Fingerprints, forever young?

Roman Kessler
roman.kessler@stud.h-da.de

Hochschule Darmstadt, ATHENE, da/sec Research Group

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Fingerprint (Template) Ageing

A decrease in mated similarity score,
with increasing time interval
between reference and probe image.

Fingerprint (Template) Ageing

children

- fingerprints grow uniformly into each direction
  e.g.
  - Gottschlich, Carsten; Hotz, Thomas; Lorenz, Robert; Bernhardt, Stefanie; Hantschel, Michael; Munk, Axel (2011). Modeling the Growth of Fingerprints Improves Matching for Adolescents. IEEE Transactions on Information Forensics and Security
  - Haraksim, Rudolf; Galbally, Javier; Beslay, Laurent (2019). Fingerprint growth model for mitigating the ageing effect on children's fingerprints matching. Pattern Recognition
  - Galbally, Javier; Haraksim, Rudolf; Beslay, Laurent (2018). A Study of Age and Ageing in Fingerprint Biometrics. IEEE Transactions on Information Forensics and Security

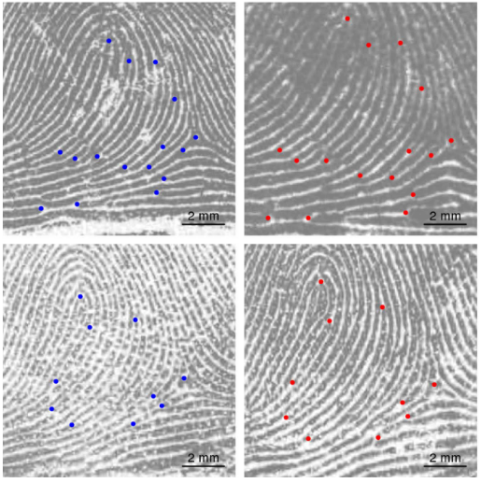

Figure adapted from: Gottschlich, T. Hotz, R. Lorenz, S. Bernhardt, M. Hantschel, and A. Munk, "Modeling the growth of fingerprints improves matching for adolescents"

Fingerprint (Template) Ageing

adults

- mated similarity scores decrease with increasing time between samples
- decreasing image quality $\longrightarrow$ decreasing similarity score
- e.g.
  - Arnold, M.; Busch, C.; Ihmor, H. (2005). [IEEE Proceedings from the Sixth Annual IEEE Systems, Man and Cybernetics (SMC) Information Assurance Workshop, 2005
  - Yoon, Soweon, and Anil K. Jain. "Longitudinal study of fingerprint recognition." Proceedings of the National Academy of Sciences
  - Galbally, Javier; Haraksim, Rudolf; Beslay, Laurent (2018). A Study of Age and Ageing in Fingerprint Biometrics. IEEE Transactions on Information Forensics and Security
  - Kirchgasser, Simon; Uhl, Andreas (2017). [IEEE 2017 IEEE International Conference on Identity, Security and Behavior Analysis (ISBA) - New Delhi, India

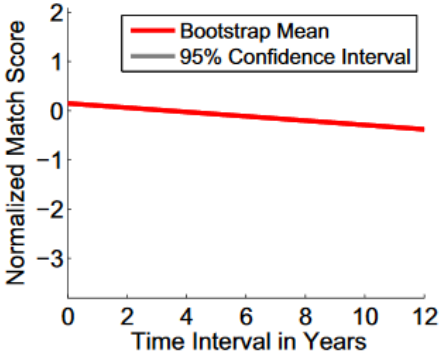

Figure adapted from: Yoon, Soweon, and Anil K. Jain. "Longitudinal study of fingerprint recognition." Proceedings of the National Academy of Sciences

Methods

data & subjects

- fingerprint scanner
  - capacitive (UPEK TouchChip)
  - embedded in an access control framework
  - 508 ppi
  - 256×360 px
- data subjects
  - $n = 20$ (6 females)
  - $21 - 58$ years (Md. 31) at enrolment
  - $1 - 4$ finger instances per data subject (left/right index finger/thumb)
  - $3 - 1772$ samples per finger
  - up to 12 years between samples

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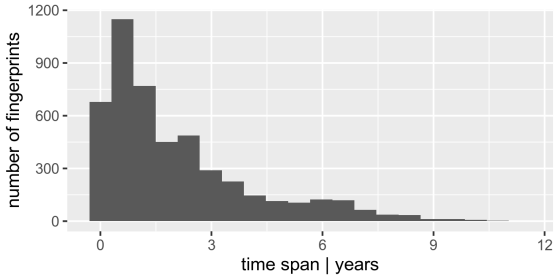

image processing

- FingerNet framework
  (minutia extraction)
  Tang, F. Gao, J. Feng, and Y. Liú, "FingerNet: A unified deep network for fingerprint minutiae extraction"
- Minutia Cylinder Code
  ($\longrightarrow$ mated similarity scores)
  Cappelli, M. Ferrara, and D. Maltoni, "Minutia cylinder-code: A new representation and matching technique for fingerprint recognition"
- NFIQ2.0
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  https://www.nist.gov/publications/fingerprint-image-qualitiy
- filtering procedure
  - only impressions with quality score > 10
  - only impressions with > 16 Minutia
  - keep only instances with a time interval > 1 year

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Hierarchical Linear Modeling (HLM)

- research question: *Can we find support for fingerprint template ageing?*
- operationalization: mated similarity scores should decrease with increasing time interval
- consider: fingerprint quality und sociodemographic factors
- modeling:

$$y_{ij} = \underbrace{\beta_0 + \beta_1 \cdot x_{ij} + \beta_2 \cdot q_{ij} + \alpha_i + \gamma_i}_{\text{fixed effects}} + \underbrace{b_{0i} + b_{1i} \cdot x_{ij} + b_{2i} \cdot q_{ij} + e_{ij}}_{\text{random effects}}$$

- model reduction

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Results

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Model backwards regression: what do eliminated terms tell us about the data?

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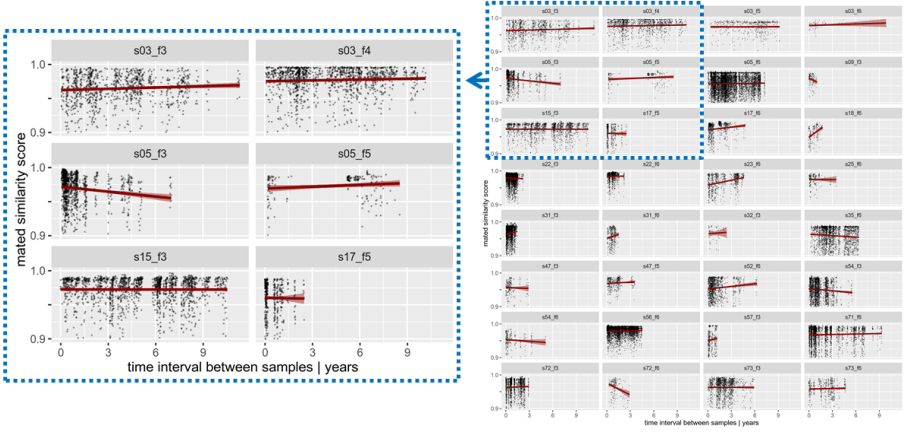
Effects on mated similarity score:

- **global** (i.e. fixed) intercept is high (high similarity scores between samples acquired closely in time)
- no **global** effect of increasing time interval
- no **global** effect of image quality
- no **global** effect of age and gender
- random intercept: significant, subject-specific deviations in intercept
- **within-subject** (i.e. random) effect of increasing time interval
- **within-subject** effect of image quality

Results

mated similarity scores behave differently within different finger instances



Results

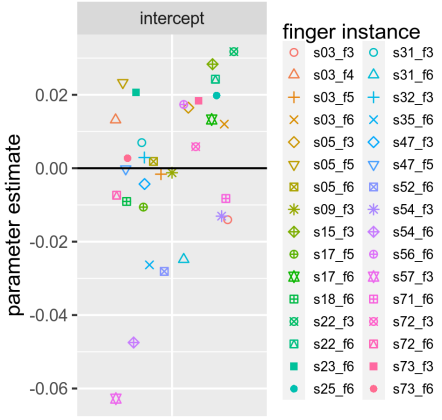
How much variability in the data is explained by each random effects term?

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + \beta_2 q_{ij} + \alpha_i + \gamma_i + b_{0i} + b_{1i} \cdot x_{ij} + b_{2i} \cdot q_{ij} + e_{ij}$$

Effects on mated similarity score:

- random intercept: 38%
- time interval: 0.5%
- image quality: 0.05%
- random error: 61%

subjects score differently well



Conclusion

Summary of findings, limitations & possible implications

- no general **fingerprint template ageing**
- no general effect of image quality
- high inter-individual variability of mated similarity scores

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Yes - at least during long periods of professional life!

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Roman Kessler
Hochschule Darmstadt, Germany &
Laboratory for Multimodal Neuroimaging
University of Marburg, Germany
roman.kessler@stud.h-da.de

Olaf Henniger
Fraunhofer Institute for
Computer Graphics Research IGD
Darmstadt, Germany
olaf.henniger@igd.fraunhofer.de

Christoph Busch
Hochschule Darmstadt, Germany &
NTNU Gjøvik, Norway
christoph.busch@h-da.de