Guidelines for Appropriate Use of Simulated Data from Bio-authentication Research $^{ab}$

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Outline

1. Introduction to Simulation
2. Taxonomy of Data
3. Guidelines
4. Illustrations
Simulation

Current Debate:

One side: Simulation is very, very bad.

Other side: Simulation is very, very good.

This talk: We offer a third way.

Simulation can be good but . . .

under what conditions?
Taxonomy

If we want to simulate data, what data?

• Images
• Features
• Match/Similarity Scores
• Decisions
Taxonomy of Biometric Data

- **Image data** - Collection of image
  E.g. raw ‘picture’ of biometric image

- **Feature data** - Measurements of features
  E.g. Iris Densities, FP minutiae, intra-pupil distance

- **Match Score data** - Distance metric
  E.g. Match Scores, Normalized scores, Hamming distance, Multi-modal

- **Decision data** - Binary Decision
  Accept or Reject, Allow or Deny Access
Notation

Let $X \sim F(X \mid \theta)$ represent the cdf of our simulation model where $X$ is a RV representing the data and

$\theta$ represents the parameters of the simulation model

Let $\hat{F}(x \mid \hat{\theta})$ represent the estimated cdf where $x$ is the realized data and

$\hat{\theta}$ represents estimates of $\theta$ using the data, $x$. 


Guidelines

Three criteria for simulation

1. Flexibility
2. Parsimonious
3. Goodness-of-Fit
Flexibility and Parsimony

Simulation needs

• Random generation via cdf say $F(X \mid \theta)$

• Enough parameters to capture data complexity

But ...

• Simple as need be
Goodness-of-fit

Idea:
Is \( \hat{F}(x | \hat{\theta}) \) similar to \( F(X | \theta) \)?

Examples

- Kolmogorov-Smirnov
- Anderson-Darling
- QQ-plot

Garren et al. (2001)
Illustrations

Data: Genuine Facial Matching Scores

Source: Michigan State University, Ross and Jain (2003)

Model: $X \sim log-normal(\mu, \sigma)$

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma x} e^{-\frac{(\log x - \mu)^2}{2\sigma^2}}, x \in (-\infty, \infty) \quad (1)$$

Estimation via MLE
Illustrations

Data: Imposter Facial Matching Scores

Source: Michigan State University, Ross and Jain (2003)

Model: $X \sim \text{Weibull}(\alpha, \beta)$

$$f(x) = \frac{\alpha}{\beta} \left( \frac{x}{\beta} \right)^{\alpha-1} e^{-\left( \frac{x}{\beta} \right)^\alpha}$$  \hspace{1cm} (2)

Estimation via MLE
Histogram of facial image match scores

(a). Genuine matching scores (b). Imposter matching scores.
Illustrations

Data: Genuine/Imposter Face, Finger, Hand Geometry Matching Scores

Source: Michigan State University, Ross and Jain (2003)

Model: Various Models (see next slide)

Estimation via MLE
## Kolmogorov Goodness-of-Fit Tests

<table>
<thead>
<tr>
<th>Modality</th>
<th>Population</th>
<th>Fitted Distribution</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Face</td>
<td>Genuine</td>
<td>Log-Normal</td>
<td>0.3030</td>
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<tr>
<td></td>
<td>Imposter</td>
<td>Weibull</td>
<td>0.1800</td>
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<tr>
<td>Hand Geometry</td>
<td>Genuine</td>
<td>Gamma</td>
<td>0.1640</td>
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<tr>
<td></td>
<td>Imposter</td>
<td>Log-Normal</td>
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<tr>
<td>Fingerprint</td>
<td>Genuine (transformed)</td>
<td>Gamma</td>
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<tr>
<td></td>
<td>Imposter</td>
<td>Truncated Mixture Normal</td>
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</tbody>
</table>
Empirical CDF and theoretical CDF

(a). Face genuine (b). Hand geometry genuine (c). Fingerprint genuine
(d). Face imposter (e). Hand geometry imposter (f). Fingerprint imposter
Decision Data

Schuckers (2003) used Beta-binomial to model Decision Data

Data: Face, Fingerprint, Hand geometry Decision data

Source: Michigan State University, Ross and Jain (2003)

Model: $X \sim Betabin(m, \pi, \rho)$
**Goodness-of-fit Hand Geometry FMR**

<table>
<thead>
<tr>
<th>Threshold</th>
<th>$\hat{\pi}$</th>
<th>p-value</th>
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<td>0.1136</td>
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<td>70</td>
<td>0.0637</td>
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## Goodness-of-fit Facial FNMR

<table>
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<th>( \hat{\pi} )</th>
<th>p-value</th>
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<td>105</td>
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Summary

• Third approach to use of simulation: model but verify
• Guidelines: Flexible, parsimonious, consistent
• Taxonomy of data
• Illustrated methods
Thank You

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