma) = \exp(-(x'^2+y'^2)/2\ \sigma 2)\ \exp(I(2\pi x'/\lambda+\psi))$

The complex 2D Gabor filters' space domain representation is provided by:

$H(x,y)=s(x,y)g(x,y)$

S(x,y) is a complexity sinusoid and g(x,y) is the envelope function, a 2D Gaussian function. The Gabor filter's equivalent frequency representation is:

$H(u,v)=\exp\{-2*pi*pi*б*g*g[(u-U)2+(v-V)\ 2]\}$

You may create a Gabor filter in any direction from 0 to 360 degrees to create a Gabor filter

(A) **(B)** **(C)** **(D)** **(E)** **(F)**

Figure 5. Primer cases pictures (A,C,E) and enhancement pictures using Gabor Filter (B,D,F).

3.4 Data Splitting

As we mentioned before that we have a dataset consisting of 154 subjects, each subject has 5 fingerprints of left thumb, the dataset was divided into 80% training and 20% testing, meaning that 4 of each newborn's and toddler's fingerprints for training and the final fingerprint for testing. Table 2 displays the number of subjects obtained from the datasets of training and testing.

Table2. Size of the training and test dataset used to assess the efficiency of the proposed method

Dataset	NITG-FDCv1
Subjects	154
The number of left thumb prints	770
Training fingerprints (80%)	616
Testing fingerprints (20%)	154

3.5 The suggested Deep learning model

The previous technique relied on the Euclidean distance, the minimal distance criterion, and the reference point identification algorithm to recognize fingerprints [21]. By dividing the Gabor (2D) filter into a Gaussian (1D) low-pass and a Gaussian (1D) band-pass filter, they were able to enhance filtering by using an eight-way filter to extract features.

We present here the proposed method through which we can extract the fingerprint features more accurately to solve the problem of fingerprint recognition Newborns and toddlers.

After obtaining and processing the dataset with two important steps represented in image cropping and enhancement we will use a pre-trained model under convolution neural networks and retrain our dataset on it.

There are many trained models that fall under convolution neural networks such as VGG16, VGG19, MobileNetV2, etc.

We will use the ResNet-50 model, and what distinguishes this model is that it solves two main problems that we have, which are the small size of the fingerprint and its insufficient clarity as adults.

The ResNet-50 model provides outstanding results in solving these two problems because it uses deeper layers to detect fingerprint features, as its layers contain 50 layers and uses 3-layer bottleneck blocks to ensure improved accuracy and shorter training times, and because it is accurate, the ResNet-50 model consists of 5 stages Each has a wrapper block and an identity block. There are three wrapper layers in each identity block and each wrapper block, Fig. 6 shows the building of ResNet50 and deep learning model flowchart.Perhaps the most important thing that hinders detecting images of newborns and toddlers is the problem of fading gradation of images, and this problem is handled by the ResNet-50 model and dealt with by enlarging the image in order to better identify its features.

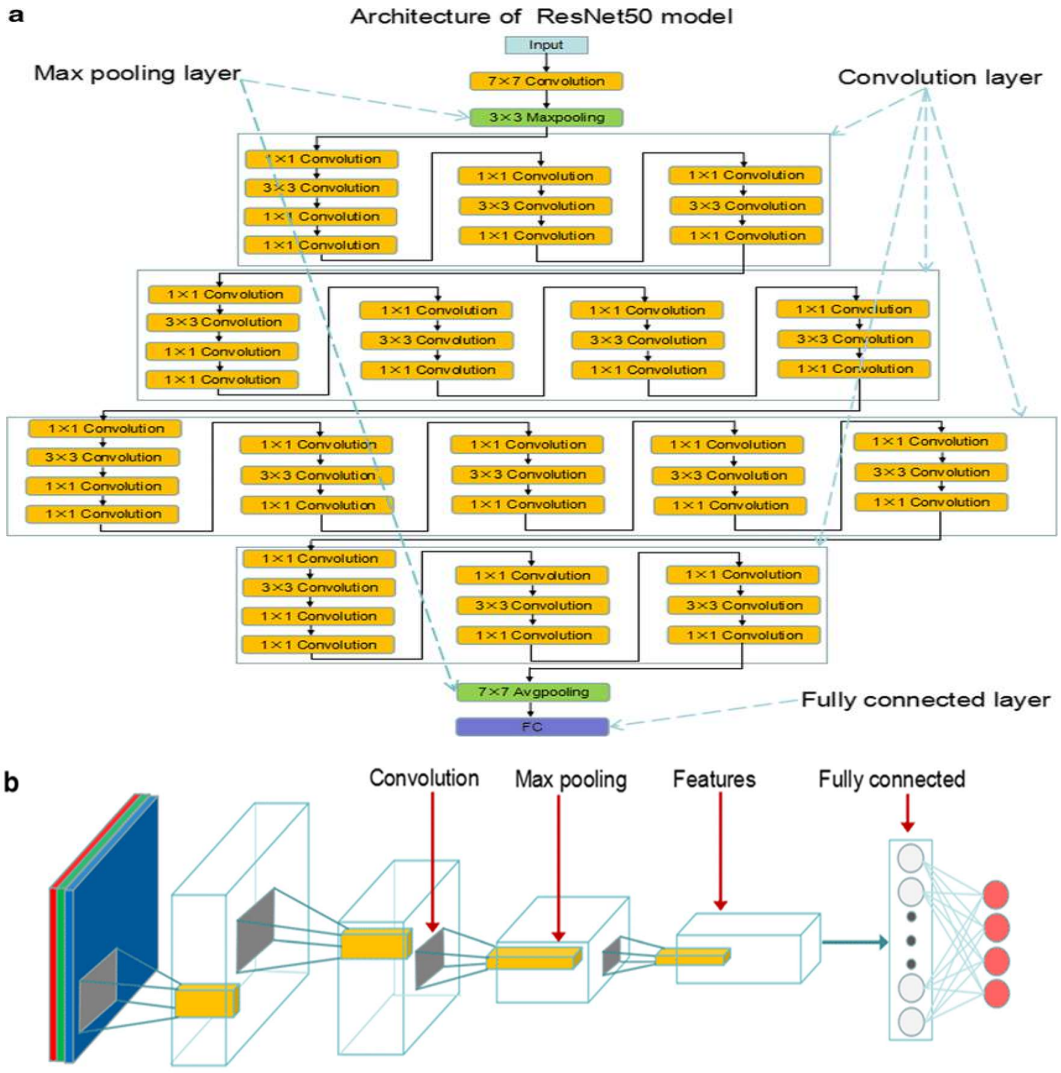

Figure 6. Building of ResNet50 and deep learning model flowchart [28]

3.6 Evaluation Metrics

The detection and classification stages were evaluated based on the standard evaluation metrics used by many researchers, such as accuracy and confusion matrix.

The accuracy of a machine learning model can be calculated as a percentage, and it can be performed using Equation (1).

$$\text{Accuracy(Acc.)} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} \quad (1)$$

Where TP (True-Positive) denotes are the correct predictions made that are matching as positive, whereas FN (False-Negative) denotes are the wrong predictions made that are matching as negative. The term TN (True-Negative) denotes are the correct predictions made that are matching as negative. Finally, FP (False-Positive) denotes are the wrong predictions made that are matching as positive.

Using these four components, we can calculate a confusion matrix to help us in analyzing the performance of the machine learning model, a confusion matrix is used to assess the model classification's performance; this is done by displaying the right and wrong values, which is an N × N matrix where N represents the number of target classes.

3.7 Execution Environment

An ASUS laptop with the following specifications was used for the experiment: AMD Ryzen 9 5900 HX with Radeon Graphics (16 CPUs), 3.3 GHz, 33 GB of RAM, and a 16 GB NVIDIA GeForce RTX 3080 GPU. This study's tests were carried out using Jupyter Notebook, Python 3.8.0, Windows 11, and the Keras and TensorFlow backend libraries.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The fingerprints of our stored children are recognition by Multiclass Classification. We have placed their fingerprints in labels, of which the number of the tested subjects was 154 from newborns and toddlers, numbered from zero to 153. Each of them has five fingerprints taken from several directions. The child comes and puts his fingerprint in the sensor, and the label containing his fingerprints appears automatically.

The deep learning model of ResNet50 was pre-trained using ImageNet. This pre-trained weight was used for this study based on the transfer learning strategy, and the optimizer used was Adam but the highest accuracy was achieved when the number of units was 1024, the learning rate was 0.001, and the number Batch size of epochs was 64.

We evaluated the proposed method using the empirical results to determine the fingerprint authentication accuracy of the proposed method; we compared each finger code from the test dataset with every other finger code in the training dataset.

The performance and efficiency results of the proposed method are shown in Table 3. As shown in Table, the proposed method achieves accuracy more than (82%) for fingerprint dataset. It has false rejection rate less then (18%). The proposed method takes on average 2 seconds for fingerprint recognition.

Table3. Display the effectiveness and performance outcomes of the proposed method

Evaluation Parameters	154 subjects
Successful Verification	127
Unsuccessful Verification	27
True Acceptance Rate/ Verification Accuracy	82.47%
False Rejection Rate	17.53%
Authentication Time (Seconds)/ Sample	2 Seconds

Table 4 shows the proposed method and compared it with previous work that used the same dataset and trained and tested it:

Table4. Compared between the proposed method and previous work

Ref.	**[21]**	**Our Proposed method**

Name Dataset	NITG-FDCv1	NITG-FDCv1
Subjects	154	154
The number of left thumb prints	770	770
True Acceptance Rate/ Verification Accuracy	81.82%	82.47%
False Rejection Rate	18.18%	17.53%
Verification Time (Seconds)/ Sample	7 Seconds	2 Seconds

Fig. 7 shows performance of Loss and Accuracy in (Training and Validation) of our proposed method.

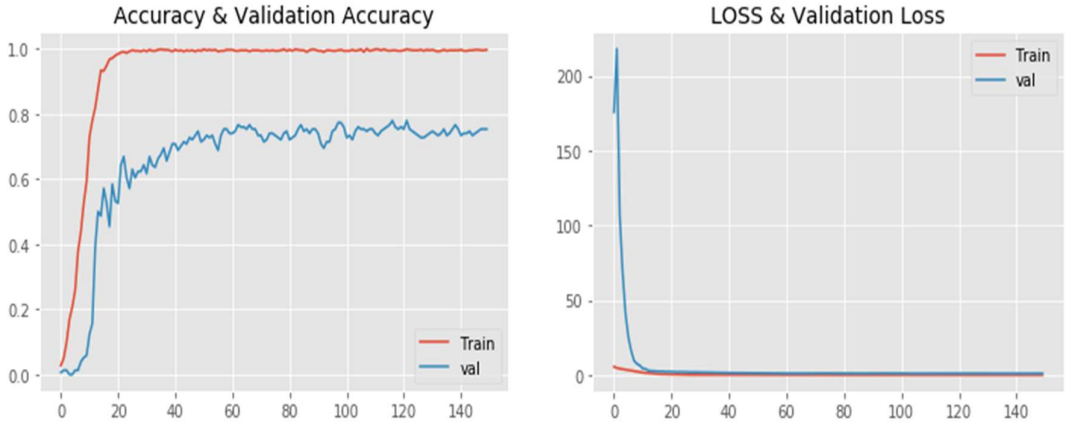

Figure7. Performance of Loss and Accuracy in (Training and Validation) of our proposed method

5. CONCLUSION

We are increasingly believing in the importance of creating an effective, accurate, and easy-to-use system within the reach of hospitals and birthing centers to reveal the identity of newborns, ensure that they are not exchanged, follow up on their vaccinations, give them the necessary nutritional supplements and take care of their health care until they reach school, and try to subsidize the United Nations Development Group No. 16.9, which calls for to the identity of all. The problems of images of newborns and toddlers are represented by the appearance of a light membrane on the fingerprints of the newborn, dryness of their fingers, sometimes getting wet and dirty, small size and their lack of cooperation with the image-taker of their fingerprints, all these things prevented their fingerprints from being clear and easy to extract their features like adult fingerprints, and yet we will spare no effort to find Modern methods using neural networks that help in extracting image features, even if they are not clear.

In this work, the trained model ResNet-50 demonstrated its ability to obtain very encouraging results under different datasets of images (good, poor, dry, half, wet, pressure, scars...etc.) by obtaining 100% on the training set and 82.47% on validation compared to previous results that used the same dataset.

Acknowledgement and Data Availability Statement

We express our gratitude to Dr. Amol D. Rahulkar of NATIONAL INSTITUTE OF TECHNOLOGY GOA, India for giving us the dataset for purpose the research, and whoever wants the dataset can contact him by e-mail: **amol.rahulkar@nitgoa.ac.in**

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