

Basics II

CSE 40537/60537 Biometrics

Daniel Moreira
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Today you will...

Get to know

Biometric system errors

Metrics to compare Biometric systems

Types of attacks to Biometric systems

Biometric System Errors

Denial of Access (1/3)

Verification

Jane Doe: Here, I'm Jane Doe.

System: No, you're not.

Identification

Jane Doe: Here, my fingerprints.

System: I don't know you.



Biometric System Errors

Denial of Access (1/3)

Possible Causes

Intrinsic failure: intra-user trait variation, due to different sensors, hardware malfunction, pose, illumination, make-up, aging, illness, cosmetic surgeries, etc.

Adversarial attack: malicious alteration of template database, etc.

Biometric System Errors

Intrusion (2/3)

Verification

Jane Doe: Here, I'm Jane Fonda.

System: Welcome, Jane Fonda!

Identification

Jane Doe: Here, my fingerprints.

System: Welcome, Jane Fonda!



<https://www.wired.com/story/10-year-old-face-id-unlocks-mothers-iphone-x/>

Biometric System Errors

Intrusion (2/3)

Possible Causes

Intrinsic failure: inter-user high similarity, due to low trait uniqueness, poor trait capture, etc.

Adversarial attack:
impersonation, spoofing, etc.



impersonation



spoofing

Biometric System Errors

Repudiation (3/3)

Verification

Jane Doe: See, I'm not Jane Doe.

System: Yeah, you're right.

Identification

Jane Doe: Here, my fingerprints.

System: Yeah, I don't know you.



Biometric System Errors

Repudiation (3/3)

Possible Causes

Intrinsic failure: hardware malfunction, intra-user trait variation.

Adversarial attack: obfuscation.



obfuscation

Biometric System Errors

Math Model

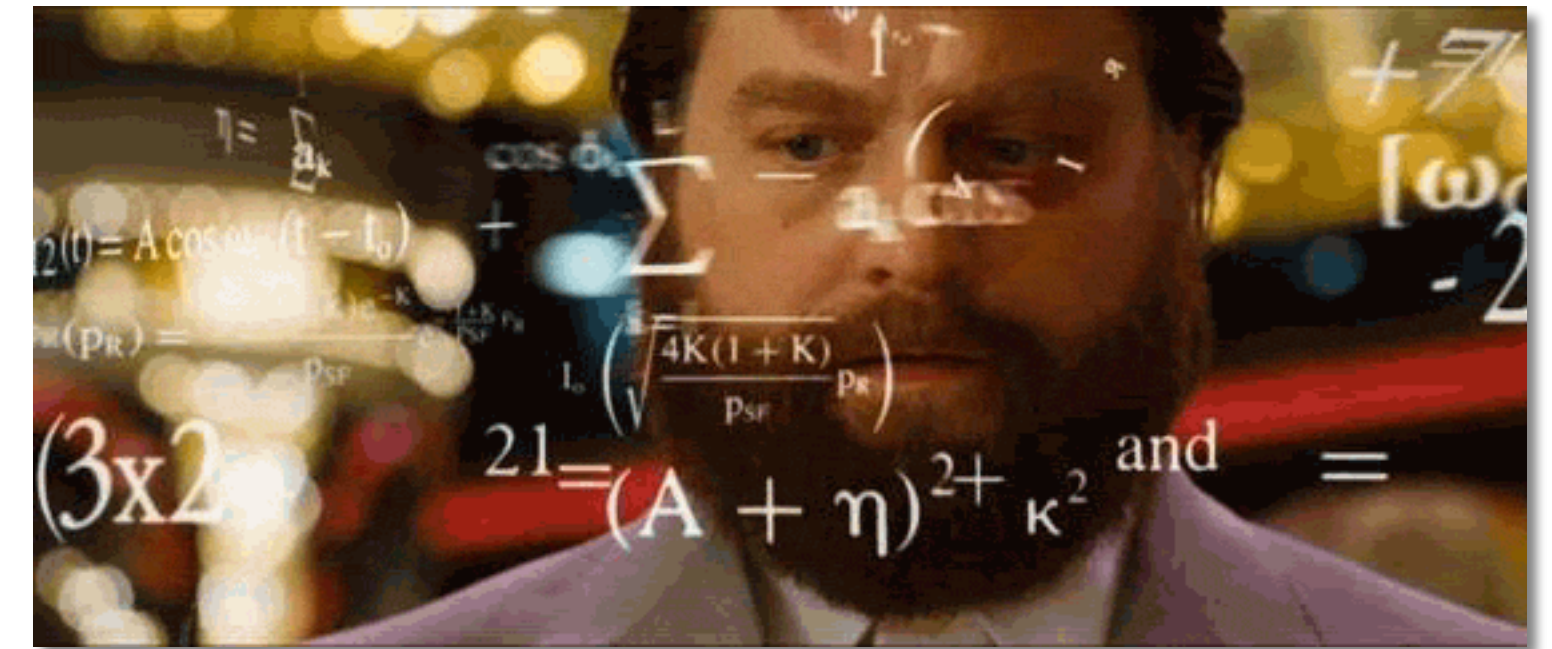
Objective definition of 2 events:

1. False Non-Match (FNM)

A comparison of two features of the same individual should lead to a match, but it led to a non-match.
It causes either a denial of access or helps repudiation.

2. False Match (FM)

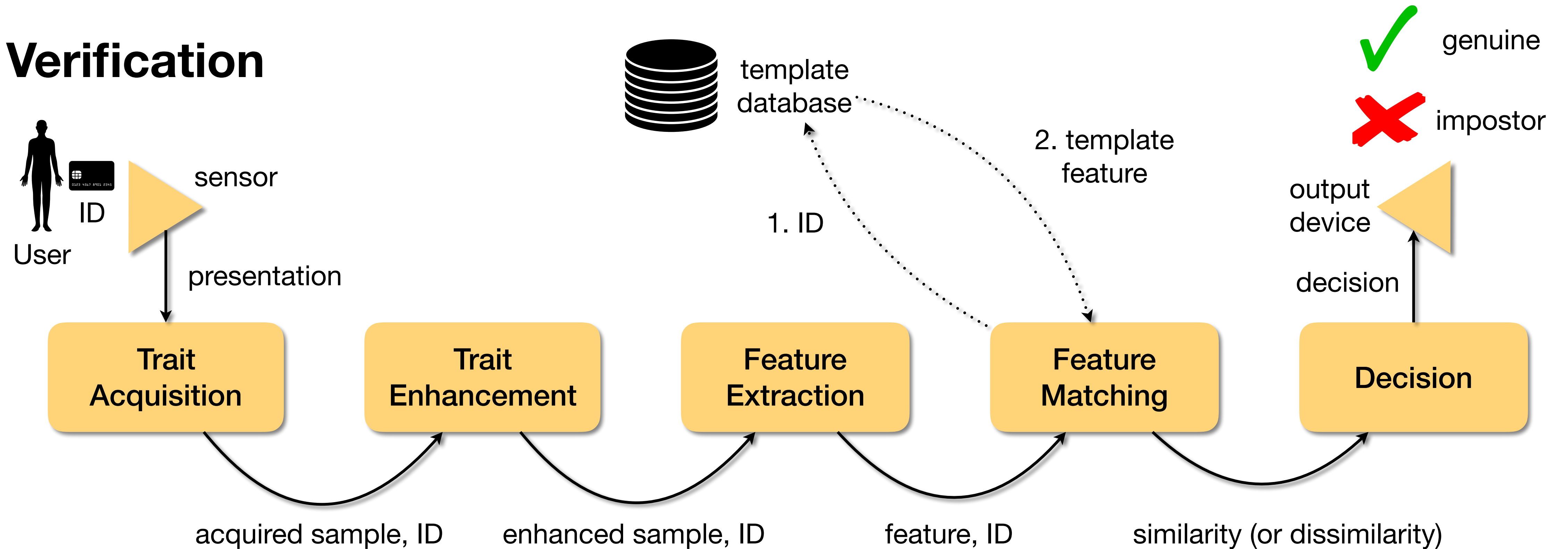
A comparison of two features from different individuals should lead to a non-match, but it led to a match.
It helps an intrusion.



Let's see how to compute them!

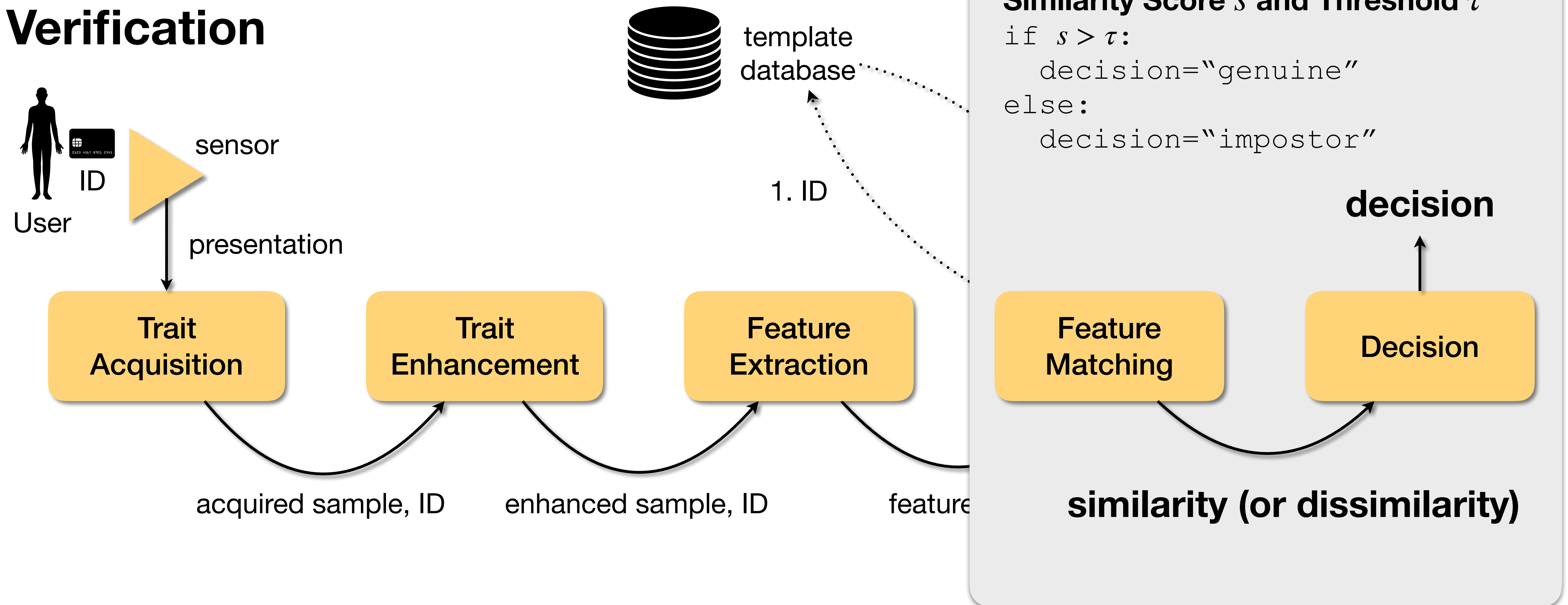
Metrics

Verification



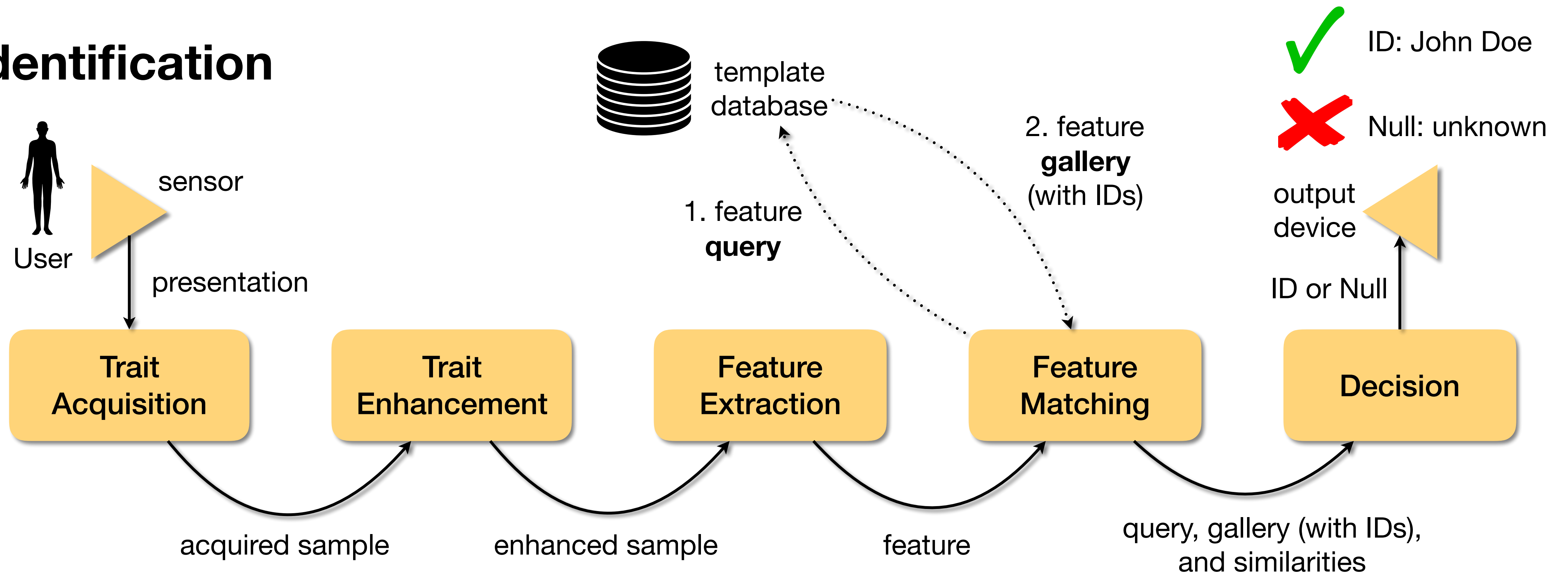
Metrics

Verification



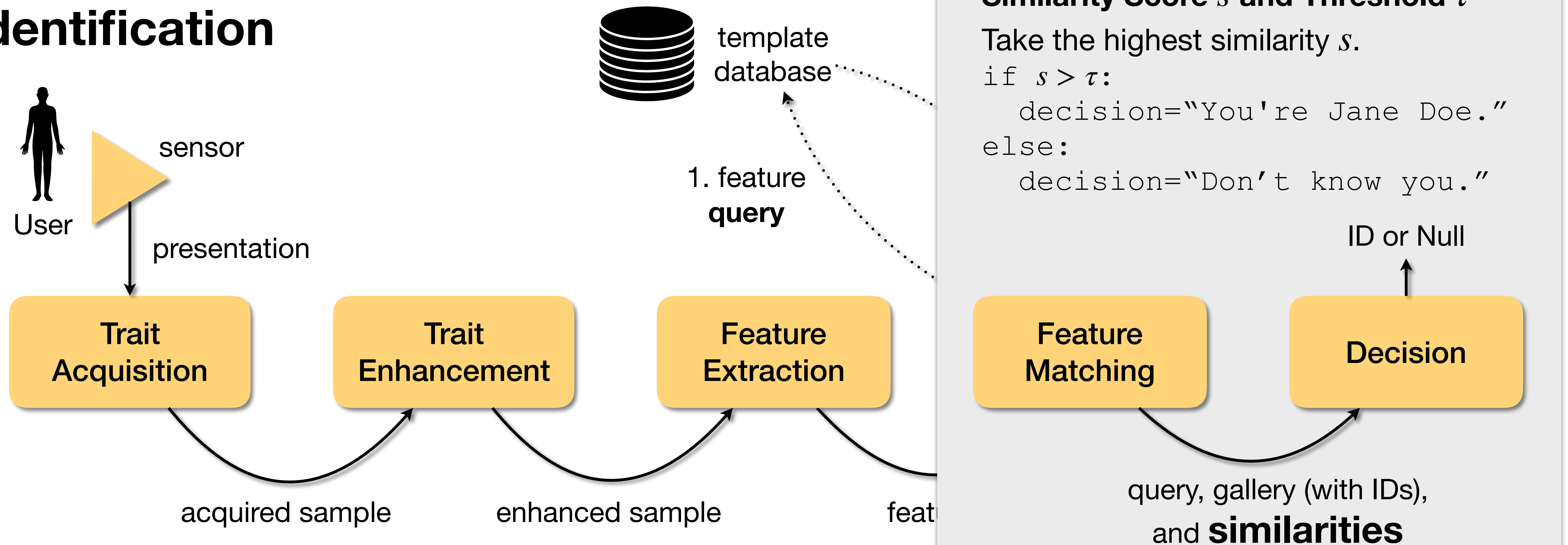
Metrics

Identification

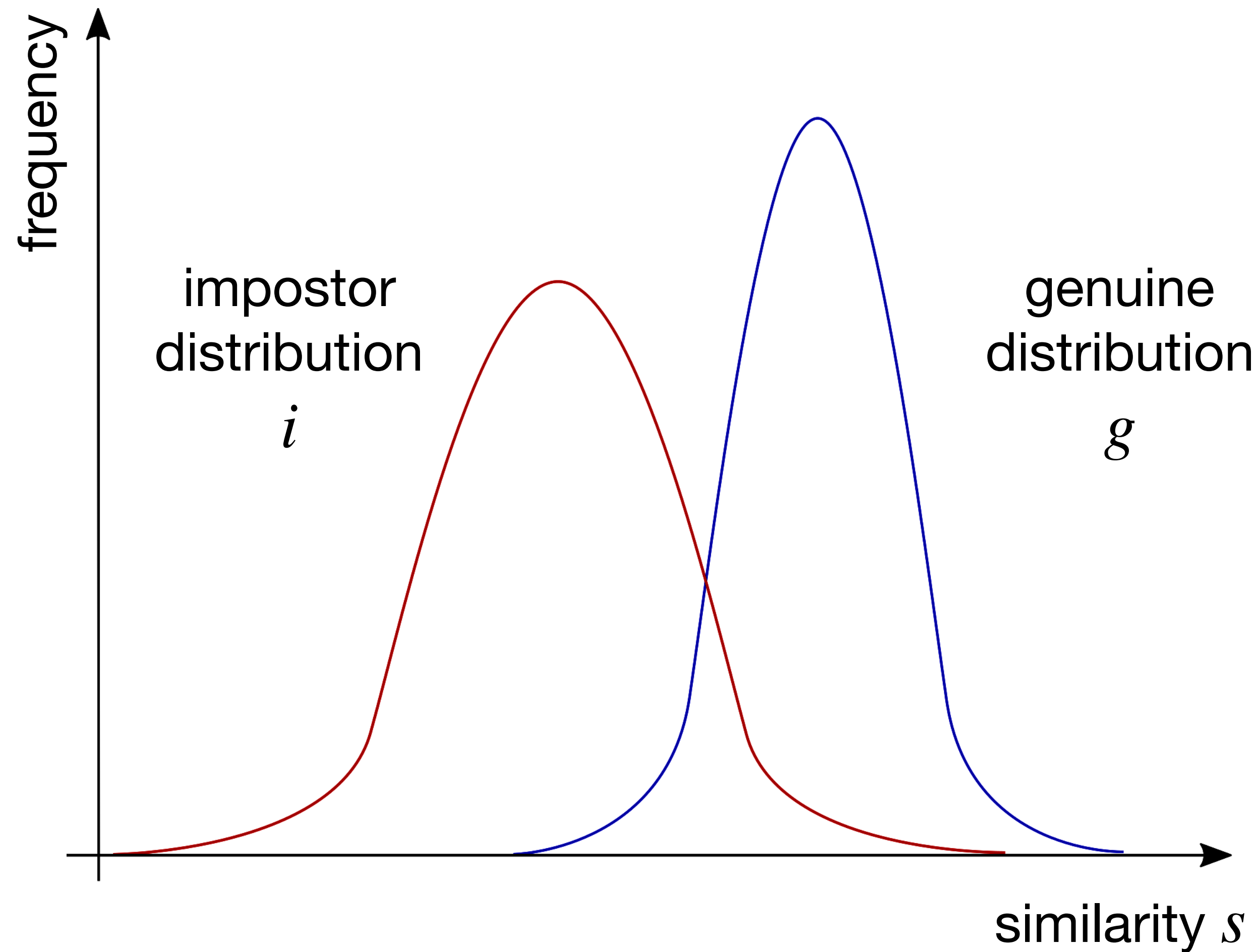


Metrics

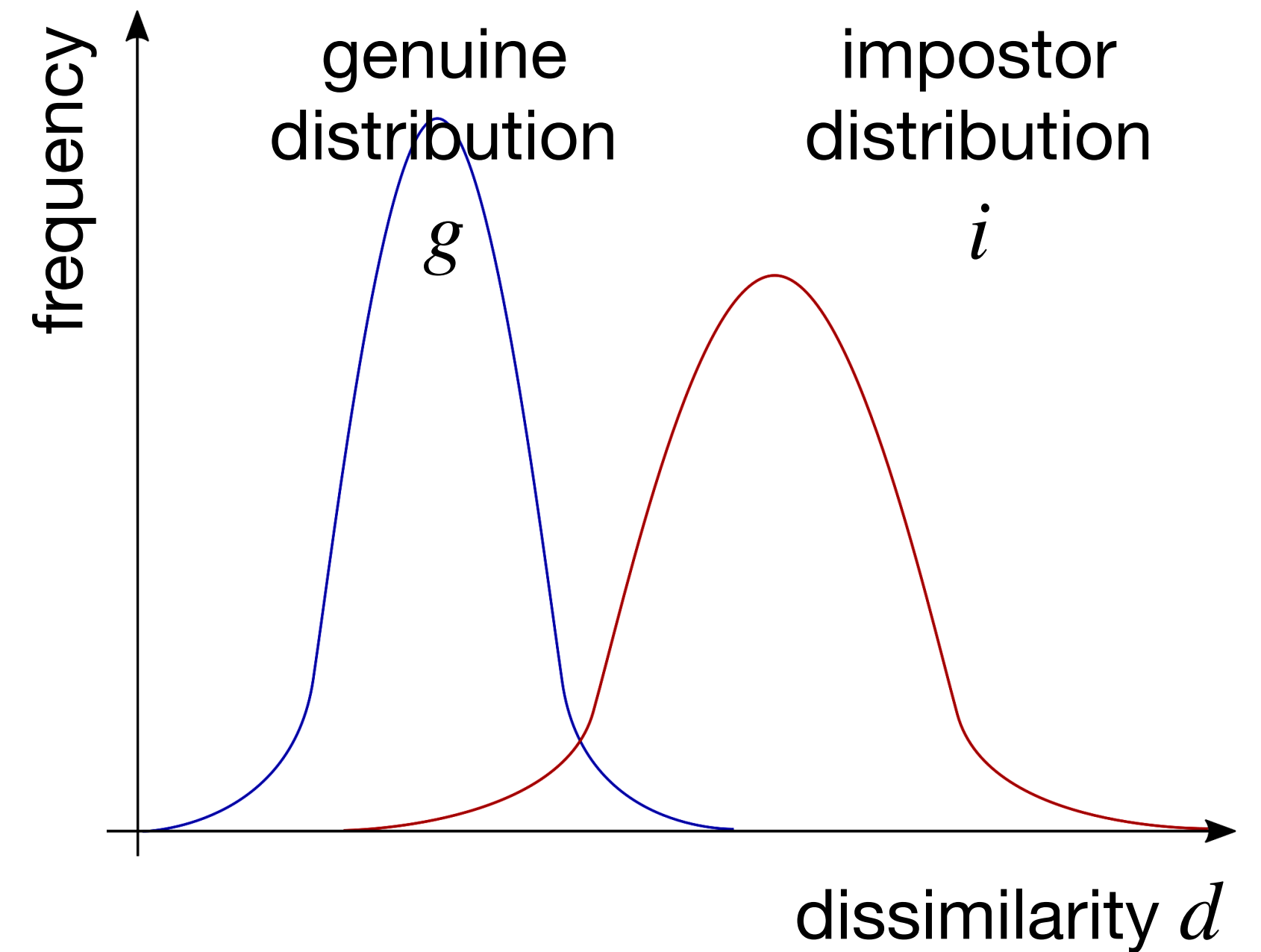
Identification



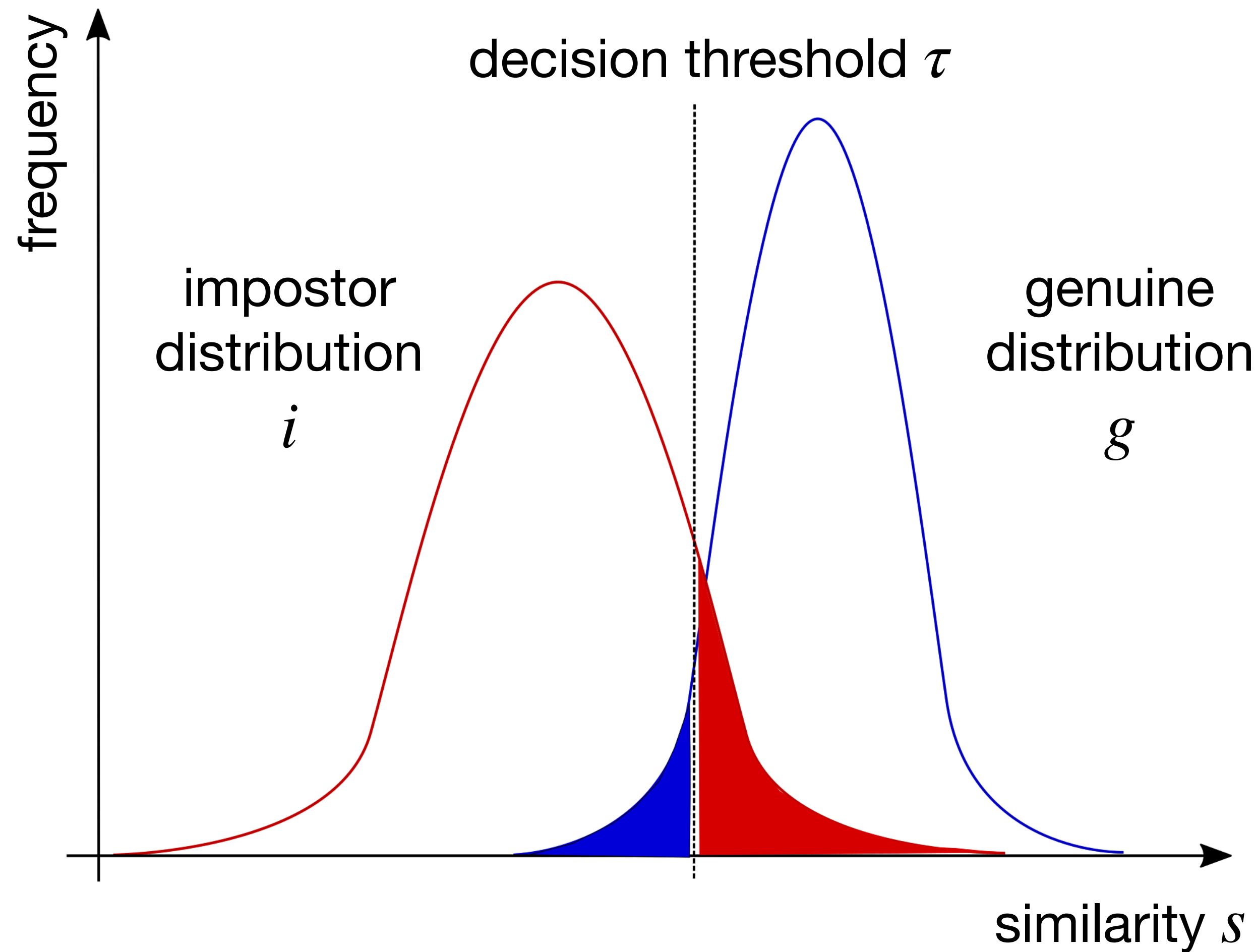
Metrics

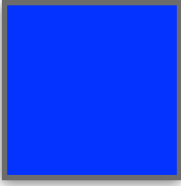


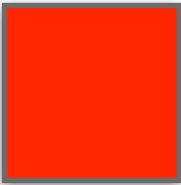
In case of dissimilarities...



Metrics



 $FNM(\tau) = \int_{-\infty}^{\tau} g(s) ds$

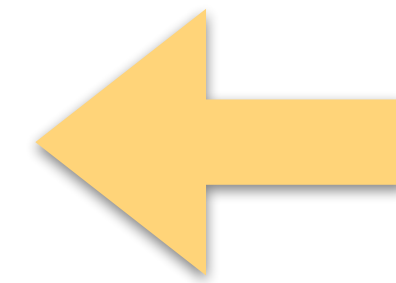
 $FM(\tau) = \int_{\tau}^{\infty} i(s) ds$

Metrics

In Practice

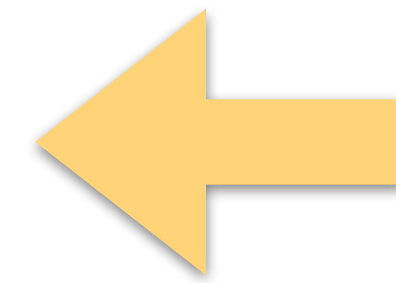
False Non-Match Rate (FNMR) and False Match Rate (FMR)

$$FNMR(\tau) = \frac{\#(\text{false non-matches for } \tau)}{\#(\text{genuine comparisons})}$$



$$\blacksquare FNMR(\tau) = \int_{-\infty}^{\tau} g(s) ds$$

$$FMR(\tau) = \frac{\#(\text{false matches for } \tau)}{\#(\text{impostor comparisons})}$$



$$\blacksquare FMR(\tau) = \int_{\tau}^{\infty} i(s) ds$$

Metrics

In Practice

False Non-Match Rate (FNMR) and False Match Rate (FMR)

$$FNMR(\tau) = \frac{\#(\text{false non-matches for } \tau)}{\#(\text{genuine comparisons})}$$

How many of the genuine comparisons are wrongly computed by the system?

$$FMR(\tau) = \frac{\#(\text{false matches for } \tau)}{\#(\text{impostor comparisons})}$$

How many of the impostor comparisons are wrongly computed by the system?

Metrics

In Practice

Interpretation of *R values.

Suppose a face recognition system with $\text{FMR}=0.1\%$

$\text{FMR}=0.001$, one error in every 1K comparisons.

Is it good?



Suppose the Newark airport

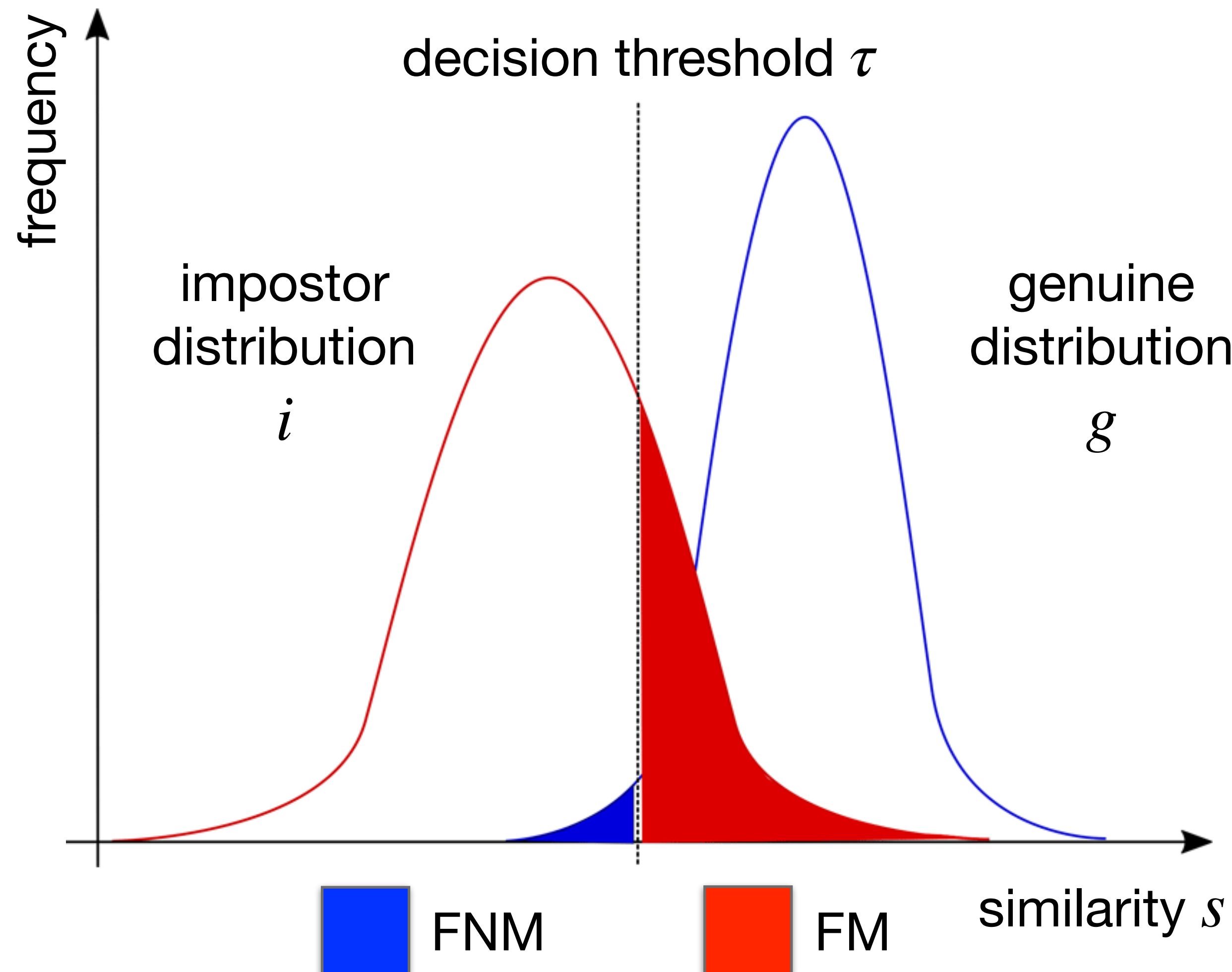
5K people per hour, 14h per day (70K people per day)

Suppose a suspect watch list with 100K people: 7 billion comparisons per day.

Average number of false matches per day: 7 million people to double check every day.

Terrorist watch list in 2016: 1,8 million people

Metrics



What is the impact of changing the decision threshold?

The larger the value of τ :
The larger the value of FNM;
The smaller the value of FM.

FNM and FM are inversely proportional.

Metrics

What to choose?

Small FNMR

Suitable to avoid denial of access and repudiation.

Increases intrusion probability, though.

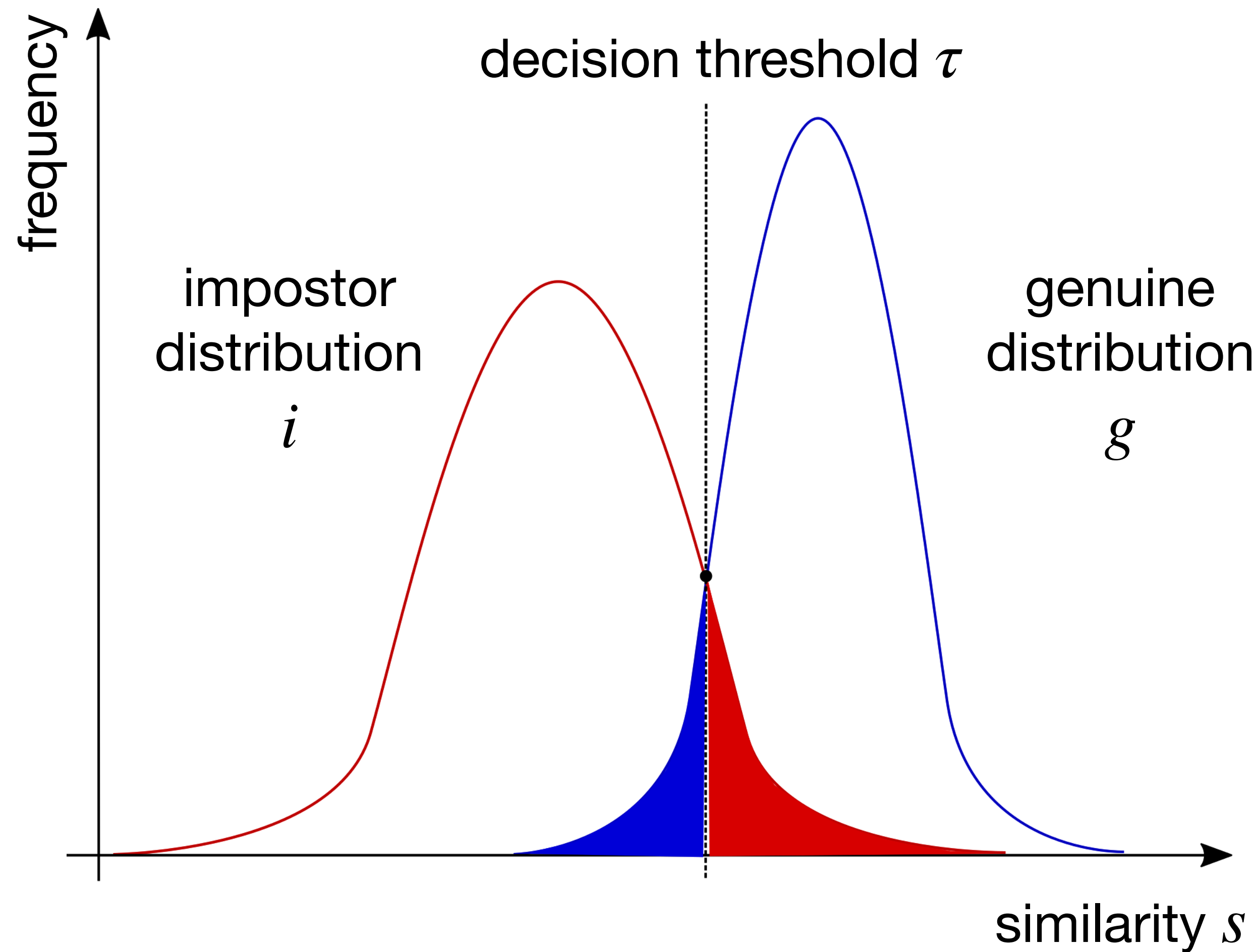
Small FMR

Suitable to avoid intrusion.

Increases denial of service and repudiation probability, though.



Metrics



What to choose?

Equal Error Rate (EER)

Common practice.

Pick the threshold where
 $\text{FNMR} = \text{FMR}$.

Metrics

How to compare two different systems?

Biometric systems *A* and *B*.

Compare both systems' FNMR and FMR at EER (1/3)

Take the one with smaller FNMR and FMR values.

What to do when system A has smaller FNMR than system B, but larger FMR (or vice-versa)?



Metrics

How to compare two different systems?

Biometric systems *A* and *B*.

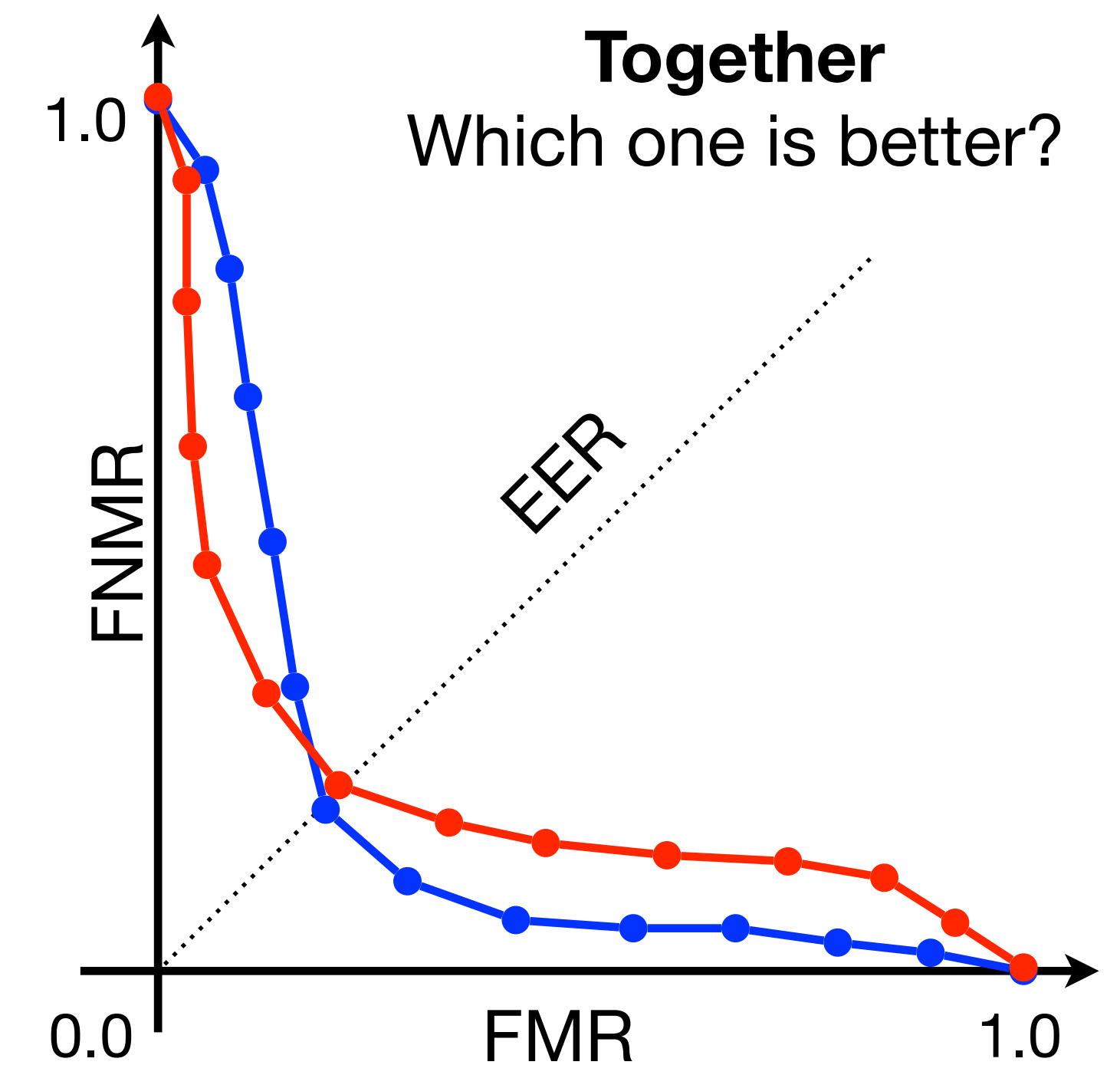
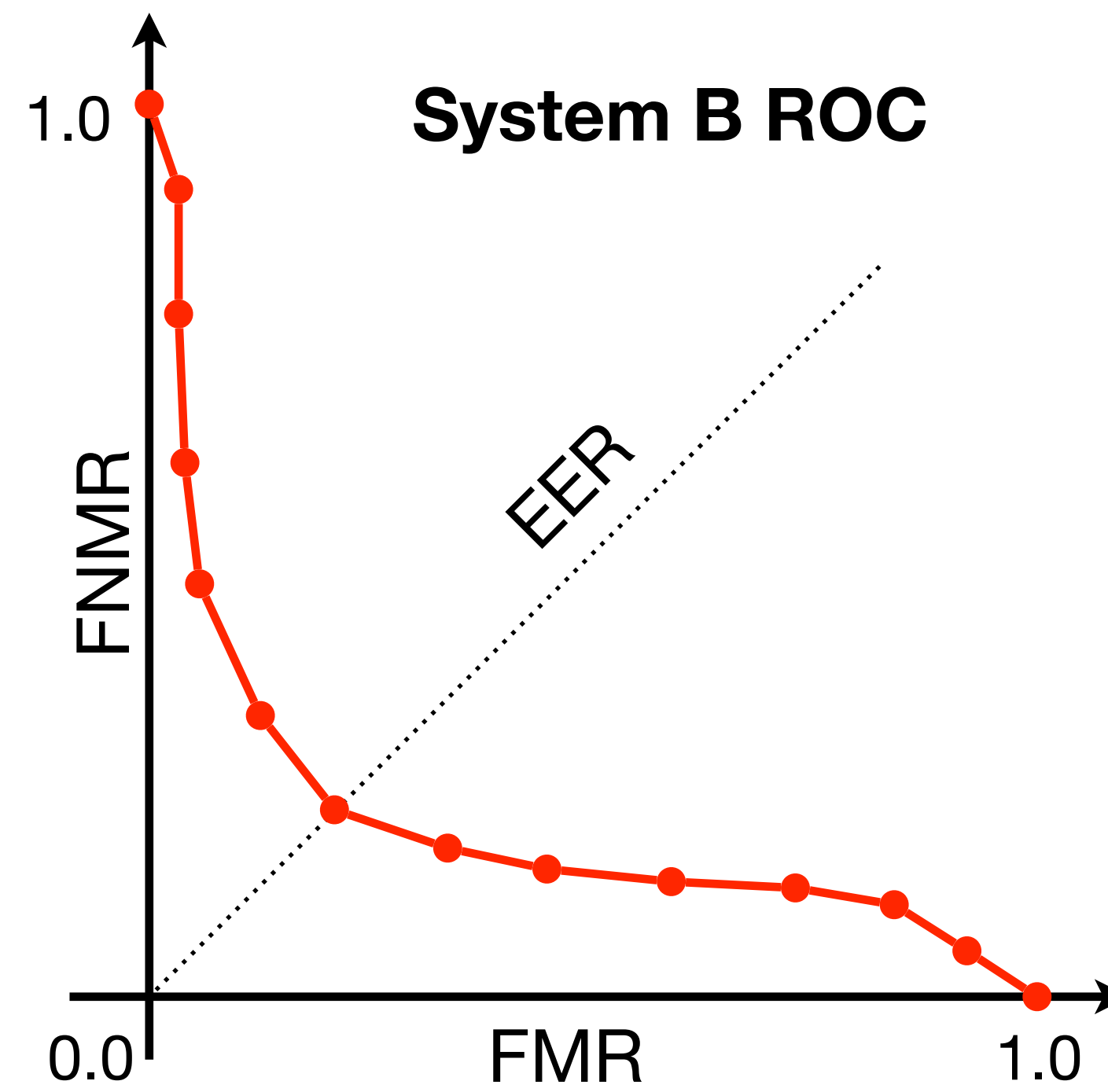
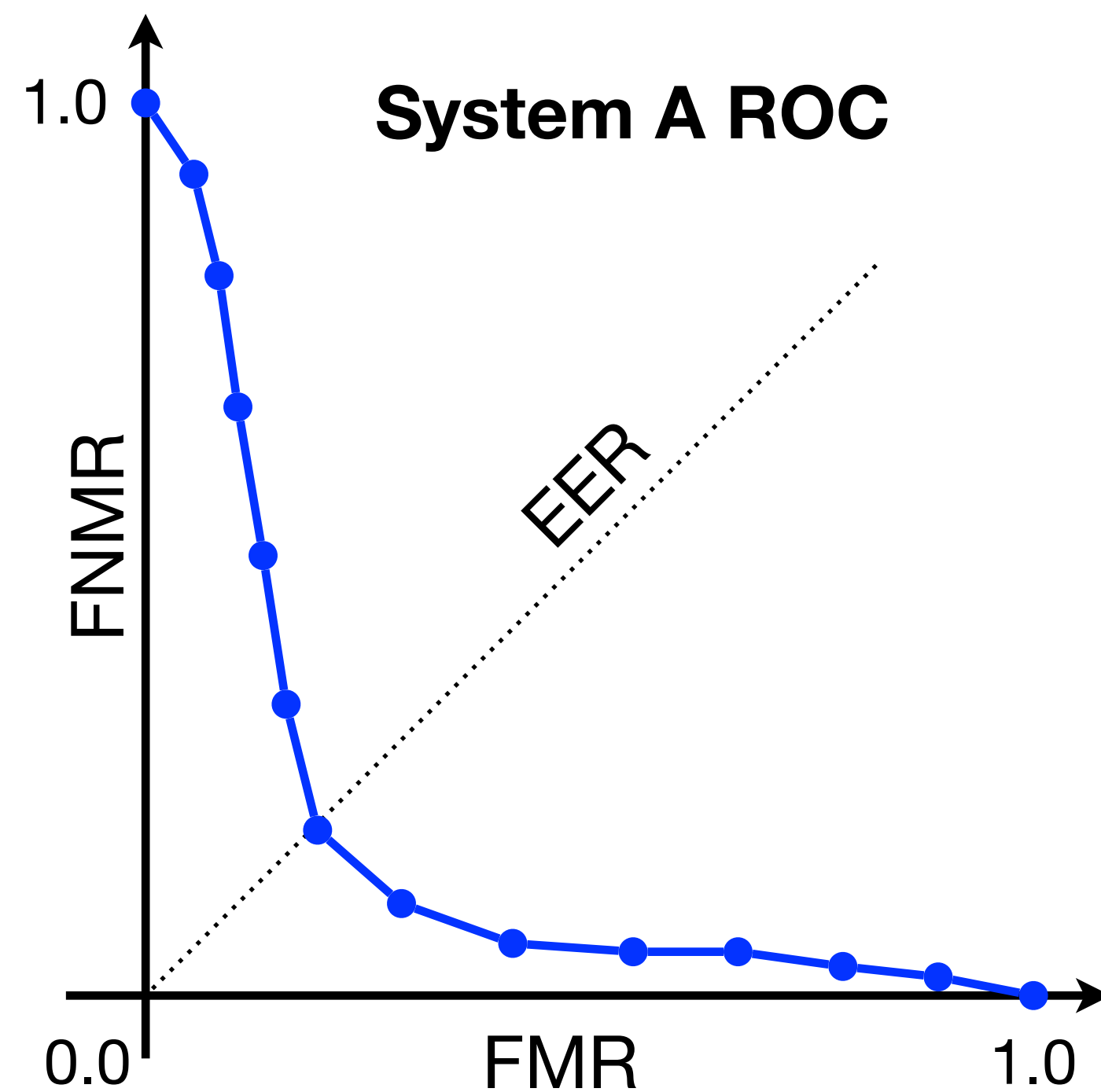
Use a Receiver Operating Characteristic (ROC) curve (2/3)



Metrics

How to compare two different systems?

Biometric systems *A* and *B*.

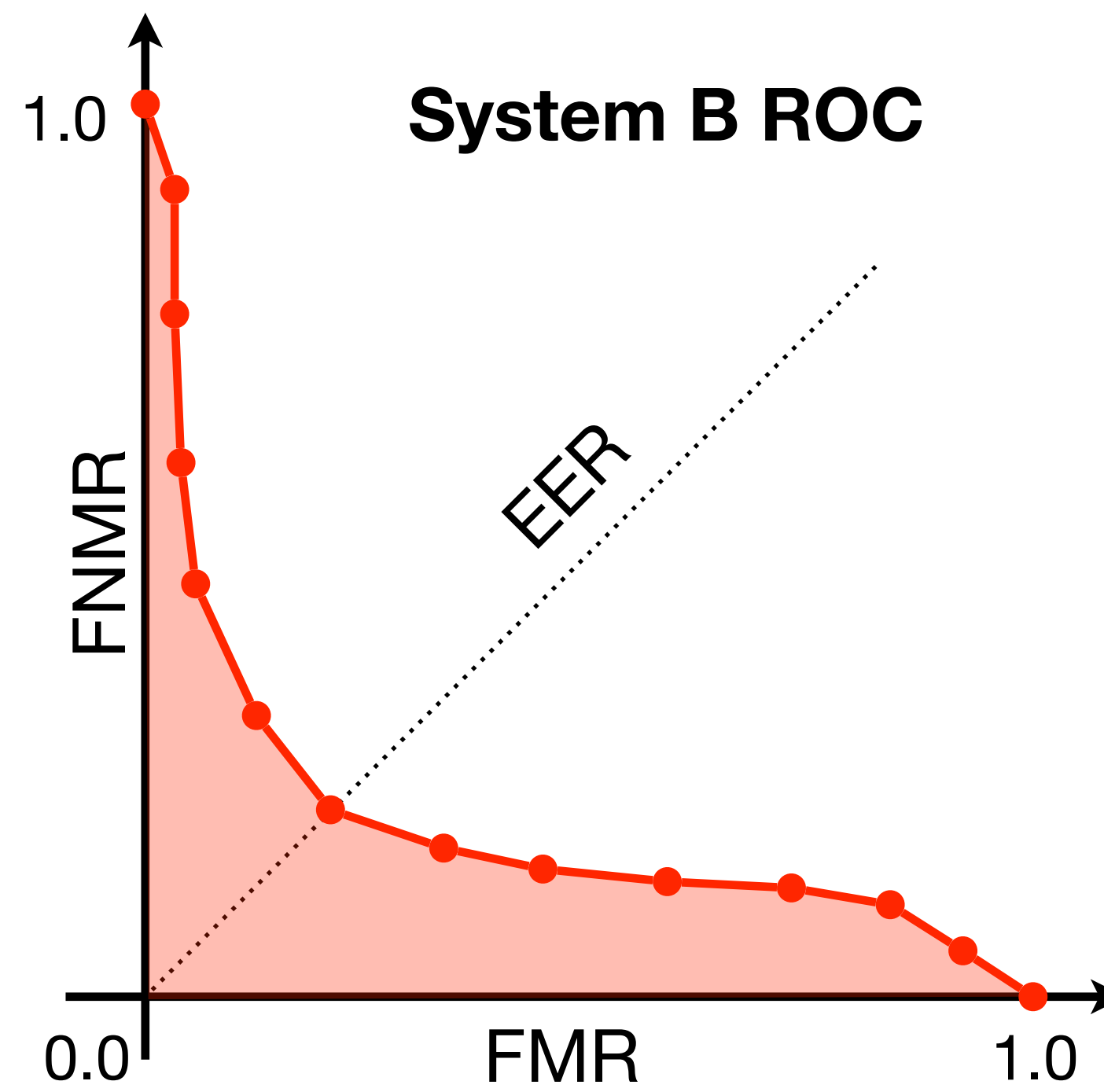
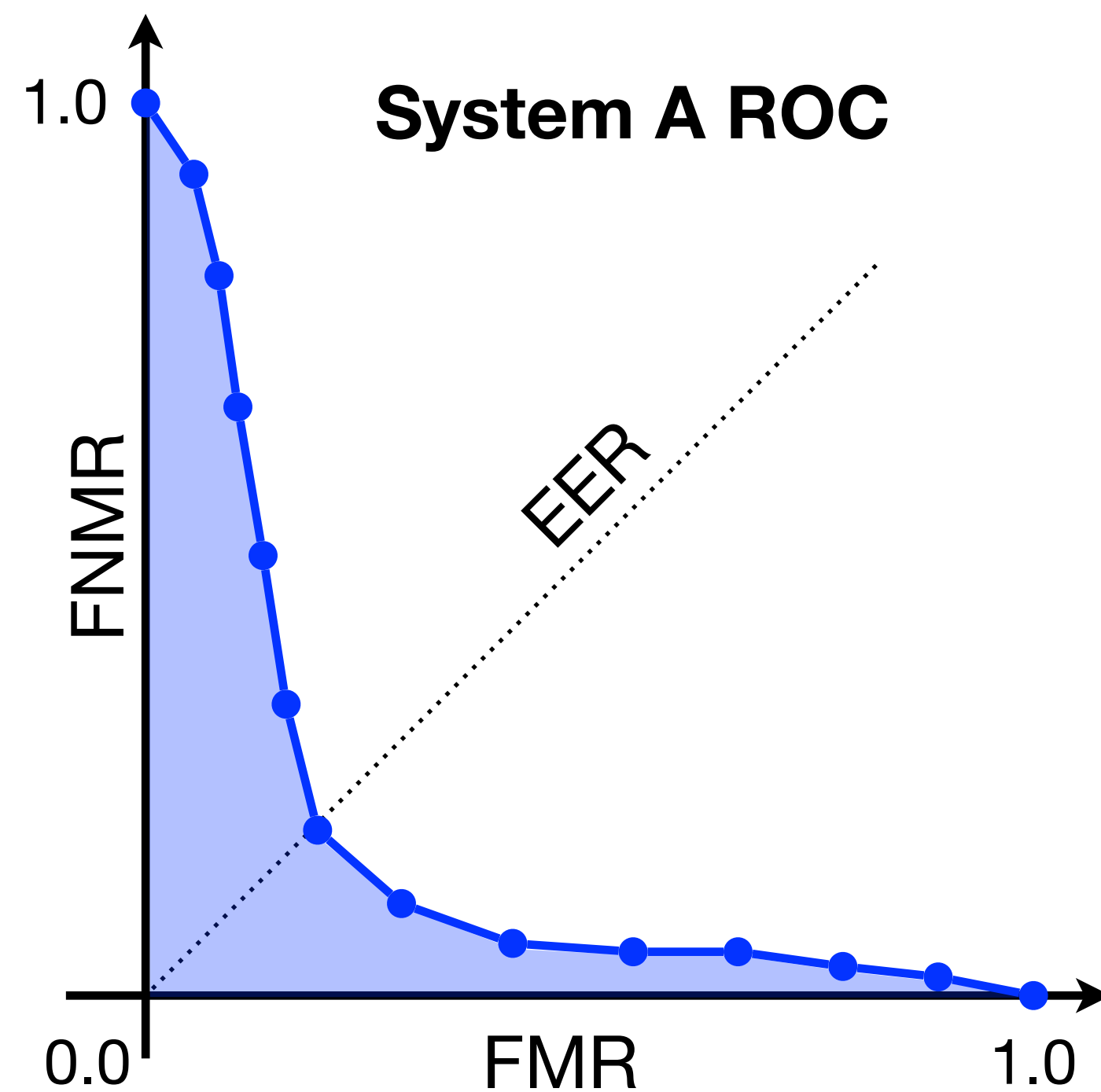


Compute FMR and FNMR for a variety of thresholds.

Metrics

How to compare two different systems?

Biometric systems *A* and *B*.



Which one is better?

Compute the Area Under The Curve (AUC).

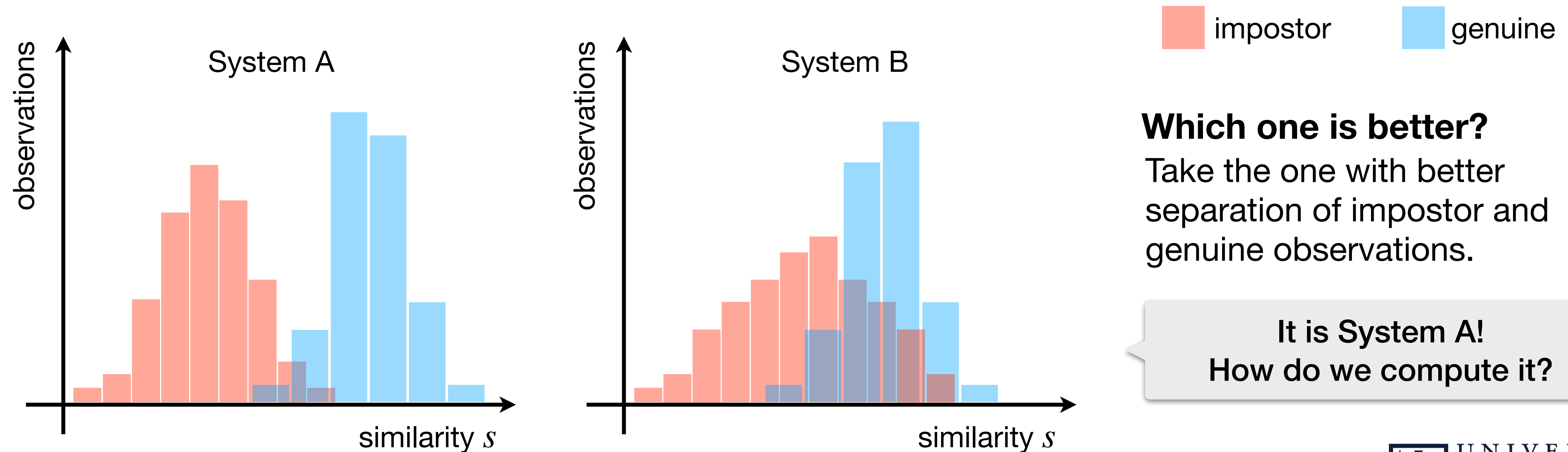
The best solution presents smaller AUC.

Metrics

How to compare two different systems?

Biometric systems A and B .

Compute the difference between impostor and genuine distributions for each system (3/3)



Metrics

How to compare two different systems?

Biometric systems A and B .

Compute the difference between impostor and genuine distributions for each system (3/3)

Which one is better?

Take the system with larger **d-prime**:

$$d' = \frac{\sqrt{2} \times |\mu_{genuine} - \mu_{impostor}|}{\sqrt{\sigma_{genuine}^2 + \sigma_{impostor}^2}}$$

Hypothesis: the distributions are Gaussians
(with mean μ and standard deviation σ).

The larger the separation between the distributions,
the larger the value of d-prime.

Metrics

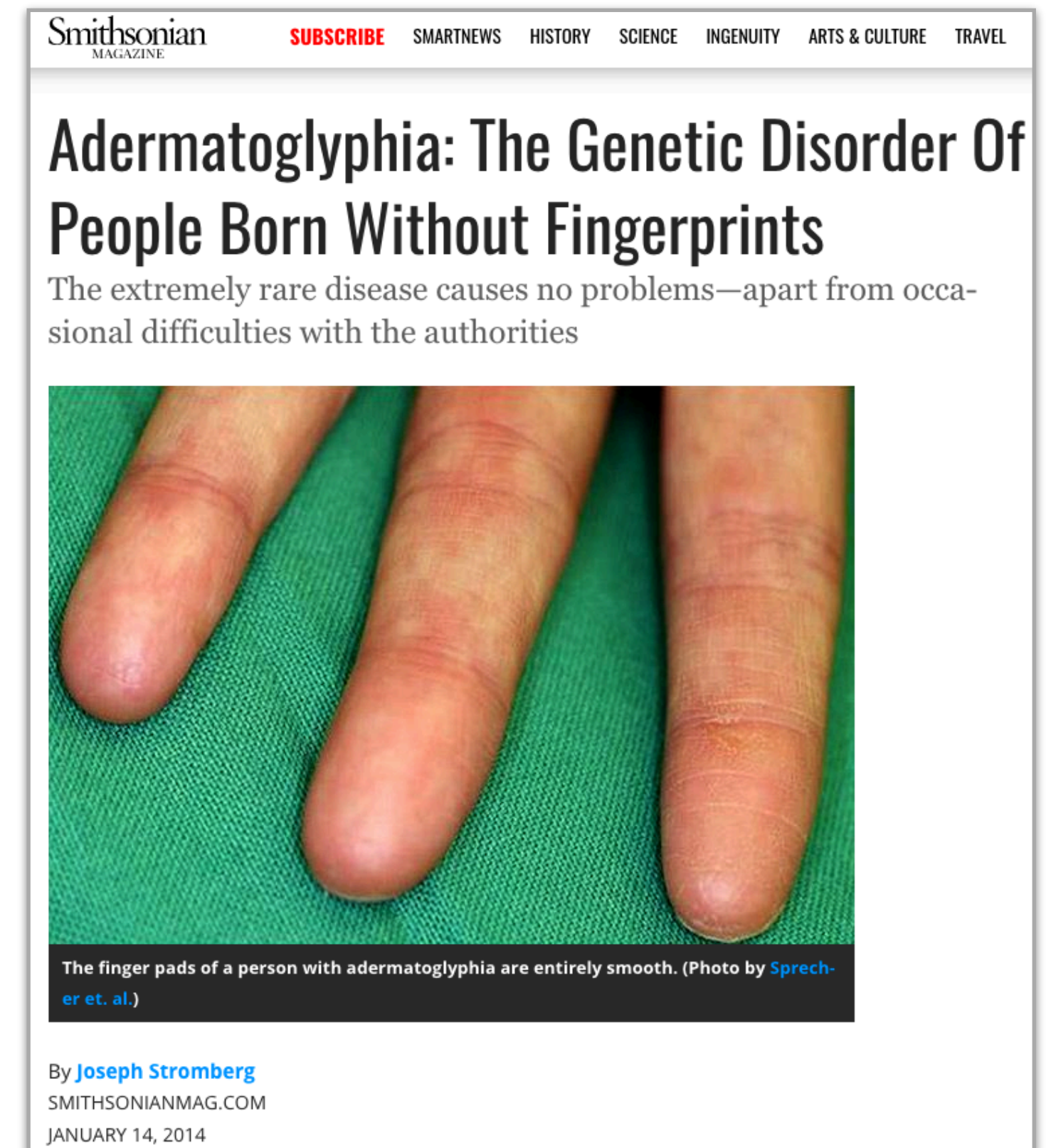
Other Metrics (1/4, 2/4)

Failure to Acquire (FTA)

Rate of falsely rejected biometric samples due to problems in acquisition.

Failure to Enroll (FTE)

The same as FTA, but during enrollment.



<https://www.smithsonianmag.com/science-nature/adermatoglyphia-genetic-disorder-people-born-without-fingerprints-180949338/>

Metrics

Other Metrics (3/4, 4/4)

Positive Metrics

True Non-Match Rate (TNMR)

$$\text{TNMR} = 1.0 - \text{FNMR}$$

True Match Rate (TMR)

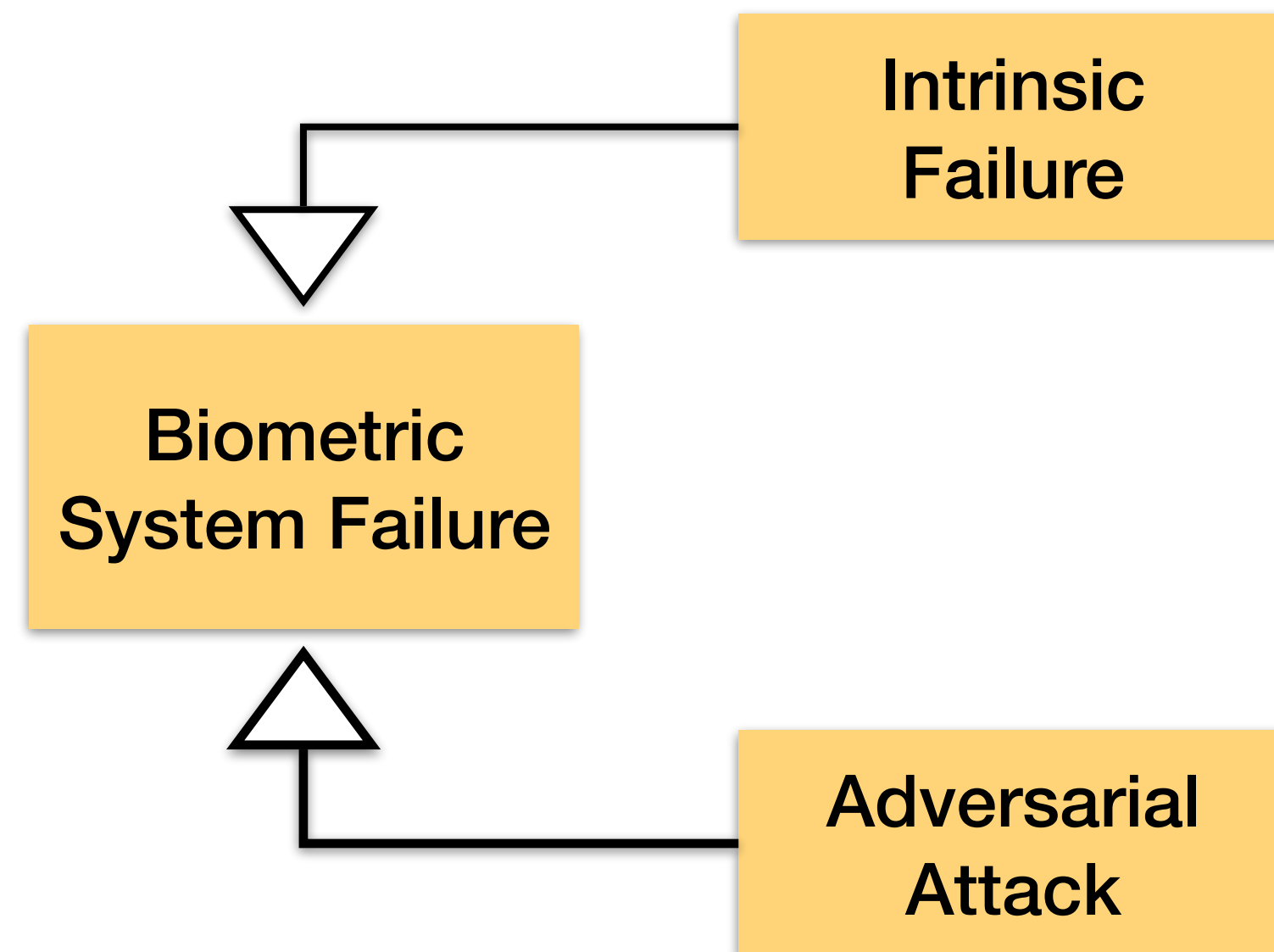
$$\text{TMR} = 1.0 - \text{FMR}$$

You want to maximize these instead of minimizing.



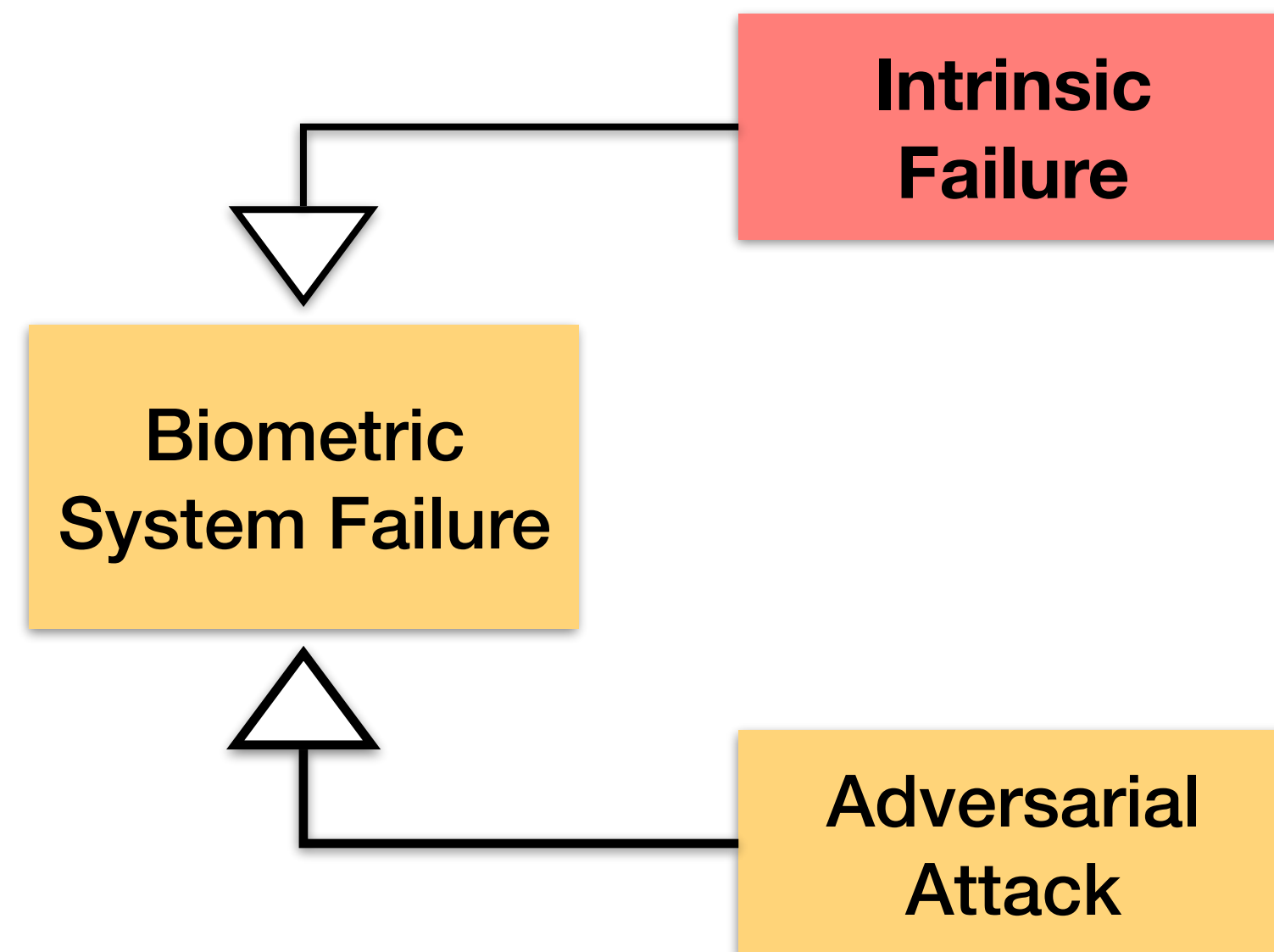
Attacks

Threat Model



Attacks

Threat Model



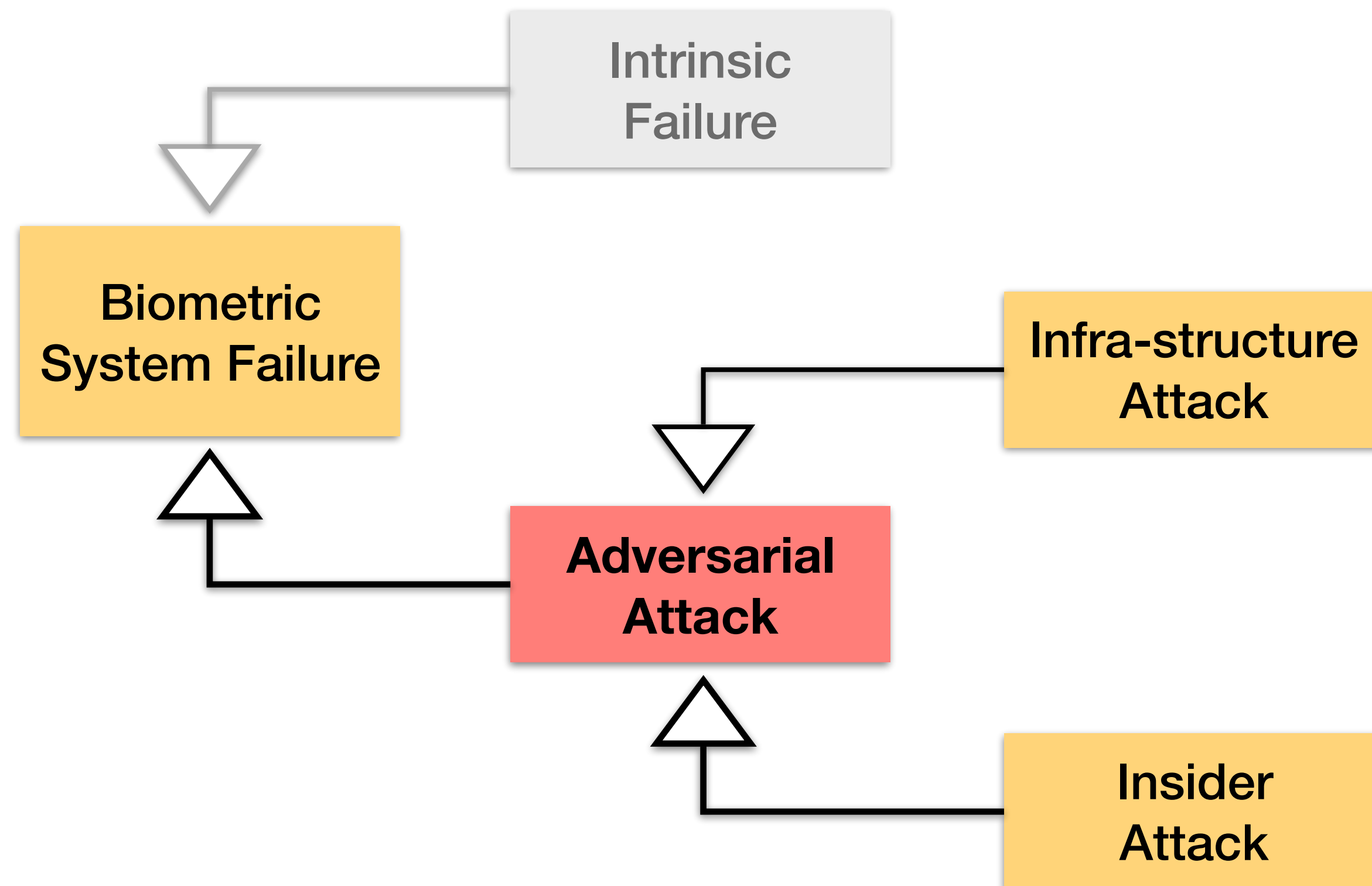
Not attacks

Errors due to the limitation of the solutions and due to hardware stress.



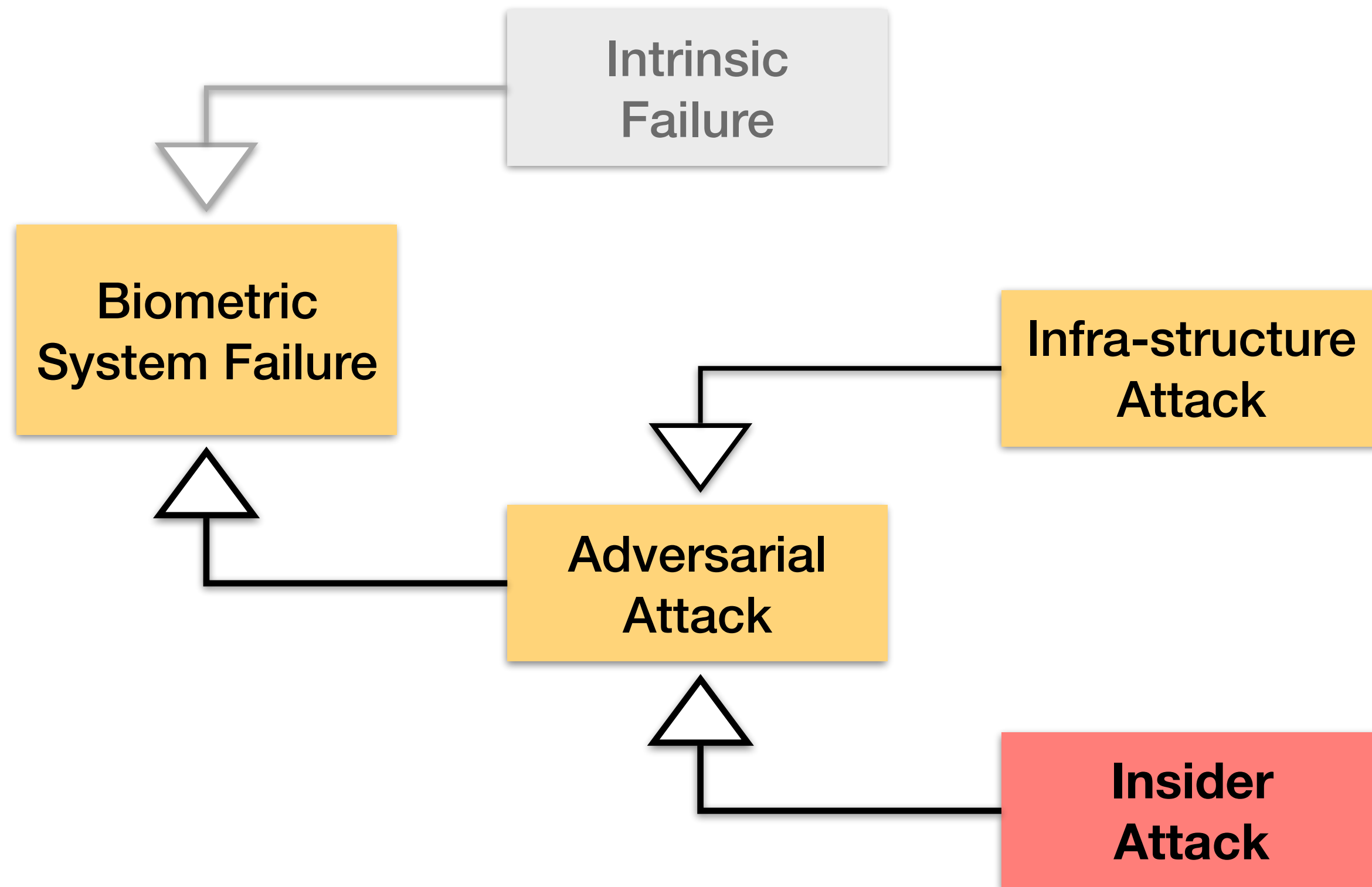
Attacks

Threat Model



Attacks

Threat Model

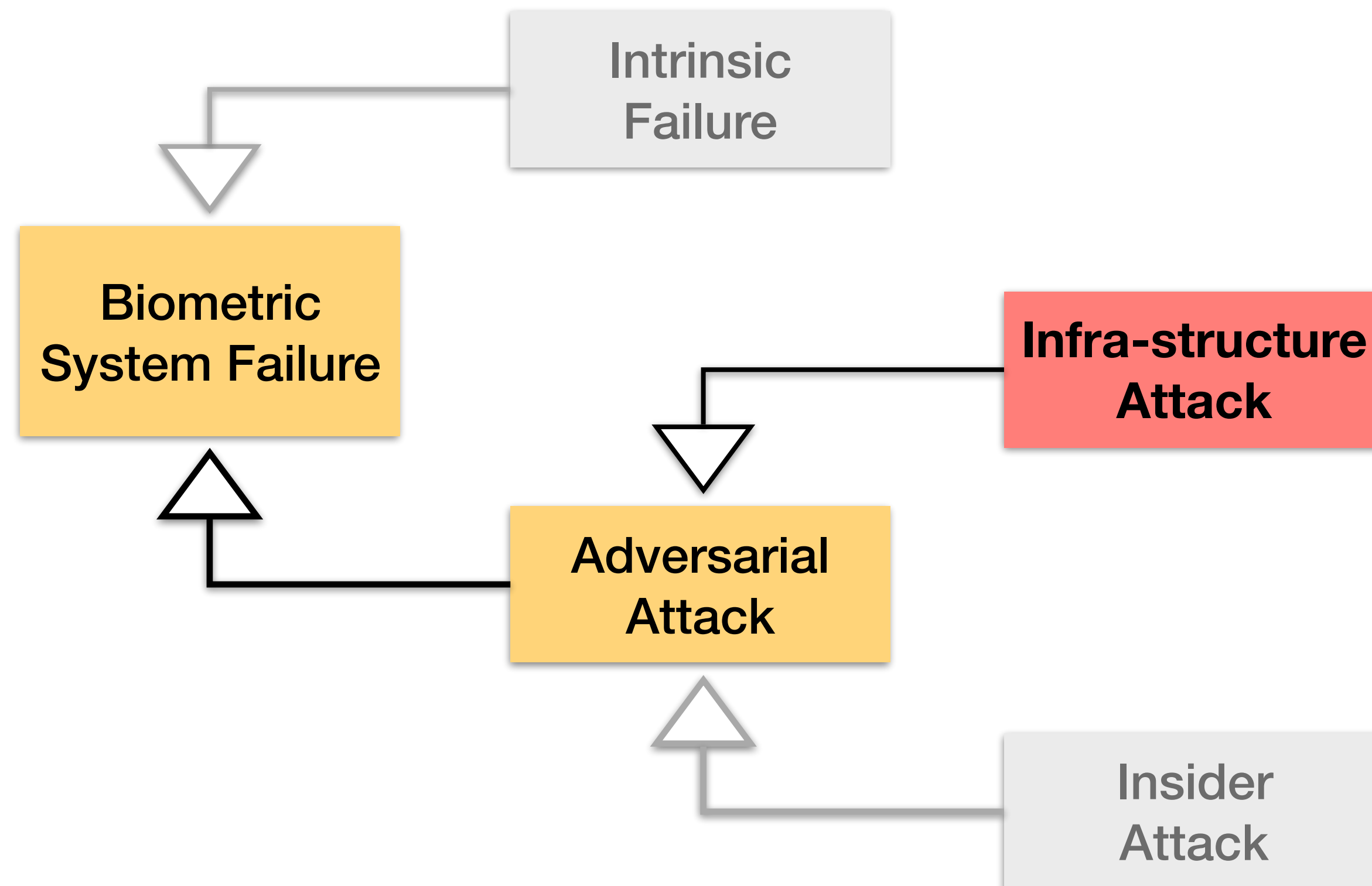


Friendly Fire

Attacks from *insiders*
(system users or operators).
Keep your system logs in
good shape.

Attacks

Threat Model

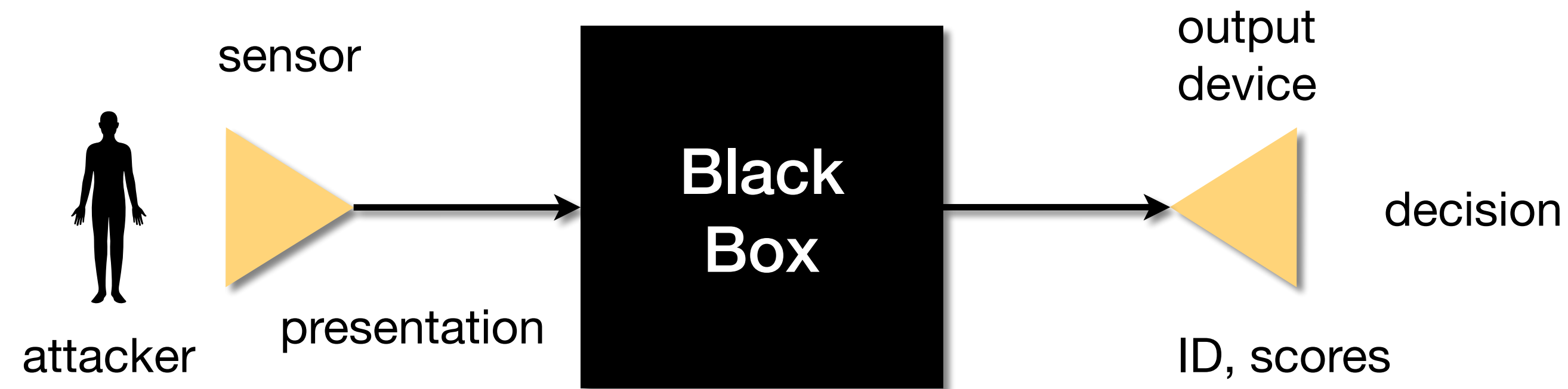


Types

Black box
White box

Attacks

Black Box Attack



Examples

Impersonation

Obfuscation

Spoofing

Attacks

Impersonation

When the attacker pretends to have somebody else's trait.
Possible solution: use more than one trait (Multibiometrics).



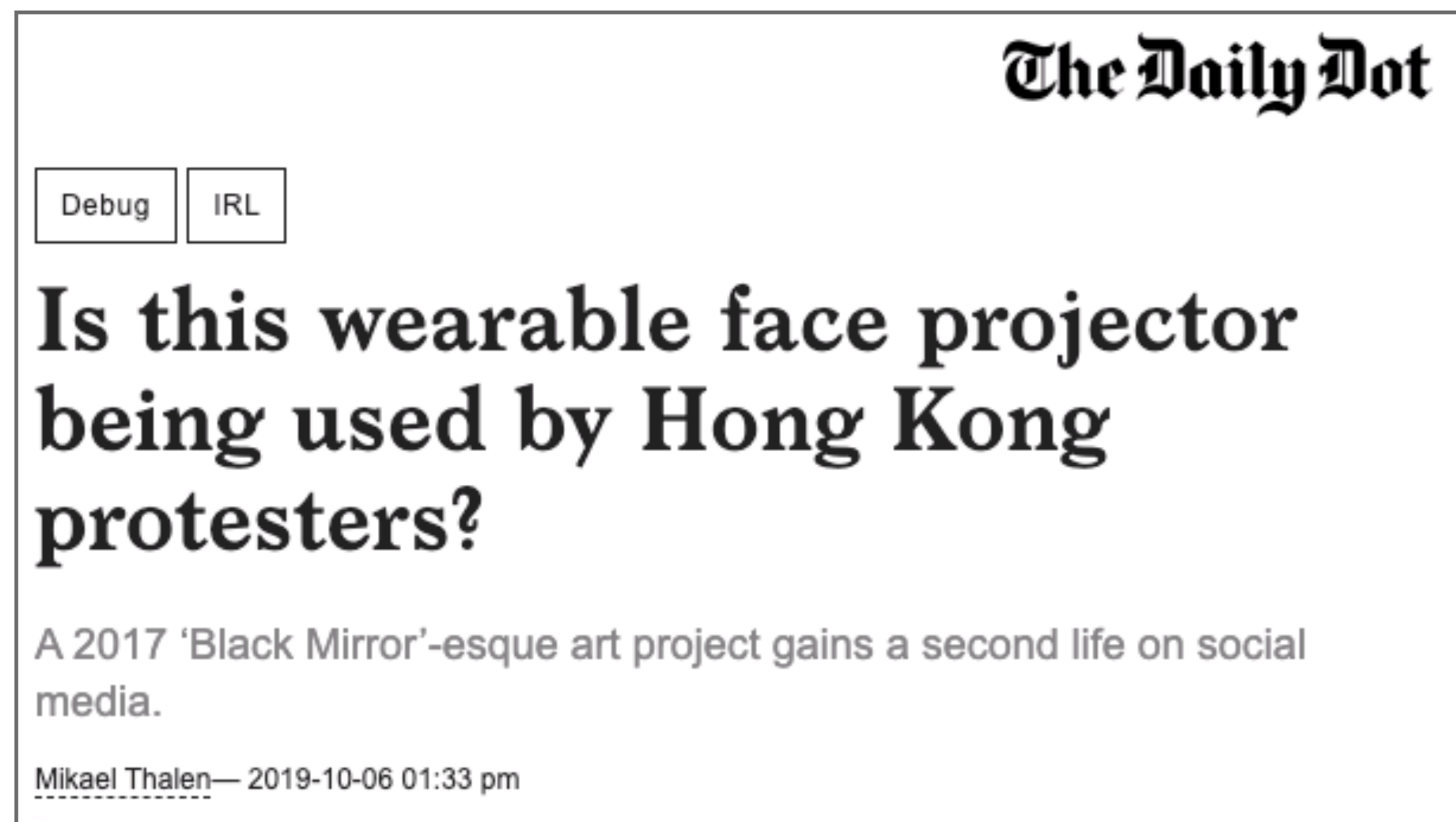
<https://www.click2houston.com/news/2019/09/18/divorce-deception-man-forges-wifes-name-on-divorce-papers-police-say/>

Attacks

Obfuscation

When the attacker tries to hide or modify their trait.

Possible solution: use more than one trait (Multibiometrics).



<https://www.dailydot.com/debug/wearable-face-projector-hong-kong-protesters/>



https://www.youtube.com/watch?v=_PoudPCevN0

Attacks

Spoofing

When the attacker presents to the system a forged non-live trait.
Possible solution: detect trait liveness.



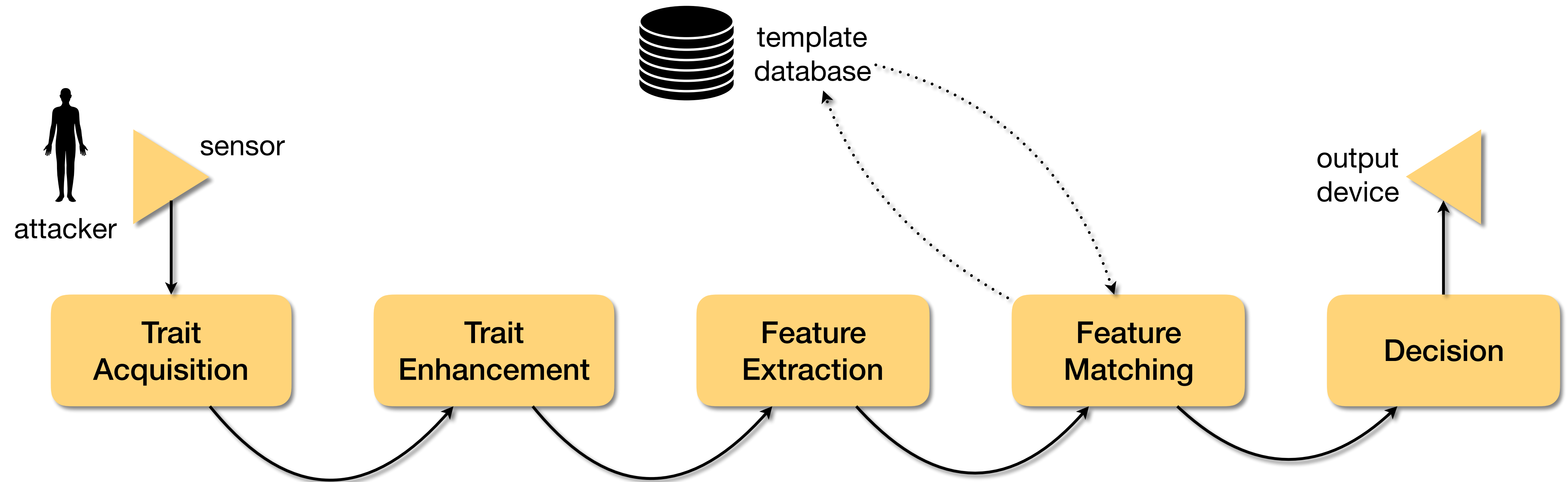
<https://www.bbc.com/news/world-latin-america-21756709>



A Brazilian doctor faces charges of fraud after being caught on camera using silicone fingers to sign in for work for absent colleagues, police say.

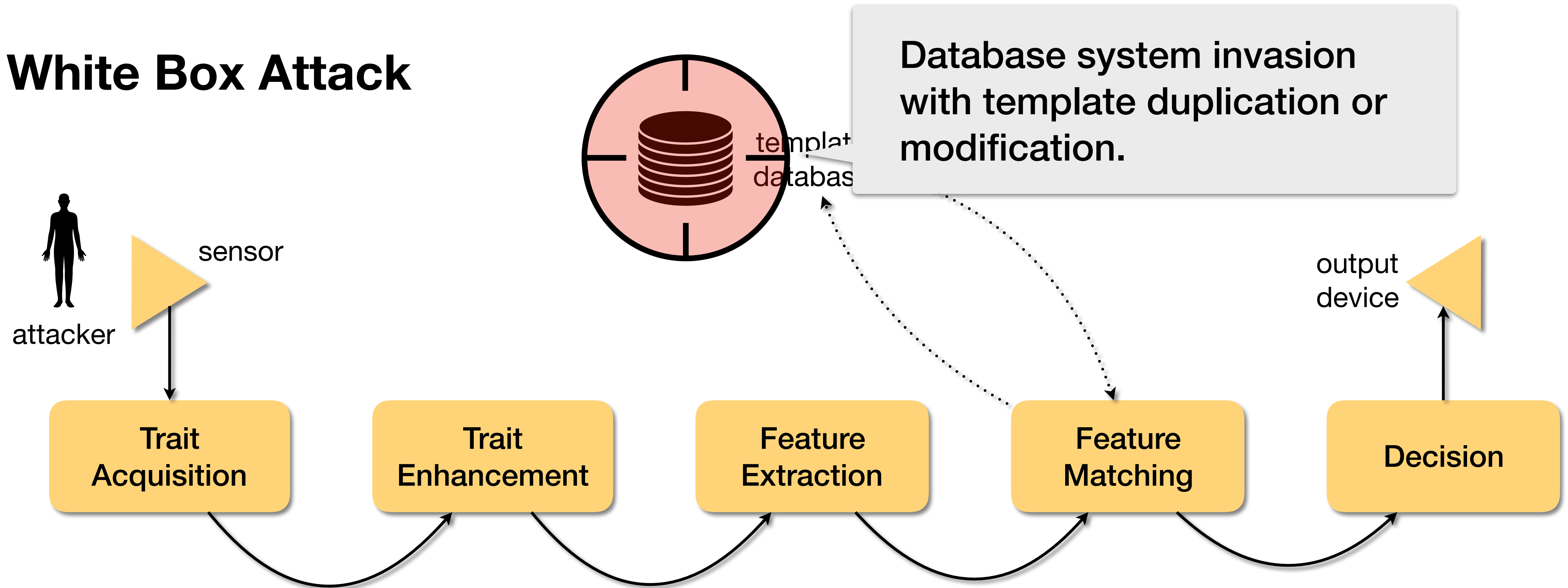
Attacks

White Box Attack



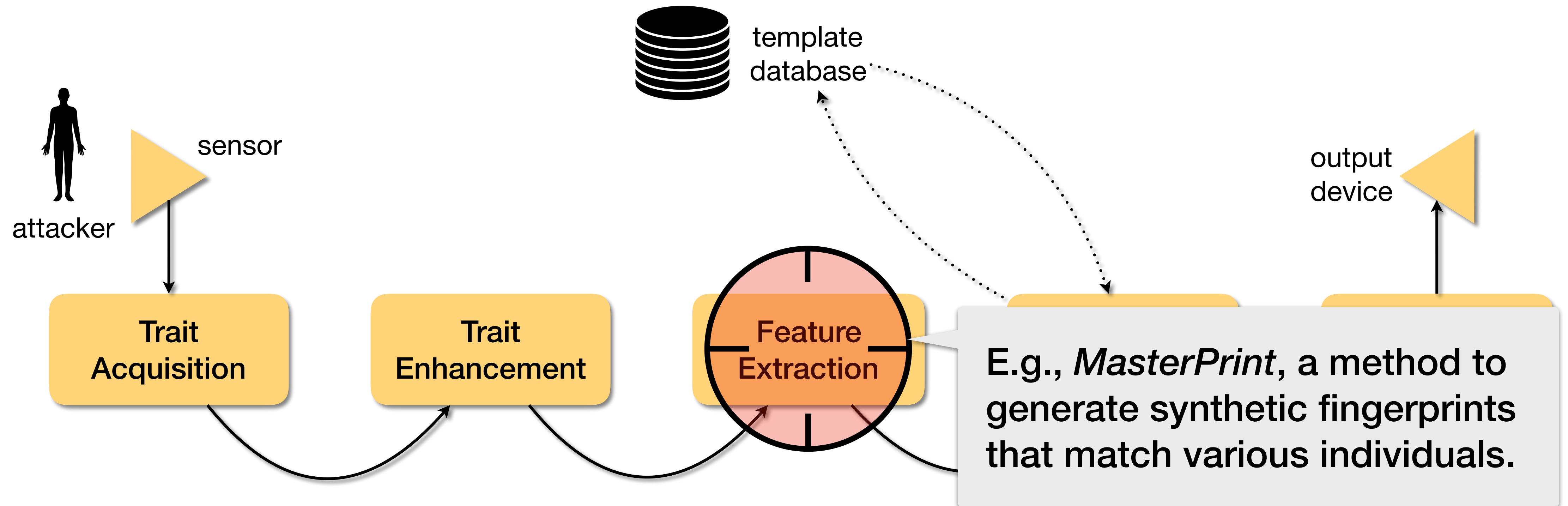
Attacks

White Box Attack



Attacks

White Box Attack



Attacks

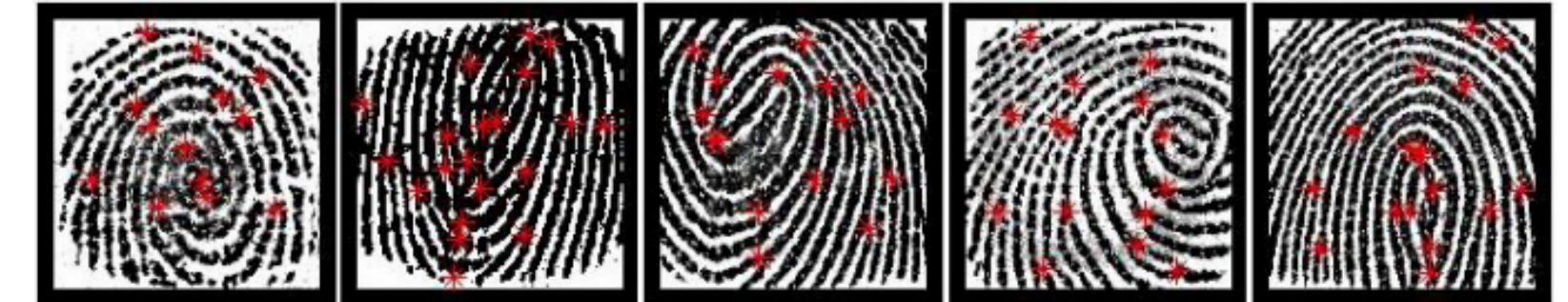
MasterPrint

IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, VOL. 12, NO. 9, SEPTEMBER 2017

2013

MasterPrint: Exploring the Vulnerability of Partial Fingerprint-Based Authentication Systems

Aditi Roy, *Student Member, IEEE*, Nasir Memon, *Fellow, IEEE*, and Arun Ross, *Senior Member, IEEE*

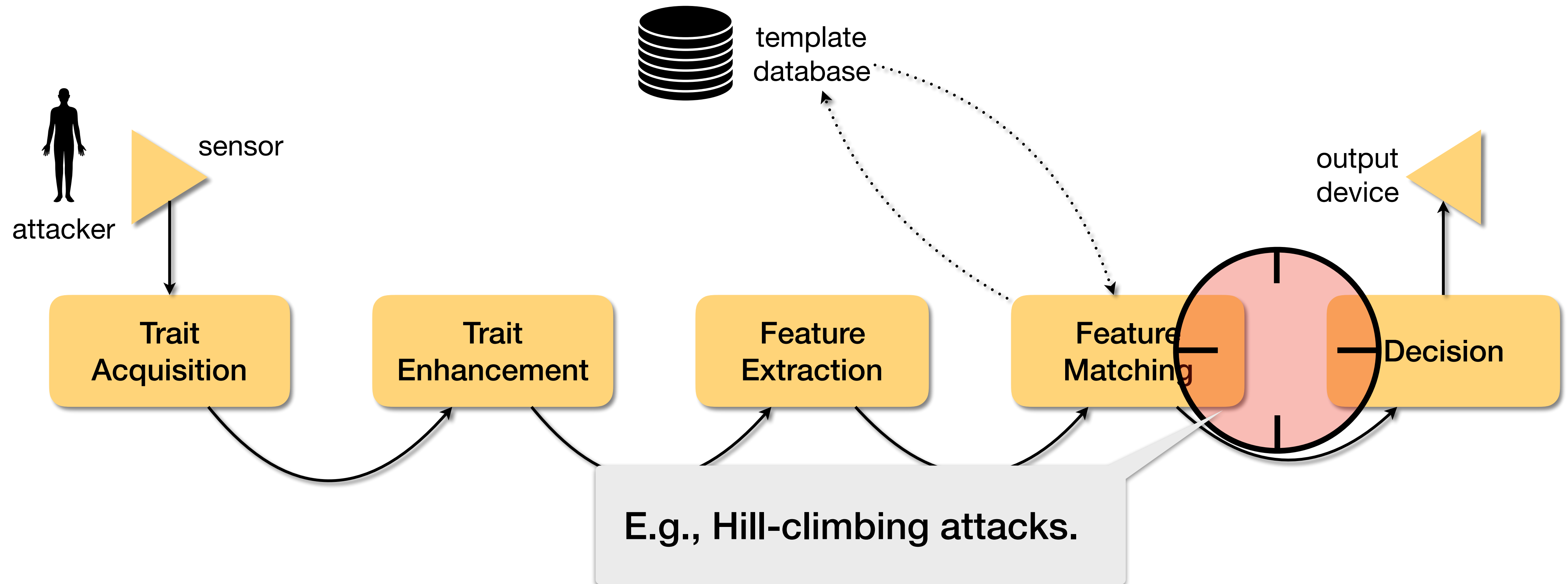


https://www.cse.msu.edu/~rossarun/pubs/RoyMemonRossMasterPrint_TIFS2017.pdf

templates. This paper investigates the possibility of generating a “MasterPrint,” a synthetic or real partial fingerprint that serendipitously matches one or more of the stored templates for a significant number of users. Our preliminary results on an

Attacks

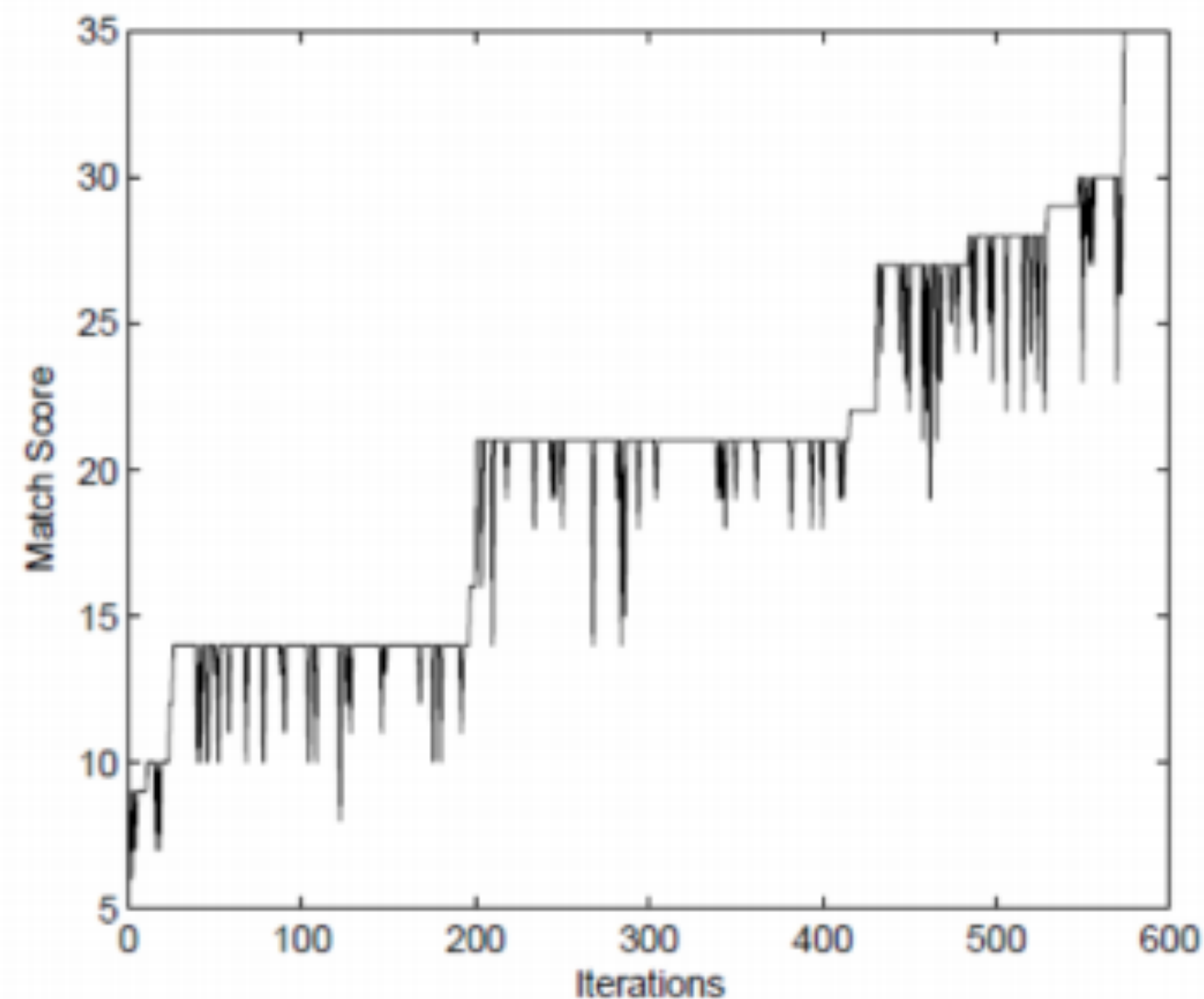
White Box Attack



Attacks

Hill-climbing Attack

E.g. Fingerprints

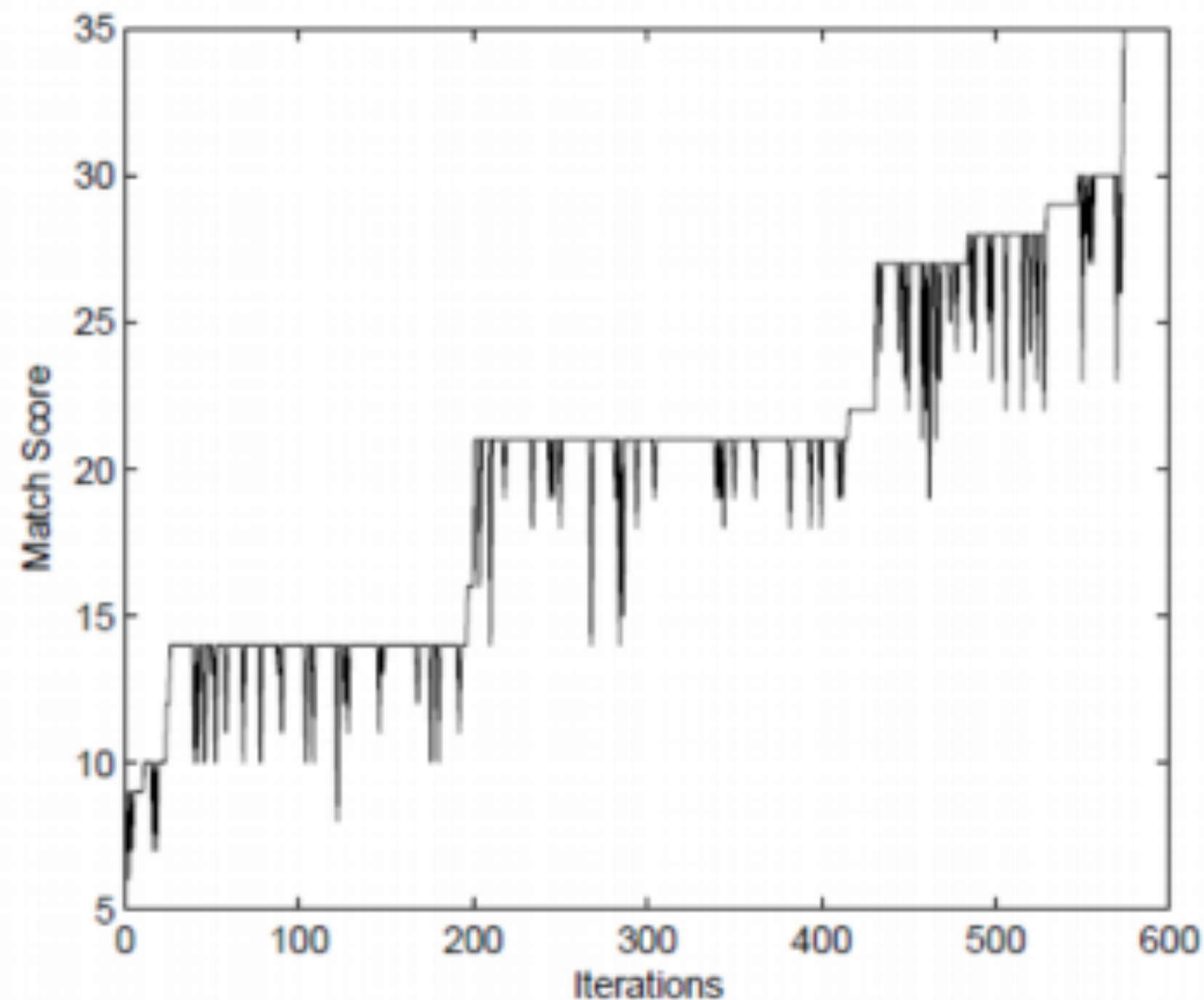


The attacker iteratively provides synthetic trait samples to the system. At each iteration, the attacker observes how the similarity scores are progressing.

Martinez-Diaz et al.
Hill-Climbing and Brute-Force Attacks on Biometric Systems: A Case Study in Match-on-Card Fingerprint Verification
IEEE ICCST, 2006

Attacks

Hill-climbing Attack E.g. Fingerprints

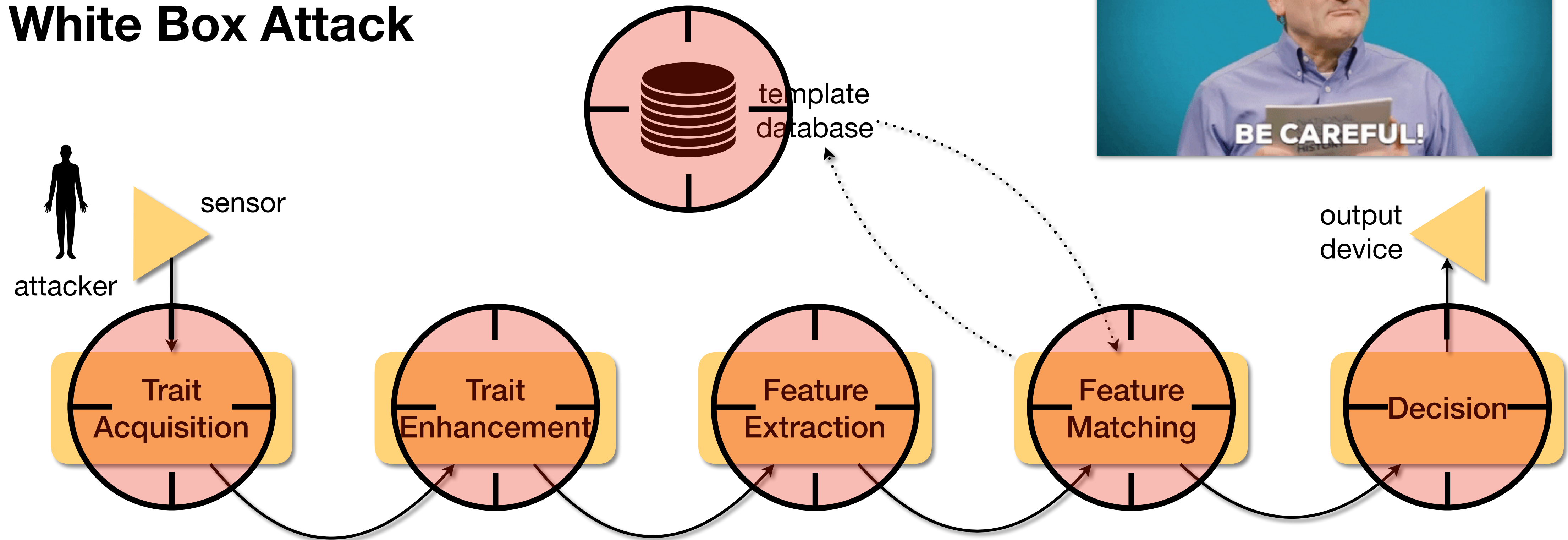


With such progress feedback, the attacker can guide the generation of better and better synthetic fingerprint samples, up the point of trespassing the decision threshold.

Martinez-Diaz et al.
Hill-Climbing and Brute-Force Attacks on Biometric Systems: A Case Study in Match-on-Card Fingerprint Verification
IEEE ICCST, 2006

Attacks

White Box Attack



S'up Next?

First Coding Day

Implementation of metrics.

Bring your computers

Don't have one?

Please let me know ASAP.

Be ready! :)

Tools: Python 3 (important), PyCharm IDE (optional).



Acknowledgments

This material is heavily based on
Dr. Adam Czajka's and Dr. Walter Scheirer's courses.
Thank you, professors, for kindly allowing me to use your material.

<https://engineering.nd.edu/profiles/aczajka>
<https://www.wjscheirer.com/>