Biometric Recognition of Children: Challenges and Opportunities

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Tracking Vaccination Schedules

“Vaccine wastage rates are higher than 50% in some of the most challenging geographies.” - VaxTrac
(http://vaxtrac.com/mission/challenge)
Vaccination Camp
(Cotonou, Benin, West Africa, May 2014)
Preventing Newborn Baby Swaps

October 30, 2013: Two newborn babies born 5 minutes apart were swapped due to negligence of the medical staff at the Vijayanagar Institute of Medical Sciences (VIMS) in Bellary; a DNA test later confirmed the swap*

Giving Child an Identity?

- Who is this child?
- Have we seen her before?

National ID, vaccination tracking, healthcare, social benefits
Why Biometrics?

- ID cards either not available or cannot be trusted
- Parents may not always accompany the child to vaccination/health camps

Linking newborn’s footprint to mother’s thumbprint
Missing Children

Amber Alert System for Child Abduction in the U.S.

<table>
<thead>
<tr>
<th>Number of Missing Children</th>
<th>2014 - 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>73,549</td>
</tr>
<tr>
<td>US</td>
<td>466,949</td>
</tr>
<tr>
<td>Worldwide</td>
<td>~8 million</td>
</tr>
</tbody>
</table>

Afghan Girl (age 13 years), from the 1985 issue of National Geographic, identified as Sharbat Gula in 2002, using her Iris image.

http://www.amberalert.gov/
http://www.missingkids.com/KeyFacts
http://pib.nic.in/newsite/PrintRelease.aspx?relid=123600
Which Biometric Trait?

- Palmprint
- Face
- Footprint
- Fingerprint
- Iris
- Ballprint
- DNA?
Friction Ridge Patterns

- Ridges are different for every finger of every person
- They do not change throughout life & survive superficial injury
- The precise patterns & minutiae are determined at ~10 weeks

Penrose and Ohara, The development of the Epidermal Ridges, J. Medical genetics, 1973
Cummins and Midlo, Finger Prints, Palms and Soles, Dover, 1961
## Comparing Biometric Traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Pros and Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>Easy to capture; difficult to control pose, illumination and expression</td>
</tr>
<tr>
<td>Iris</td>
<td>Child may be sleeping or crying; parental concerns</td>
</tr>
<tr>
<td>Fingerprint</td>
<td>Need compact, high resolution (&gt;1000 ppi) sensor to resolve ridges; wet and dry fingers</td>
</tr>
<tr>
<td>Palmprint</td>
<td>Large surface area; surface concavity; infants keep their fists closed</td>
</tr>
<tr>
<td>Footprint</td>
<td>Large surface area; surface concavity; removing socks and shoes; dirty feet</td>
</tr>
</tbody>
</table>

- Acquisition: uncooperative child, capture conditions, throughput
- Properties of trait: Capacity (1:N comparison) and persistence
Development of Friction Ridge Patterns of Fetus

Ring finger, 13 weeks of gestational age

Thenar area of palm, 15 weeks and 4 days of gestational age

Hypothenar area of palm, 16 weeks and 5 days of gestational age

Middle finger, gestational age unknown, crown-rump length 140mm

Toes, gestational age unknown, crown-rump length 100mm

Fingerprints of Young Children

• Galton (1892) collected all ten fingerprints of a newborn from birth until she was 4.5 years old

• Key observations:
  – “Far more delicate printing is needed on account of the low relief of features and minuteness of the pattern”
  – “Babies are the most difficult to deal with, the persistent closing of their fists being not the least of the difficulties”
  – “Many undecipherable blurs are made before one moderate success is attained”

“The print of a child at the age of 2.5 years would serve to identify him ever after”
Child Fingerprinting

• Challenges
  – Small finger size; high ridge density; low contrast; wet & dirty fingers; image distortion

• Requirements
  – Compact, high resolution, low cost sensor; fast image capture; \textit{longitudinal study}
The Dayalbagh Longitudinal Fingerprint Study

Saran Ashram Hospital, DEI, NEC, Silk ID, Digital Persona, Gates Foundation, VaxTrac, MSU

Four sessions: March & Sept. 2015; Jan. & March 2016
# Fingerprint Readers

<table>
<thead>
<tr>
<th>Reader</th>
<th>U.are.U 4500</th>
<th>NEC Zakuro</th>
<th>Silk ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Optical</td>
<td>CMOS+SLDR</td>
<td>Optical</td>
</tr>
<tr>
<td>Image Capture Area (L x W) in mm</td>
<td>14.6 x 18.1</td>
<td>35.4 x 21.8</td>
<td>20.3 x 15.2</td>
</tr>
<tr>
<td>Maximum resolution (DPI)</td>
<td>512</td>
<td>1,270</td>
<td>1,000</td>
</tr>
<tr>
<td>Size (L x W x H) in mm</td>
<td>65x36x15.6</td>
<td>72x35x7.5</td>
<td>44.2x36.2x15.9</td>
</tr>
<tr>
<td>Capture mode</td>
<td>Automatic</td>
<td>Manual</td>
<td>Automatic</td>
</tr>
</tbody>
</table>

![Image of U.are.U 4500](image1.png)

![Image of NEC Zakuro](image2.png)

![Image of Silk ID](image3.png)
Fingerprint Capture

- 500 ppi DP & 1270 ppi NEC readers
- 3 fingerprint images/thumb/session; 3 face images/session
- Total of 319 children; 161 came to all the four sessions
Left Thumbprint of “Baby of Renu”

(NEC Zakuro sensor, 1270 ppi)

6 hour old
Recognition Protocol

Reference Database
Subject enrollment images + 32K images of 16K children

Matcher

Top-9 hits

Preprocessing

Left thumb
Right thumb

Face
Face Matching

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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>3 months 0.598</td>
<td>0.543</td>
<td>0.510</td>
<td></td>
</tr>
<tr>
<td>4 months 0.545</td>
<td>0.597</td>
<td>0.650</td>
<td></td>
</tr>
<tr>
<td>5 months 0.539</td>
<td>0.410</td>
<td>0.145</td>
<td></td>
</tr>
<tr>
<td>1 year 0.632</td>
<td>0.300</td>
<td>0.487</td>
<td></td>
</tr>
<tr>
<td>2.5 years 0.415</td>
<td>0.473</td>
<td>0.469</td>
<td></td>
</tr>
<tr>
<td>3 years 0.723</td>
<td>0.613</td>
<td>0.828</td>
<td></td>
</tr>
</tbody>
</table>

Threshold @ 0.1% FAR = 0.615
## Fingerprint Verification (1:1 Comparison)

<table>
<thead>
<tr>
<th>Session gap</th>
<th>TAR@FAR=0.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 ppi DP sensor</td>
<td>1270 ppi NEC sensor</td>
</tr>
<tr>
<td>Age @ enrollment &gt;12 months</td>
<td>Age @ enrollment ≤ 3 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of subjects</th>
<th>119</th>
<th>47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 4 vs. 2</td>
<td>6 months</td>
<td>100% (100%)</td>
</tr>
</tbody>
</table>

95% accuracy for Infants > 6 months using 1270 ppi images
Summary

• Growing opportunities for large-scale child biometric systems

• The Dayalbagh longitudinal study shows fingerprint recognition is viable for infants

• Challenges:
  – Uncooperative subjects
  – Difficult capture conditions
  – Large scale de-duplication
  – Which biometric trait(s)?