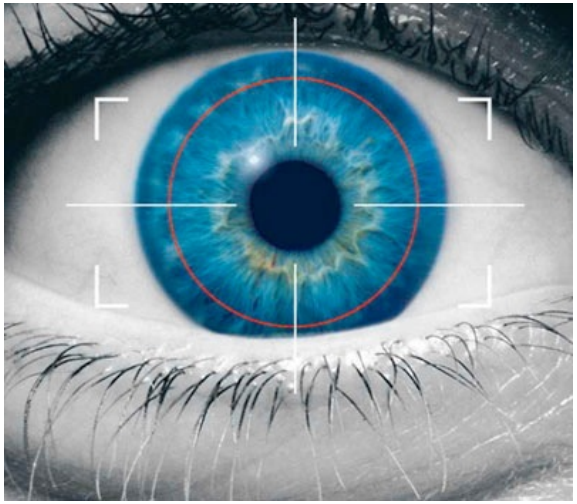
Biometrics - Trust But Test

Tomáš Rosa

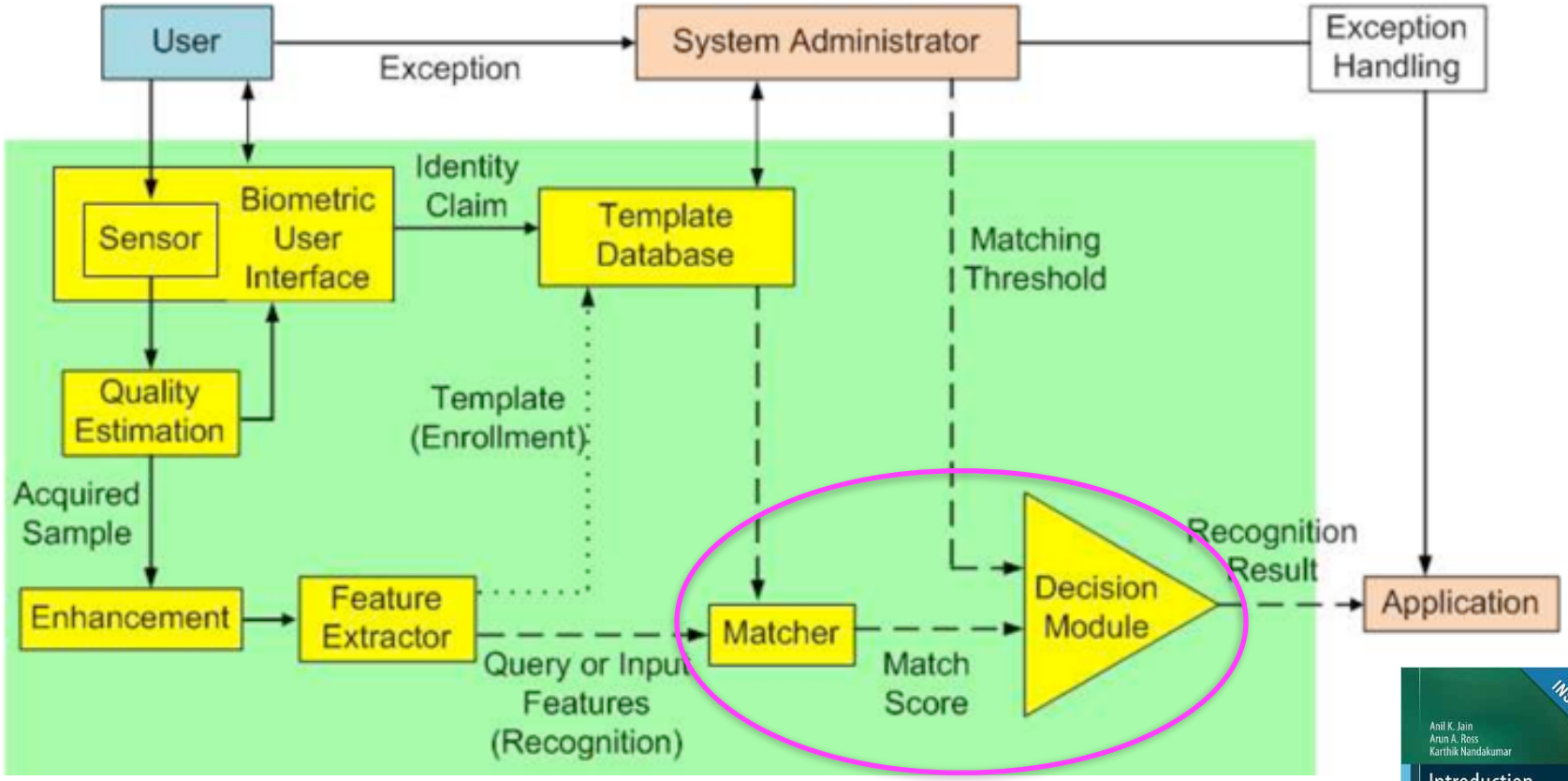
crypto.hyperlink.cz

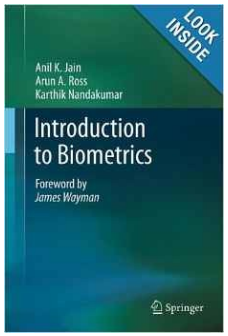
Biometric Identification/Verification

...automated establishment of a human identity based on their physical or behavioral characteristics.



Biometric System Topology



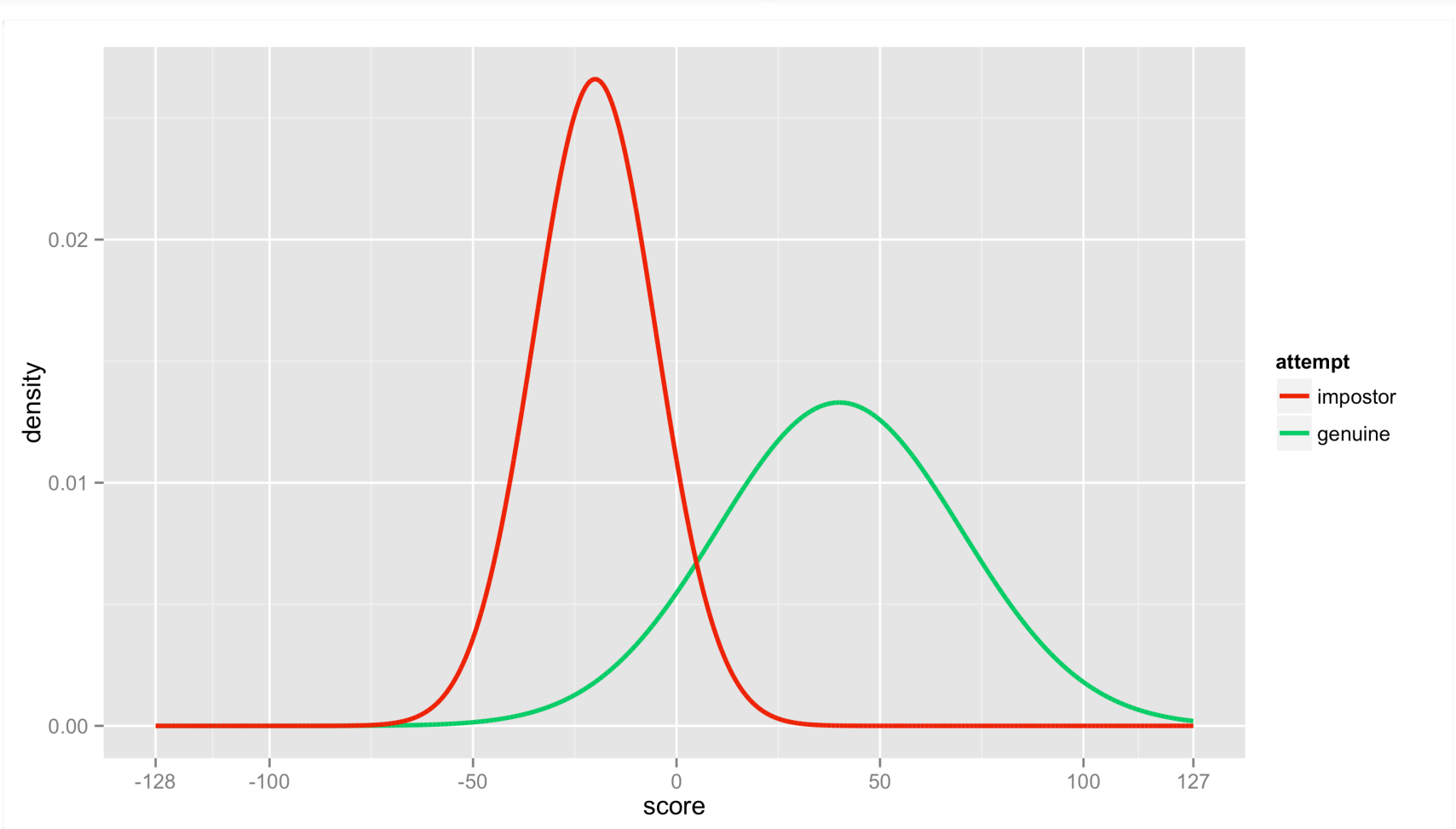


Jain, Ross, and Nandakumar: Introduction to Biometrics, Springer, 2011

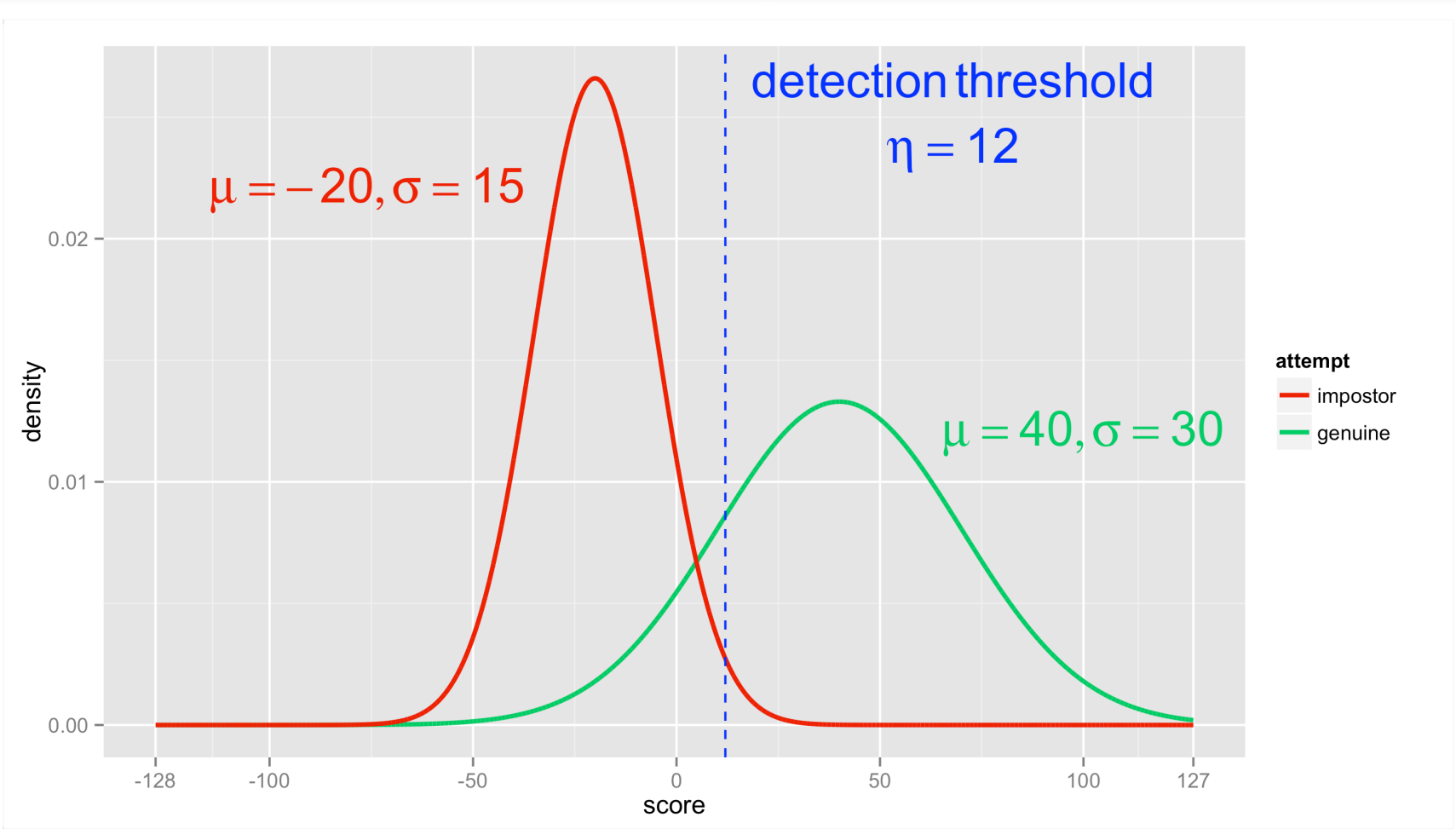
Match Score

- It would be nice if we had a simple true/false result.
  - As in conventional crypto.
  - But we cannot...
- All we have is a value of random variable *X* that follows two conditional distributions.
  - $f(x \mid \text{impostor})$
  - $f(x \mid \text{genuine})$

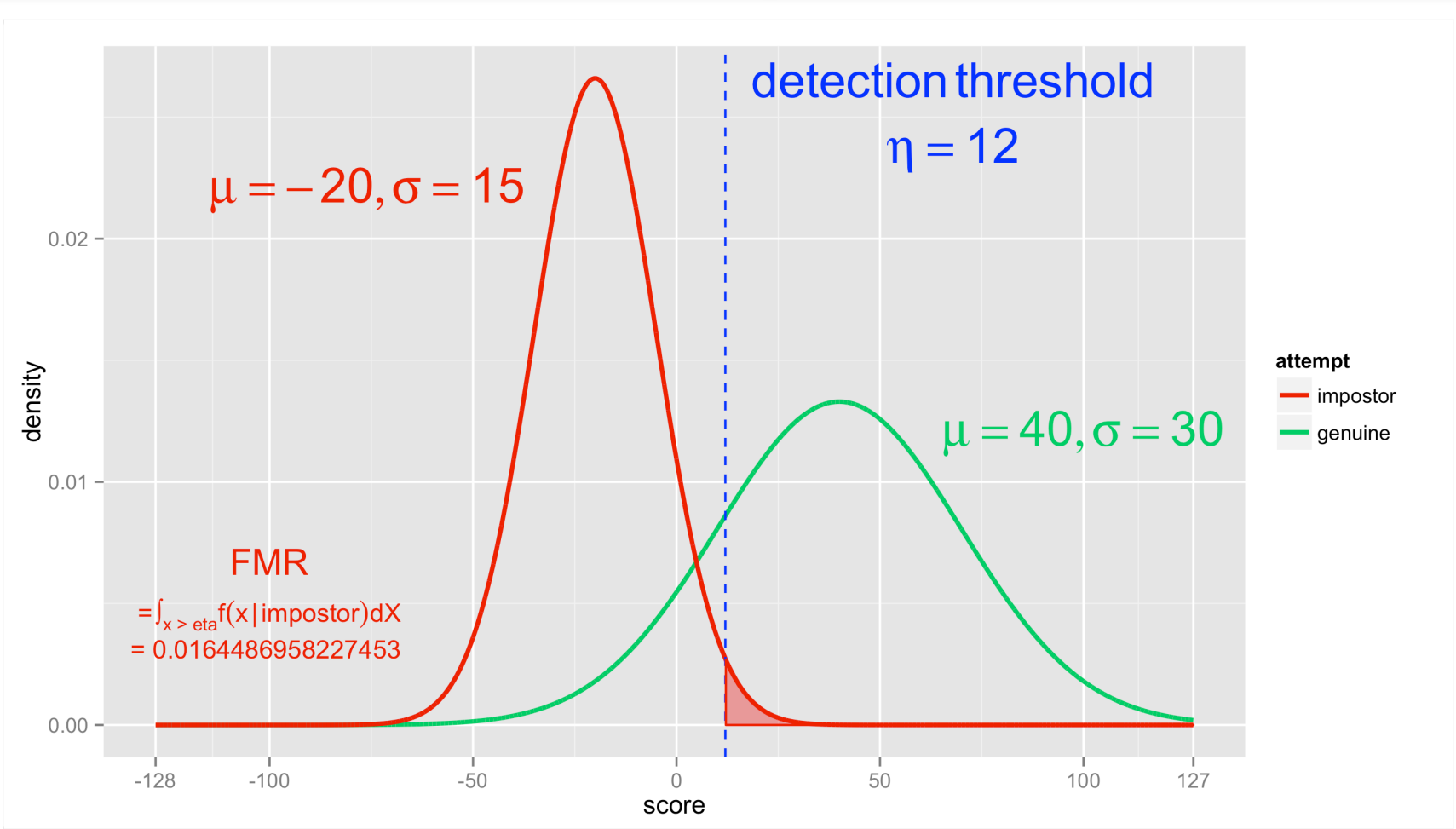
Base “Camel” Graph



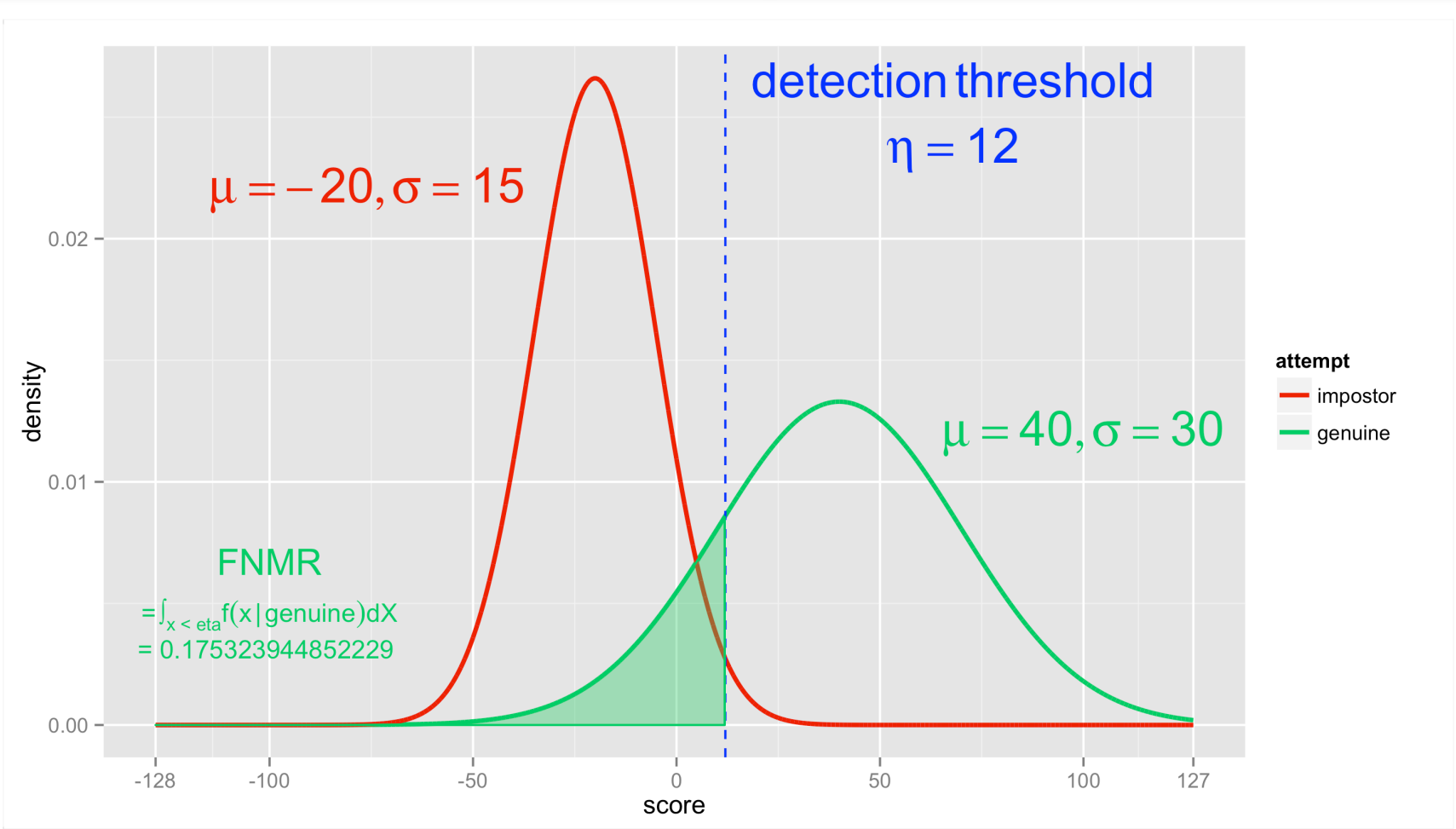
Signal Detection Approach



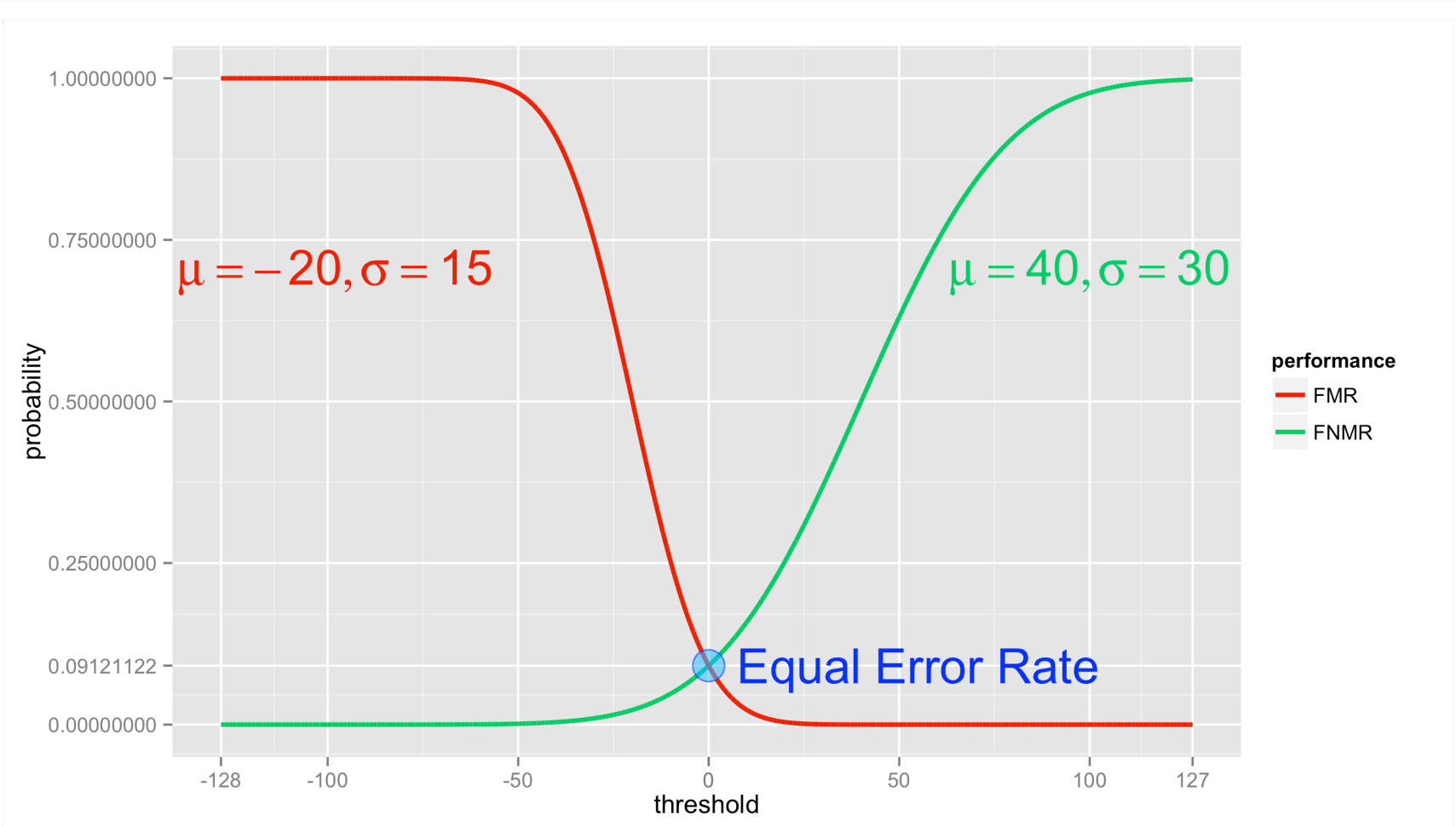
False Match Rate



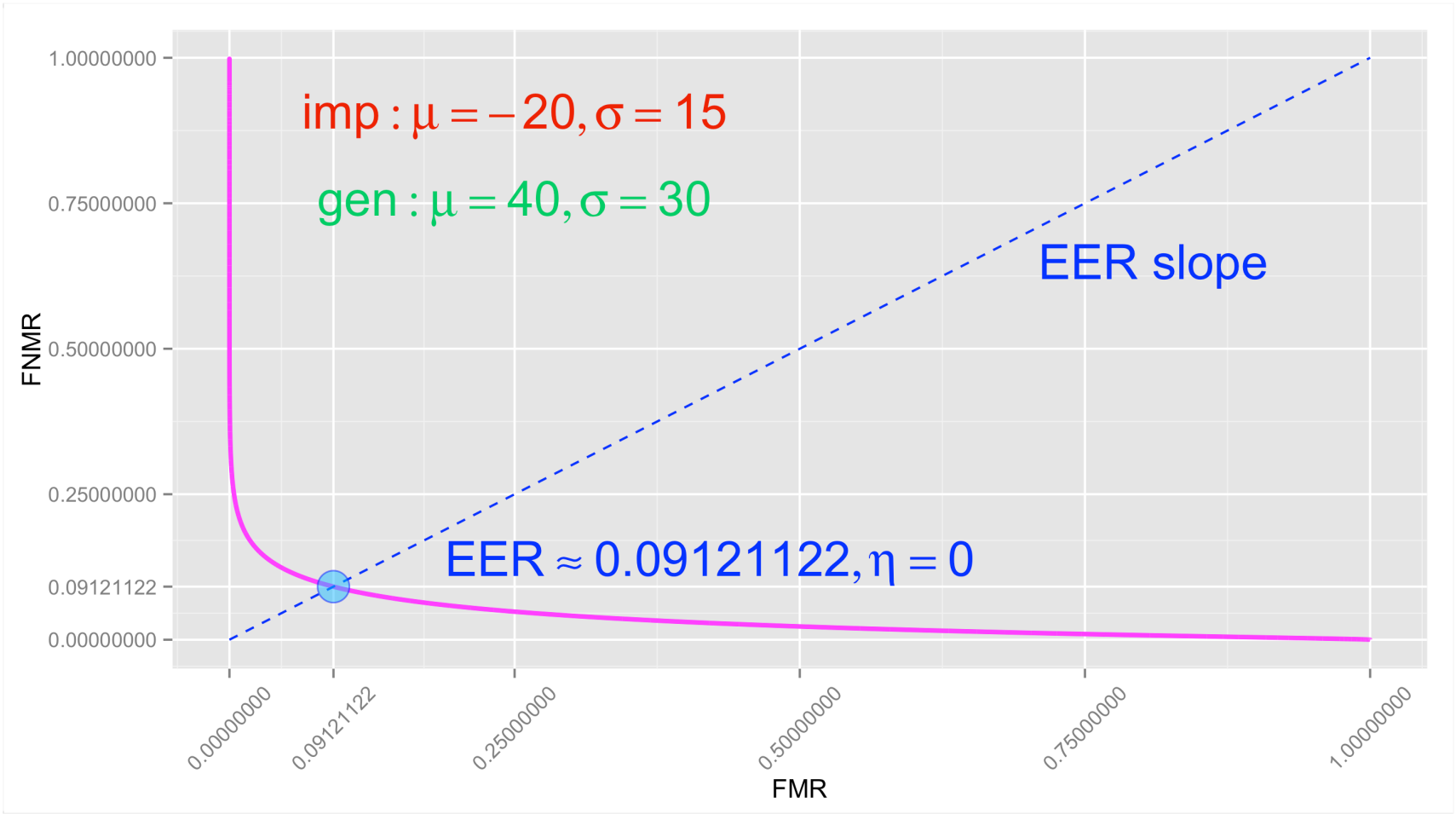
False Non-Match Rate



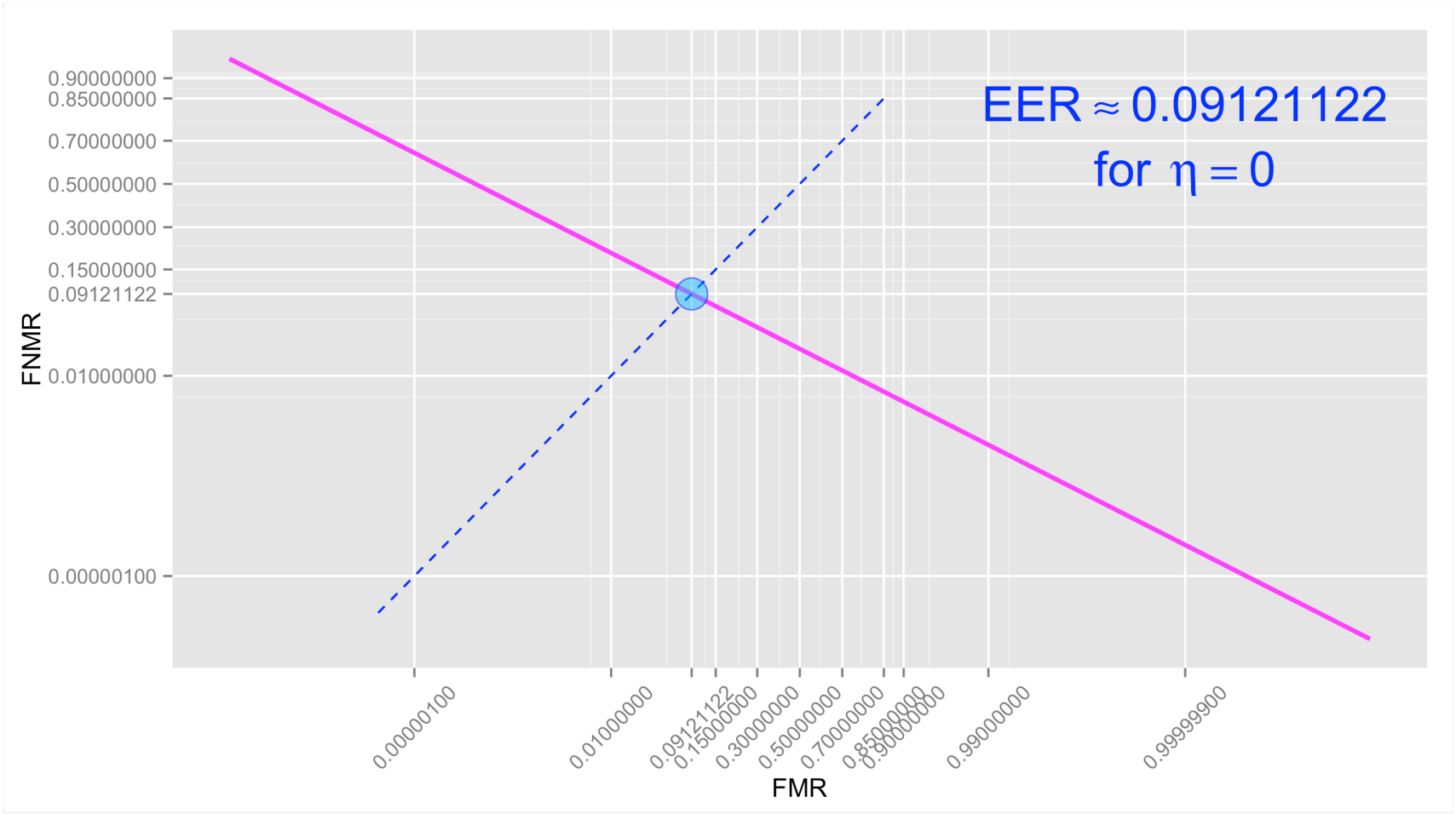
Error Distribution Functions



Receiver Operating Characteristics



Detection Error Trade-Off



ISO/IEC 19795

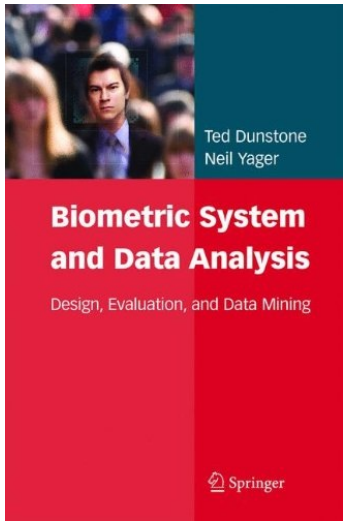
- Performance test methodologies for different life-cycle phases:
  - technology evaluation
  - scenario evaluation
  - operational evaluation
- We get comparable results with plausible confidence intervals.

Bunch of Parameters

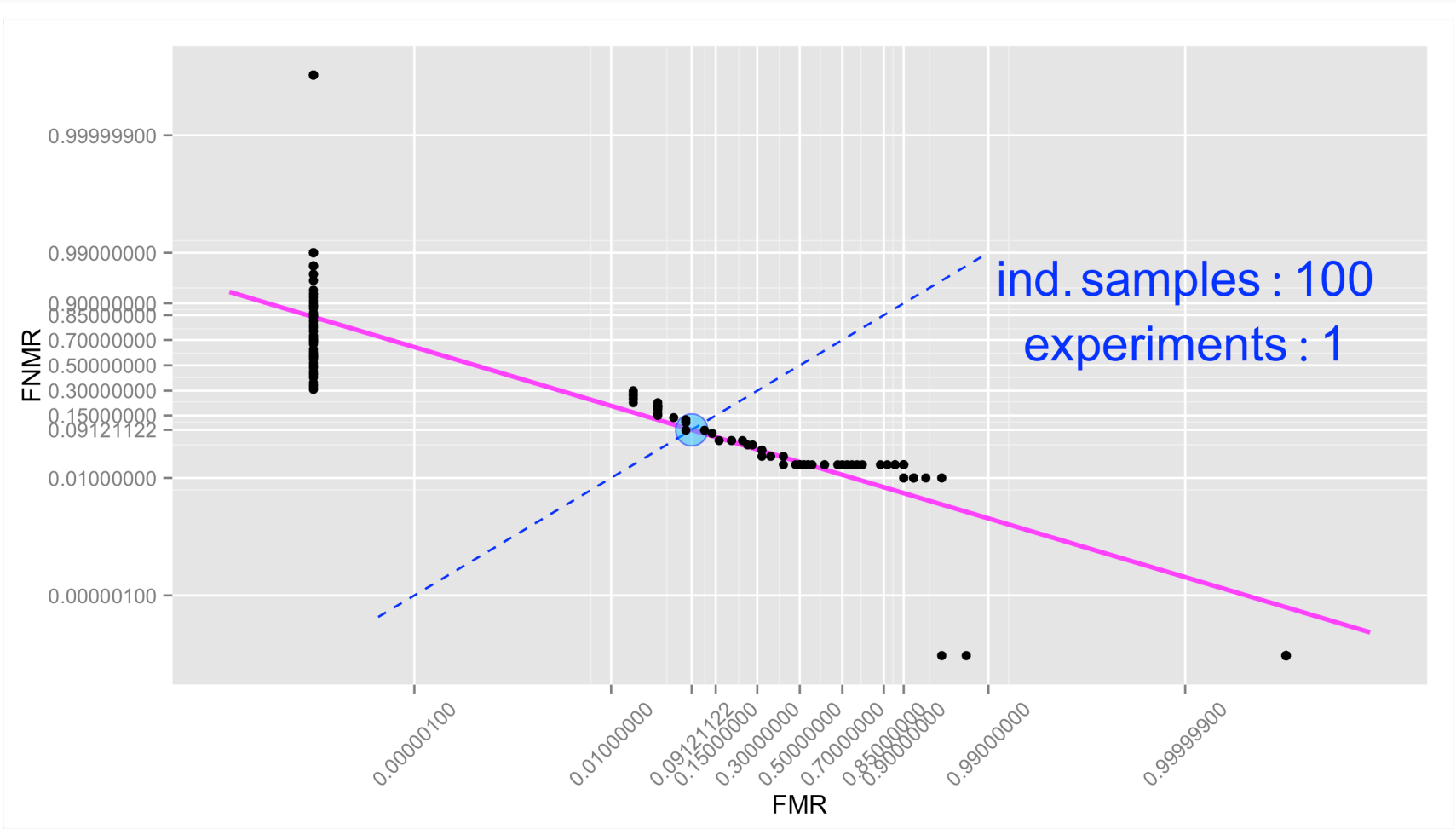
- False Match Rate / False Non-Match Rate
  - attempt oriented
- False Acceptance Rate / False Rejection Rate
  - transactional version of FMR/FNMR
- Failure To Acquire
- Failure To Enroll
  - both attempt and txn-oriented versions

Biometric Data Mining

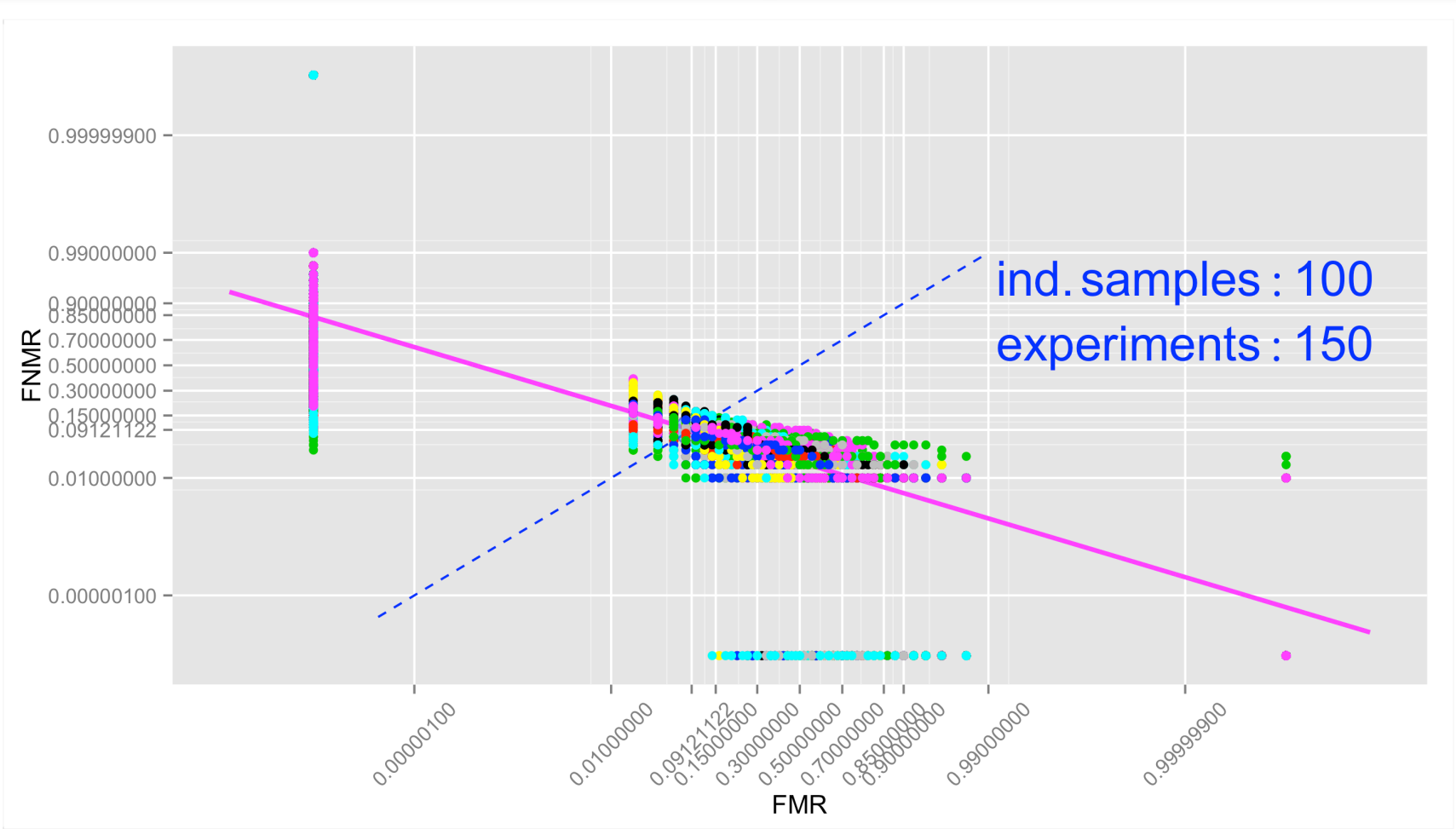
- In any life-cycle phase, we shall gather as much data as we can to estimate the performance or check we are still operating in expected margins.
- Anomalies may indicate a component malfunction or even a **fraud**.
- Again, be careful about confidence.
- Misleading statistics can be worse than none!



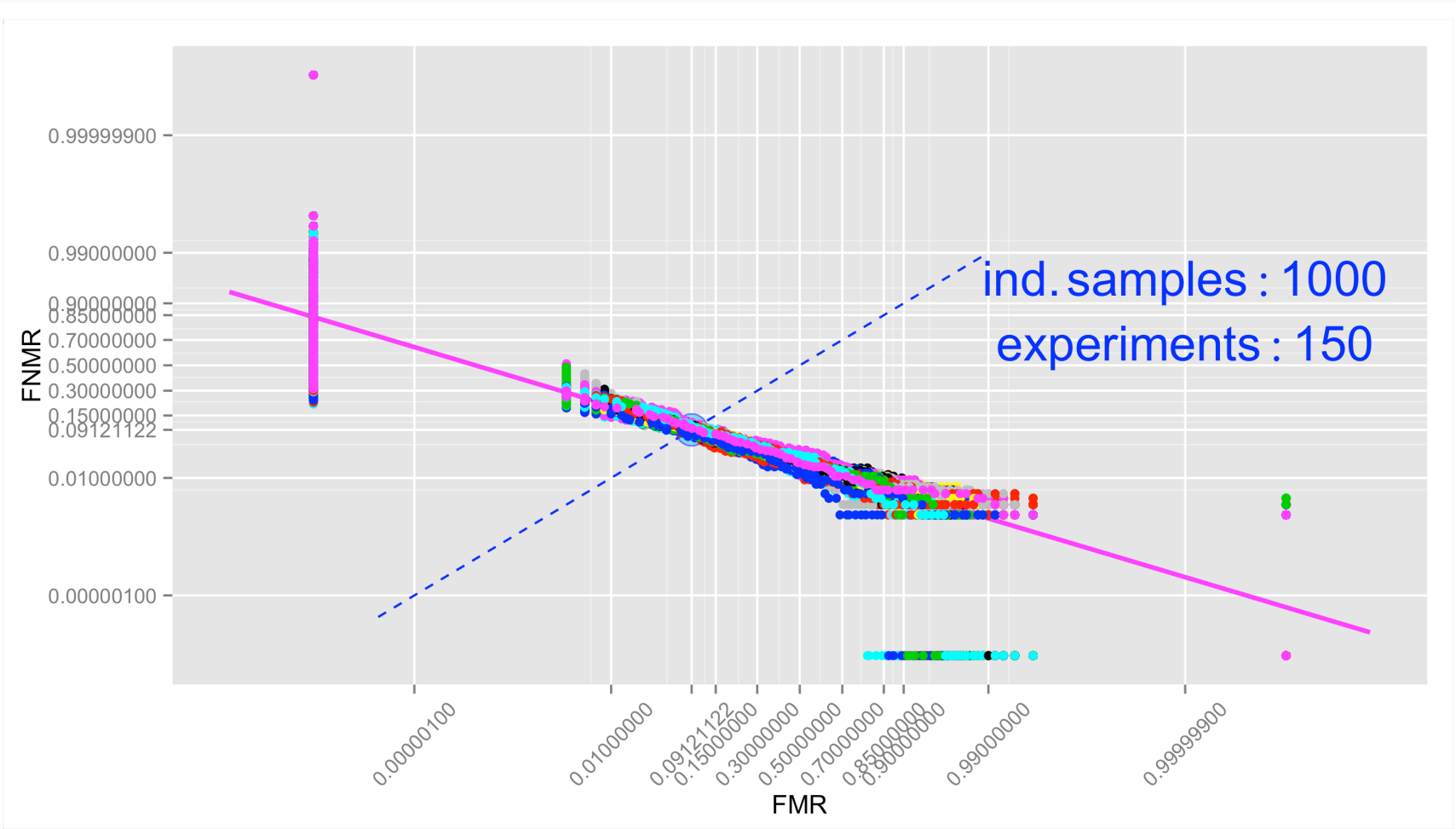
DET Estimation Simulation



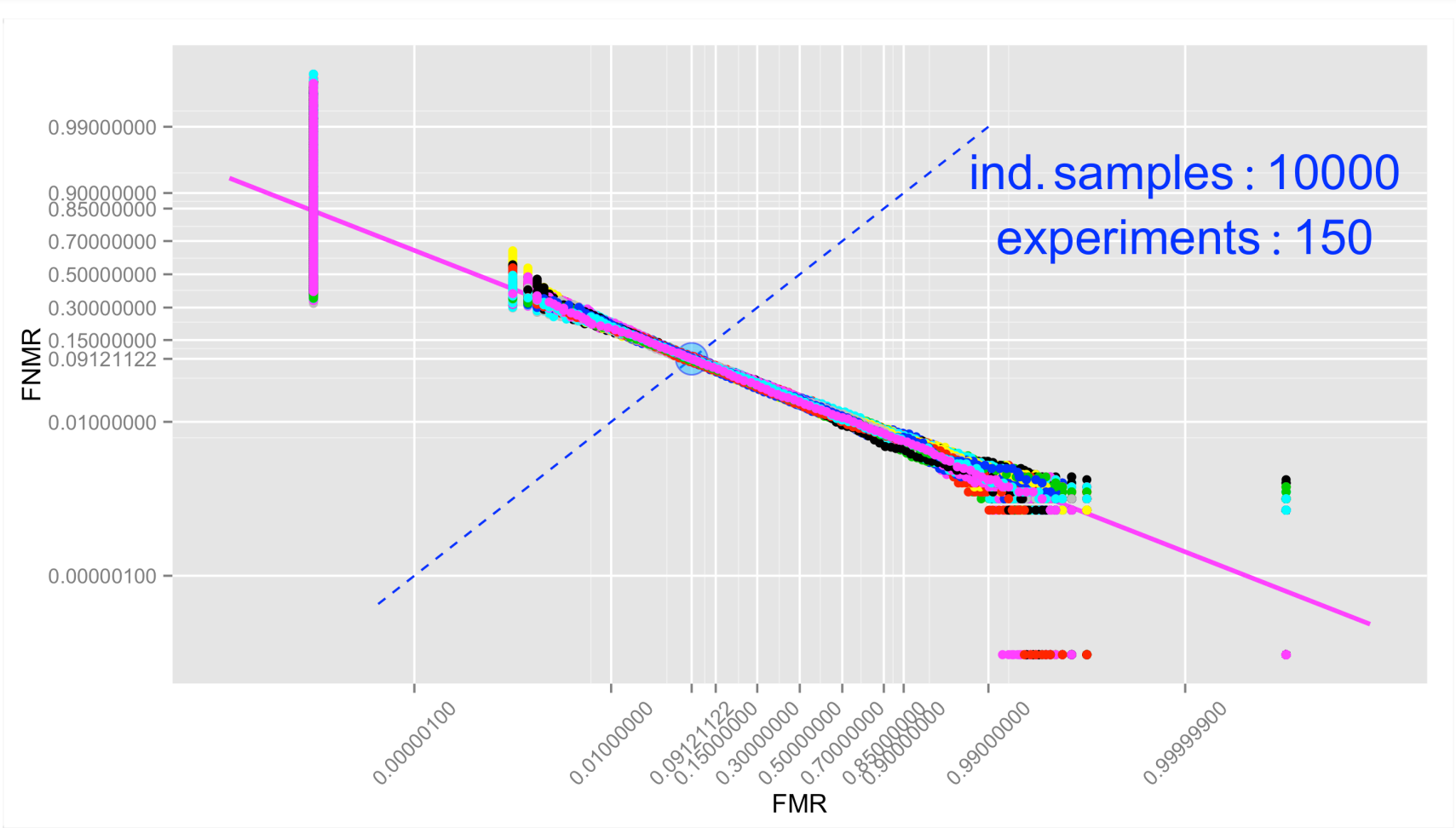
Confidence Intervals?!



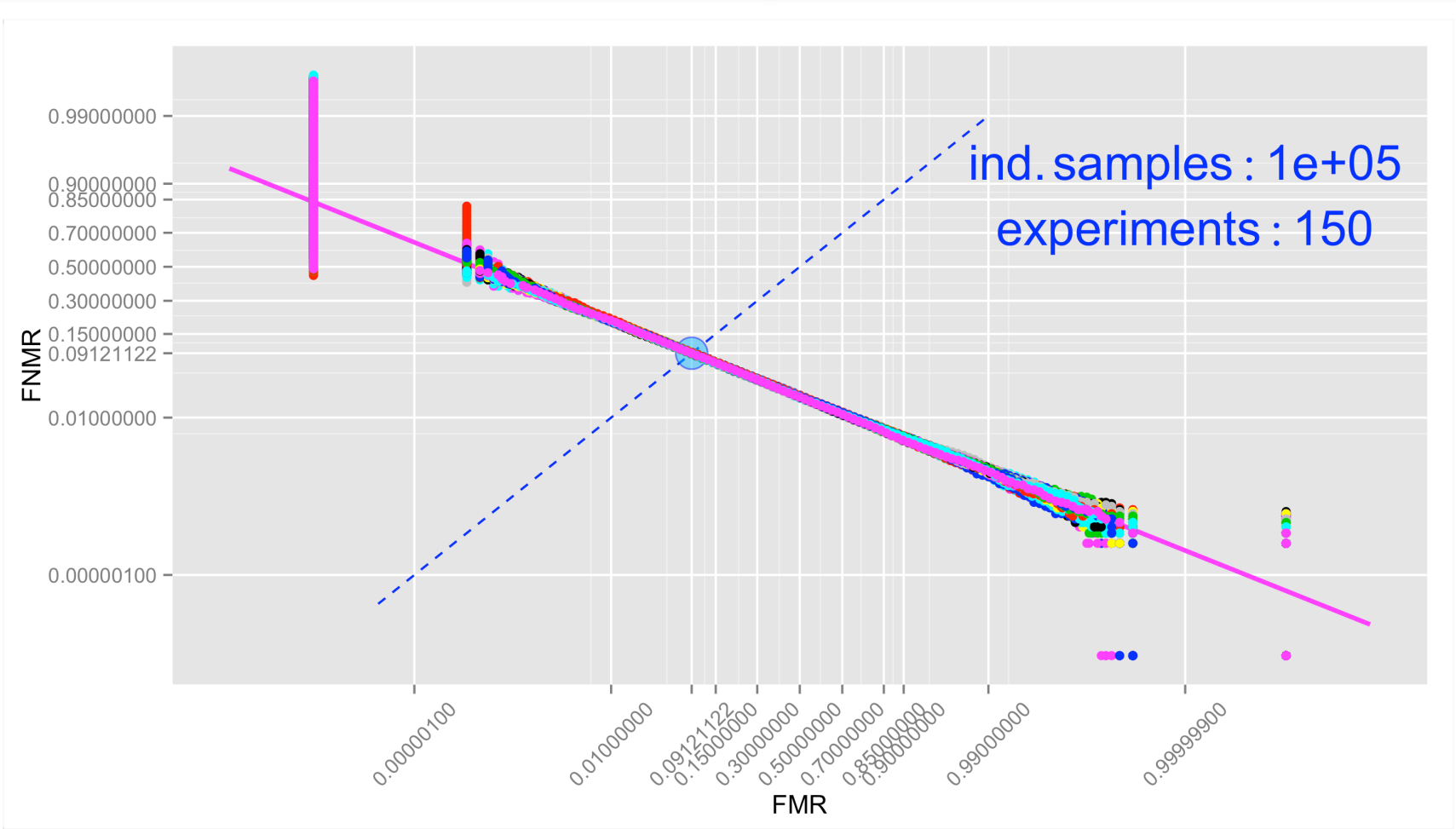
Any Confidence, Yet?



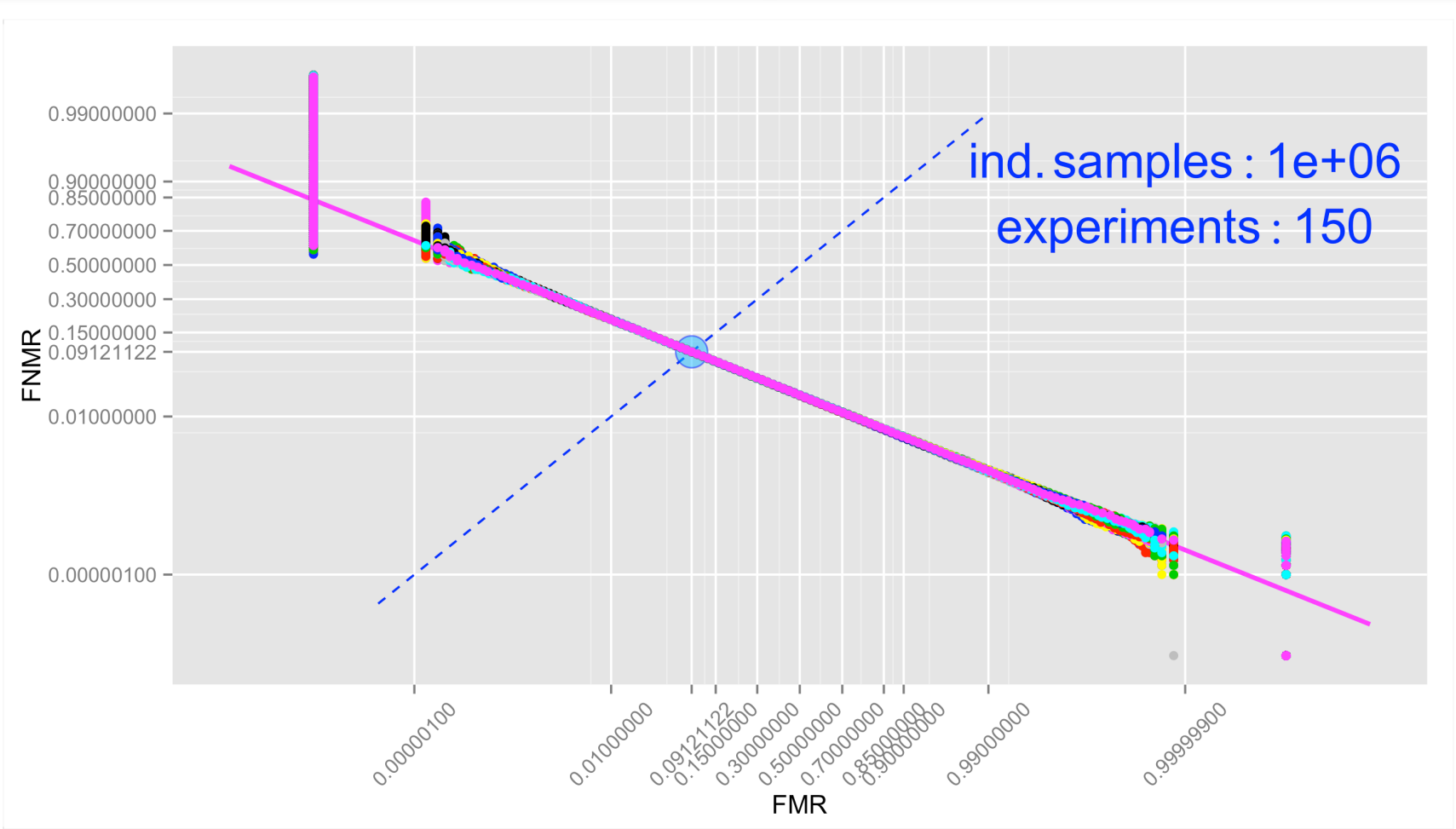
Fair Confidence



We Can be Proud



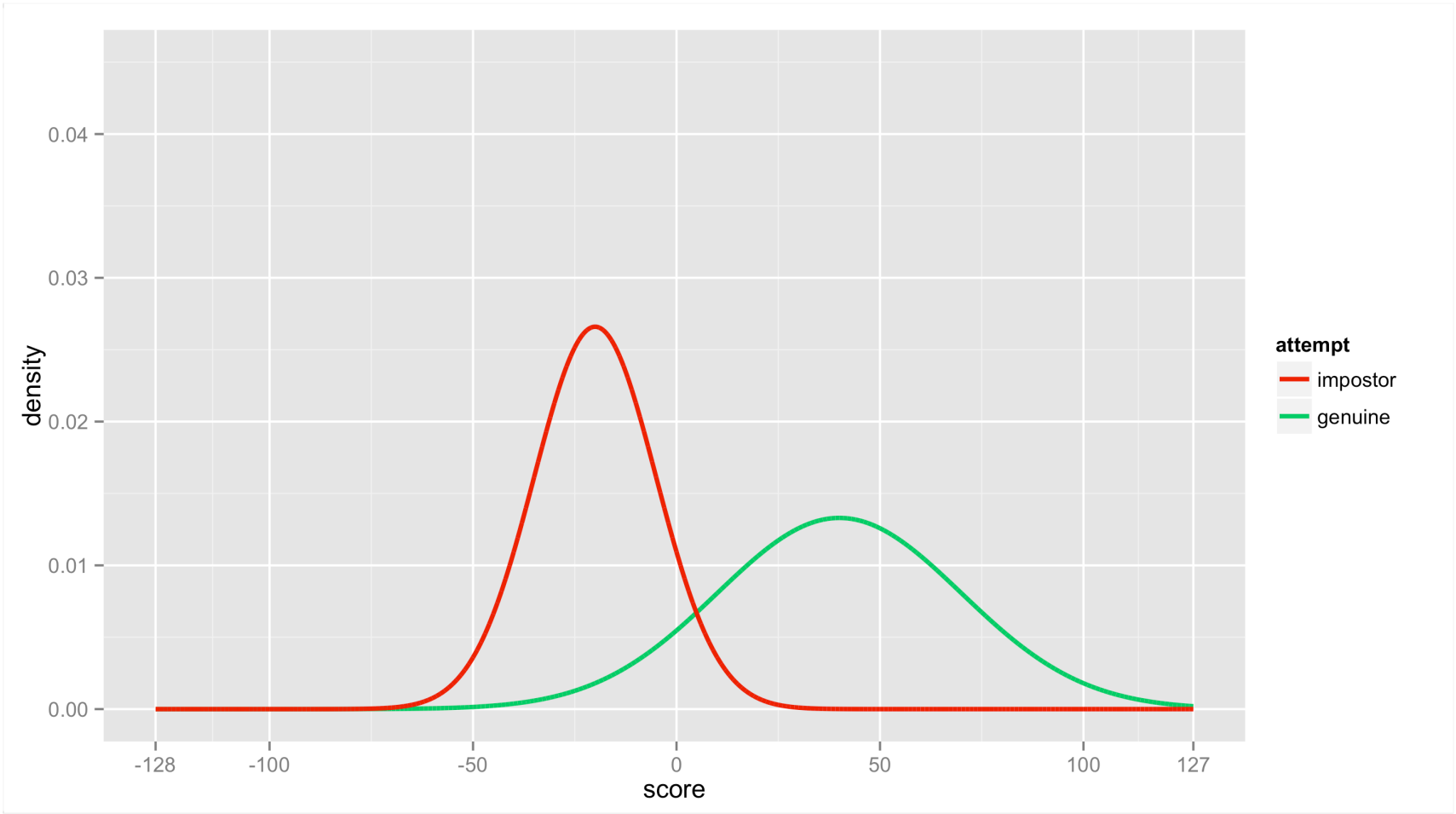
Just a Dream…


ind. samples : 1e+06
experiments : 150
FNMR
0.99000000
0.90000000
0.85000000
0.70000000
0.50000000
0.30000000
0.15000000
0.09121122
0.01000000
0.00000100
FMR
0.00000100
0.01000000
0.09121122
0.15000000
0.30000000
0.50000000
0.70000000
0.85000000
0.90000000
0.99000000
0.99999900

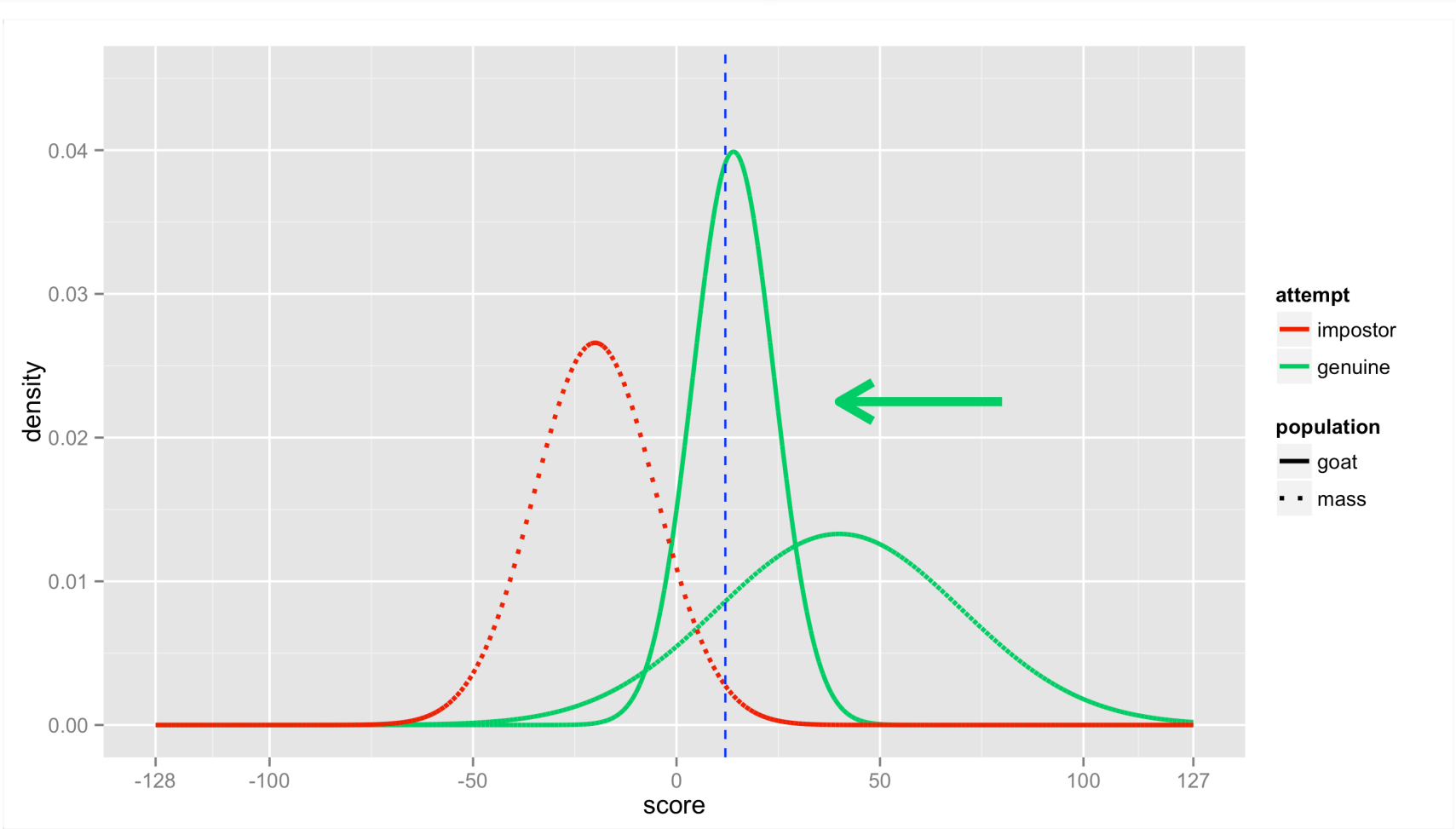
Biometric Menagerie

- To further complicate biometrics testing, those score distributions are usually **not** person-independent.
  - That means the performance is **not** the same for all people.
- There are plenty of anomalies we shall be aware of to interpret the system behaviour correctly.

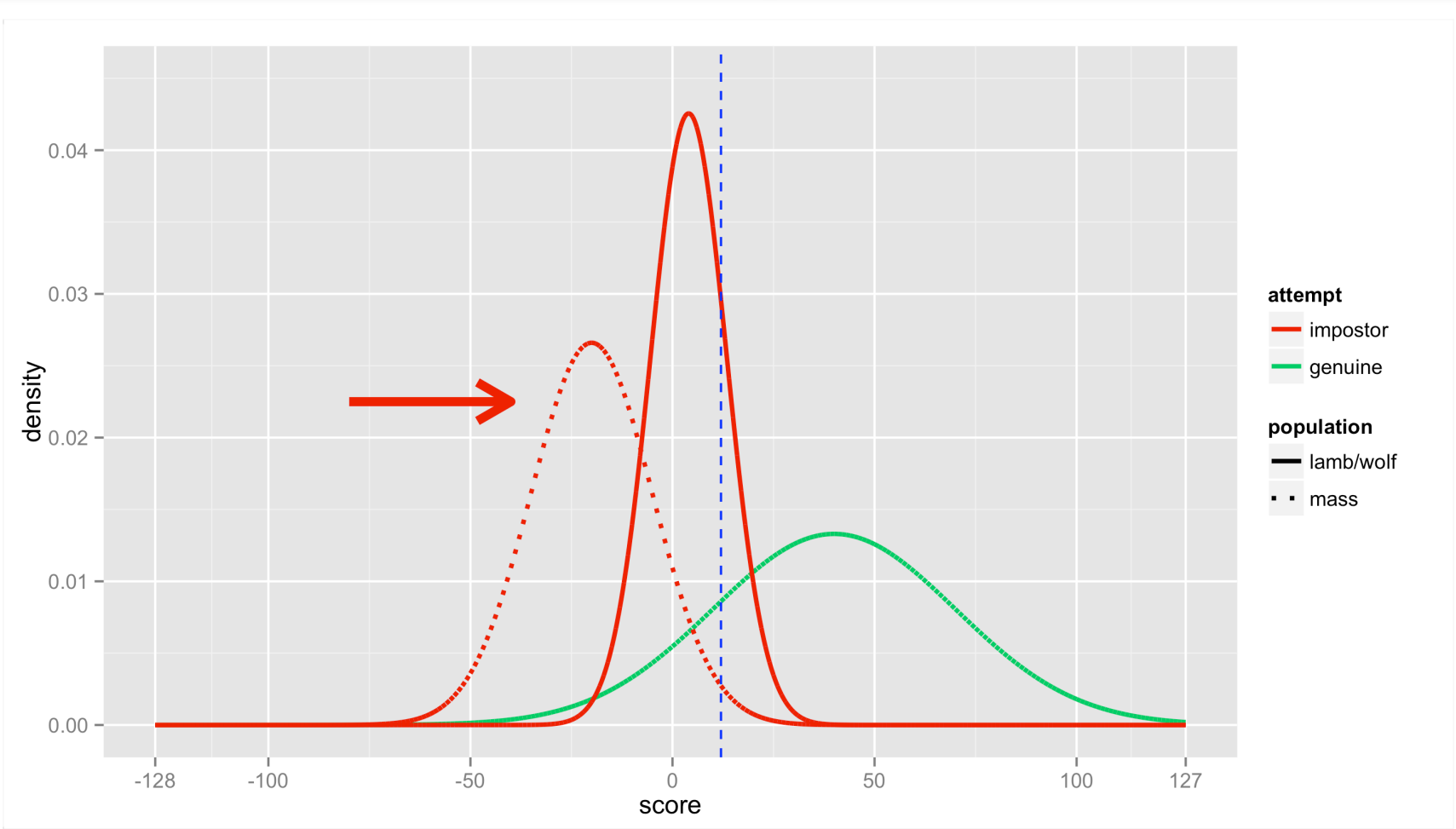
Sheep: An Ordinary User



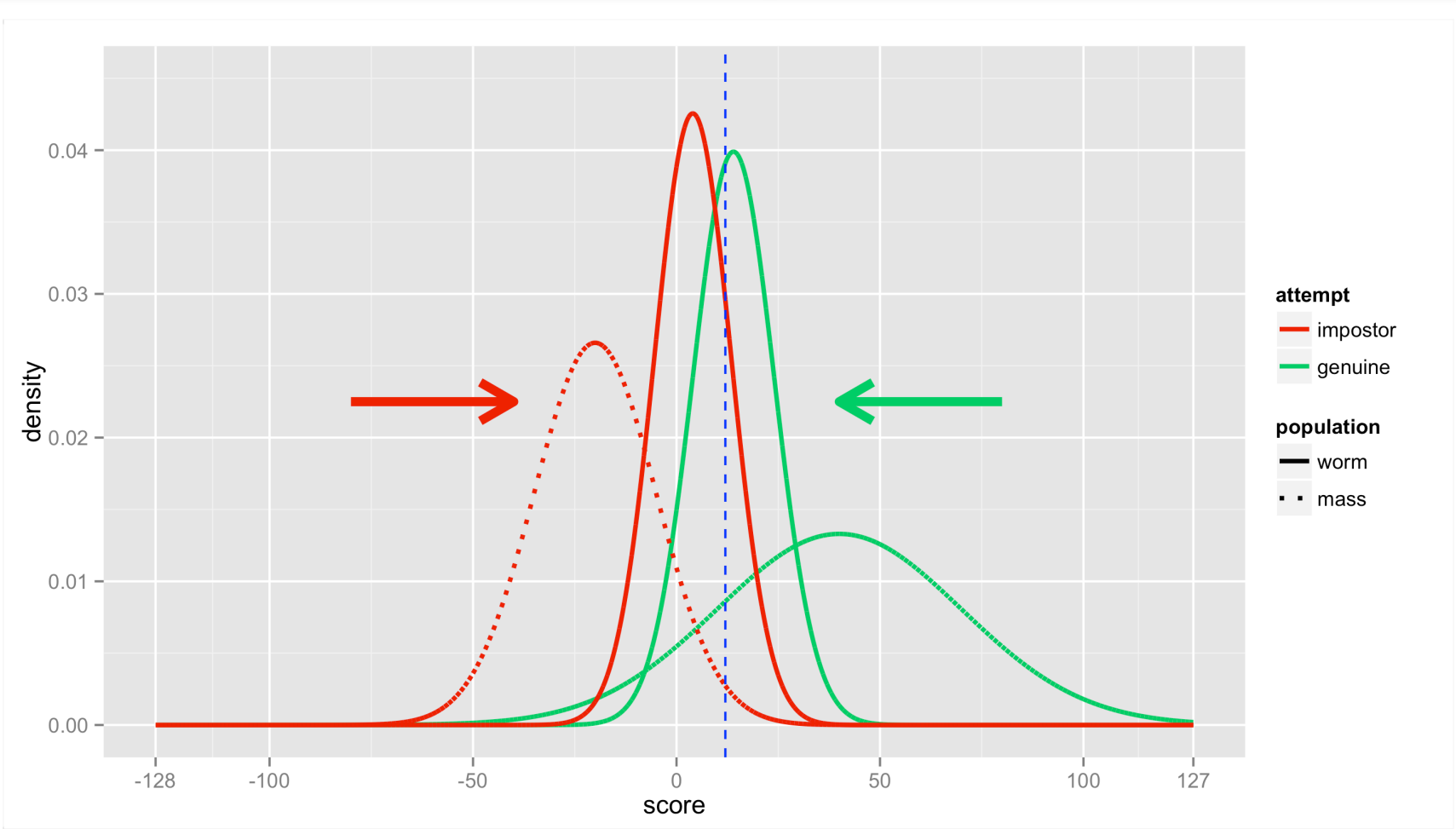
Goat: Problematic FNMR



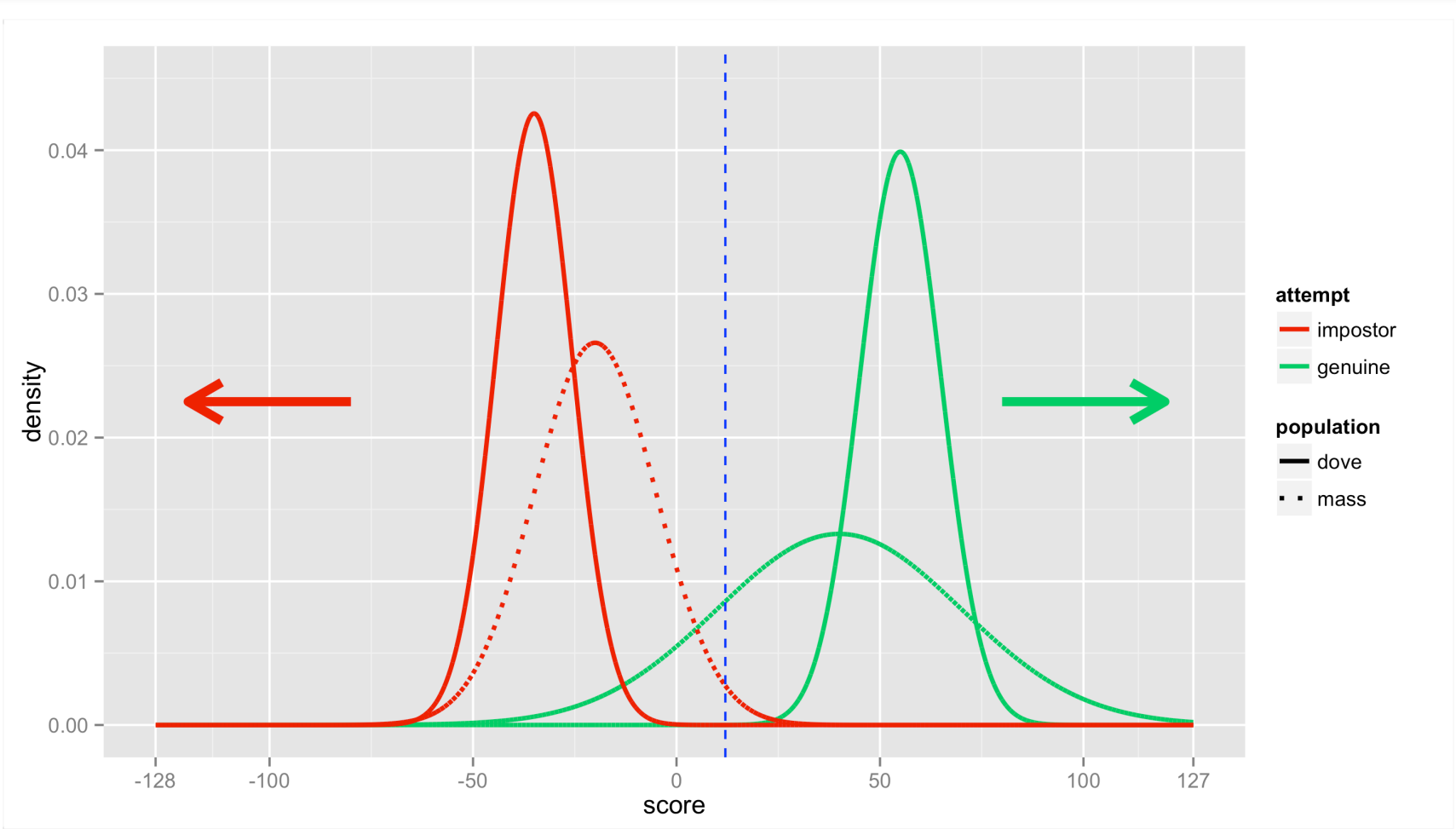
Lamb/Wolf:
Easy Target and-or Effective Predator



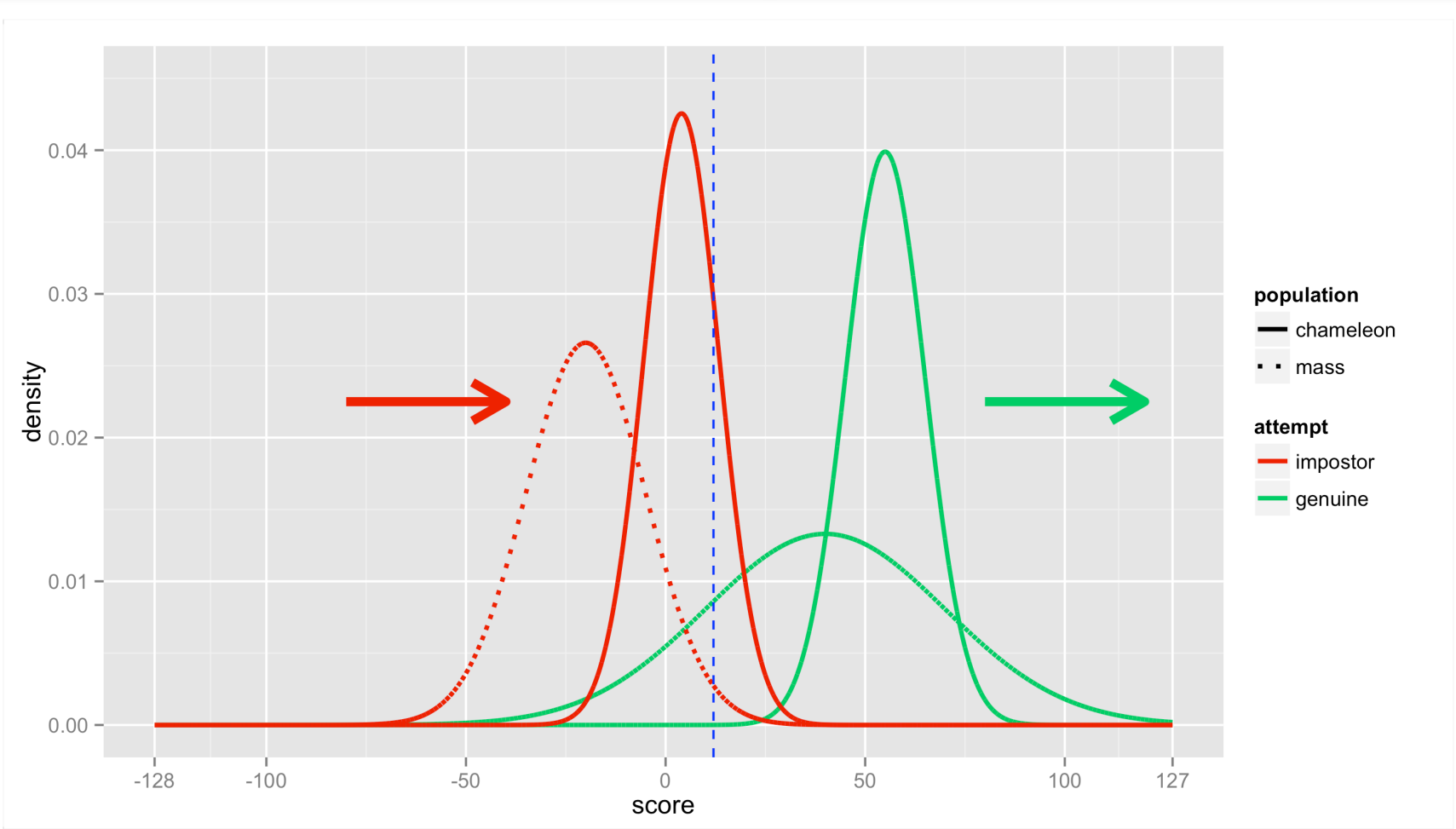
Worms:
Both FNMR and FMR Increased



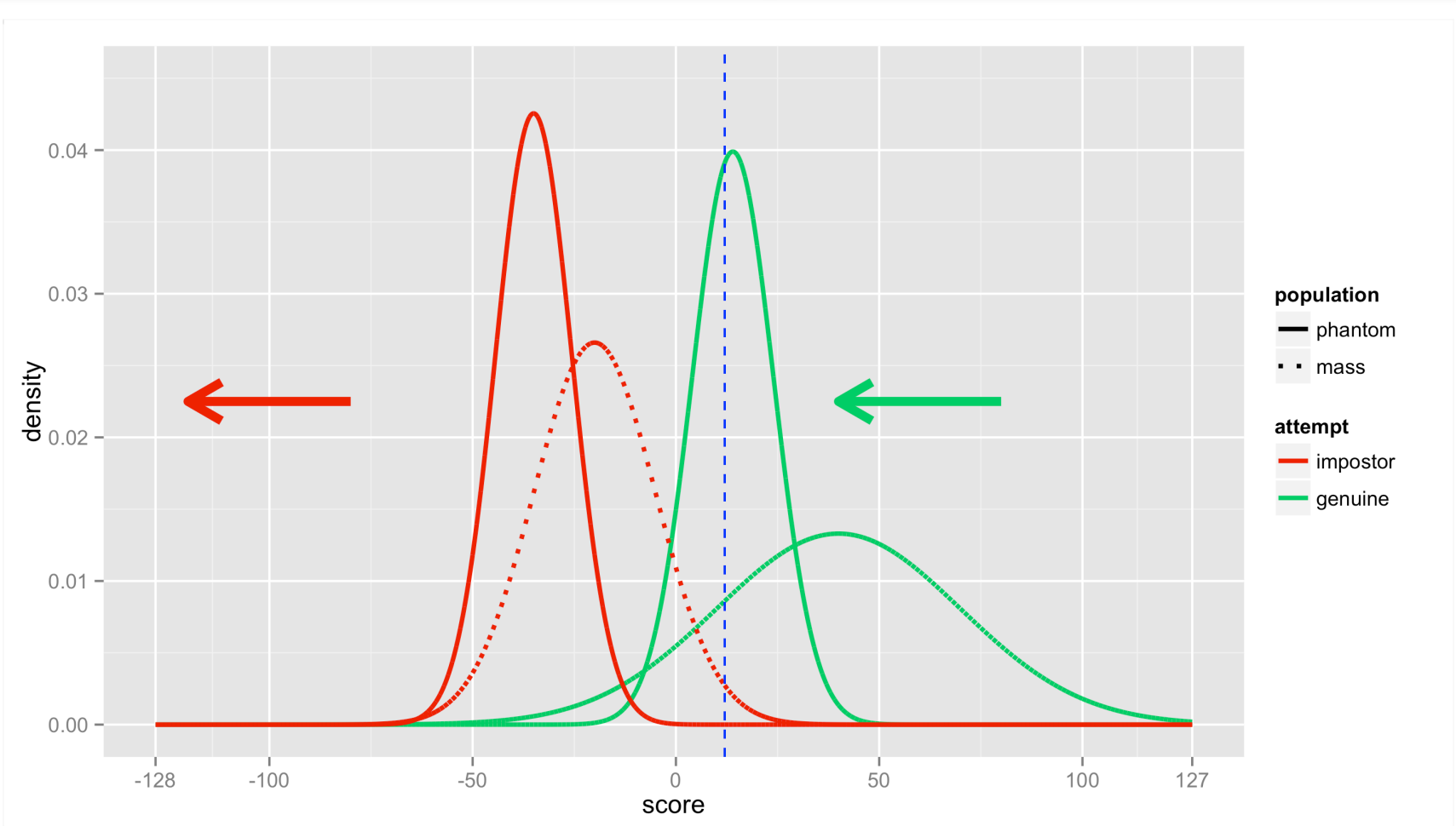
Dove: Excellent User



Chameleon: Excellent Scores, Anyway(!)



Phantom: Problematic Matching, Anyway




Secret Files
on Biometrics

Reactive Forensics

I am solving criminals recognition and this just works...

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Alphonse Bertillon, 1883

Turned Into Proactive Security

...such a massive invocation of the hidden algorithm design!

Turned Into Proactive Security

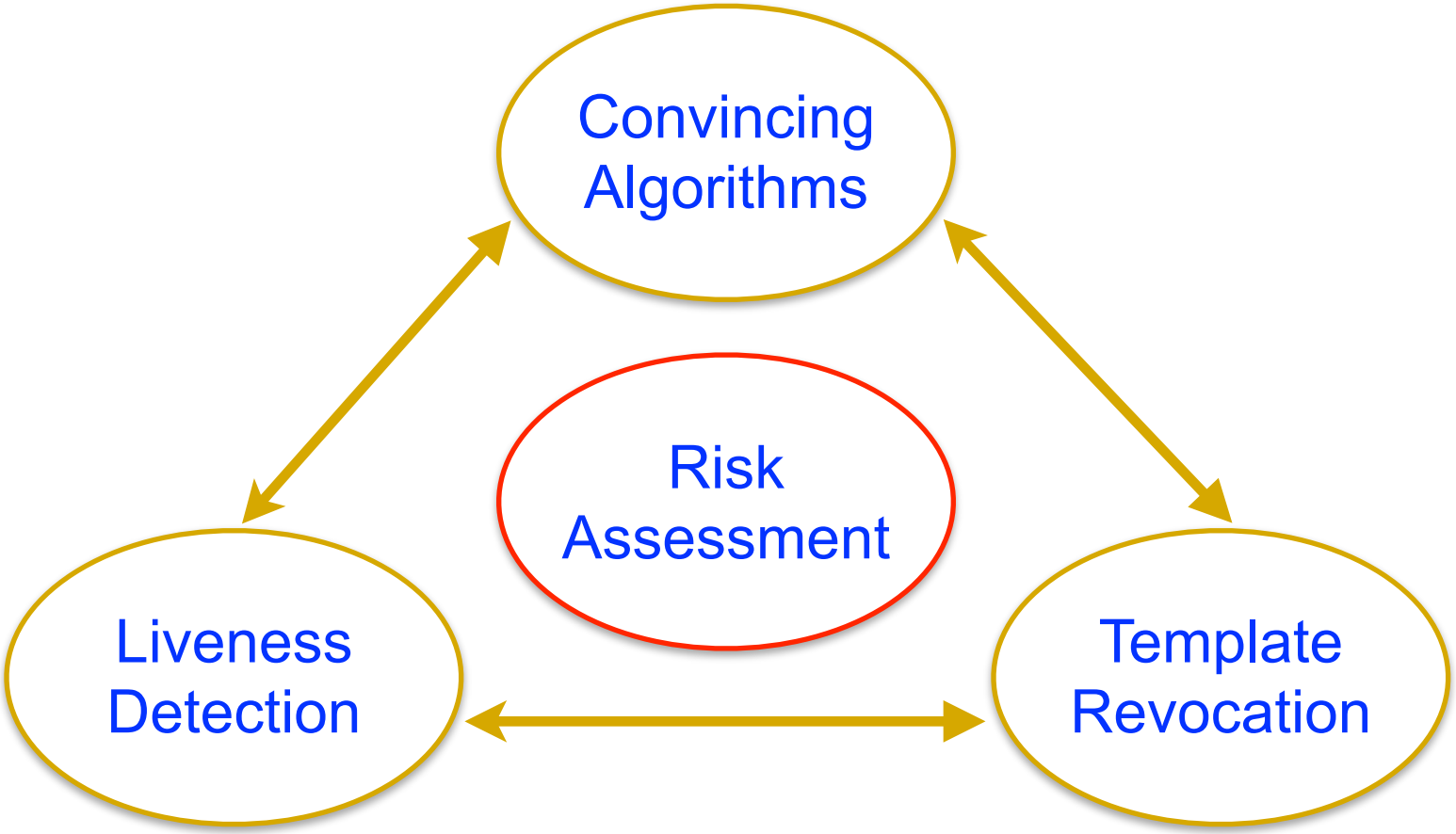
...such a massive invocation of the hidden algorithm design!

Auguste Kerckhoffs, 1883

Contrasting Design Approach

- Classic cryptography
  - infeasible mathematical problems
- Quantum cryptography
  - intractable physical problems
- Biometric identification
  - statistical signal detection
  - intractability is usually ***not*** the prime concern
  - we hope the Mother Nature complexity *somehow* guarantees the security

Open Problems




Convincing Algorithms?


Safe Template Revocation?

Liveness Detection?

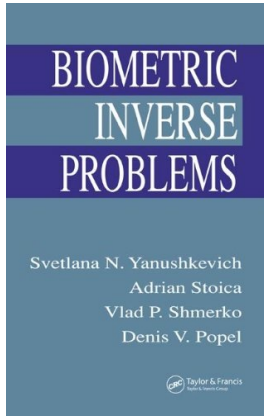
Internal Experts Are Ready

Consultants Always Eager to Help!


Anyway, do the Pentest!

BIO Brute Force Attack

- Randomly generate plausible circa 1/FMR samples and put them to the test.
  - Also termed “Zero-Effort”, denoting that the attacker makes no special effort to imitate the original person characteristic.
- Synthetic samples generation is quite feasible today.



Cryptanalysis-Like Attacks

- Masquerade attacks, can be a variant of "Hill-Climbing" denoting the attacker iteratively improves the BIO sample data based on:
  - scoring feedback *(side channels)*
  - stolen template *(pre-image attacks)*
  - independent template trained from intercepted BIO samples *(correlation attacks)*
  - known scoring anomaly *(differential analysis. etc.)*
  - implementation faults *(general hacking)*

Spoofing

- *The process of defeating a biometric system through the introduction of fake biometric samples.*
  - *(Schuckers, Adler et al., 2010)*
- Particular modus operandi on how to deploy the attacking data vectors.
  - Can be seen as being orthogonal to the aforementioned ways of gaining fake samples.

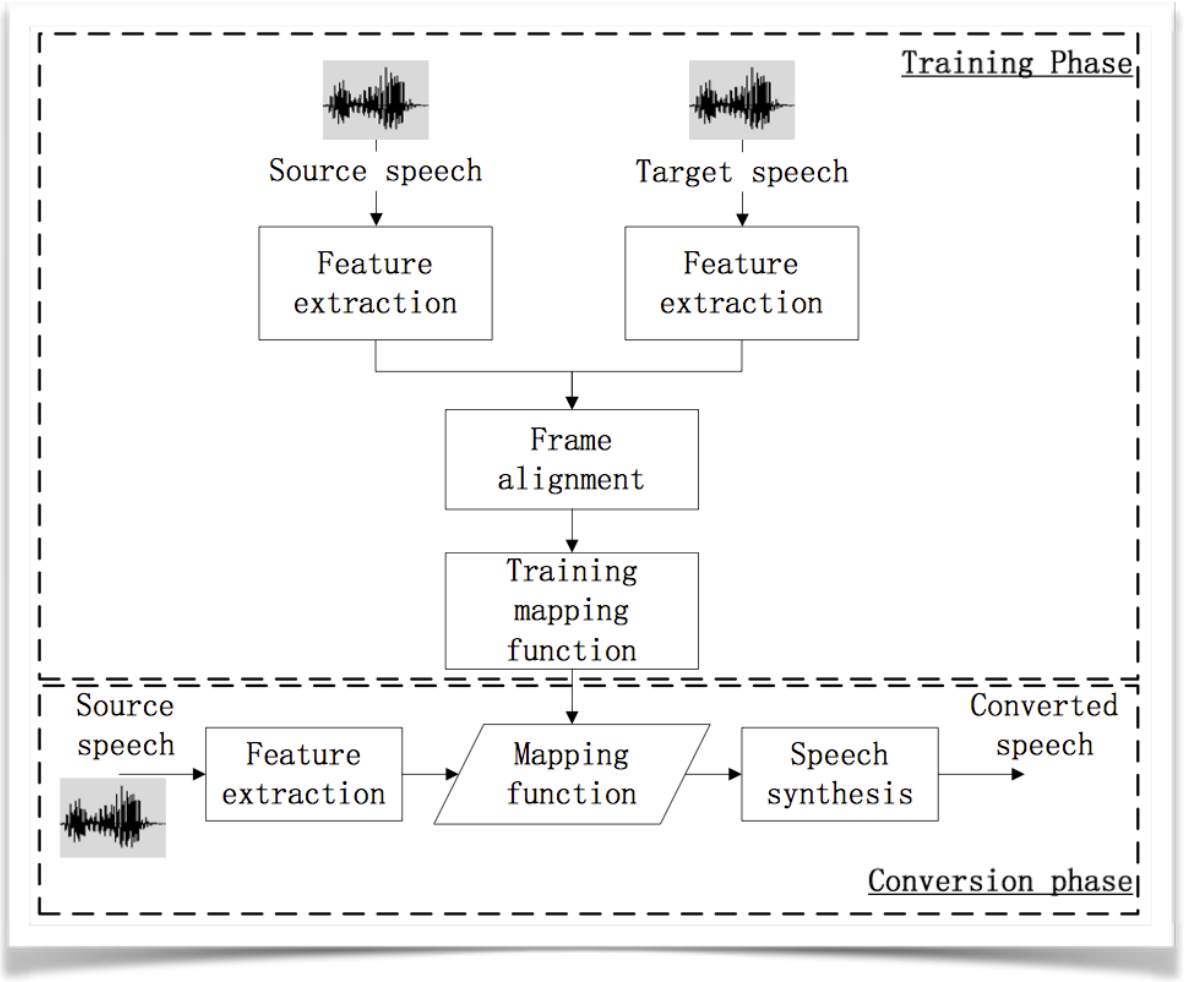
Sensor-Bypass Attacks

- Do not expose API service for unrestricted automated sample verification!
  - Recall the zero-effort attack complexity is often trivial.
  - Furthermore, masquerade attacks can shift FMR significantly.

Sample Generator + Spoofing

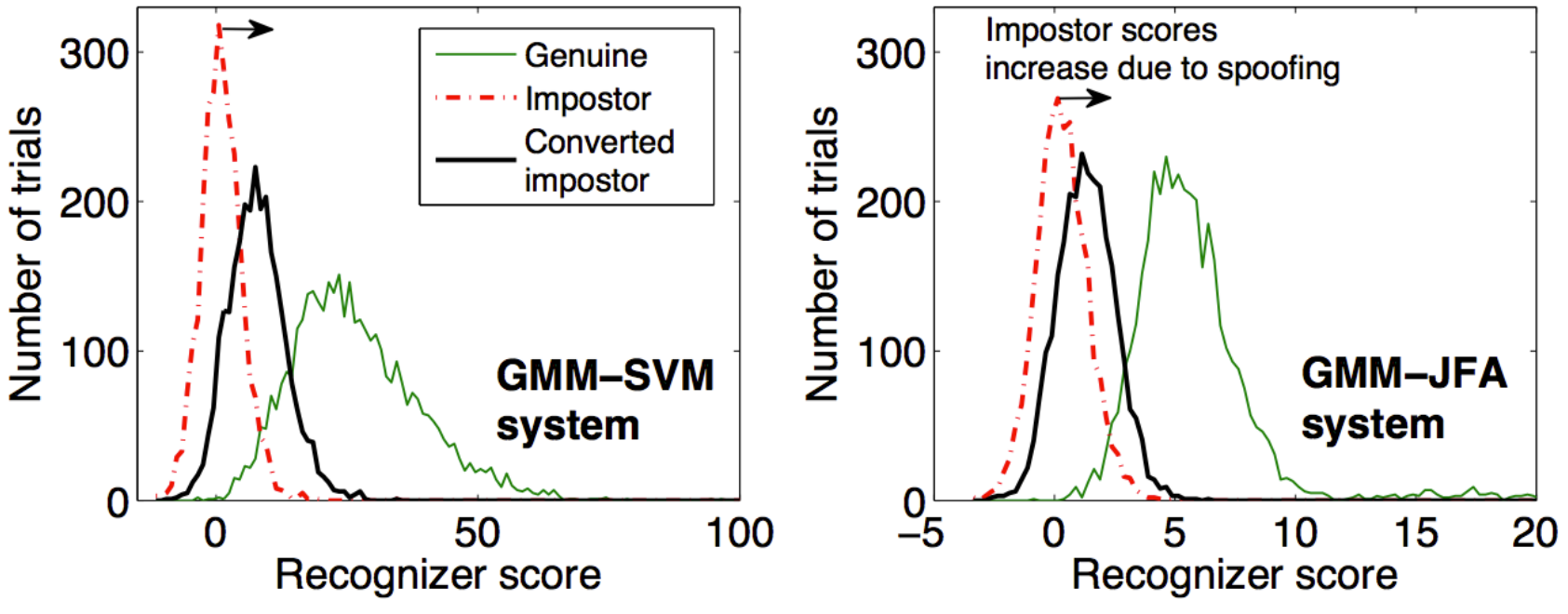
- Spoofing techniques are, however, not “just helpers”.
- They are tightly interconnected with the fake samples generator to create complex attacks, as e.g.:
  - Text-To-Speech Synthesis
  - Voice Conversion
  - Artificial Signals

Conversion Attack Example



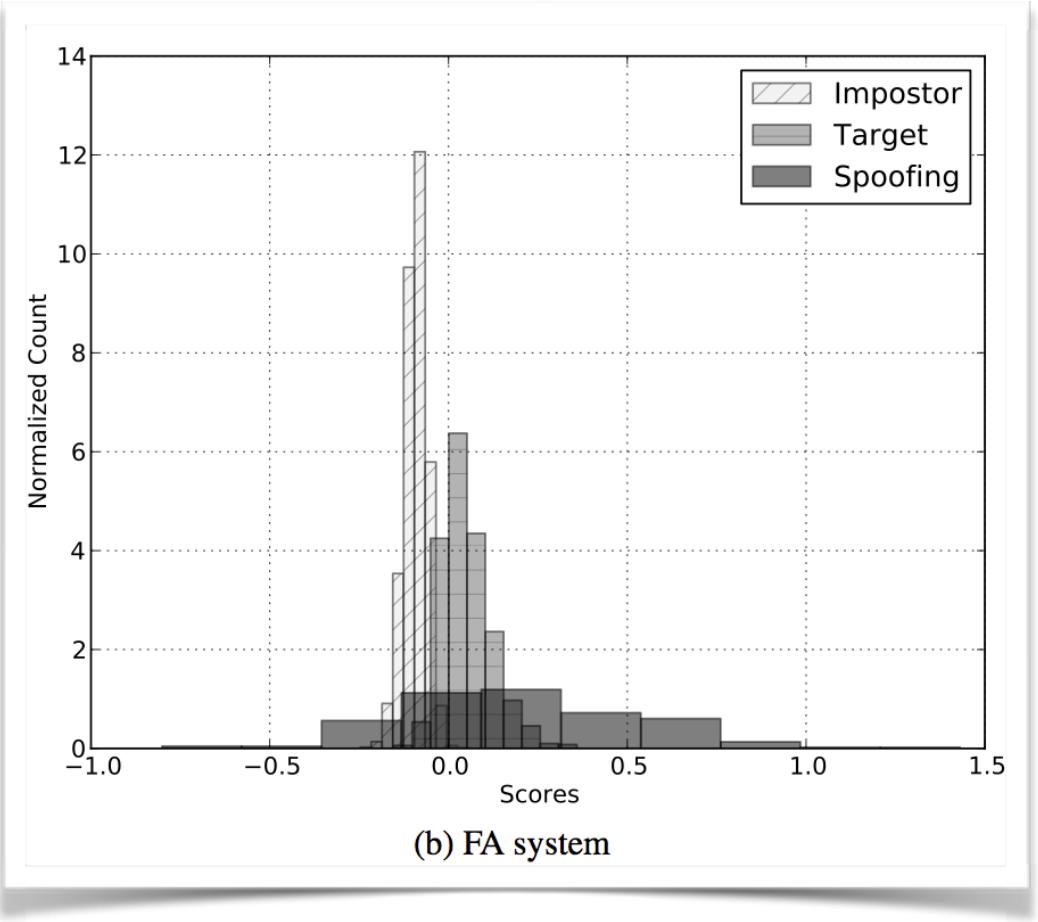
Kinnunen et al., ICASSP 2012

Reporting Attack Impact



Kinnunen et al., ICASSP 2012

Artificial Signals Impact



Alegre et al., EUSIPCO 2012-13

Biometric Cryptography?

Cryptography Exactness

Let $y = AES_K(x)$ for a random K.

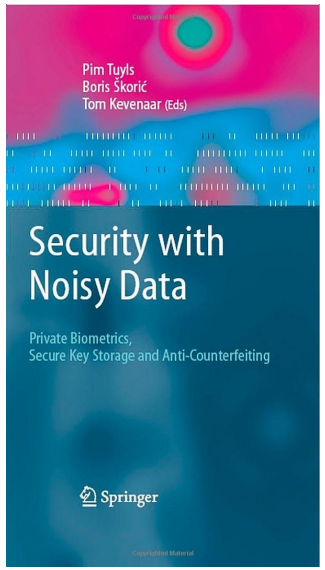
Then $AES_K^{-1}(y) = x$, while

$AES_{K \oplus 1}^{-1}(y) \neq x$ (probability ≈ 1).

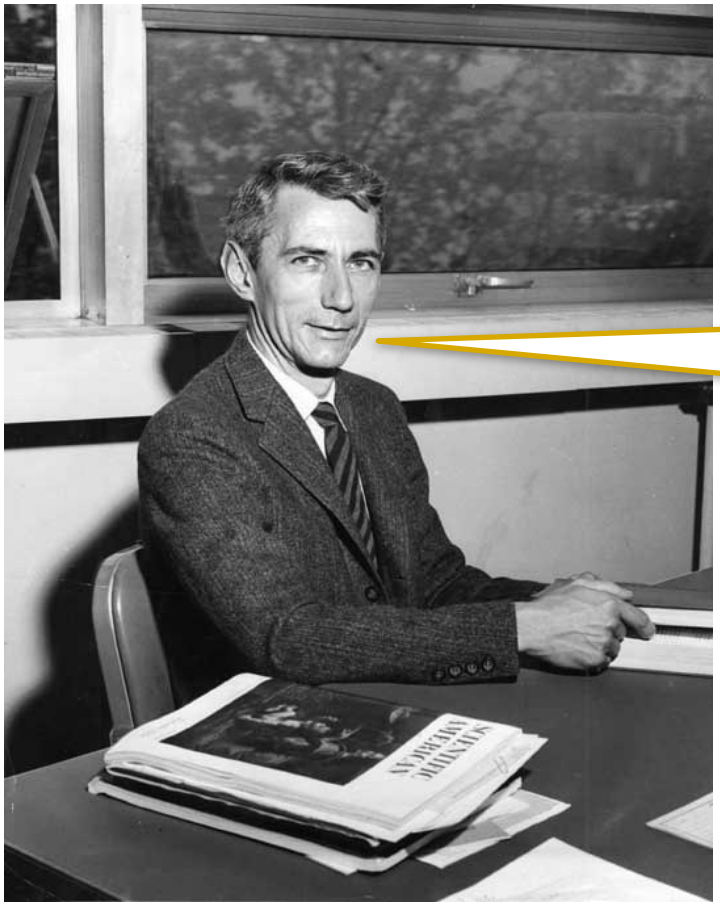
- The better the algorithm is the more randomized response we get for even one-bit error.

Biometrics Fuzziness

- We seldom get the same data in the subsequent scans of the very same person.
  - Actually, this is usually a clear sign of a spoofed sample.
- To overcome this (intra-user) variability, we can employ the *biometric cryptography*.

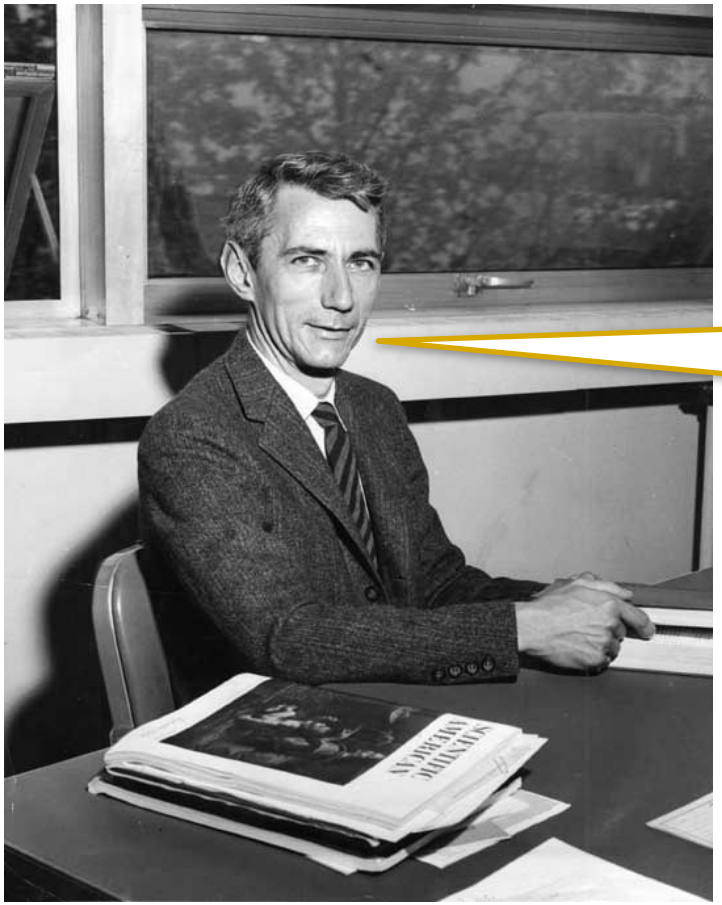


Back To the Origin



1. analyse the entropy gain from inter-class variation
2. use an error-correction code to cope with intra-class noise

Back To the Origin



1. analyse the entropy gain from inter-class variation
2. use an error-correction code to cope with intra-class noise

Claude Elwood Shannon, 1948-49

ISO/IEC 24745 Requirements

- Renewability
  - allows multiple independent *biometric references* created ad hoc
  - a particular leaked template does not compromise the other ones (provably!)
- Revocability
  - user can revoke the ability of being successfully verified by a particular template from now on
- Biocryptography is an effective way on how to achieve these goals.

Is It Enough?

- Template protection in contemporary systems is often quite questionable (*to be polite*).
- On the other hand, is it the only one problem?
  - **No.** We shall not push the concept of bio-keys too hard anyway.

One Key to Rule Them All…

- Conventional cryptographic keys can be freely discarded and re-generated from a scratch.
  - There is no nature-wide master-key that would compromise all these keys at once (hopefully).
- On the other hand, for all your bio-keys, You are the “master” key!

Bio-Skimming

- Once the problem of template protection is solved, this will become a new attack vector.
  - Attackers use a fake sensor (or hack into an original one) to skim the “bio-master-key”.
  - At the end of the day, how many eyes, fingers, faces, vocal tracts (etc.) do we have?
  - It is like having few master-keys for a whole life.
  - Furthermore, we prove the master-key possession by simply handing it over to almost any device that asks so (again, again, and again…).

Spoofing Still Matters!

- That said, liveness detection will be always important!
  - Remember, biometrics is nothing but a signal detection.
  - It all works as long as we can assume the signal is coming from a live human being!

Tamper-Resistant Sensors

- It signs the output samples with its private key to indicate it already has sampled the signal from a living individual.
  - Furthermore, the sample shall be then processed as soon as possible.
  - Otherwise, we have to mitigate the risk of a sensor compromise in the intermediate time by a further time-tamping ("**L**ong**T**erm**V**erifiable bio-samples").
  - This concept is all too often neglected in the emerging handwritten signature biometrics!

Conclusion

- We shall **require ISO 19795 methodology** during biometric application selection, comparison, and operation testing.
- Use **independent penetration test** to verify:
  - zero-effort attack complexity (*look for automated APIs!*)
  - masquerade attacks
  - spoofing possibilities
  - template security
  - system security in general (*threshold settings and template tampering, etc.*)

Thank You For Attention

Tomáš Rosa, Ph.D.

http://crypto.hyperlink.cz

Movie Snapshots Taken From

- *Tajemství hradu v Karpatech*, ČR, 1978
- *Císařův pekař*, ČR, 1951
- *The Magnificent Seven*, United Artists, USA, 1960
- *Slunce, seno, jahody*, ČR, 1983

Quotations

All the quotations of Alphonse Bertillon, Auguste Kerckhoffs, and Claude E. Shannon were purely fictional.