Biometric Identification and Identical Twins

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What biometrics can tell "identical twins" apart, to what degree?

How and to what extent are "identical twins" different?

How do people distinguish between "identical twins"?
Distinguishing between pairs of identical twins is one the more challenging problems in face recognition.

https://www.youtube.com/watch?v=XGQAAAs5quf4
(classic)

https://www.youtube.com/watch?v=zV-Y0GBL5D8
(modern)
A detour through a computer scientist’s understanding of some biology about twins …
Frequency of Twins

- Twin birth rate: 33.7 per 1,000 live births in US in 2013 (CDC stats).
- About $\frac{3}{4}$ of twins are “fraternal” and $\frac{1}{4}$ are “identical”.
- More frequent for older mothers, and with use of fertility drugs; becoming more frequent overall.
Figure 5. Number and rate of twin births: United States, 1980–2013

NOTE: Access data table for Figure 5 at: http://www.cdc.gov/nchs/data/databriefs/db175_table.pdf#5.

Fraternal Twins

- Two different fertilized egg cells (zygotes)
- “Dizygotic” or DZ.
- No more genetically alike than non-twin siblings. (though they develop in the womb at the same time)
- Share 50% of genes.
“Identical” Twins

- Fertilized egg cell splits into two.
- “Monozygotic” or MZ.
- Two individuals with same genetic makeup,

But identical twins are not necessarily identical in appearance.
“Mirror” Identical Twins

- Single fertilized egg cell splits later than regular identical (at 9-12 days).
- Physical asymmetries expressed opposite: left / right handed, mirror-image dental irregularities, ...
- About ¼ of MZ twins are mirror.
Mirror Twins
Fascinating Facts About Mirror Image Twins

Mirror twins (also known as mirror image twins) are one of the most fascinating types of twin pairings of the 100 million+ twins all around the world. It's an interesting concept and refers to twins who, when facing each other, appear as matching reflections.

Identical and Non-Identical Twins
The majority of twins are not the rare mirror twins. Fraternal twins win the title of most common. Also known as dizygotic, fraternal twins are created from the fertilization of two separate eggs by two separate sperms. The resulting twins have half of the same DNA, the same as any other sibling, and may or may not have similar physical features.

Even More Complicated ...

- Identical twins can be monoamniotic or diamniotic.
- Identical twins can be monochorionic or dichorionic. (placenta)
- Monoamniotic is also monochorionic.
- Early-splitting zygotes are diamniotic and dichorionic.
Point to remember:
Reports of 100% accuracy on images of a few sets of twins may be an accident of the twins being mirror twins.
A long-held truism of biometrics …

By definition, identical twins cannot be distinguished based on DNA.


These twins are genetically identical, with the same chromosomes … they cannot be distinguished using the same DNA.

Turns out not to be true given the most recent DNA analysis techniques …

Finding the needle in the haystack: Differentiating “identical” twins in paternity testing and forensics by ultra-deep next generation sequencing

Jacqueline Weber-Lehmann, Elmar Schilling, Georg Gradl, Daniel C. Richter, Jens Wiehler, Burkhard Rolf*
Where do you get biometric datasets of identical twins?
Twins Days Festival in Twinsburg, Ohio

The World's Largest Annual Gathering of Twins! Next Festival: Aug 7-9, 2015

Welcome

Come celebrate Twins Days' 40th!

The Twins Days Festival in Twinsburg, Ohio is the largest annual gathering of twins (& other multiples) in the world! 2015 marks a major milestone for the Twins Days Festival and its twin family...its 40th festival!

https://www.youtube.com/watch?v=uQJH64QyzPs
• ND-TWINS-2009-2010. The data set contains 24050 color photographs of the faces of 435 attendees at the Twins Days Festivals in Twinsburg, Ohio in 2009 and 2010. All images were captured by Nikon D90 SLR cameras. Images were captured under natural light in "indoor" and "outdoor" configurations ("indoor" was a tent). Facial yaw varied from -90 to +90 degrees in steps of 45 degrees (zero degrees was frontal). To obtain access to this data set, retrieve the license agreement and

• 3D Twins Expression Challenge ("3D TEC") Dataset. The data set contains 3D face scans for 107 pairs of twins. There are $107 \times 2 = 214$ individuals, each with a 3D face scan with a smiling expression and a scan with a neutral expression, and so $214 \times 2 = 428$ total scans. The scans were acquired with a Minolta Vivid 910. To obtain access to this data set, retrieve the license agreement and forward it to your institution or

http://www3.nd.edu/~cvrl/CVRL/Data_Sets.html
How hard is it for face recognition algorithms to tell twins apart?
Impostor distribution for images of twins

Impostor distribution for images of non-twins
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.2%</td>
<td>0.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>A</td>
<td>4.7%</td>
<td>5.9%</td>
<td>11.5%</td>
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<td>B</td>
<td>35.9%</td>
<td>40.7%</td>
<td>41.4%</td>
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<tr>
<td>C</td>
<td>9.0%</td>
<td>34.1%</td>
<td>32.3%</td>
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<tr>
<td>D</td>
<td>14.5%</td>
<td>20.9%</td>
<td>26.5%</td>
</tr>
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<td>E</td>
<td>10.2%</td>
<td>13.8%</td>
<td>24.0%</td>
</tr>
<tr>
<td>F</td>
<td>7.3%</td>
<td>12.4%</td>
<td>19.4%</td>
</tr>
<tr>
<td>G</td>
<td>8.0%</td>
<td>7.8%</td>
<td>16.2%</td>
</tr>
</tbody>
</table>

A to G = 3 top alg’s in MBE 2010 + 4 commercial.
Baseline = Algorithm A with non-twin impostor pairs.
### EER Results for Cross-Year Illumination

<table>
<thead>
<tr>
<th>Alg.</th>
<th>Probe-Gallery Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cont.-Cont.</td>
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<tr>
<td>Baseline</td>
<td>0.8%</td>
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<tr>
<td>A</td>
<td>12.8%</td>
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<tr>
<td>B</td>
<td>43.3%</td>
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<tr>
<td>C</td>
<td>41.9%</td>
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<tr>
<td>D</td>
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</tr>
<tr>
<td>E</td>
<td>49.3%</td>
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<tr>
<td>F</td>
<td>49.3%</td>
</tr>
<tr>
<td>G</td>
<td>49.5%</td>
</tr>
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Best algorithm EER on twins is 13% to 17%.
## EER Results for Cross-Year Expression

<table>
<thead>
<tr>
<th>Alg.</th>
<th>Neutral-Neutral</th>
<th>Neutral-Smiling</th>
<th>Smiling-Smiling</th>
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<tbody>
<tr>
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<tr>
<td>A</td>
<td>8.6%</td>
<td>15.8%</td>
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<tr>
<td>B</td>
<td>42.7%</td>
<td>46.0%</td>
<td>44.9%</td>
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<tr>
<td>C</td>
<td>34.8%</td>
<td>55.5%</td>
<td>35.7%</td>
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<tr>
<td>D</td>
<td>31.2%</td>
<td>32.0%</td>
<td>25.7%</td>
</tr>
<tr>
<td>E</td>
<td>48.8%</td>
<td>47.4%</td>
<td>50.1%</td>
</tr>
<tr>
<td>F</td>
<td>47.4%</td>
<td>50.0%</td>
<td>52.0%</td>
</tr>
<tr>
<td>G</td>
<td>48.4%</td>
<td>50.0%</td>
<td>49.8%</td>
</tr>
</tbody>
</table>

Best algorithm EER of 9% to 16%.
<table>
<thead>
<tr>
<th>Alg.</th>
<th>Probe-Gallery Conditions</th>
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<th></th>
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</thead>
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<tr>
<td></td>
<td>Male</td>
<td>Female</td>
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<tr>
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<td>A</td>
<td>6.5%</td>
<td>13.7%</td>
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</tr>
<tr>
<td>B</td>
<td>46.7%</td>
<td>43.6%</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>39.7%</td>
<td>46.9%</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>23.6%</td>
<td>29.0%</td>
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</tr>
<tr>
<td>E</td>
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<td>50.8%</td>
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<td>F</td>
<td>47.1%</td>
<td>50.3%</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>43.5%</td>
<td>51.3%</td>
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</table>

Best algorithm EER of about 7% to 14%.
### EER Results for Cross-Year Age

<table>
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<tr>
<td>A</td>
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<td>B</td>
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<td>C</td>
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<tr>
<td>D</td>
<td>29.7%</td>
</tr>
<tr>
<td>E</td>
<td>20.4%</td>
</tr>
<tr>
<td>F</td>
<td>23.9%</td>
</tr>
<tr>
<td>G</td>
<td>21.1%</td>
</tr>
</tbody>
</table>

Best algorithm EER of about 15% to 16%.
Point to remember. Twin discrimination by face analysis is hard, with room for improvement that could help face recognition in general.
How do humans perform at distinguishing identical twins from facial appearance?
Twins or images of same person?
Twins or images of same person?
Twins or images of same person?
Twins or images of same person?
Twins or images of same person?
Humans are more accurate than current face matching algorithms.
Humans do better with more time.
Humans appear to use skin markings as a major factor in this task.
Point to remember.
Humans appear to learn to discriminate twins by interpreting skin marks in a “forensic” manner.

(This interpretation is compatible with results by Sarah Stevenage, *British Journal of Psychology*, 2011.)
What about 3D face analysis for identical twins?
Figure 1: Images of two twins acquired in a single session. The top row shows the images obtained from one twin and the bottom row, the other twin. The left two images contain the neutral expression. The right two are of the smiling expression. (The texture images were brightened to increase visibility in this figure.)
- Minolta 910 with “tele” lens.
- About 100K points on face.
- 107 pairs of twins.
- Smile + neutral expression.
- “Same session” data.
<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Rank-1 Recognition Rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Alg. 1 ($E_{pkn}$)</td>
<td>93.5%</td>
</tr>
<tr>
<td>Alg. 1 ($E_{minmax}$)</td>
<td>94.4%</td>
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<tr>
<td>Alg. 2 (SI)</td>
<td>92.1%</td>
</tr>
<tr>
<td>Alg. 2 (eLBP)</td>
<td>91.1%</td>
</tr>
<tr>
<td>Alg. 2 (Range PFI)</td>
<td>91.6%</td>
</tr>
<tr>
<td>Alg. 2 (Text. PFI)</td>
<td>95.8%</td>
</tr>
<tr>
<td>Alg. 3</td>
<td>62.6%</td>
</tr>
<tr>
<td>Alg. 4</td>
<td>98.1%</td>
</tr>
</tbody>
</table>

Alg. 4 = I. Kakadiaris, U. of Houston’s “UR3D”.
Good, but compare to performance on FRGC v2.
What about irises of identical twins?
“... comparisons among the eyes of actual monozygotic twins also yielded a result expected for unrelated eyes ...”

Verification of John Daugman’s claim.
Twins or Unrelated?
Twins.
Twins or Unrelated?
Twins or Unrelated?
Twins.
Twins or Unrelated?
Unrelated.
Twins or Unrelated?
Twins.
Twins or Unrelated?
Unrelated.
76 pairs of twins, plus non-twins.
Image pair presented for 3 sec.
5-point response scale.
Over 80% accurate in twins / non-twin classification.
92% - 93% accuracy for “certain” responses.
Point to remember.
Humans readily perceive iris texture similarity that current iris recognition technology does not.
What about fingerprints of identical twins?
Essence of Jain et al conclusions:

- Twin prints match more closely than those of unrelated persons.
- Twin prints very likely to have same print category: whorl, ...
- Twin prints may be like matching unrelated person prints within the same category.
Point to remember. Fingerprints do allow reliable means of distinguishing between identical twins.
Twins studies have been done for various additional modalities:

- Speaker identification
- Handwriting
- Gait
- Ear
- …
Limitations of biometric studies of twins to date include:

- “Small” size of dataset
- Over-focus on identical twins without fraternal twins, siblings
- Lack of verified MZ status
- Focus on one or a small number of biometrics
Questions?
Figures and tables in this talk are borrowed from:


http://www3.nd.edu/~kwb/PaoneEtAlTIFS_2014.pdf


http://www3.nd.edu/~kwb/VijayanEtAllJCB_2011.pdf


