NEWBORN'S BIOMETRIC IDENTIFICATION: CAN IT BE DONE?

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Abstract: In this article we propose a novel biometric identification method for newborn babies using their palmprints. A new high resolution optical sensor was developed, which obtains images with enough ridge minutiae to uniquely identify the baby. The palm and footprint images of 106 newborns were analysed, leading to the conclusion that palmprints yield more detailed images then footprints. Fingerprint experts from the Identifcation Institute of Paraná State performed two matching tests, resulting in a correct identification rate of 63.3% and 67.7%, more than three times higher than that obtained on similar experiments described on literature. The proposed image acquisition method also opens the perspective for the creation of an automatic identification system for newborns.

1 INTRODUCTION

Identification of newborns is one of the main tasks of the medical team following birth. Especially in developing countries like Brazil, where security in public maternity wards is not very tight, and overcrowding is common, the risks of a baby swap or kidnap are above acceptable.

According to a speech by Police Officer Nilma Azevedo (Azevedo, 2005), another frequent problem is illegal adoption. Police Department of Pernambuco State is trying to increase controll over mothers fingerprint verification, in order to avoid situations in which they enter the maternity using identification documents of another person, to which they afterwards sell/give the newborn child.

Situations like these could be avoided, or strongly reduced, if reliable and fast methods for identification of newborns were made available and used inside maternities and hospitals, as well as on airports or bus stations. Thus it is surprising that so little research regarding newborn identification is published, while biometric identification of adults receives so much attention and funding.

There are a variety of commercially available systems for adult biometric identification (Mainguet, 2007; Maltoni et al., 2003), but to the best of our knowledge, there is not a single biometric system developed for identification of newborn babies, so that most maternities still rely on bracelets and/or stamps for this purpose. Most published articles about this subject date from the beginning of the 20th century, and usually only evaluate the usefullness of footprinting with ink and paper, without new identifition methods proposals or evaluations.

The purpose of this article is to propose a novel biometric identification method for newborn babies using their palmprint. We make a survey of the newborn identification techniques based on dactyloscopic impressions and then present a newly developed digital sensing equipment capable of providing high definition images of the baby's palms and soles. These images, collected moments after the birth, can be used by an expert for confrontation in case of identity doubt and for the development of automatic identification systems. They can also be used for confrontation during the adult life of the individual.

Work on this project involved a multidisciplinary team composed of computer scientists, medical doctors, nurses and police officers. We are also grateful for the parents that gave their consent to the testing of the new equipment on their newborn babies.

2 NEWBORN IDENTIFICATION

2.1 Fingerprints and Palmprints

Very few articles refering to the use of fingerprints or palmprints on newborns were found. Worth mentioning is Sir F. Galton's work (Galton, 1899) where he presented a study of newborn fingerprinting with ink and paper, concluding that fingerprints taken before 17 months after birth are not usefull for identication.

Morgan and Pauls (1939) presented a technique for collecting palmprints of newborns, and stated that they resulted in images good enough to be used for identification, although no objective analysis of the resulting images were provided, nor did they perform a matching test to support their statement.

2.2 Footprints

Acquisition of newborns footprints at birth is used as means of identification in many countries since the beginning of the 20th century (Shepard et al., 1966; Cat, 2003; Vaesken, 2006). Usually the footprints are collected with ink spread on the foot with a cylinder and then printed on the newborns' medical record, along with the mothers fingeprint. That way, it is expected that any identity doubt about the baby or his/her mother can verified.

Unfortunately, due to illegibility problems, the use of these footprints for identification purposes is not possible in the majority of cases. According to several studies (Cat, 2003; Shepard et al., 1966; Pelá et al., 1975; Lomuto and Duverges, 1995; Thompson et al., 1981), the main reasons for illegible footprints are:

- Use of inadequate materials (ink, paper, cylinder);
- Untrained personal for footprint acquisition;
- Baby's skin covered with an oily substance;
- Reduced thickness of the newborn epidermis, easily deforming the ridges upon contact and filling the valleys between ridges with ink;
- Reduced size of the newborns ridges, which are three to five times smaller than on adults.

Montgomery (Montgomery, 1926) is the only author who said that he could get footprints of newborns with clearly visible ridges, using a technique (not described) developed (but not published) by Prof. J.H. Mathews, of the Wisconsin University. He collected footprints of 191 newborns, at one to seven days after birth, and most of them had visible ridges, allowing him to classify the footprints using a system proposed on the same article. Unfortunatelly this footprinting technique was not found on our revision, nor any other reference to it.

After the beginning of the 20th century, there were no new publications on techniques for obtaining good newborn dactiloscopic prints. Most articles only evaluate footprinting with ink and paper, arguing about their usefullness for identification purposes.

Wierschem (Wierschem, 1965) described a study in which footprints collected by Chicago's hospitals (USA) were analysed, concluding that 98% could not be used for identification. After providing trainment and the right equipment to the medical team, a new analysis of the collected footprints was performed, showing that 99% allowed the newborn's identification. But this identification was not based on dactiloscopic ridges. It used the flexion creases of the foot, which change during the first months of life.

Shepard *et.al.* (Shepard et al., 1966) collected footprints of 51 newborns, one at birth and another 5 to 6 weeks after, sending the resulting 102 impressions to the California State Justice Department of Criminal Investigation and Identification (USA) for analysis. There, expert fingerprint technicians analysed the sample and were only able to identify 10 babies, resulting in approximately 20% identifiable footprints. However it was felt that the majority of these 20 correctly matched prints would not stand up under legal scrutiny in the courts.

Pelá *et.al.* (Pelá et al., 1975) made a large scale analysis of footprints in order to verify their quality and the usefulness of collecting them. They analysed 1,917 footprints collected during a year in a Brazilian maternity ward, and concluded that none provided details that could be used for identification purposes, although they were collected by trained personel.

Thompson *et.al.* (Thompson et al., 1981) collected 100 footprints of 20 newborns and verified that only 11% where technically acceptable, and only one footprint (1%) had all elements needed for a legal identification. They also acquired the footprints of 20 premature babies weighting less than 1500g at birth. Many prints were obtained from each baby: at birth and then 4 to 8 weeks later, and the best pair of prints were chosen for a matching attempt. Conclusion was that none of these footprints were suitable for identification purposes.

Thus, most authors concluded that it is safe to state that footprinting as currently done is not useful for identification purposes, and that the acquisition of footprints should be abandoned because it only generates unnecessary work and costs. These authors also state that even with well-trained personnel, good materials and appropriate techniques, it is impossible to obtain good footprints. A recent email discussion between biometric researchers[1] also showed that

[1]Biometric Consortium's Electronic Discussion Group

it is considered to be impossible to obtain any dactiloscopic impressions from newborns, because of incomplete ridge formation, their skin being covered by an oily substance and their extremely fragile ridges.

Besides footprinting, other identification methods are also used, such as: bracelets, signals with chemical solutions or ink, and the withdrawal of genetic material to allow the DNA examination. The problem is that the bracelets or inks serve only for the period of permanence of the child in the hospital unit, and even during this period these IDs can be removed or altered. On the other hand, the DNA examination is proven to be efficient in the univocal identification of individuals, but it comes at high cost and cannot be used in real time applications, demanding sophisticated laboratory procedures.

The use of the iris as identification feature, even though it is increasingly used in adults (Bolle et al., 2003), is a difficult method for newborns, especially the premature, because they hardly open their eyes, they do not have the ability of looking into a scanning device, and touching their eyelids to collect an image could hurt them. Besides, the iris pattern only stabilizes after the child's second year (Jain et al., 2004).

The format of the ear is a biometric feature of easy acquisition, but possesses little discriminatory capacity (Bolle et al., 2003; Victor et al., 2002) and changes throughout the life of the individual.

Given the limitations of these and other identification methods, the idea of using dermatoglyphic prints continues to be very attractive, since it is a non invasive method, of easy applicability, high availability, wide acceptance and has effectively been used for more than 100 years.

2.3 Ridges on newborns

The ridges of the fingers, palms and soles of the human embryo are formed between the $12th$ and $16th$ week of gestation, first appearing in the tip of the fingers and finally in the sole of the feet. They do not change in the subsequent months or during the adult life of the individual (except in case of some illnesses or physical wounds). After the $18th$ week of intrauterine life the embryo has its ridges completely formed and they become visible in the surface of the epidermis (Cummins and Midlo, 1943; Castellanos, 1953; Holt, 1973; Kücken and Newell, 2005).

Despite being fully formed and invariant in numbers of lines, drawings or details (minutiae), ridges do change in size throughout the growth of the child, becoming thicker and widening the gap between them (Cummins and Midlo, 1943; Castellanos, 1953). According to Castellanos (1953), the ridges of the fingers of newborns are 3 to 5 times smaller than in adults, and are very fragile, easily deforming upon contact. Figure 1 illustrates this difference showing the finger of a newborn and an adult side by side.

Figure 1: Comparison between the forefinger of a newborn and an adult.

The automated fingerprint identification systems (AFIS) homologated by the FBI for use in adults demand a minimum resolution of $500dpi$ (Maltoni et al., 2003). As the ridges of adults measure, on average, $0.45mm - -0.5mm$, its safe to assume that for newborns, whose ridges measure $0.1 - -0.15mm$ (Cummins and Midlo, 1943; Castellanos, 1953), a resolution of at least $1500dpi$ is necessary.

3 FOOT/PALMPRINT IMAGES ACQUISITION

In order to develop a new footprint acquisition method, the first step was to appropriately prepare the newborns' skin, in order to remove the oily substance covering it and provide a clean surface.

First tested was the traditional ink and paper method: carefully collected footprints of newborns were taken and analysed, with help from fingerprint experts from the Identification Institute of Paraná State (IIPR). This test confirmed the knowledge that very few prints show visible ridges, and none were suitable for identification.

As a second step, some commercially available optical finger/palmprint sensors, ranging from $250dpi$ to $500dpi$, were tested, but in neither case the images obtained showed any usable ridge patterns.

The next attempt was to use a high resolution light scanner to scan the babies sole and palm, in order to

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test if a greater resolution would yield better results. Images were obtained at $1200dpi$ and $2400dpi$.

However the scanned images were not deemed suitable for large-scale utilisation, the reasons being: firstly that the scanning process takes almost 2 minutes, during which the baby should not move his/her foot/hand, or the image is corrupted. Secondly, the scanned images have a low contrast, making it difficult to segment the valleys and ridges. And thirdly, the pressure that has to be applied on the foot/hand to keep it quiet cause blood vessels on the skin surface to be emptied, reducing the contrast even further.

3.1 Optical sensor for newborn foot/palmprints

To the best of our knowledge, and based on the discussion above, there is no available method or equipment that allows the acquisition of high definition palm/sole images from newborns. Furthermore, there is no market-available equipment capable of satisfying this application's requirements. We thus developed a sensor (Figure 2) consisting of a 8 megapixels digital camera attached to a rectangular optical glass prism, capable to generate images of approximately $1400dpi$ with a capture area of $35mm \times 45mm$.

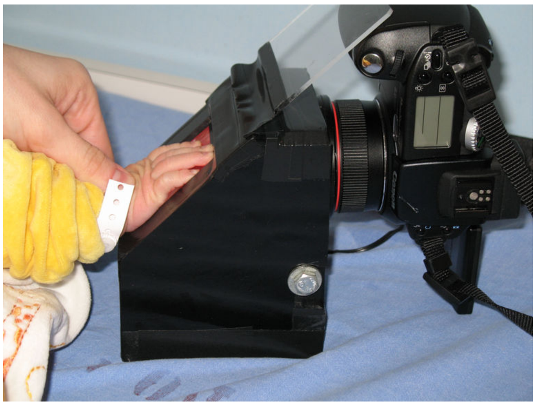


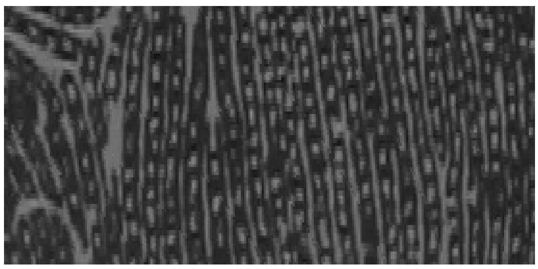
Figure 2: Optical sensor with capture area of $35mm \times 45mm$ and approximate resolution of $1400dpi$, used to acquire newborn palm and footprints.

The working principle of the sensor is the same as other existing optical fingerprint sensors, based on the total reflection characteristic of a prism. When a palm or sole is placed on top of the prism's inclined surface, light is absorbed by the ridges touching the prism, yielding dark points on the image, while at the valleys light is reflected into the camera. This method provides high contrast images, and the main advantages of the developed sensor are its high resolution.

Acquisition of good quality images requires that the newborns palm and sole be cleaned and moisturised. Figure 3a shows the image of a newborns palm as provided by the sensor (after distortion corrections). Figures 3b and 3c are magnifications of that image for better visualisation. It is possible to observe well defined ridges and some pores. The ridges are relatively close to each other (with narrow valleys) due to deformation caused by the pressure applied to the hand. But the image has the typical high contrast obtained with this kind of sensor, and allows the identification of minutiae points and even pores.

(a)

(b)



(c)

Figure 3: (a) Palmprint of a newborn, (b) and (c) subsequent magnifications of a region in (a).

4 EXPERIMENTAL RESULTS

In order to test the effectiveness of the proposed method for identification purposes, palmprints and footprints of 106 newborns were collected at the maternity ward of the University Hospital (Universidade Federal do Paraná). The images were collected during the first 24 hours following birth (T24h), and again before the babies completed 48 hours (T48h). Each time two prints of the hand and two of the sole were collected, so that each baby had four images of its palm and four of its sole.

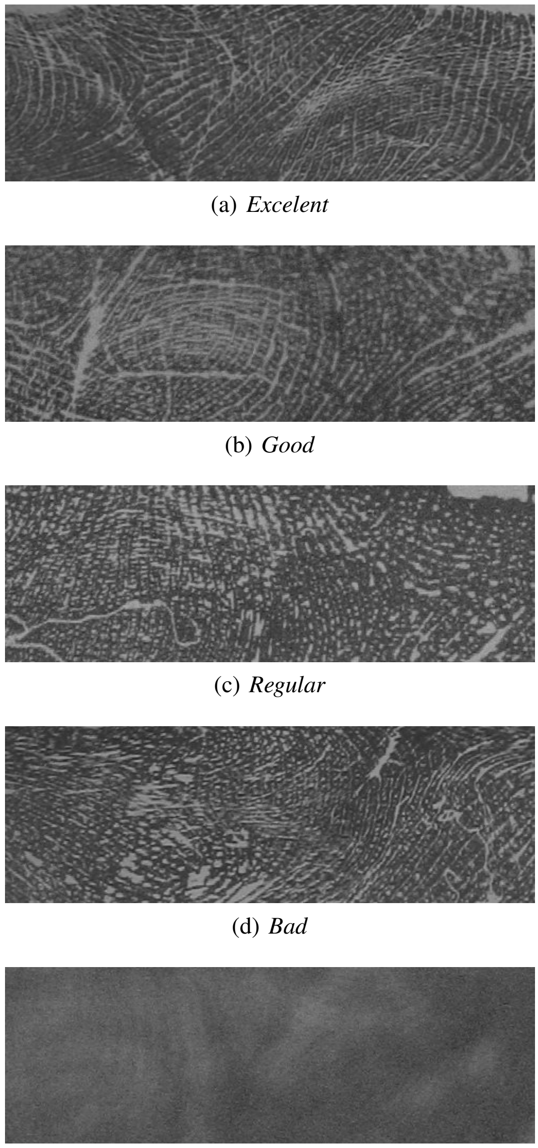
Analysis of the images was performed simultaneously by two observers. The best footprint and palmprint of each newborn, out of two collected at T24h, was classified into one of five categories, according to its quality:

- **Excelent**: a) When the figure(s) or form(s) were clearly visible (arch, whorl or loop); b) the dermatoglyph lines were visible; c) one or more triradi (or delta(s)) were found; and d) minutias were visible (Figure 4a);
- **Good**: a) When the figure(s) or form(s) were clearly visible; b) the dermatoglyph lines were visible; and c) one or more triradi (or delta(s)) were found (Figure 4b);
- **Regular**: a) When the figure(s) or form(s) were clearly visible; and b) the dermatoglyph lines were visible; or c) one or more triradi (or delta(s)) were found (Figure 4c);
- **Bad**: When only the dermatoglyph lines were visible (Figure 4d);
- **Doodle**: No visible dermatoglyphs (Figure 4e).

The results of the quality analysis (Table 1), show that palmprints yield better quality images than footprints, since 83% of the babies provided palmprints classified as *Excelent* or *Good* (suitable for identification), whilst 37.7% of the footprints were classified into these categories. This is quite surprising, especially if considered that newborns do not wantingly open their hands, which makes palmprint acquisition more difficult. But according to the fingerprint experts, obtaining the palmprint at birth is of much greater use for comparisons in later adult life, since it is the usual identification procedure in most countries along with fingerprinting.

Table 1 also shows that only 8 newborns (7.5%) would not be identifiable with the palmprints collected at birth, which is a far better result than in any previous method.

In addition to the test above, two palmprints of 30 randomly choosen newborns, collected on subsequent days (T24h and T48h) were randomly numerated (from 1 to 60) and given to three fingerprint experts from the IIPR, which had to match the pairs. They were able to correctly identify 19 pairs out of 30, a score of 63.3%. From the 11 misclassified, two were considered classification errors, which means both images were *Good* but were incorrectly matched by mistake. The matching test was then repeated with another set of 30 newborns, randomly choosen from the remaining 76, and the experts were able to correctly identify 20 pairs out of 30 (67.7%), confirming the previous identification rate.



(a) *Excelent*

(b) *Good*

(c) *Regular*

(d) *Bad*

(e) *Doodle*

Figure 4: Illustration of different palm/footprint image quality.

Table 1: Quality evaluation of the best palmprint and footprint of each newborn.

Quality	Palmprint		Footprint	
Excelent	33	31.1%	16	15.1%
Good	55	51.9%	24	22.6%
Regular	10	9,4%	57	53.8%
Bad	8	7.5%	9	8.5%
Doodle	0	0.0%	0	0.0%
Total	106	100.0%	106	100.0%

5 CONCLUSION

In this article we presented a newborn palmprint acquisition technique that uses a high-resolution optical sensor and provides an identification rate at least three times higher than ink and paper based footprints. Whilst most authors have concluded that footprints taken at birth do not provide good images, with correct identification rates ranging from 0% to 20%, the method developed in this paper was able to correctly identify 63.3% and 67.7% of the babies, and 83% had palmprints with enough quality to allow identification.

Results also show that palmprints yield better quality images than footprints despite having a more difficult acquisition, since babies do not willingly open their hands.

Finally, the images obtained with this method are still not as good as adult fingerprints returned by $500dpi$ sensors. Reasons for this include the fragile constitution of newborn's ridges and their dry skin. Improvements in the technique could be attained by changing or applying less moisturiser; modifying the sensor so that images can be analysed straightaway after acquisition, and making it more comfortable for newborns hand, so that less pressure has to be applied.

Future research should focus on two remaining tasks: (1) improve the image acquisition method and sensor; and (2) develop a software to automatically identify newborns using these images.

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