Advances in Capturing Child Fingerprints: A High Resolution CMOS Image Sensor with SLDR Method[1]

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Abstract: The use of biometrics technology for person identification has become prevalent due to several innovations as a result of research and development in this field. The purpose of this study is to find a solution which realizes newborn and infant (younger than 12 months old) fingerprint (hereinafter called as "child print") identification under operational difficulties, especially as it relates to the capturing process. The focus here will be on design and prototyping of a fingerprint sensor for overcoming the difficulties in capturing newborn and infant fingerprints that have previously been difficult to obtain.

Keywords: Child Fingerprint Capture, High Resolution CMOS, SLDR Method.

1 Introduction

The use of biometric technologies for person identification has expanded due to several innovations in the field. Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals and are often categorized as physiological versus behavioral characteristics [JRN11]. The focus here will be on physiological characteristics such as, fingerprint, palm print, facial recognition, and iris recognition. Various kinds of biometric identification methods have distinct advantages, depending on the purpose of achieving identification as well as the accuracy and usability of each method.

Selection of a biometric identification method may also depend on the amount a client is willing to invest in biometric technology. There are many high-cost solutions across each identification method. Due to market expansion, fingerprint identification is now ubiquitous and is an acceptable tool for identification (one-to-many comparisons) or authentication (one-to-one comparison). However, fingerprint technology still has some difficulties in reaching its full market realization. This paper mentions one method which overcomes a specific difficulty, namely stable and precise operation of child print identification.

[1] SLDR Method stands for "Scattered Light Direct Reading Method" described in 4.2.
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2 Social needs for child print identification

The innovation of fingerprint technology would be of particular interest to markets where a national ID system is either in place or being contemplated. At present, there are many national registry systems which do not support fingerprint registration (enrollment) of children younger than five years old. For example, India has a national ID program, known as Aadhaar (also referred to as the UID Program) [Un16]. It is managed by UIDAI, Unique Identification Authority of India. This agency defines its registration obligation for all residents of India older than five years of age. However, since the enrollment does not require a proof of age, it is possible that some children enrolled are indeed under 5 years old. Therefore, the ability to capture newborn prints could be a process conducted within a hospital system, greatly reducing the administrative costs as well as providing an additional layer of security for newborn patient management and to eliminate misidentification in the hospitals.

Another application of child print identification is in the area of immunization record management. The 2011 Grand Challenges in Global Health Explorations Round 7 [Bi16] issued by the Bill and Melinda Gates Foundation states that “each year approximately 25 million infants do not receive the necessary immunizations, and at least 2.4 million children die from vaccine-preventable diseases.” [JCA14]. Within developing countries, organizations such as UNICEF and WHO as well as some NGOs support activities to immunize and protect children from various diseases. However, managing individual vaccination histories and increasing awareness among families about the protections vaccination provide remain a serious concern. Inaccurate vaccination histories for children can lead to parents mistakenly thinking their child has been properly immunized or for children to be given the wrong vaccinations. This not only can potentially be a health risk to the child, it is also not a cost effective way to manage the supply and distribution of vaccines that could potentially lead to vaccine shortages thereby negatively impacting entire communities.

Before discussing the development of new sensing technology that can capture child prints, we must understand all of the complex issues surrounding the development of such a device. For example, at present, fingerprint sensing devices have difficulties capturing fingerprint from the slim, soft and thin-skinned baby fingers.

3 Taking on the challenges with innovations

In order to best capture a child print, our project team determined that a high resolution CMOS image sensor (hereinafter called as “CMOS”) combined with an image enhancement method was necessary. The sensor needed to be able to capture the image under various conditions that may arise when trying to capture the image of a child fingerprint. During its preliminary research, the project team realized that fingerprint sensors currently on the market do not have the capability to capture child prints (Fig. 1).

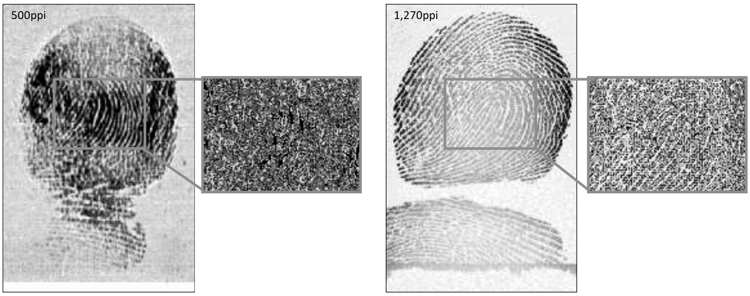

Fig. 1: Captured left-thumb fingerprint image quality difference at 500ppi vs 1,270ppi

3.1 1,270ppi high resolution CMOS sensor

The project team determined that the use of a sensor having at least 1,000 pixels per inch (ppi) resolution is required to capture a child's print. The project team decided 0.1 mm inter-ridge distance as the target for capturing a child print. This target inter-ridge distance, 0.1mm, is almost the same as the specification in another report [We08] and it supports that this target size is not far from the inter-ridge distance observed in a child print. To capture a stable image with 0.1mm inter-ridge spacing, the project team evaluated various high resolution CMOS. Stability was seen as a key requirement in capturing a child print.

After conducting several evaluations, the project team considered that achieving the 0.1 mm inter-ridge distance required the creation of an image with clear contrast by additional enhancement. Through their evaluation, the team concluded that a combination of "20μm pitch 1,270ppi CMOS + φ12μm Forward Slant Sugawara Higuchi Fiber (hereinafter called as "SHF") + Scattered Light Direct Reading Methods (SLDR, described later)" was the best method for capturing the image. The advantage of this combination was confirmed by the use of a second-generation prototype fingerprint sensor which was our first evaluation unit with 20μm pitch 1,270ppi CMOS + φ12μm SHF +SLDR; a combination of φ12μm Forward Slant SHF + SLDR was determined to be a fundamental design block of the desired fingerprint capture device.

3.2 Scattered Light Direct Reading Method (SLDR)

The SLDR utilizes the features of 360 degrees of light scattering inside of the lighted object, i.e. finger. This method uses Infrared LEDs (IrLEDs) located around the sensing area, and these IrLEDs irradiate the infrared light into the target finger. Irradiated light inside the finger scatters around 360 degrees; the scattered light waves reach the sensing surface with different contrast, revealing finger ridges as well as valleys. Light scattered from the ridges has a higher intensity than from the valleys. Further, as light waves fill the ridge portion, they reach the sensor directly because the ridges are in direct contact with the sensing surface (Fig. 2).

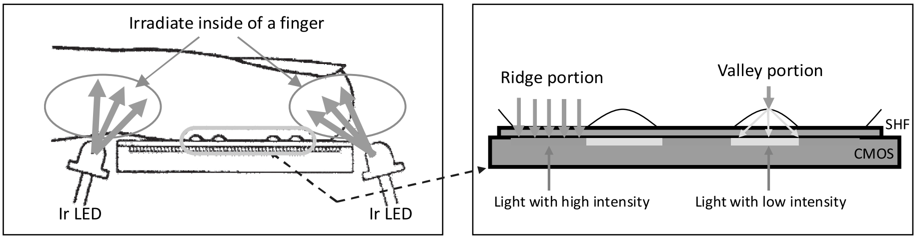

Fig. 2: Scattered Light Direct Reading (SLDR) Method

This holds true even in the presence of a liquid substance on the finger surface, as in the case of wet fingers. The glass is used to enhance the contrast and maintain clarity of light between the finger and the CMOS. This SLDR and SHF combination generates a clear friction ridge image from the finger and can do so under various conditions, including dry, moist or wet fingers. Fig. 3 shows the captured fingerprint image comparisons of the CMOS without SHF and with SHF. This comparison shows that SHF contributes to enhance the image. This is one of the reasons we consider SLDR to be suitable for child print capture because the presence of foreign objects like water on finger surface adversely affects child print capture. SHF also provides shock resistance for bare CMOS.

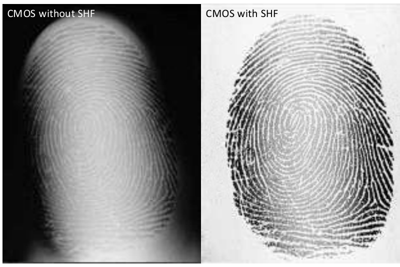

Fig. 3: Images taken by the CMOS with/without SHF under normal conditions

3.3 Target area and length computation

We took into consideration the need to have a design that would make child print capture easy for both the child and the operator. A small, lightweight and slim design was deemed mandatory for meeting this requirement. The child print capture process needs to consider both the length and area (size) of a distal segment. From the perspective of capturing the most effective friction ridge image, it was determined to use the thumb as the target finger for capturing an image. The use of a thumb print is also used in current operations of NGOs for immunization services [Va16]. We empirically calculated the length of distal segment from newborns to 12 months old babies. Based on this, we determined that a minimum target area of distal segment = 12mm x 12mm, with a minimum target length between root and 1st joint of 8mm is required.

The effective area for the selected CMOS is 30mm x 20mm. This capture area meets the target requirement. However, the length of 8mm between root and 1st joint means that the total height of entry point and distance between product edge and sensor edge has to be smaller than 8mm, otherwise, operator would need to open child's closed fist by force to place their finger onto the sensing surface. The design needed to be slim enough to allow for it to be slipped in between a child's closed hand so that the image could be captured even when the hand is grabbed and closed. In order to make the device height sufficiently small for ergonomic and usability considerations, the capture method needs to be something other than optical. With a high resolution CMOS + SHF + SLDR, not only a high resolution image is captured, but it can be designed and manufactured as a compact package. It must stay within the 8mm or lower height/length desired for the sensing area. Under this target length setting, a total height to length ratio of 7mm was targeted, with 4mm at the height of entry point plus 3mm at the length between hardware edge and effective sensing area.

3.4 Final design for officially released prototype, ZAK-108

As described, the target design of prototype would need to have the length between hardware edge and edge of the effective sensing area to be smaller than 3mm, the height to be smaller than 8mm, and the height at entry point (where the finger first comes in contact with the reader) to be smaller than 4mm. After releasing several prototypes, the project team succeeded in producing one that met all target size requirements with an eighth generation prototype model, the ZAK-008. The device had a length of hardware edge to effective sensing area of 2mm, a height of 7.5mm, and a height at entry point of 3mm. The complete concept of the eighth generation prototype ZAK-008 was approved during an internal confirmation meeting with the Michigan State University biometric team (hereinafter called as "MSU") and renamed as an officially released prototype, ZAK-108 (Fig. 4). ZAK-108 achieved the target size as well as some additional design packaging requirements for child print capture. The design includes a tapered shape at the entry point and a rounded shape for the entire device, making child print capture easy for the operator and comfortable for the child. It also includes a backside mechanical switch for stable image capture and a heatsink mechanism for sensing surface temperature management (Fig. 4). One of the key components designed into the prototype is the backside mechanical switch.

Since most infants are non-cooperative, one of the operator's hands has to hold the sensor while the other hand has to hold the child's finger on the sensor. Working together with software named ZAKURO software, it eliminates the need for an operator to activate image capture at the attached laptop. This is a significant advantage as many existing hardware and software capturing combinations require the use of a software switch at the host. This requires the operator to remove his or her hand from the device, which might inhibit stable and clear image capture. The other key design feature is the heatsink which also works with the software. The thin design of the device makes overheating of the mechanism a problem due to power consumption. The heatsink works with the software to manage power to the device.

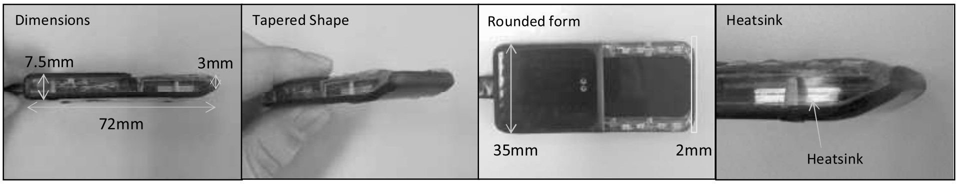

Fig. 41: ZAK-108 packaging design

4 Results from onsite research

After confirming the prototype design, the project team received permission to conduct onsite research in India for collecting child print samples. MSU, a prime organization of this research, arranged for and guided the research at Saran Ashram charitable hospital in Dayalbagh, India. Four units of the ZAK-108 were given to MSU researchers to confirm the functionality of the child print sensor.

4.1 Onsite capturing process

During onsite research in Dayalbagh, India, The MSU research team captured the images of child prints from about 300 child volunteers including 66 infants younger than 6 months. The youngest volunteer was just six-hour old newborn, an unexpected opportunity for the project team (Fig. 5).

Note that the study had the proper IRB (Institutional Review Board) approval, and parental consent was acquired before taking child prints. An internal evaluation of the newborn's print revealed that the ZAK-108 captured 0.08mm (80μm) pitch between ridges. This result showed the effectiveness of the 20μm pitch, 1,270ppi CMOS + φ12μm Forward Slant SHF + SLDR for the child print capture process. The MSU team also confirmed that the hardware design of the ZAK-108, with its tapered shape at the entry point, made child print image capture easy for the operator. It was also noted that the combination of a backside switch and a preview window helped the entire capture process, allowing fingerprint capture without the operator losing control of the sensor. Fig. 5 shows the operator holding the target finger onto the sensor with his right hand and pressing the backside switch to capture the image displayed at the preview window of software by his left index finger at the same time. Fig. 5 also shows the "tapered shape" design at the entry point of the ZAK-108, which does not require the newborn hand to be open. The NEC project team obtained the feedback from MSU team and increased the team's confidence in the prototype's design and function evaluated through the onsite research [Ja16].

Fig. 5: Capturing fingerprint of a six-hour old newborn

4.2 Captured image and the output of feature extraction

After receiving some sample images collected from the newborns, these images were analyzed by the project team using the software tool to visually verify the image with feature extraction data. Fig. 6 shows the feature extraction result for one of the images. We note that the image data taken by the ZAK-108 creates an effective fingerprint image area which includes a clear friction ridge image without any blurring. During the internal evaluation, examiner tool revealed approximately 50 minutiae points in the child print. This demonstrates that the captured images taken by ZAK-108 are effective for use in actual identification scenarios like expansion of an existing national ID system to include infants.

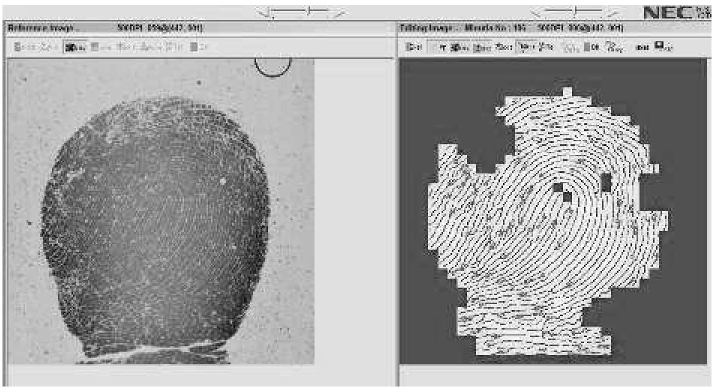

Fig. 6: Fingerprint image and extracted features from a 6-hour old newborn baby

As additional information, recognition accuracy data have been calculated by MSU research team. Some of their calculation used data captured from the babies younger than 4 weeks. An image enhancement method, designed for child-prints, was applied on the data set before the feature extraction process. A verification result in this case (younger than 4 weeks) was TAR of 43.43% at FAR 0.1% [Ja16]. This result shows the project team has to improve both the device to capture the child print as well as image enhancement, feature extraction and matching modules.

5 Conclusion

NEC has provided a novel solution for capturing child fingerprint images that would be of benefit to the global community and have a positive impact on the welfare of children. Our evaluation shows actual fingerprint images captured and matched from onsite research using ZAK-108 fingerprint sensor and ZAKURO software. From this research, it was confirmed that a combination of 20μm pitch 1,270ppi CMOS + φ12μm Forward Slant SHF and SLDR is effective for capturing child prints. The project team is confident that further research and evaluation will continue to demonstrate the stability and reliability of this new method of capturing and matching child prints for identification purposes. The use of this technology has many applications that can be a benefit to society that include the maintenance of accurate health and immunization records, immigration processing and more accurate statistics on population and birth rates.

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