Information content of biometric features

Andy Adler, Richard Youmaran, Sergey Loyka

University of Ottawa,
Canada

Question:
How much information is in a biometric measurement?

Or

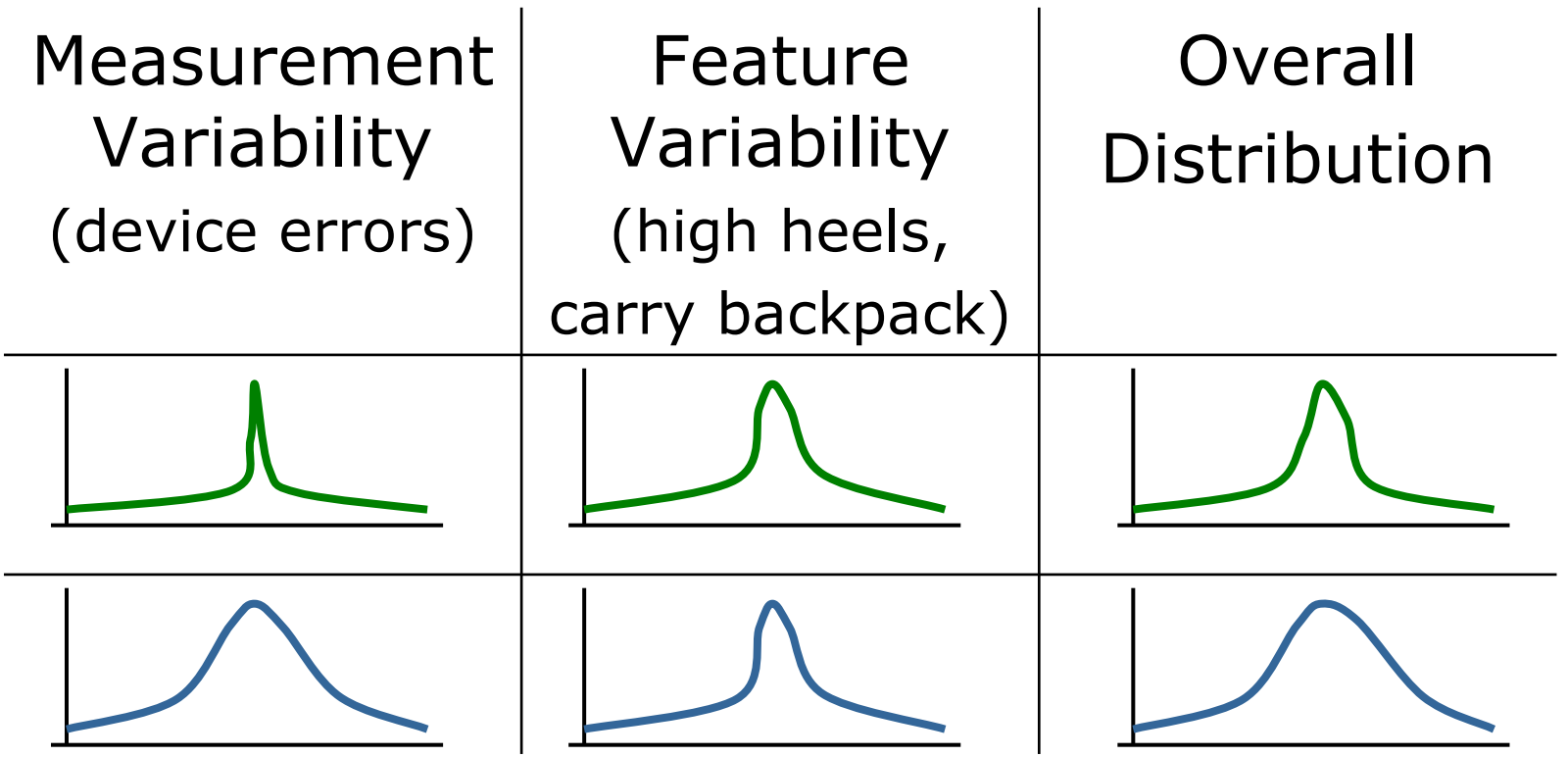
- How much do we learn (about identity) from a biometric image

Or

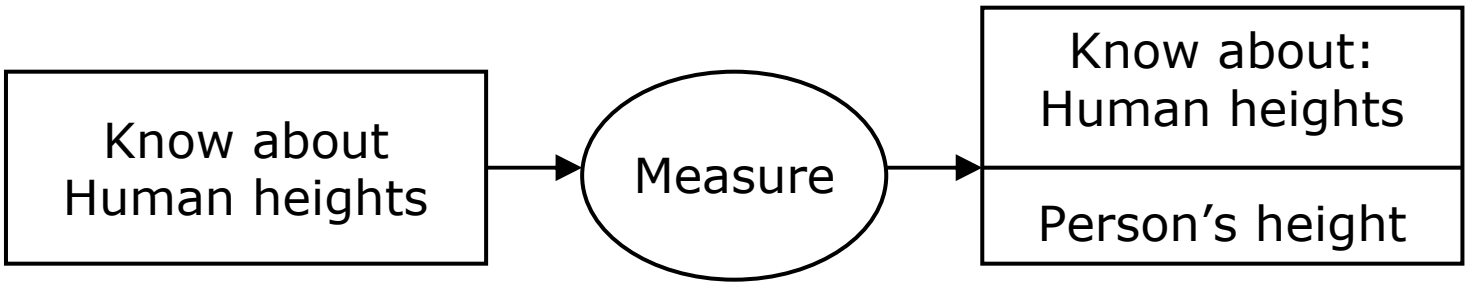
- How much privacy do we loose on releasing a biometric image

Example: measure *Height*

- Measure #1 (at doctor's office, ie. accurate)
- Measure #2 (via telescope, ie. inaccuate)



Example: measure *Height*



- How much information learned?

	Average (5½′ tall)	Tall (7½′ tall)
Measure #1	Low	Quite a lot
Measure #2	Almost zero	Low

Proposed measure: *relative entropy* $D(p||q)$

- Given biometric feature vector **x**
- Distributions
  - intra-person distribution, $p(\mathbf{x})$
  - inter-person distribution, $q(\mathbf{x})$
- $D(p||q)$ measures inefficiency of assuming q when true distribution is p

Or,

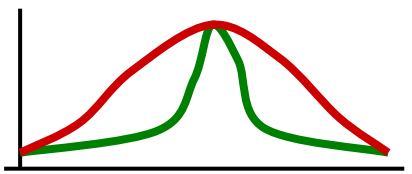
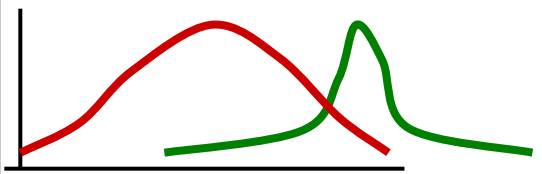
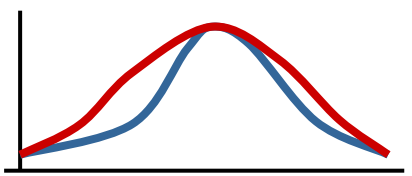
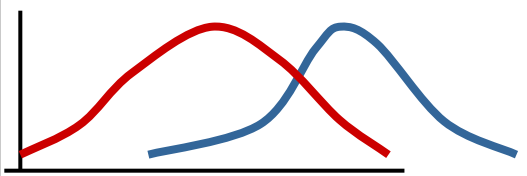
- $D(p||q)$ measures extra information in p than q

Relative entropy

$$D(p \,\|\, q) = \int p(\mathbf{x}) \log_2 (p(\mathbf{x}) / q(\mathbf{x}))\, d\mathbf{x}$$

- Need to calculate feature distributions
  - Population (q)
  - Individuals (p)
- Real features are correlated (eg. height and weight)
- Entropy, $H(\mathbf{x})$, is not appropriate
  - Doesn't account for individual variability (p)
  - Example: if hair is blue in face image, that is not information for identity

Relative Entropy for height

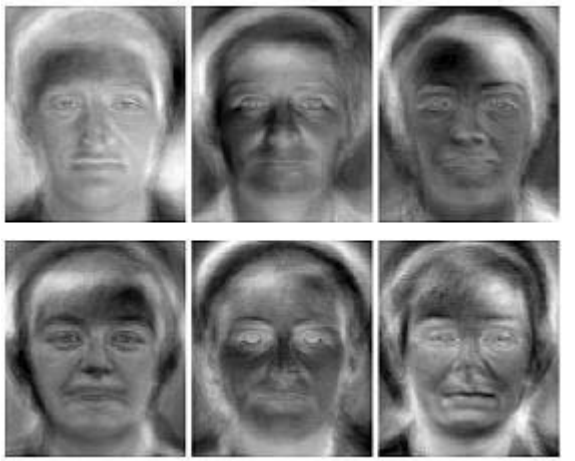
	Average (5½′ tall)	Tall (7½′ tall)
Measure #1 (accurate)	 D = 0.23 bits	 D = 2.7 bits
Measure #2 (inaccurate)	 D = 0.05 bits	 D = 1.1 bits

Example 2: *Face Recognition*

Motivation:

- Eigenface feature dimensionality is constant (unlike FP minutiae)
- Our work with biometric encryption with FR fit about 20 bits of key
- Explore ways to understand human ability to identify faces

Approach



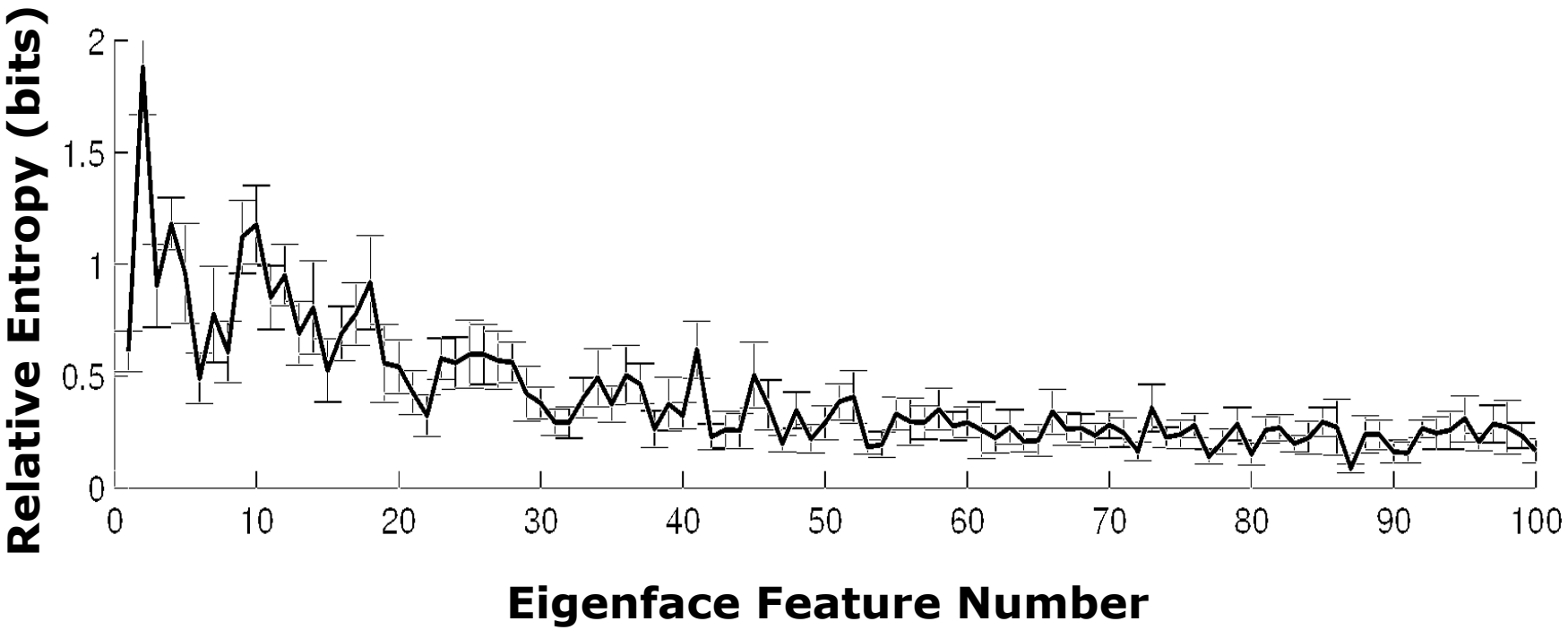
- Decompose faces to eigenface features
- Fit features to Gaussian
  - Mean $\boldsymbol{\mu_q}$, $\boldsymbol{\mu_p}$
  - Covariance $\boldsymbol{\Sigma_q}$, $\boldsymbol{\Sigma_p}$
- Calculate $D(p||q)$ for each individual
- Average $D(p||q)$ for all indivduals

Face Database

- Used Aberdeen Face database
  - 18 frontal images of 16 persons
  - Variability in lighting and expression between images

- Correlation calculations are limited
  - Given 18 images, $\boldsymbol{\Sigma_p}$ is non-singular for more than 17 features
  - Don’t calculate overall information

Average Information per feature



- Most informative feature: #2
- Decreasing information with EF number

Applications: *biometric*

- Meta algorithm
  - Evaluate a new biometric feature
- Biometric Performance limits
  - Template size limits
  - Inherent match performance limits
- Feasibility of Biometric Encryption
  - Limits to Key Length

Applications: *abstract*

- Quantify privacy
  - What is the privacy risk due to the release of certain information?
  - What is the privacy gain in obscuring faces?
- Uniqueness of biometrics
  - Approach to address: “Are faces / fingerprints / irises unique?”

Issues with biometric features

- Calculation requires feature representation
- Feature dimension may not be constant
  - Fingerprint minutiae
- Raw images must be aligned and scaled
  - Errors in pre-processing will affect measure

Issues with Entropy measure

- Features are correlated
  - e.g. height and weight
  - Multiple measures of same underlying feature (PCA vs. ICA Face Rec.)
- Feature distributions are complex
  - Gaussian model used is not correct for minutiae angle
- Lots of data required to model
  - Currently researching approaches using less data

Conclusions

- Approach to measuring information content of a biometric system
- Relative Entropy is appropriate measure
- Help explain *legal, social, performance* issues