# Basics I

CSE 40537/60537 Biometrics

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Spring 2020

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# Today you will...

*Get to know*
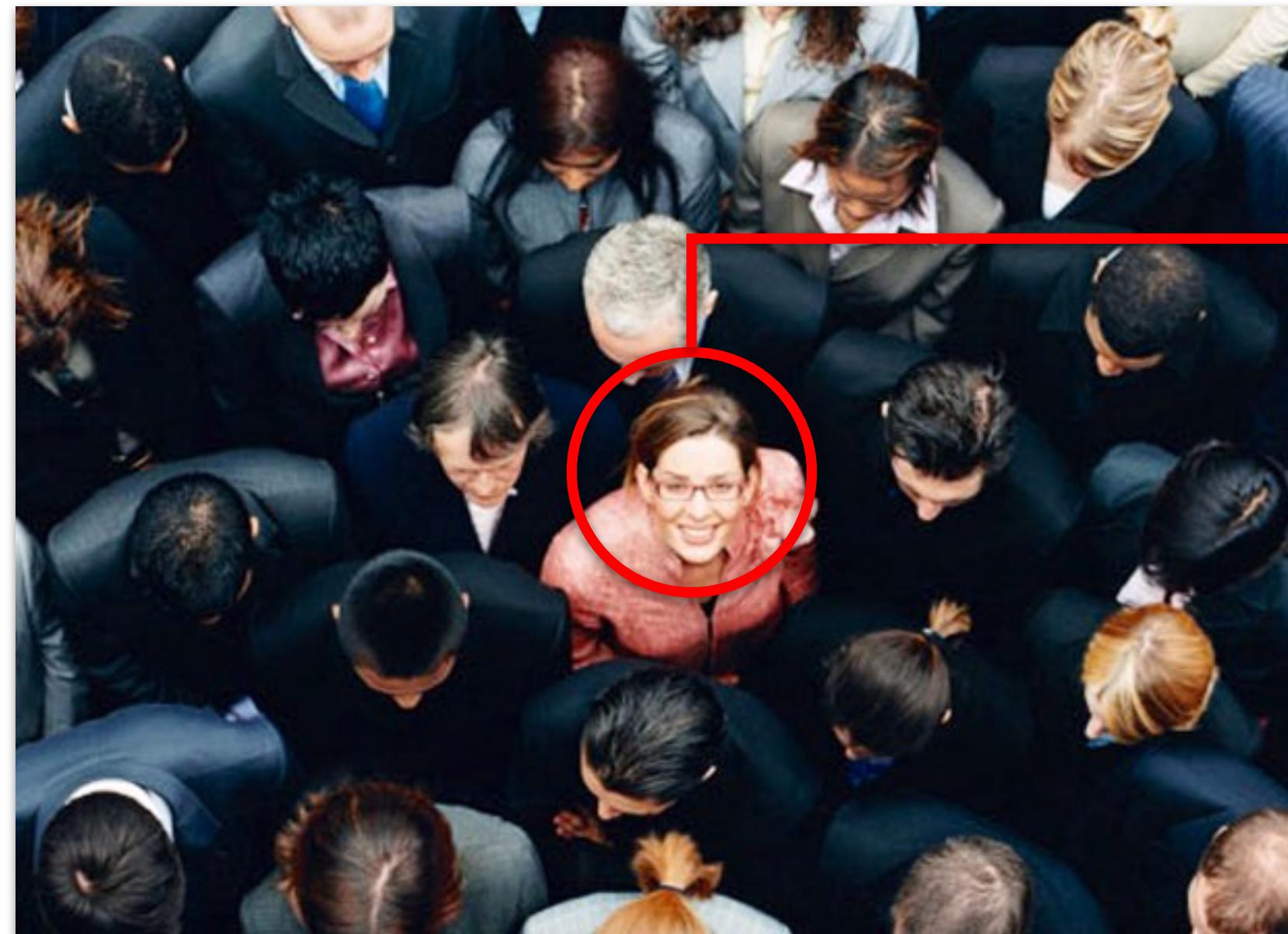
What Biometrics is.

Reasons to use Biometrics.

Biometric traits.

How Biometric systems look like.

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# What is Biometrics?



**7 billion people**
Who is this person? *(Identification)*
Is this person Jane Doe? *(Verification)*

Biometrics aims at **identifying** or
**verifying** the claimed or denied identity
of an individual based on their *physical*,
*chemical* or *behavioral* traits.

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# What is Biometrics?

In this course, we aim at **computer-aided Biometrics**.

We'll focus on **software solutions** rather than hardware.

But we'll get to use some **cool devices**, I promise.

# What is Biometrics?

**Why computers?**
High throughput
Repeatability
Predictability
Accountability

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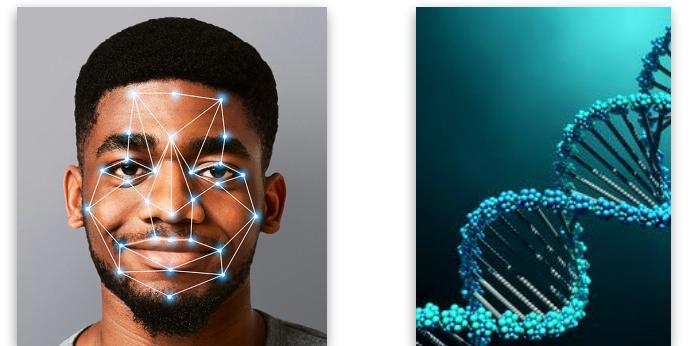
# What is Biometrics?

Identity verification through:

✅ A unique trait of yours.
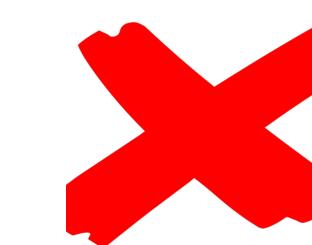

physical


chemical


behavioral

❌ Not something you **have**.



❌ Not something you **know**.



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# Why use Biometrics?

**Consumers prefer biometric authentication to traditional passwords, Visa says**

Jan 6, 2020 | Chris Burt
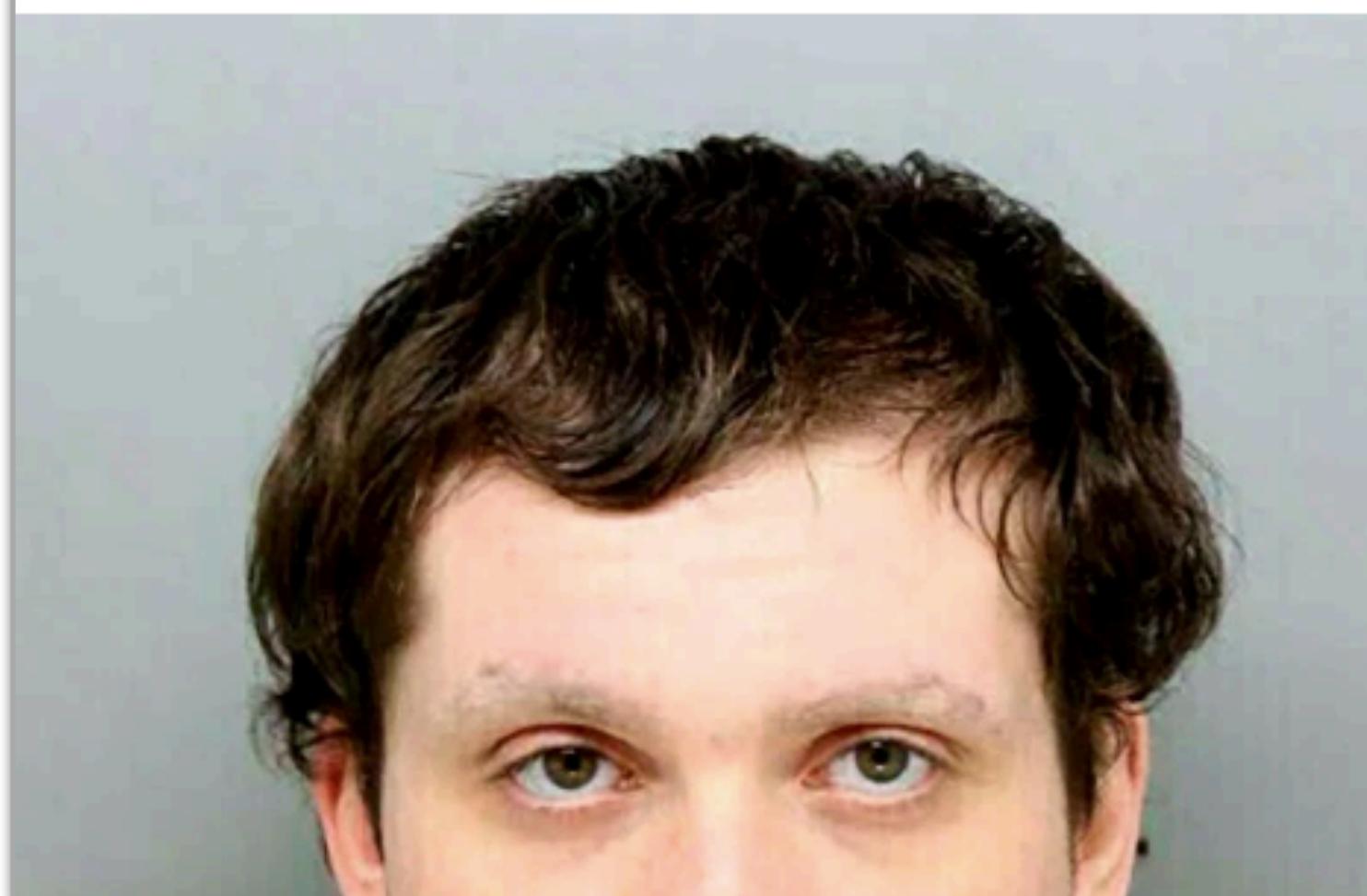
CATEGORIES     Biometrics News | Financial Services

Almost 70 percent of U.S. shoppers did not go through with an online purchase because they either forgot the password, couldn't log in or couldn't receive a one-time passcode, according to research conducted by Visa, while another report from Verizon found that as many as 80 percent of data breaches are caused by compromised and weak passwords.

https://www.biometricupdate.com/202001/consumers-prefer-biometric-authentication-to-traditional-passwords-visa-says

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# Why use Biometrics?



**OHIO**

**Ohio Man Who Claimed to Be Missing Boy Gets 2 Years in Prison On Identity Theft Charges**

(CINCINNATI) — An Ohio man who claimed to be a child who disappeared at age 6 pleaded guilty Wednesday to aggravated identity theft and will serve two years in prison, minus time served.

Federal authorities said they were suspicious after he refused to be fingerprinted. DNA testing quickly revealed his true identity.

https://time.com/5762223/brian-rini-missing-child-pleads-guilty/

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# Why use Biometrics?

**Biometrics is safer**
But not absolutely safe!



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.

# Why use Biometrics?

**Biometrics is safer**
But not absolutely safe!





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

# Why use Biometrics?

**Biometrics is safer**
But not absolutely safe!



RIO DE JANEIRO (Reuters) - A masked Rio de Janeiro inmate dressed as a woman tried to break out of a Brazilian jail this weekend in a surreal act of derring-do, only to be thwarted on the cusp of freedom by state prison authorities.

https://www.reuters.com/article/us-brazil-crime/the-man-in-the-plastic-mask-disguised-brazil-inmate-busted-in-brazen-jailbreak-idUSKCN1UV1E6

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# Why use Biometrics?

**Biometrics is safer**
But not absolutely safe!
Even humans fail.


latent
fingerprint


collected
fingerprint



The New York Times

## Report Faults F.B.I.'s Fingerprint Scrutiny in Arrest of Lawyer

By David Stout

Nov. 17, 2004
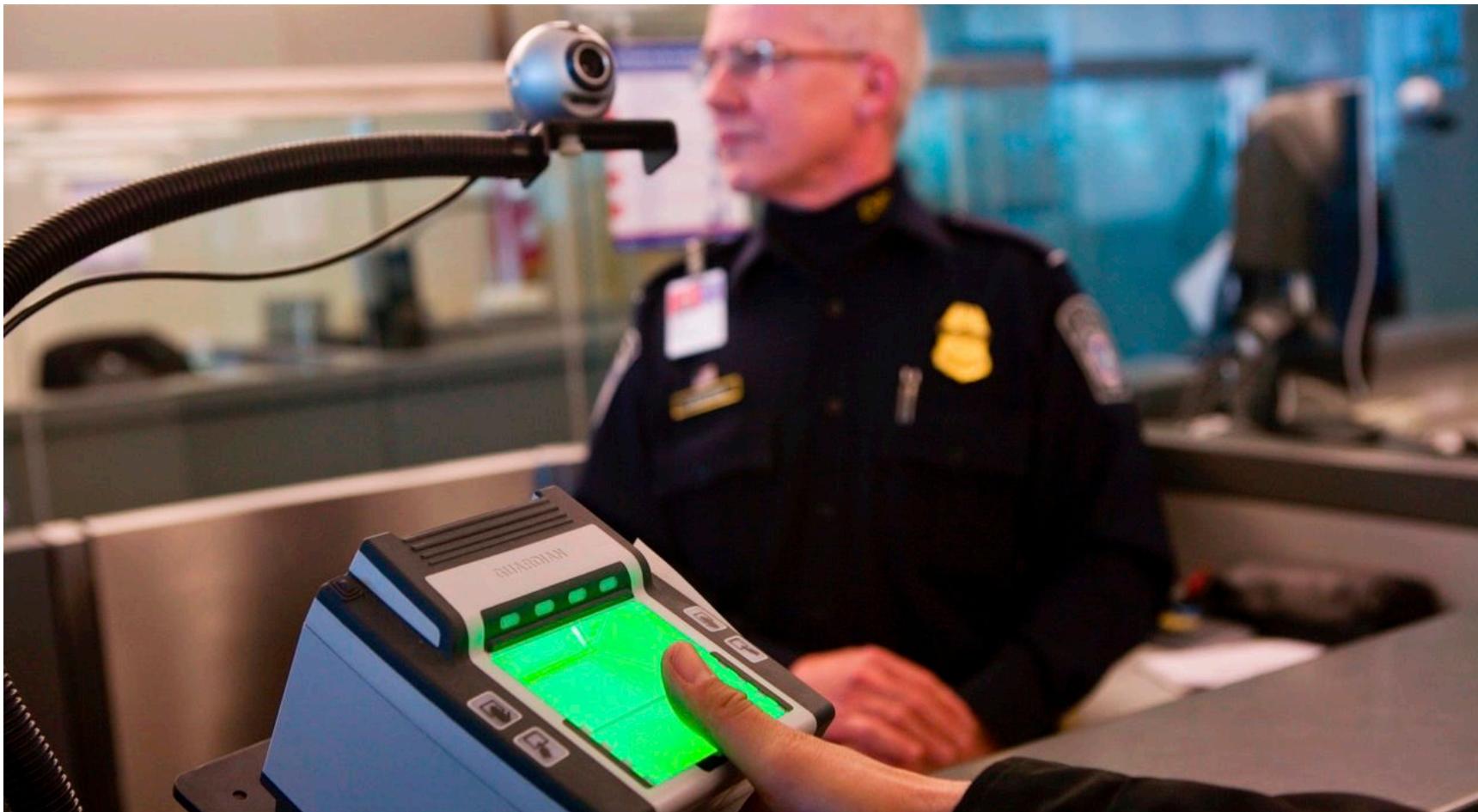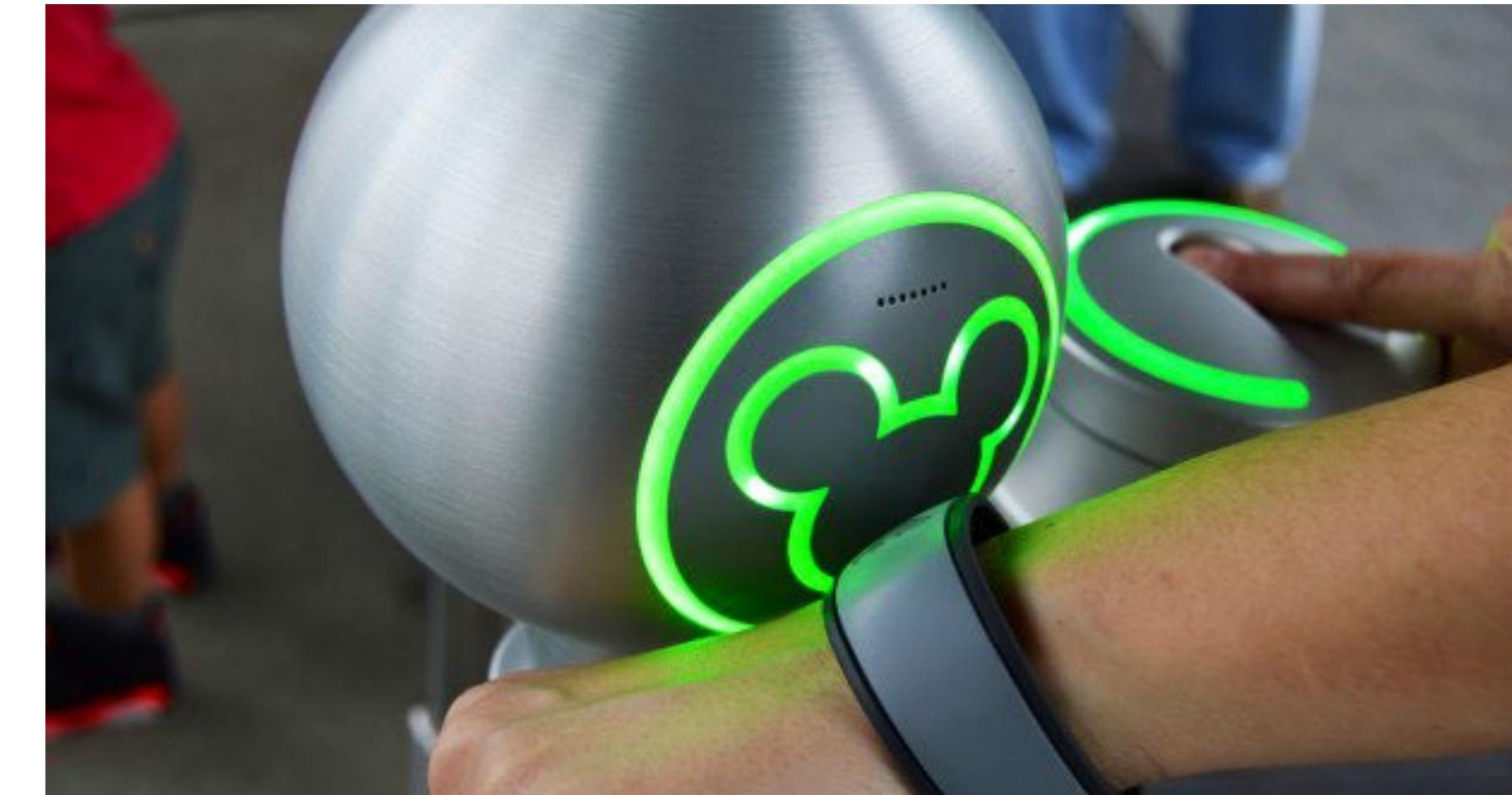
WASHINGTON, Nov. 16 - The Federal Bureau of Investigation wrongly implicated an Oregon lawyer in a deadly train bombing in Madrid because the F.B.I. culture discouraged fingerprint examiners from disagreeing with their superiors, a panel of forensic experts has concluded.

https://www.nytimes.com/2004/11/17/politics/report-faults-fbis-fingerprint-scrutiny-in-arrest-of-lawyer.html

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# Biometrics Use

**Biometrics is a reality**
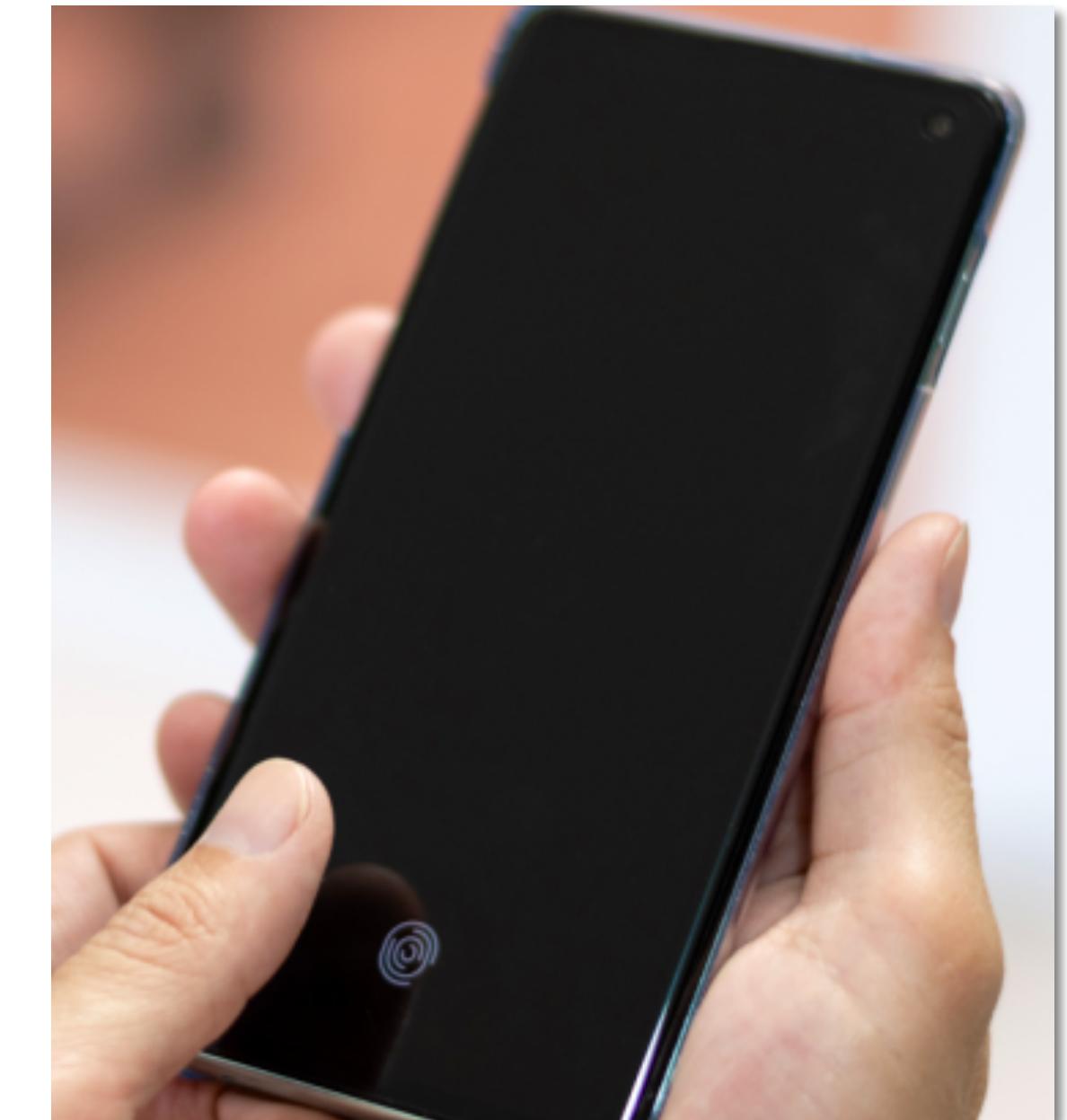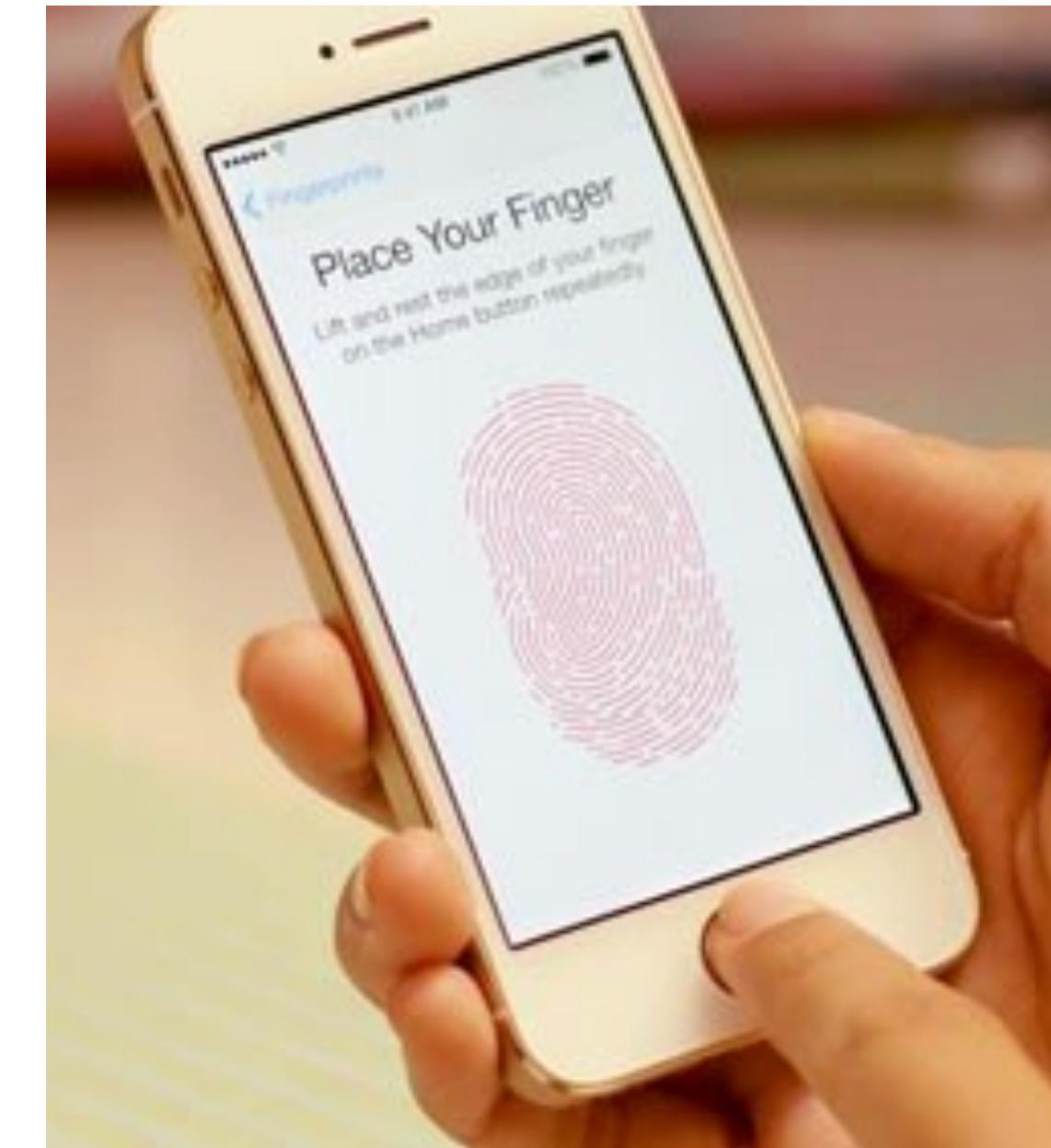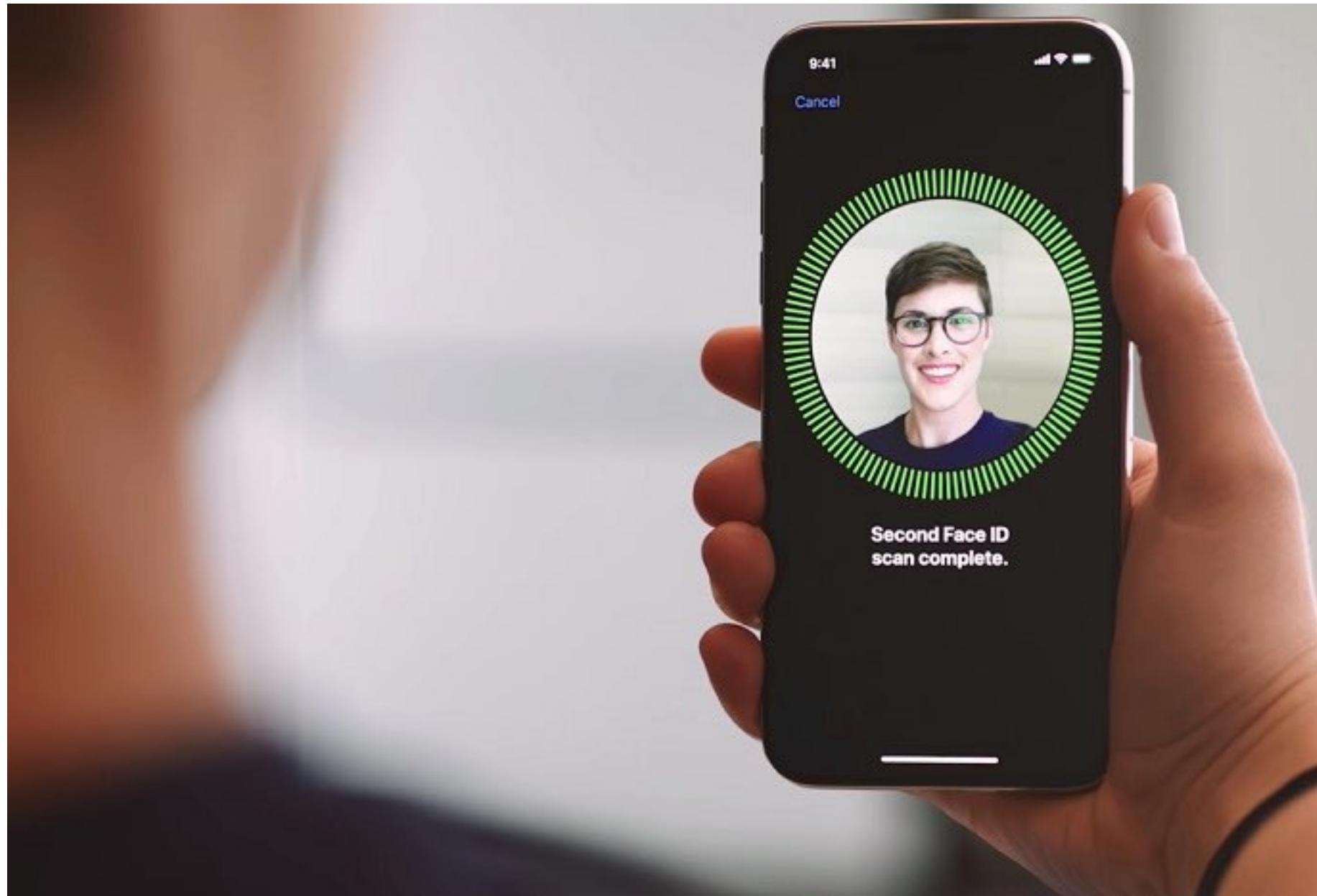


border patrol



entertainment

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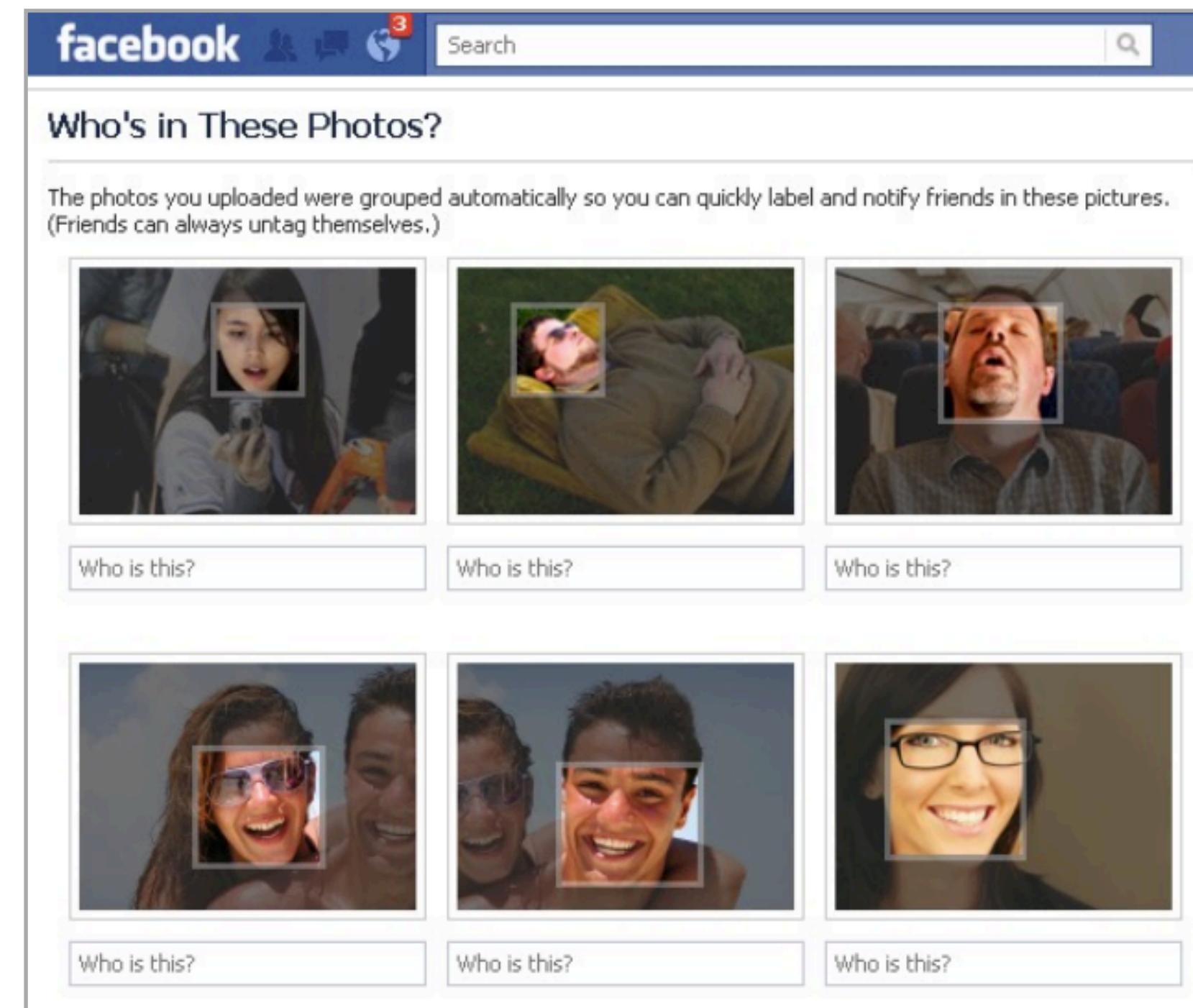
# Biometrics Use

**Biometrics is a reality**
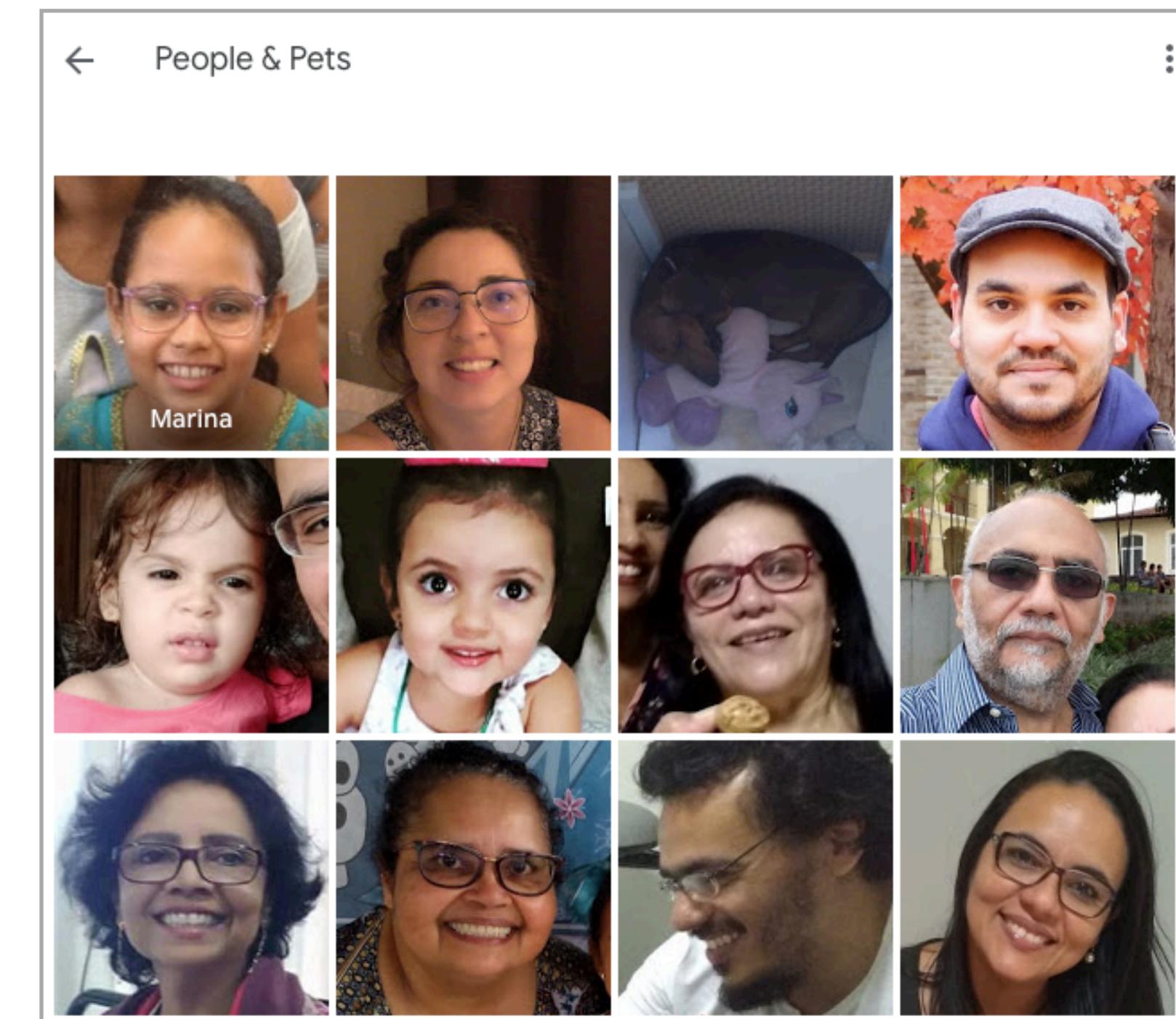


personal devices

# Biometrics Use

**Biometrics is a reality**



Facebook



Google Photos

# Biometrics Use

**Biometrics is a reality**

**Indian AADHAAR program**
10-year initiative.
1.2 billion people enrolled
(99% of adult population).
Iris scans, faces, and fingerprints.
Claimed to have saved the
Indian government $12.4 billion.
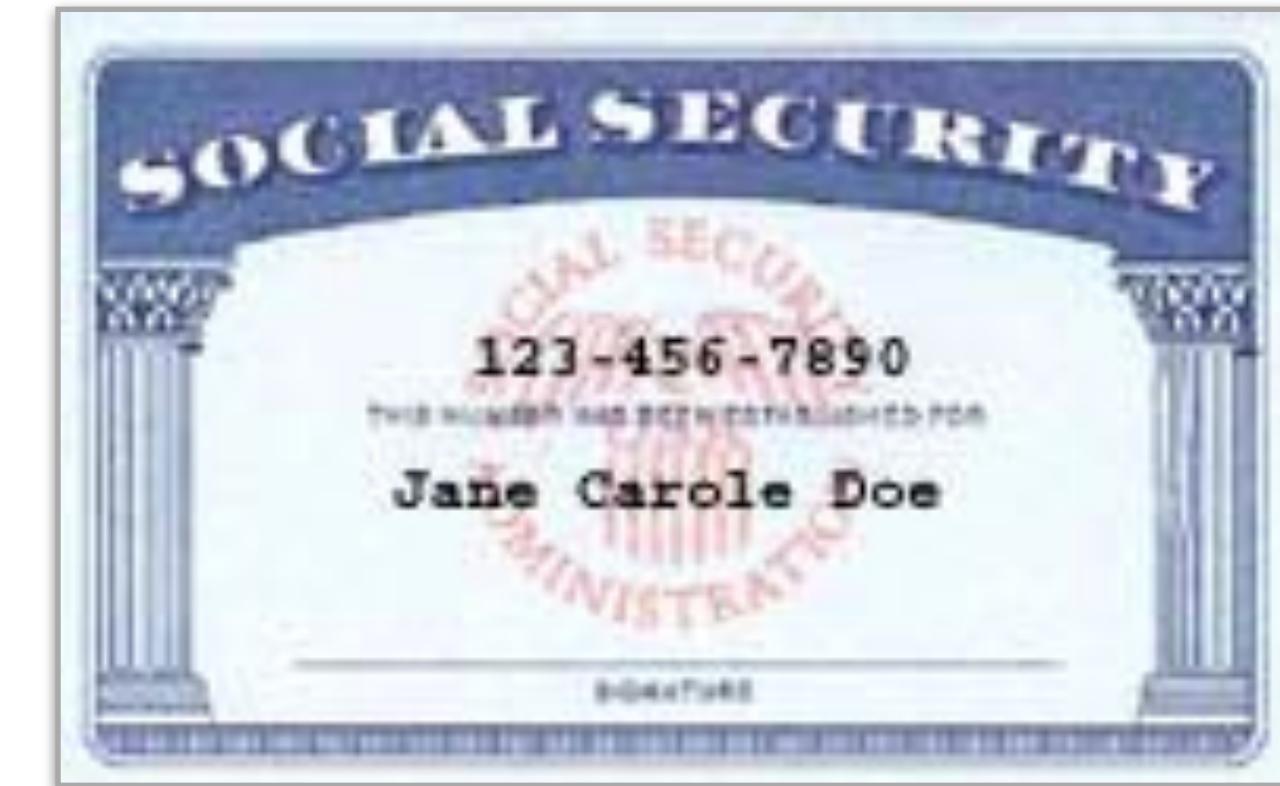




civil rights

# Biometrics Abuse

**Function Creep**
Widening of the use of a technology
beyond the purpose for which
it was originally intended.

US typical example: SSN

The same may happen with Biometric systems.

# Biometrics Abuse

**Function Creep**

In 2001, Colorado state was caught selling its DMV* face and fingerprint databases to corporations.



*Department of Motor Vehicles
Source: https://i2i.org/wp-content/uploads/2011/02/IP-8-2001-1.pdf

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# Biometrics Abuse

**Segregating Profiling**



https://www.hindustantimes.com/bhopal/
linking-benefits-for-aids-patients-to-aadhaar-
triggers-privacy-concerns/story-
iR6HB8RmqPDaNwkX2Oj5EJ.html

# Biometrics Abuse

**Segregating Profiling**



The New York Times

## China Uses DNA to Map Faces, With Help From the West

Beijing's pursuit of control over a Muslim ethnic group pushes the rules of science and raises questions about consent.

By Sui-Lee Wee and Paul Mozur

Published Dec. 3, 2019   Updated Dec. 10, 2019

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https://www.nytimes.com/2019/12/03/business/china-dna-uighurs-xinjiang.html

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# Biometrics Abuse

## Data Leakage



https://www.tribuneindia.com/news/archive/
rs-500-10-minutes-and-you-have-access-to-
billion-aadhaar-details-523361

# Biometrics Abuse

**Compromised biometric data**
People cannot change their biometric data in response to a leak. Irreversible for whole lifetime.
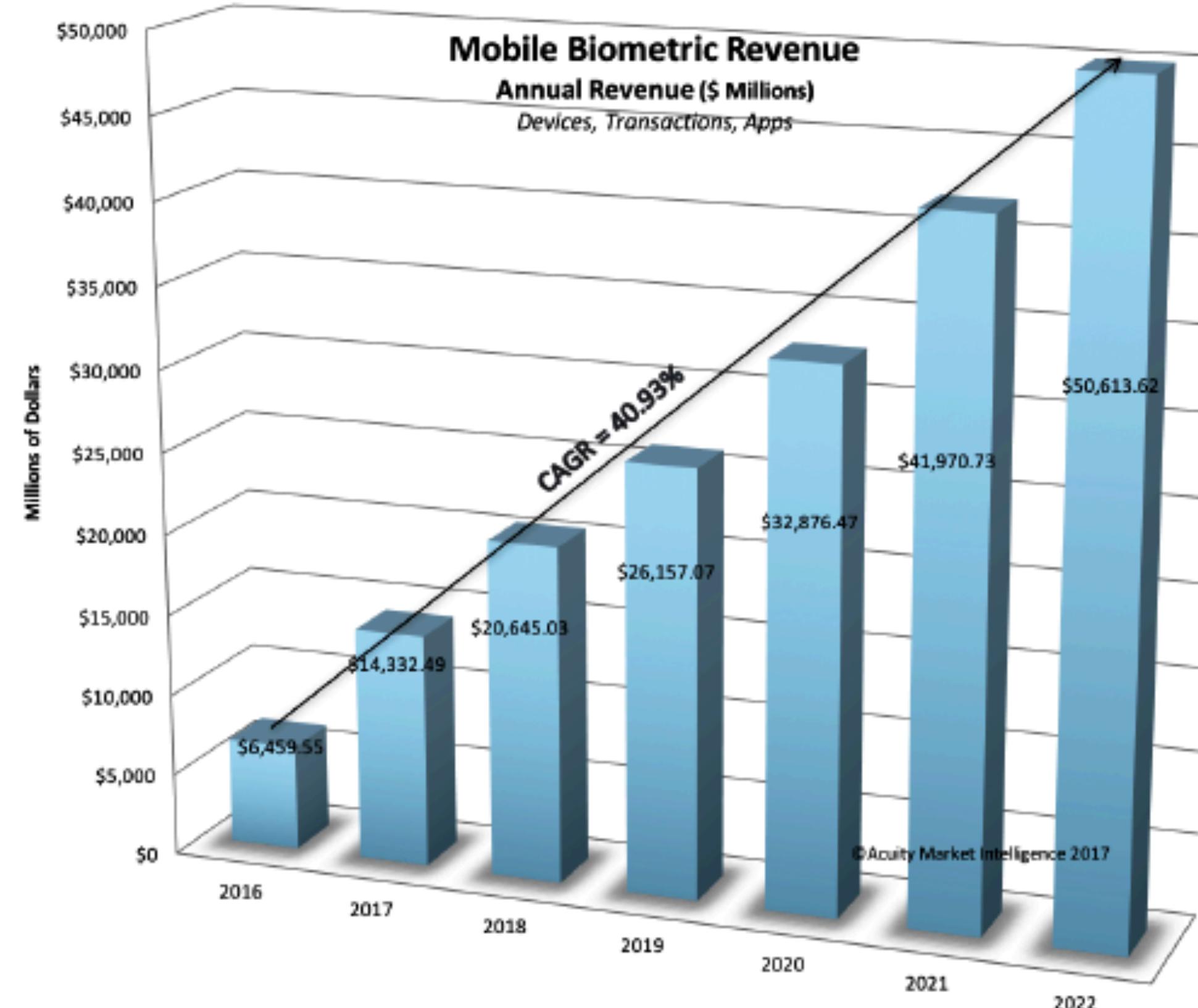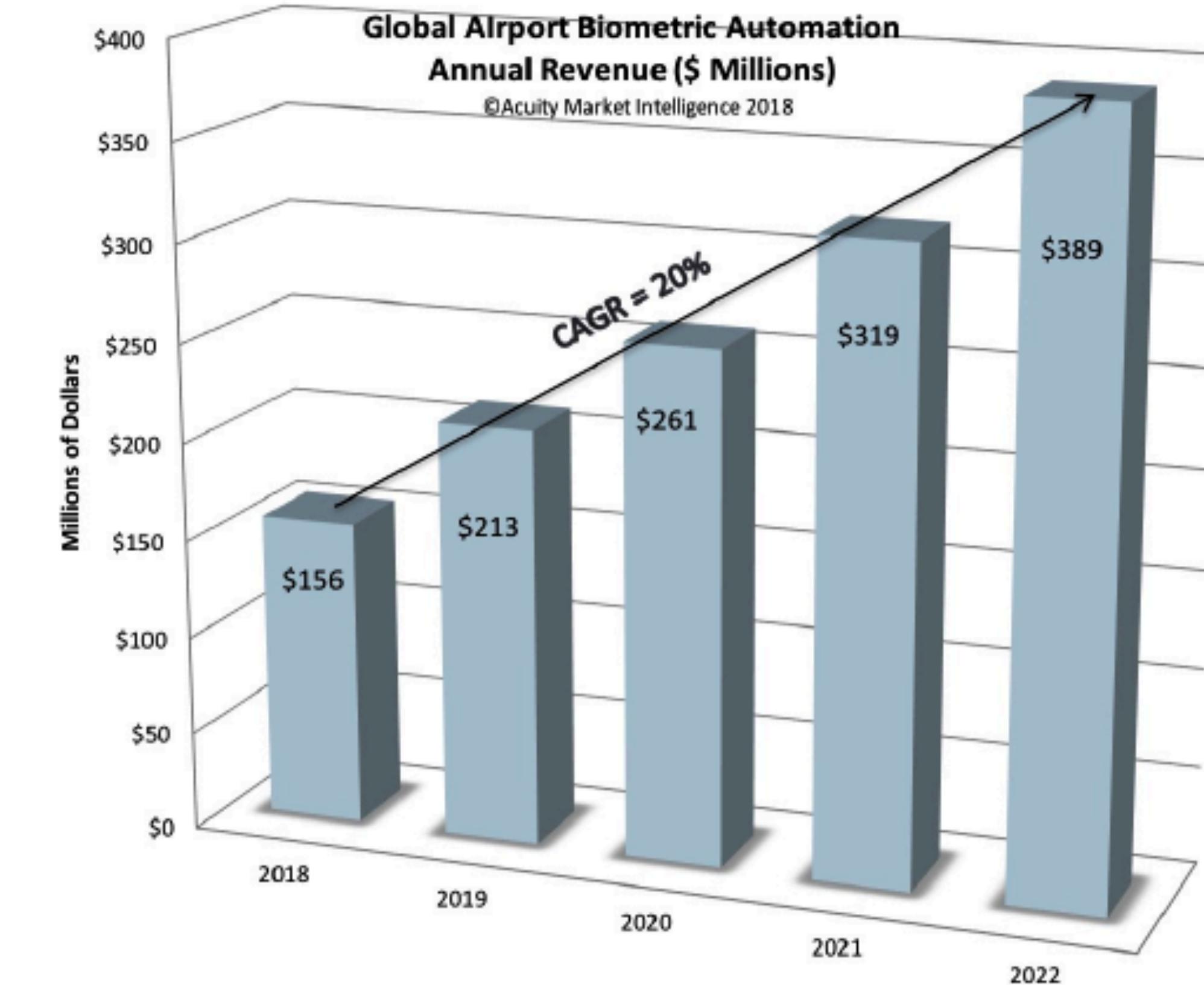


Please, don't.

# Biometrics Appeal



2017 Forecast
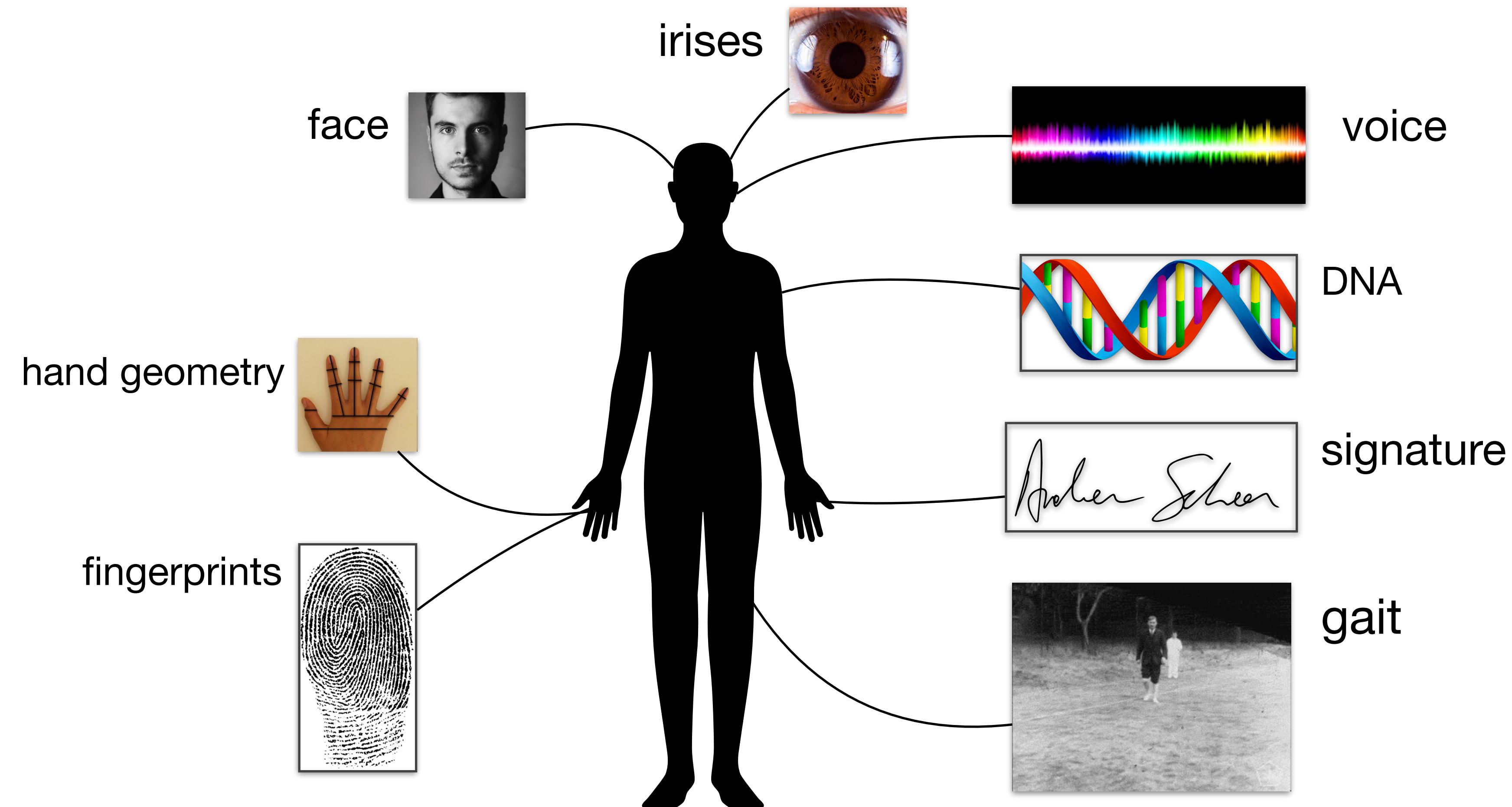
2019 Forecast

Source: Acuity Market Intelligence (https://www.acuitymi.com/)
CAGR: Compound Annual Growth Rate
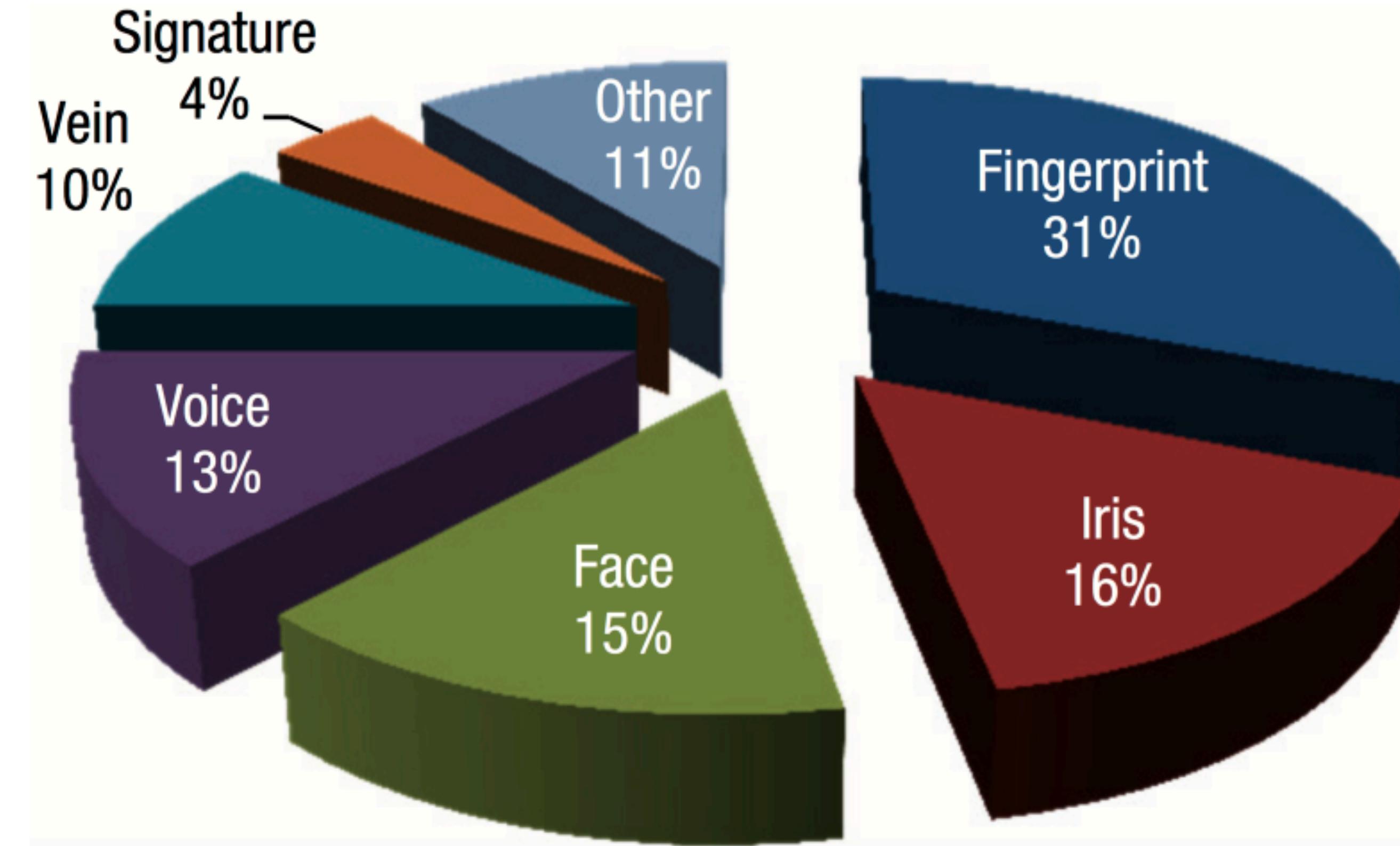
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# Biometric Traits



face

irises

voice

hand geometry

DNA

signature

fingerprints

gait

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# Biometric Traits

**Market**



Source: Mani and Nadeski, *Processing solutions for biometric systems,* Texas Instruments, 2015

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable
than others.

**Universality (1/8)**
Does everybody have the trait?

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Uniqueness (2/8)**
How likely two or more individuals will present the same trait?

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Uniqueness (2/8)**
How likely two or more individuals will present the same trait?



The New York Times

*Who's the Daddy? Neither Twin Would Say. But They Both Will Pay.*

By Ernesto Londoño and Lis Moriconi

April 3, 2019

RIO DE JANEIRO — The judge was stumped.

He had ordered a pair of identical twins to take DNA tests in a paternity case in the central Brazilian state of Goiás. Both came back positive.

https://www.nytimes.com/2019/04/03/world/americas/brazil-paternity-dna.html

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# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Uniqueness (2/8)**
How likely two or more individuals will present the same trait?



https://www.buzzfeednews.com/article/danvergano/failed-paternity-test-vanished-twin

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable
than others.

**Permanence (3/8)**
How does the trait change
over time?
How can diseases affect the trait?

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Measurability (4/8)**
How easy is it to acquire and digitize the trait?

# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Acceptability (5/8)**
Will individuals collaborate during data collection?
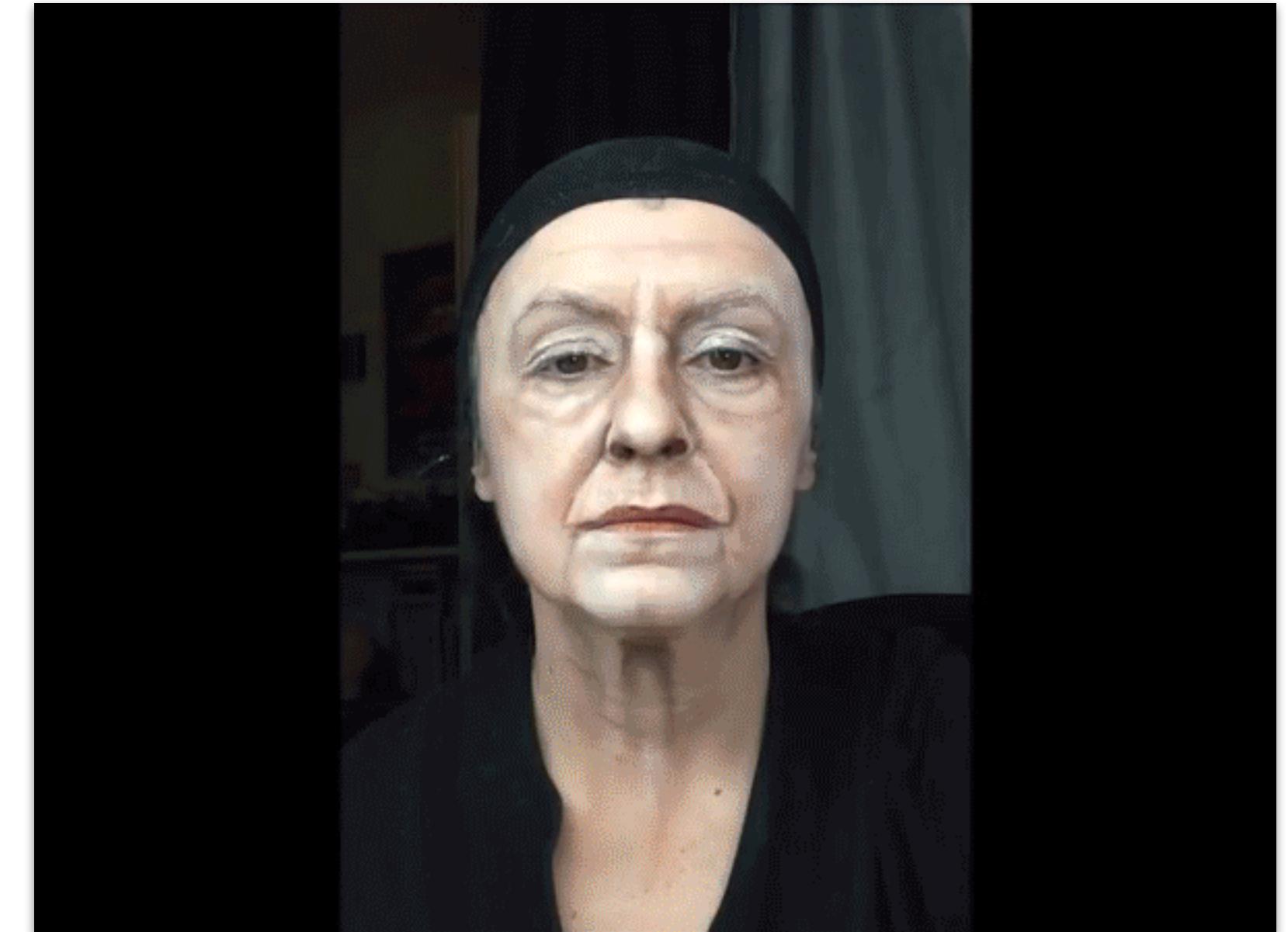


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# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.

**Circumvention (6/8)**
How easy can the trait be forged or imitated?
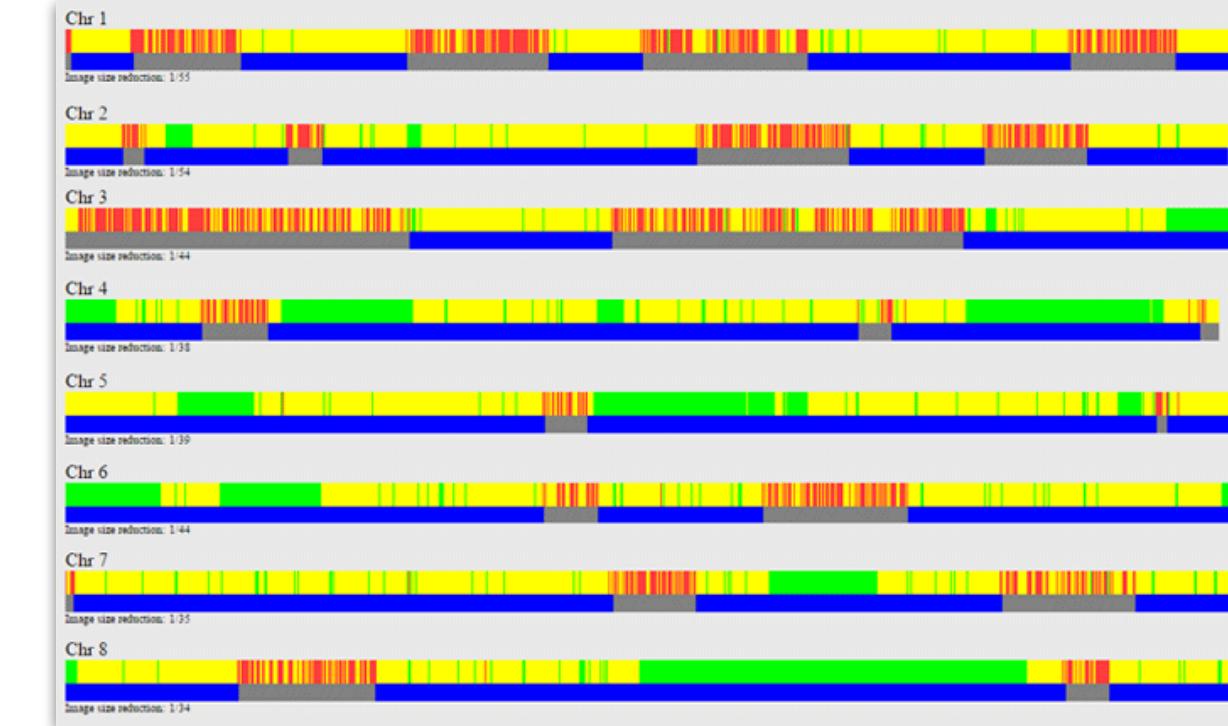


https://www.youtube.com/watch?v=SIIl8L43nng

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# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable
than others.

**Accountability (7/8)**
How easy is it for the everyman
to understand the trait comparison?
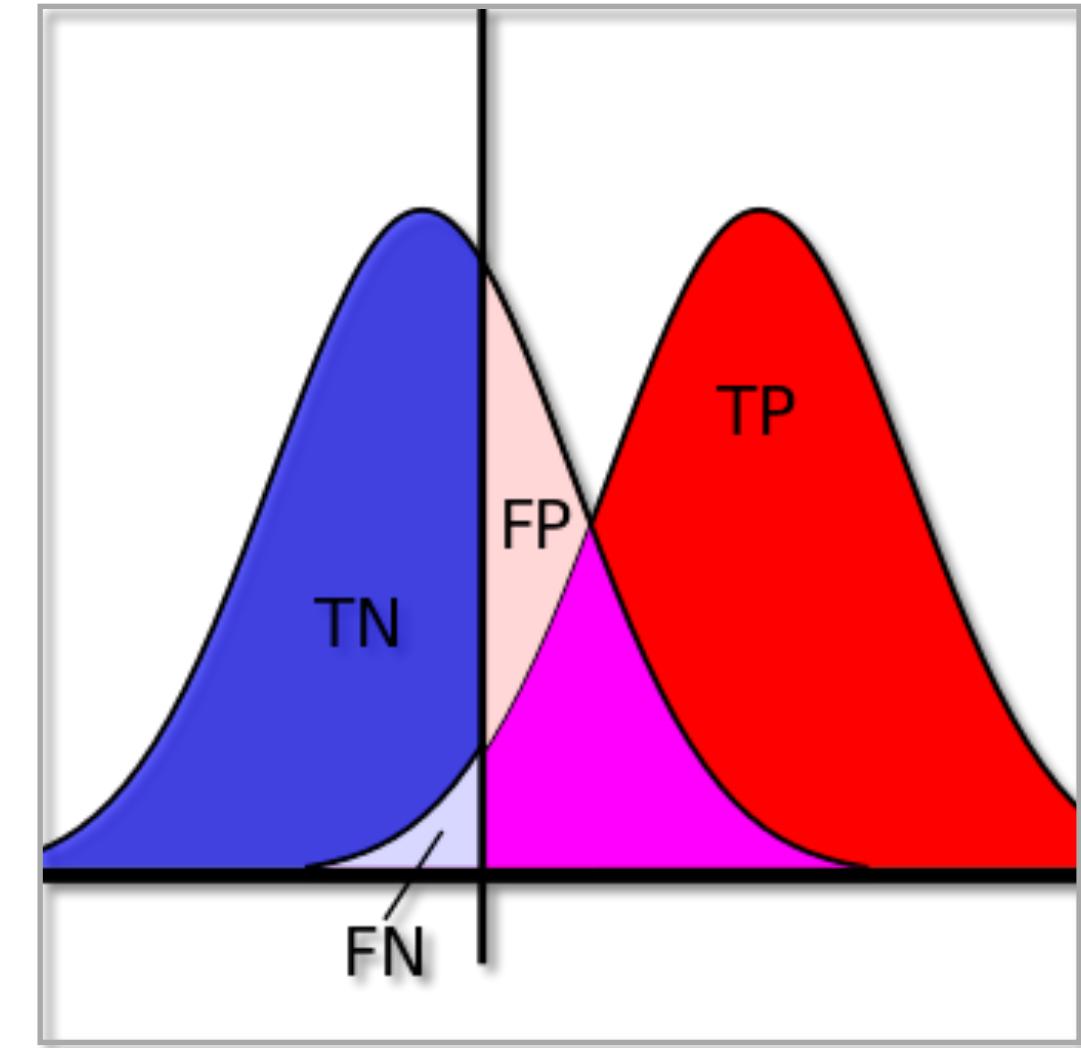




SEARCHING DATABASE.

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# Biometric Traits

**What do we want to consider?**
Some traits might be more suitable than others.
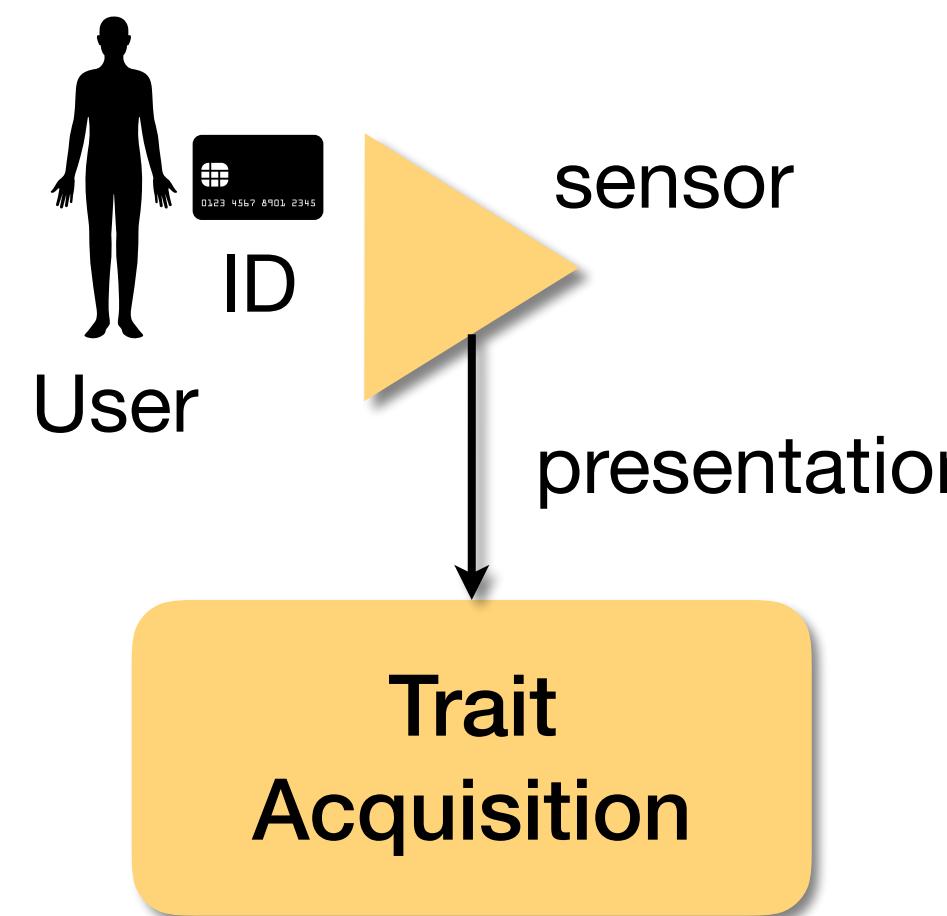
**Performance (8/8)**
How good is the trait quantitatively according to objective **metrics**?
(we'll see them soon)

# Biometric Systems

## Enrollment

**User**
ID
sensor
presentation

**Trait Acquisition**
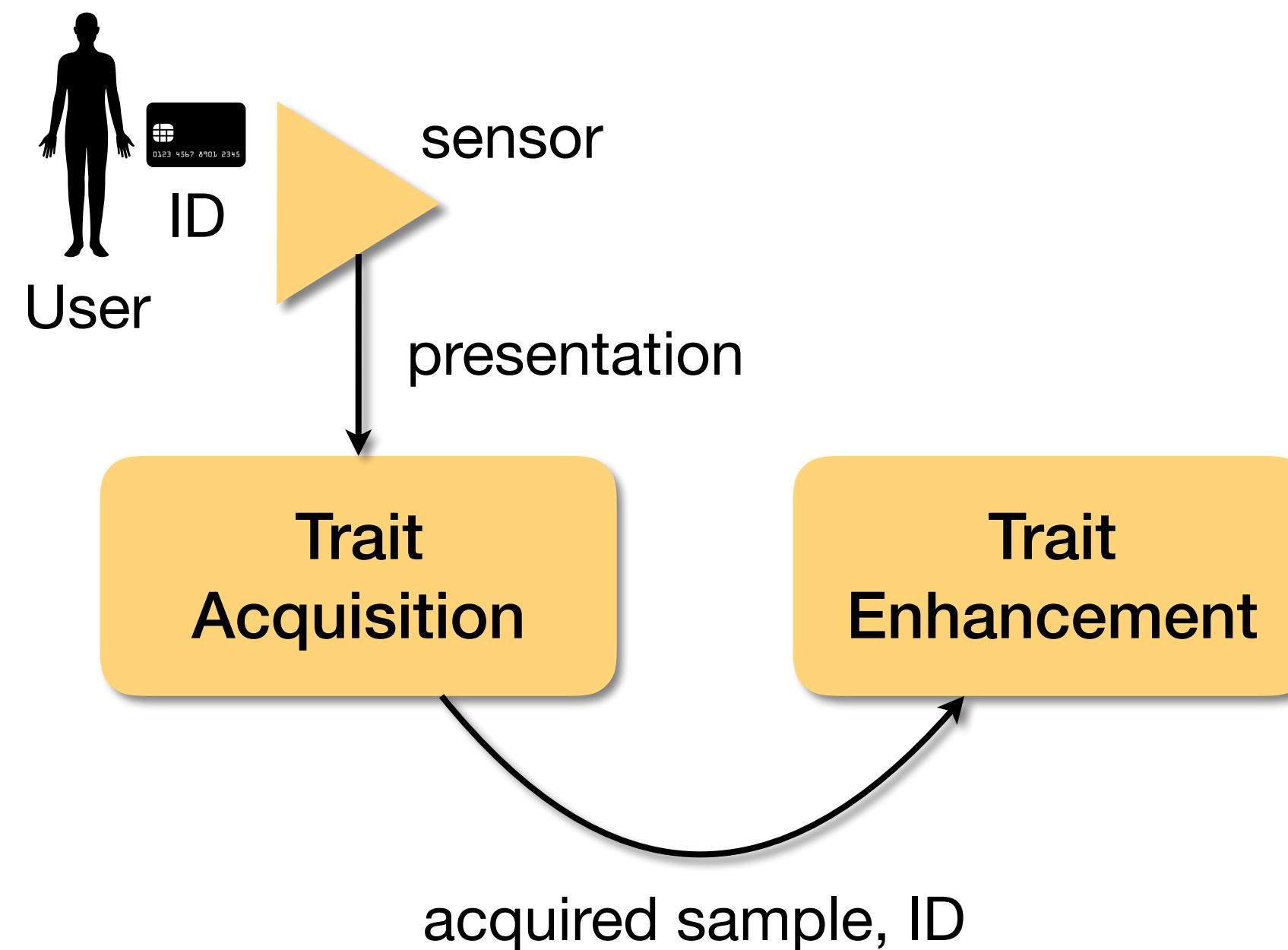
**Trait Acquisition**
We'll have data-collection classes.
We'll use real-world sensors.

**What to observe?**
Sensors have different **quality**
(in terms of precision, resolution,
presence of noise, and usability)

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# Biometric Systems

## Enrollment



User
ID
sensor
presentation

**Trait Acquisition**

**Trait Enhancement**

acquired sample, ID

**Trait Enhancement**
Noise removal.
Operations to keep only **essential** information (consider universality, uniqueness, permanence, circumvention, accountability, and performance).
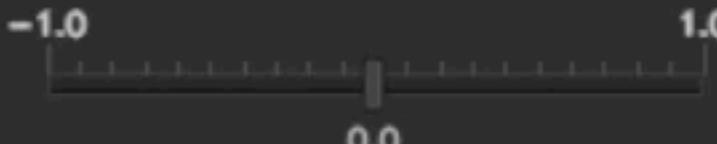
Load irises    Load examination    Save examination    Save report    Quit program

Brightness

−1.0                                    1.0

0.0

Contrast

0.0                                    2.0

1.0

Sharpening

0.0                                    10.0

0.0

Segment iris

Brightness

−1.0                                    1.0

0.0

Contrast

0.0                                    2.0

1.0

Sharpening

0.0                                    10.0

0.0

Segment iris

1.0                                    3.0

1.0

1x

1.0                                    3.0

1.0
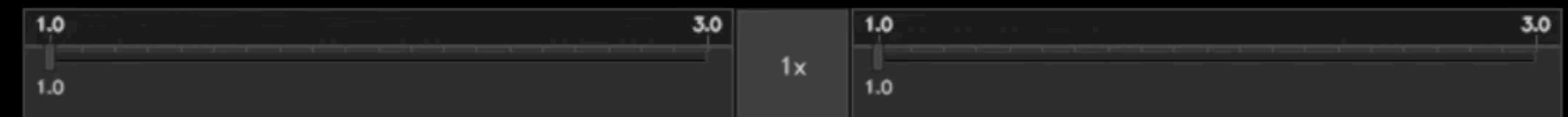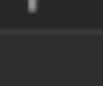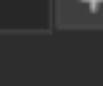
**Human−Interpretable Features**

■ TSHEPII    ☑ Show Matched         −  0  +  out of 0
             ☑ Show Unmatched       −  1  +  out of 0

■ SURF       ☑ Show Matched         −  0  +  out of 0
             ☑ Show Unmatched       −  1  +  out of 0

■ Crypts     ☑ Show Matched         −  0  +  out of 0

■ MSER       ☑ Show Matched         −  0  +  out of 0
             ☑ Show Unmatched       −  1  +  out of 0

■ SIFT       ☑ Show Matched         −  0  +  out of 0
             ☑ Show Unmatched       −  1  +  out of 0

Undo last removal

**Manual Annotation**

Annotate...

■ ☑ Matching Regions          ■ ☐ Non−Matching Regions

■ ☑ Show Matching Regions

■ ☑ Show Non−Matching Regions
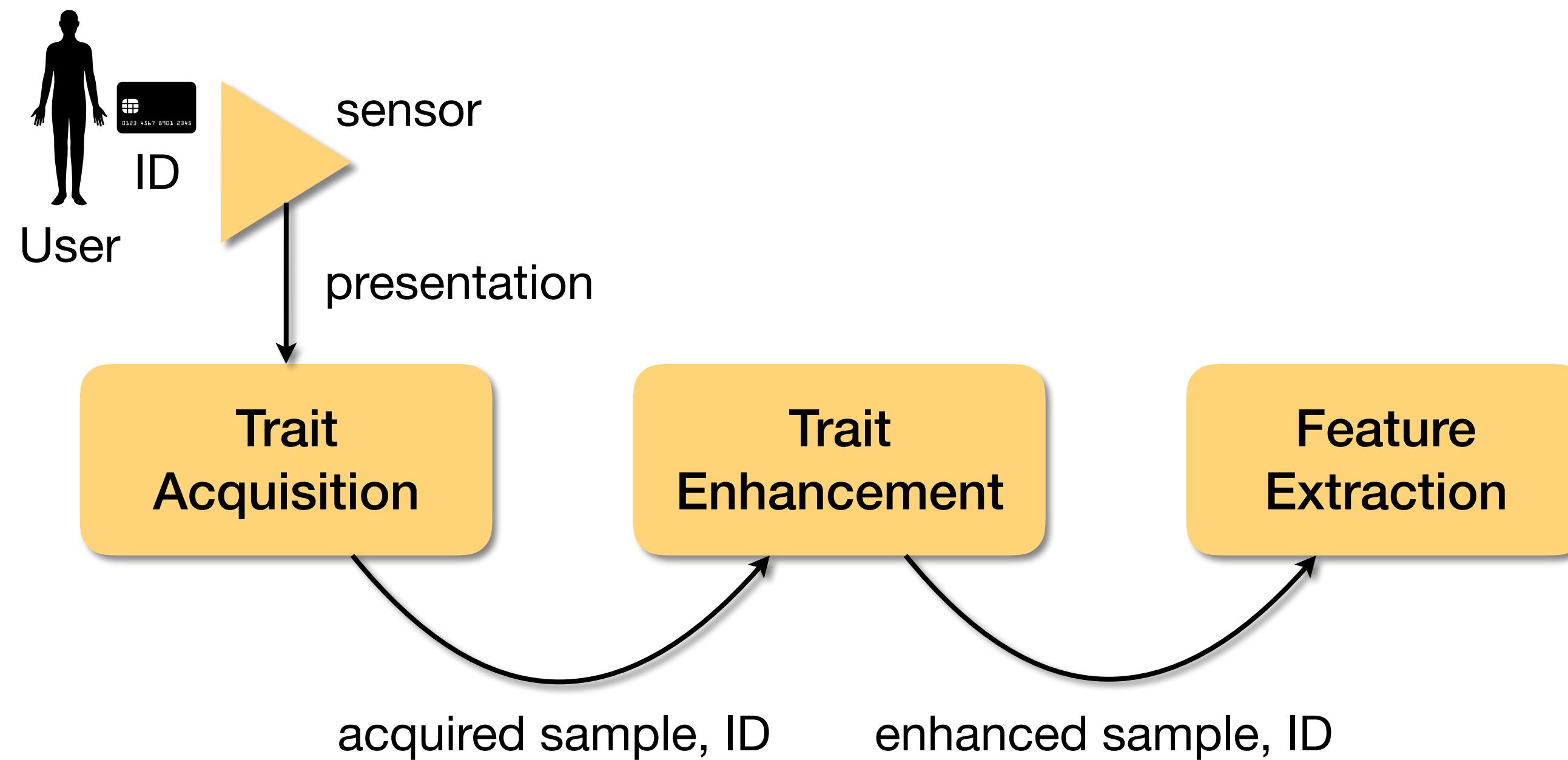
**Non−Human−Interpretable Features**

Gabor Filters          BSIF Filters

thr: 0.4461        thr: 0.4216

**Global match score**

# Biometric Systems

**Enrollment Modules**

User
ID
sensor
presentation

Trait Acquisition

Trait Enhancement

Feature Extraction

acquired sample, ID

enhanced sample, ID
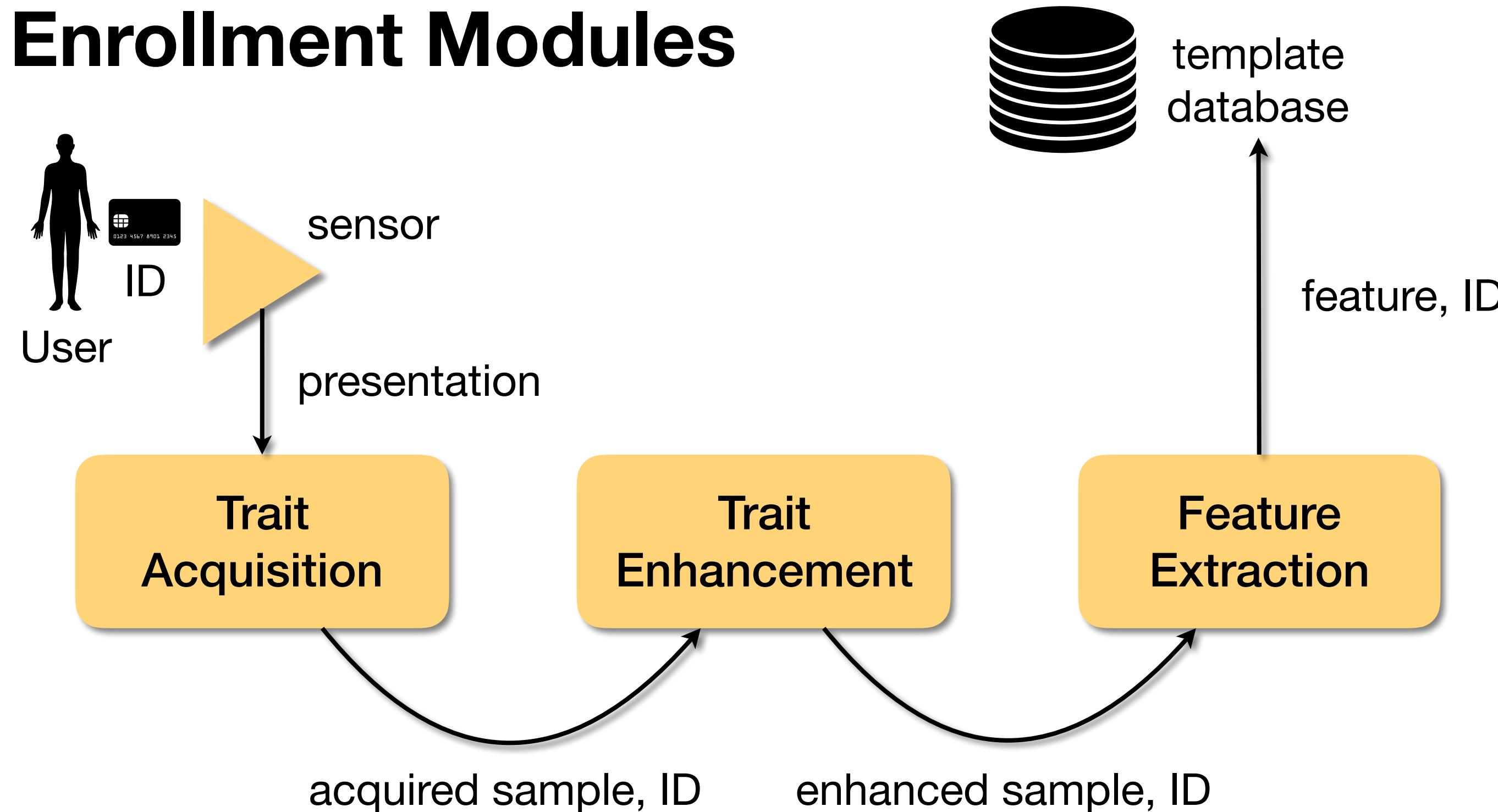
**Feature Extraction**
Compact but expressive digital representation of the trait.

**Types**
**Handcrafted** or **learned** with machine learning. We'll see both cases.

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# Biometric Systems

**Enrollment Modules**
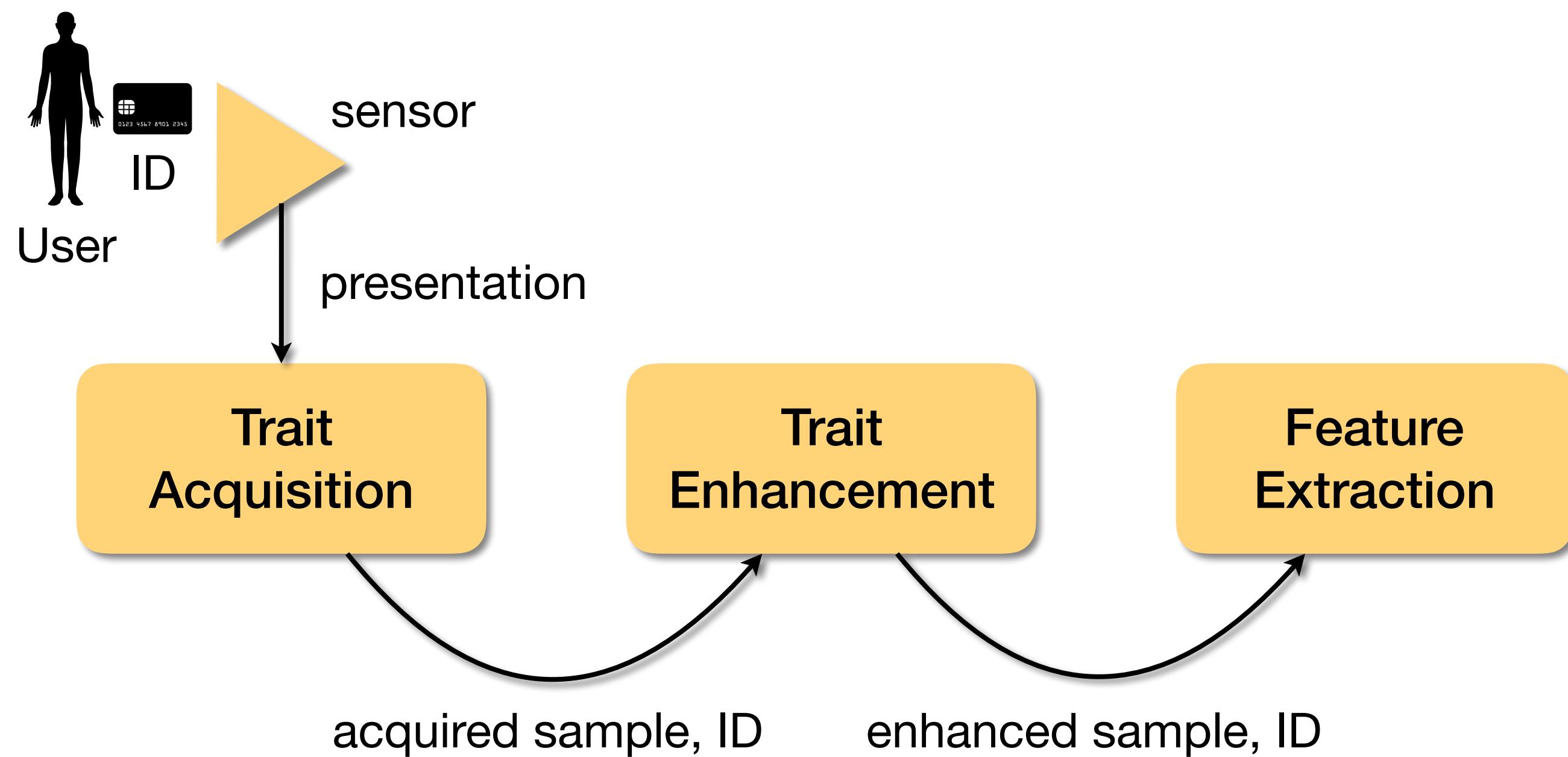


**Template Database**
It inherits all the security and privacy issues from database systems.
Be careful with invasions, leaks, etc.
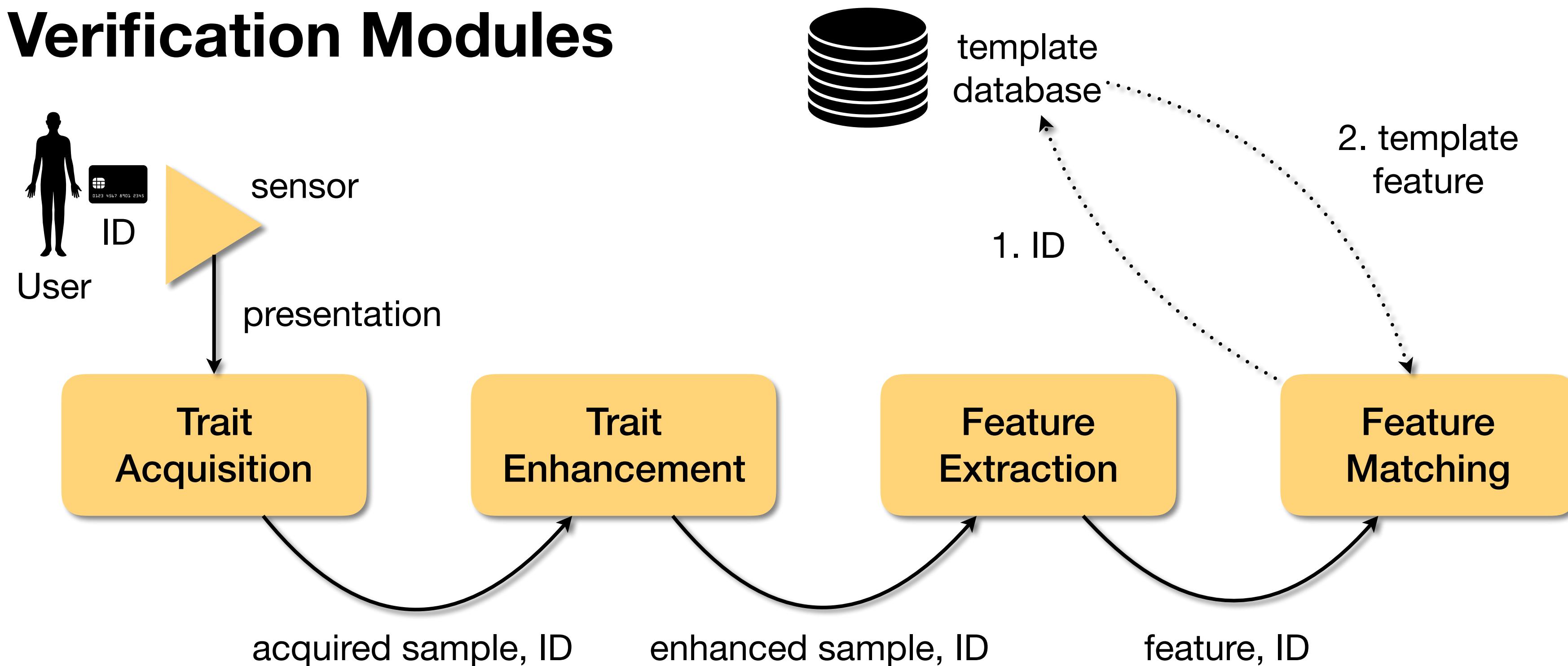
# Biometric Systems

**Verification Modules**
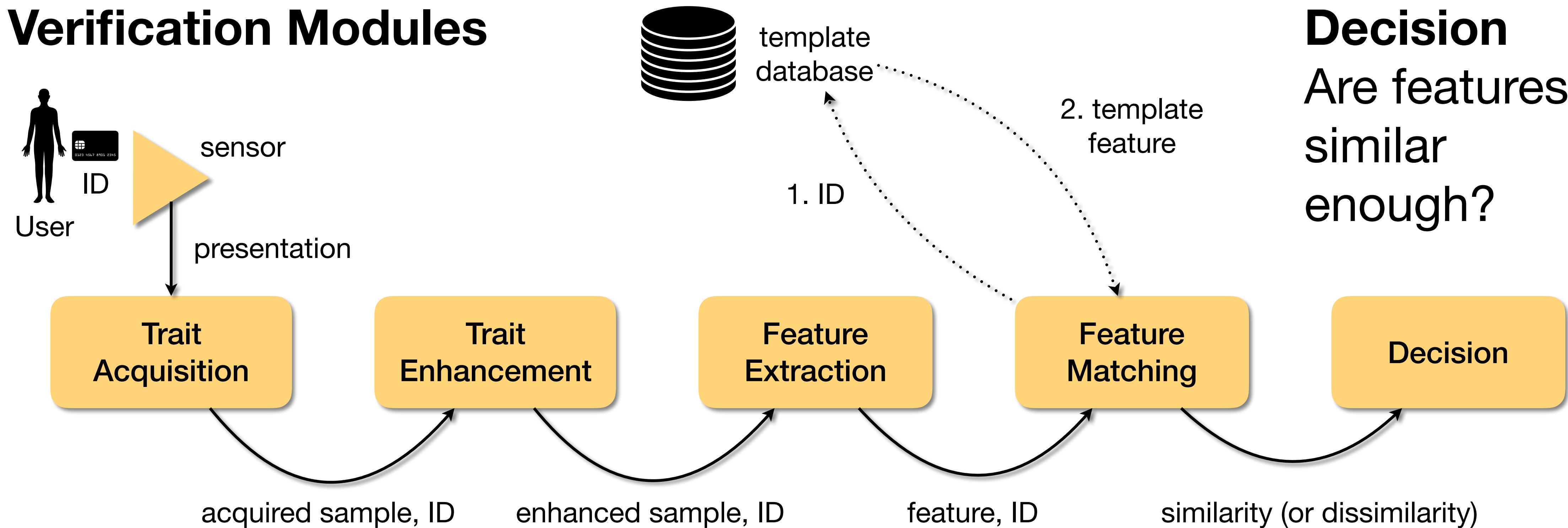
# Biometric Systems

**Verification Modules**



Feature Matching: Comparison of **acquired** and **template** features.

User → ID → sensor → presentation → Trait Acquisition → acquired sample, ID → Trait Enhancement → enhanced sample, ID → Feature Extraction → feature, ID → Feature Matching

template database
1. ID
2. template feature

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# Biometric Systems

**Verification Modules**

template database

**Decision**
Are features similar enough?

User
ID
sensor
presentation

2. template feature

1. ID

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |

acquired sample, ID          enhanced sample, ID          feature, ID          similarity (or dissimilarity)

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# Biometric Systems

**Verification Modules**

# Biometric Systems



**Identification Modules**

**Gallery**
Closest template features to query.

# Biometric Systems

**Query and Gallery Example**
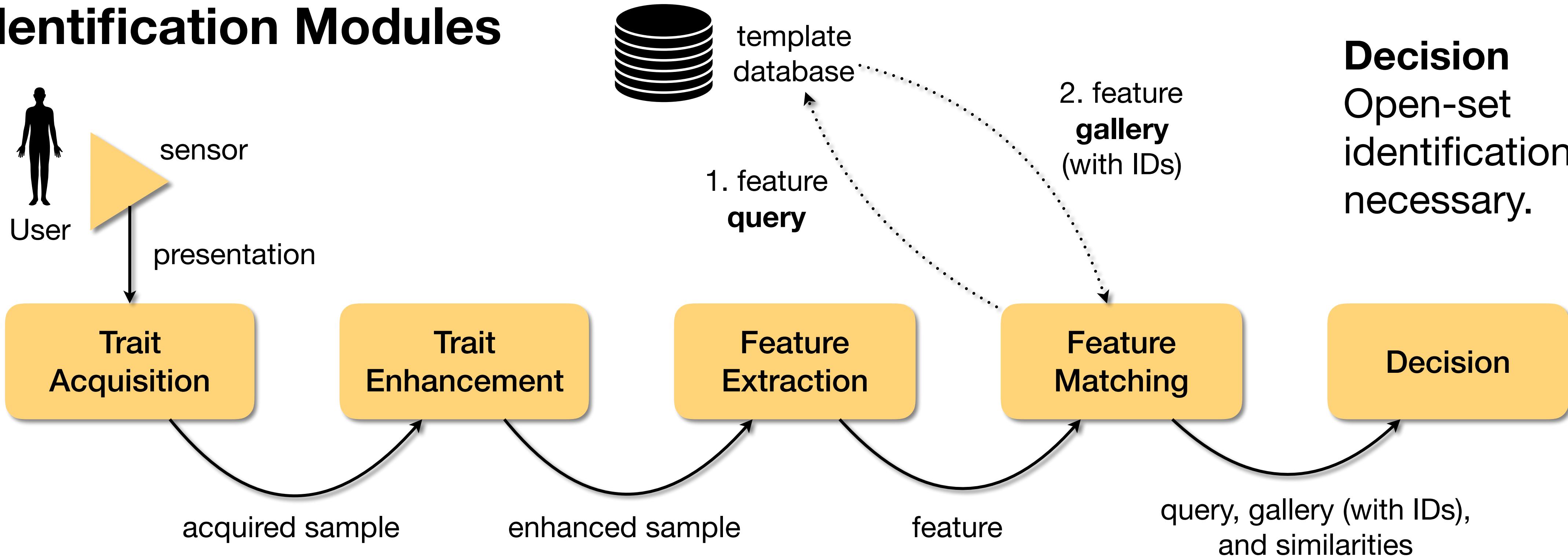


query

gallery

# Biometric Systems
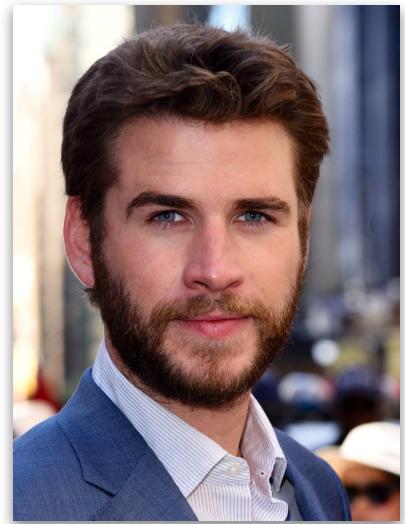
**Identification Modules**



**Decision**
Open-set identification is necessary.

User — sensor — presentation

template database

1. feature **query**

2. feature **gallery** (with IDs)

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |
|---|---|---|---|---|

acquired sample — enhanced sample — feature — query, gallery (with IDs), and similarities

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# Biometric Systems

## Open-set Identification



**Query**
(Liam Hemsworth)

**Dataset**

Robert Downey Jr.

Scarlet Johansson

Chris Evans

Mark Ruffalo
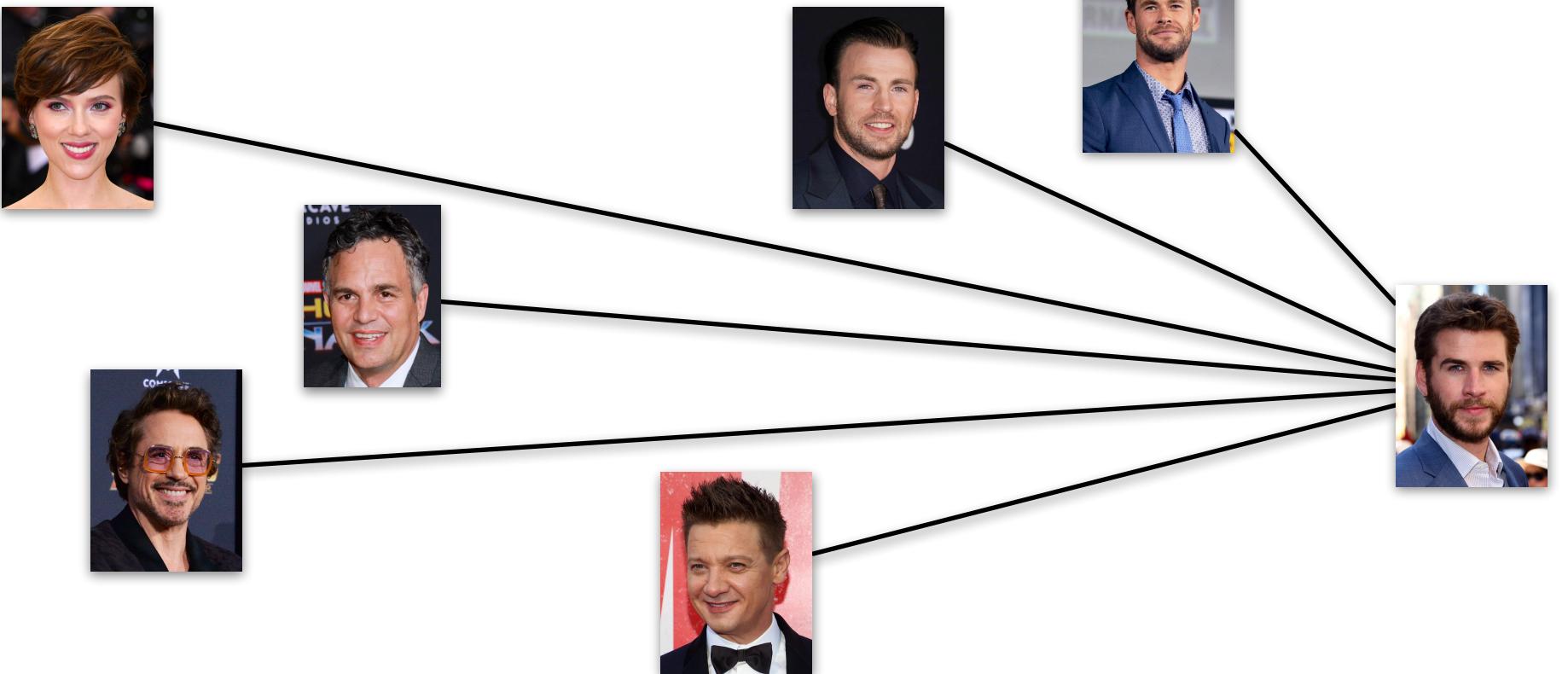
Chris Hemsworth

Jeremy Renner

**Feature Space**

**Closet Set**

**Output**
This is
Chris Hemsworth! ❌

**Open Set**
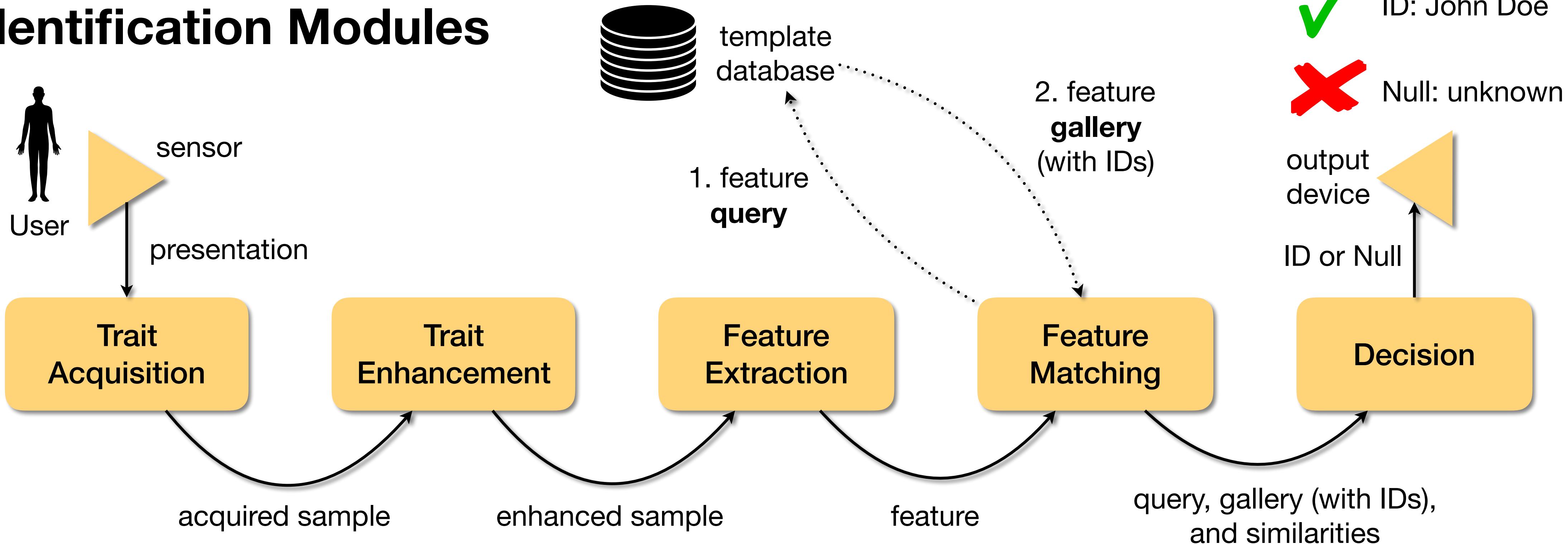
**Output**
I don't know
this person! ✓
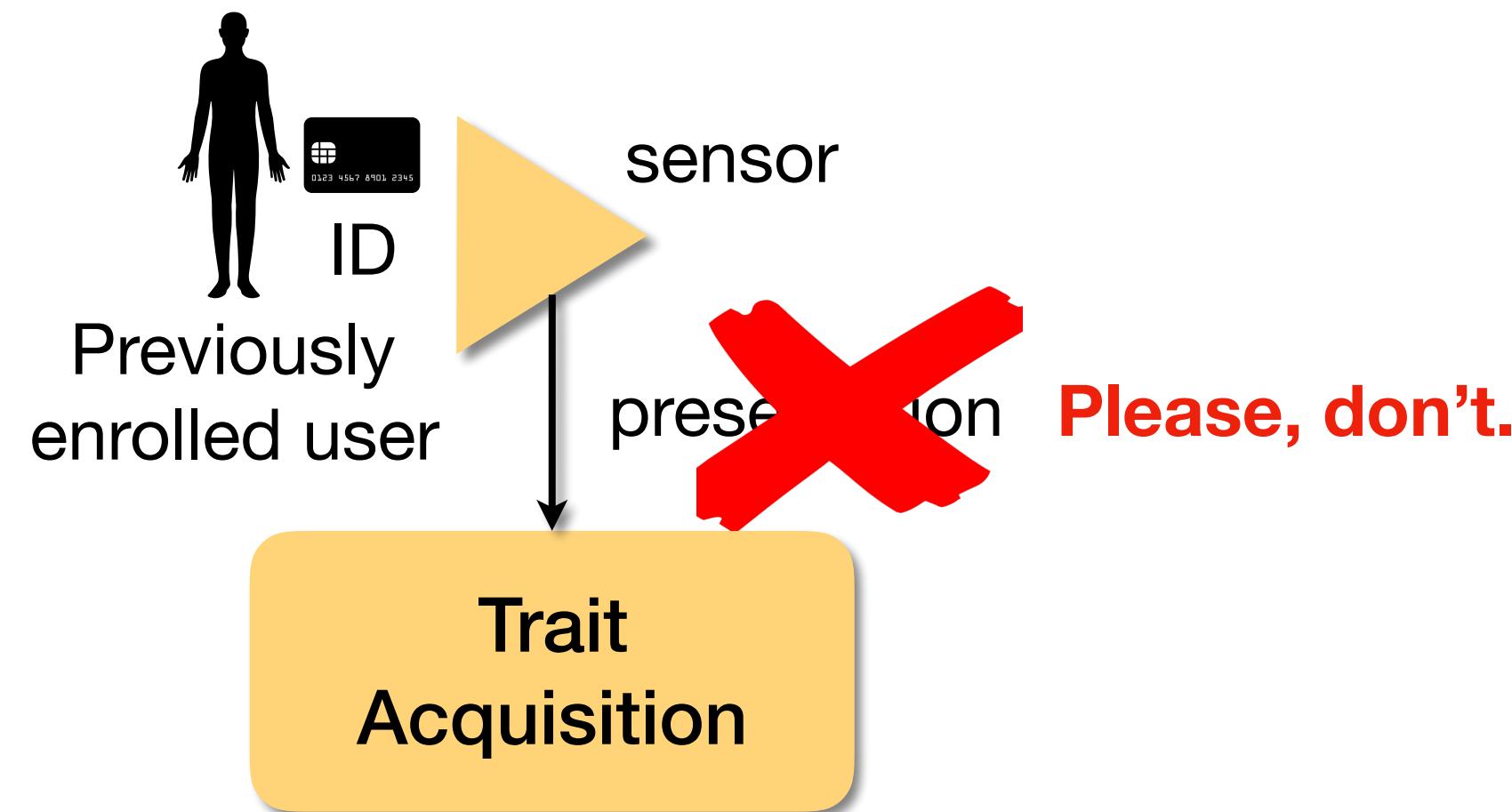
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# Biometric Systems

# Biometric Systems

**Enrollment Revision**



ID
Previously
enrolled user

sensor

presentation  **Please, don't.**

Trait
Acquisition
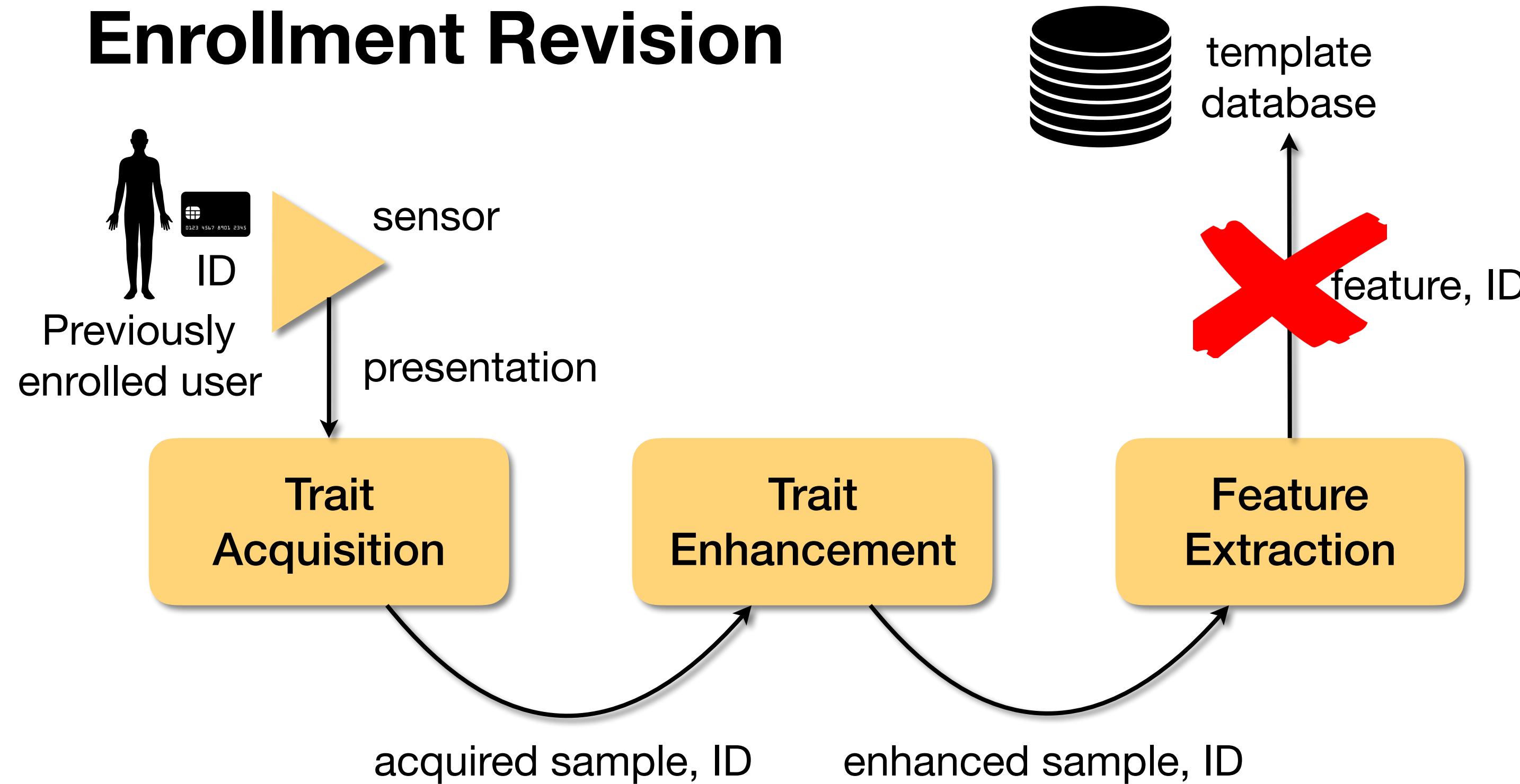
**Attended operation?**
"I'm seeing here in my notes
that you are already enrolled."

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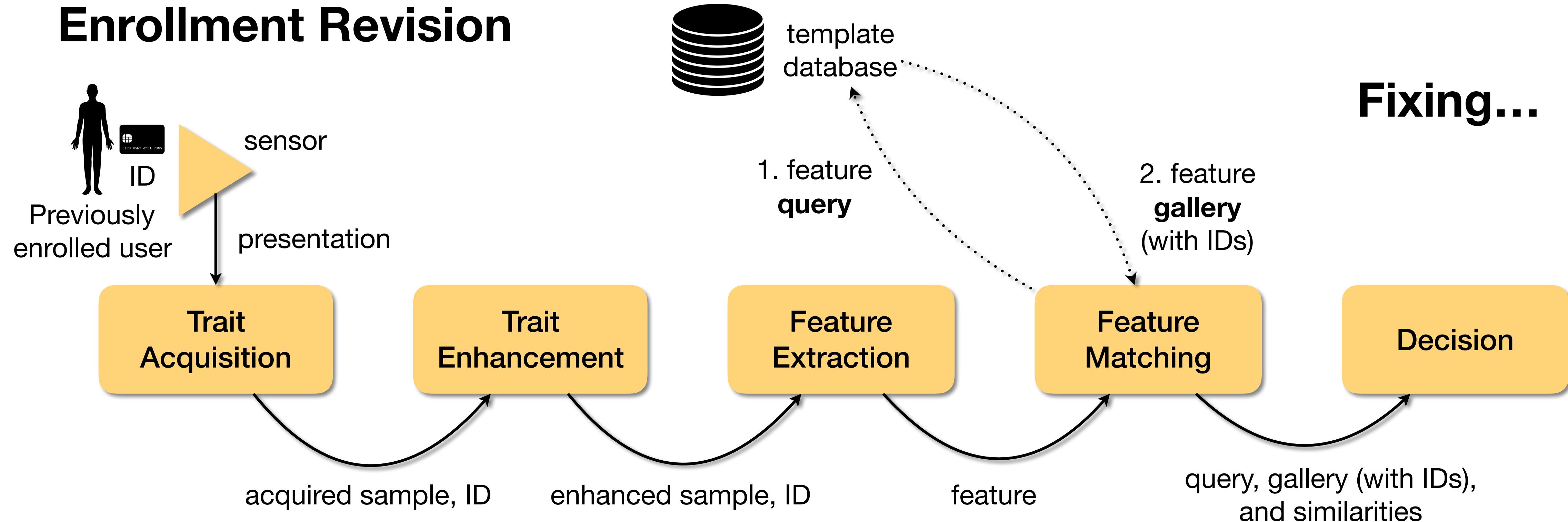
# Biometric Systems

**Enrollment Revision**



**Unattended operation?** The system must deal with re-enrollment attempts.

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# Biometric Systems

**Enrollment Revision**

**Fixing…**

template database

sensor

ID
Previously enrolled user

presentation

1. feature **query**

2. feature **gallery** (with IDs)

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |
|---|---|---|---|---|

acquired sample, ID

enhanced sample, ID

feature

query, gallery (with IDs), and similarities

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# Biometric Systems



**Enrollment Revision**

template database

✓ Null: Enrolled!   ❌ ID: Already-enrolled error.

ID
Previously enrolled user

sensor

presentation

1. feature **query**

2. feature **gallery** (with IDs)

ID or Null

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |

acquired sample, ID    enhanced sample, ID    feature    query, gallery (with IDs), and similarities

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# Biometric Systems

## Enrollment Revision

template database

**Fast Enrollment**
There might not be time to process these 2 modules.
E.g., if you have millions of enrolled users, or a distributed template database.

ID

Previously enrolled user

sensor

presentation

1. feature **query**

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |
|---|---|---|---|---|

acquired sample, ID          enhanced sample, ID          featu

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# Biometric Systems

## Enrollment Revision
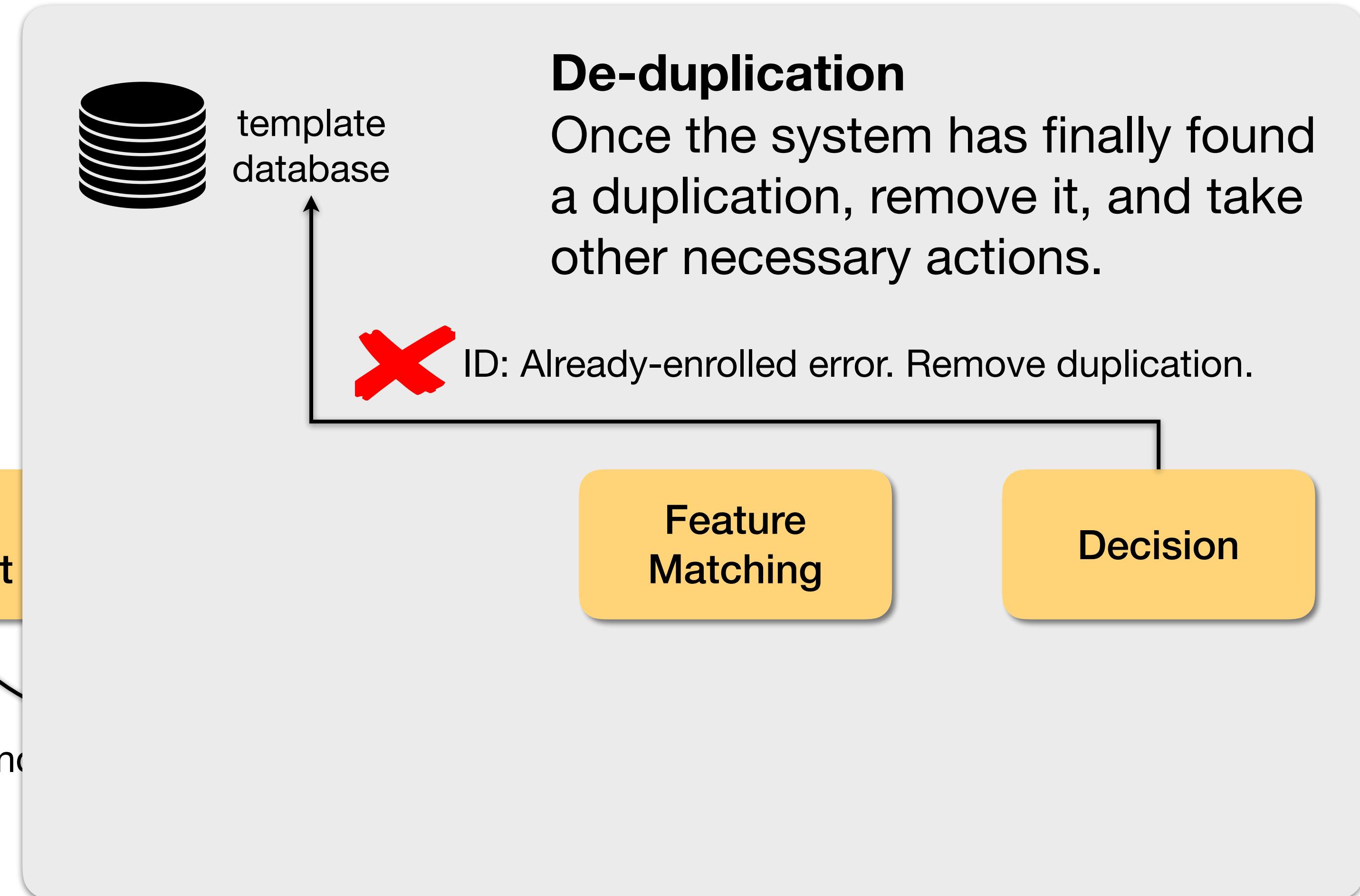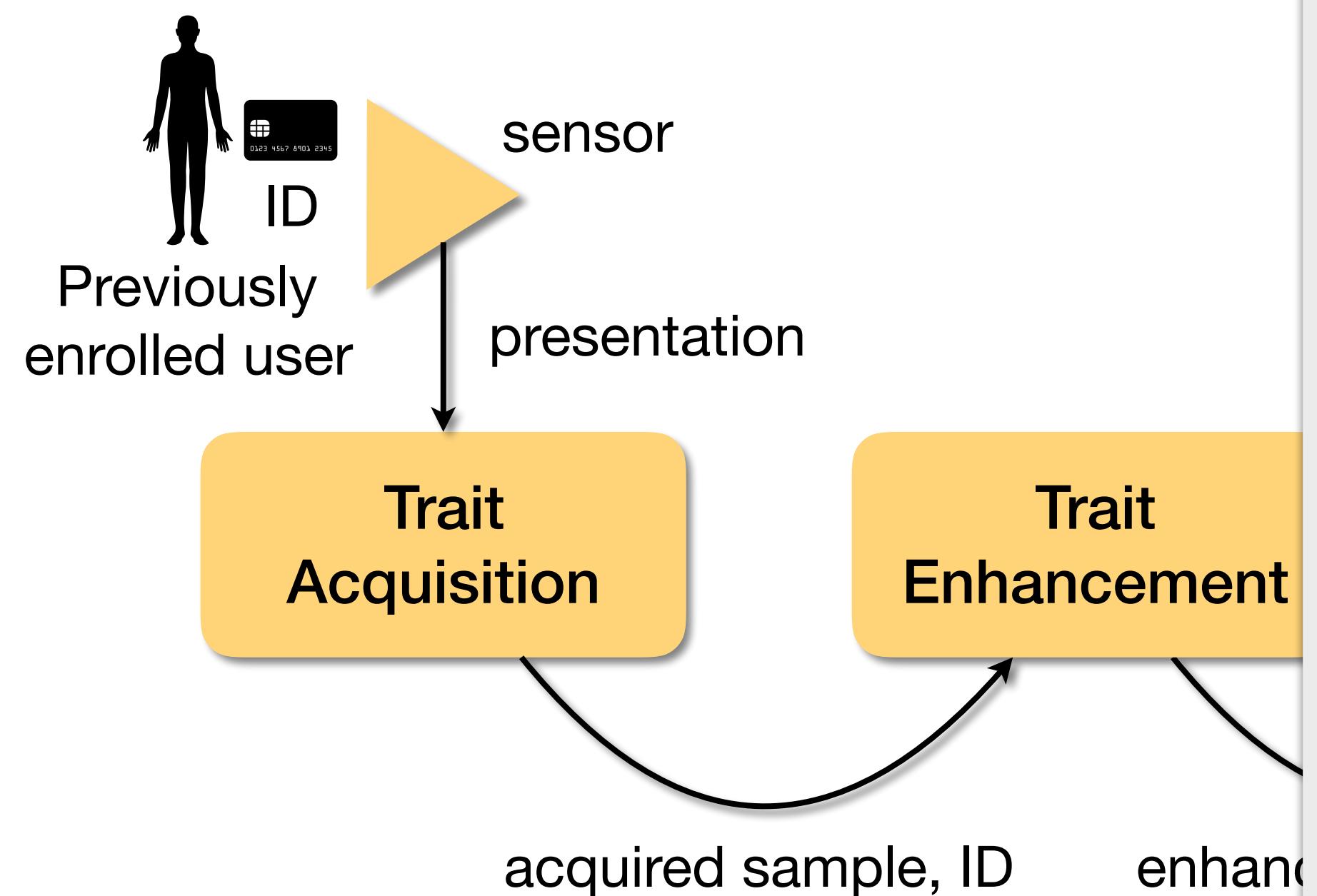
**Fast Enrollment**
Possible solution: conclude enrollment after *Feature Extraction*.

sensor

ID

Previously enrolled user

presentation

template database

feature, ID

| Trait Acquisition | Trait Enhancement | Feature Extraction | Feature Matching | Decision |

acquired sample, ID

enhanced sample, ID

Proceed to *Feature Matching* and *Decision* and take the needed time.

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# Biometric Systems

## Enrollment Revision

sensor

ID

Previously
enrolled user

presentation

**Trait
Acquisition**

**Trait
Enhancement**

acquired sample, ID

enhanc

template
database

**De-duplication**
Once the system has finally found
a duplication, remove it, and take
other necessary actions.

ID: Already-enrolled error. Remove duplication.

**Feature
Matching**

**Decision**

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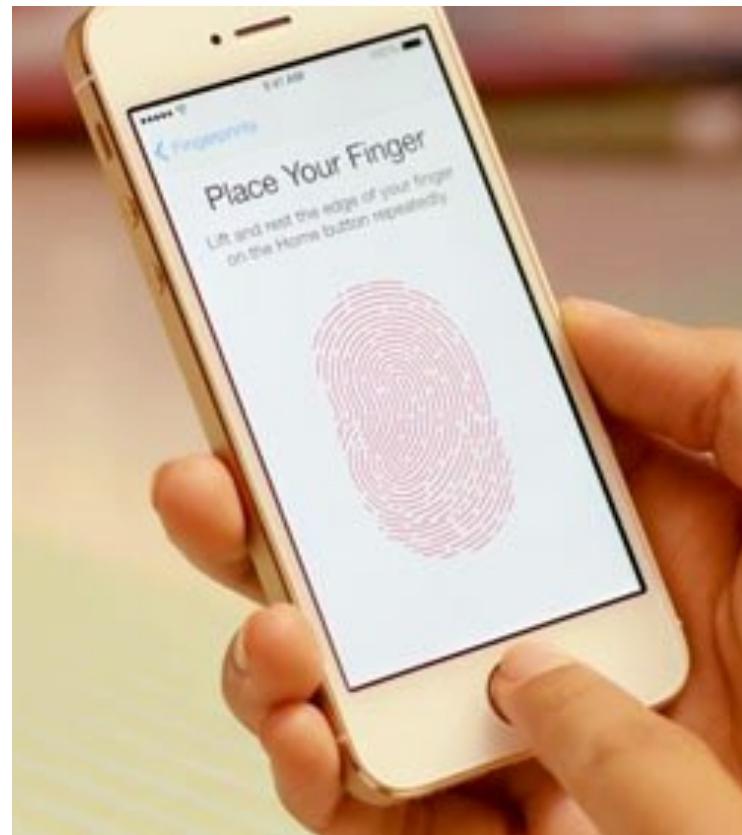
# Biometric Systems

**Deployment**



From all modules integrated within single chips…



To disperse modules independently deployed in diverse platforms.
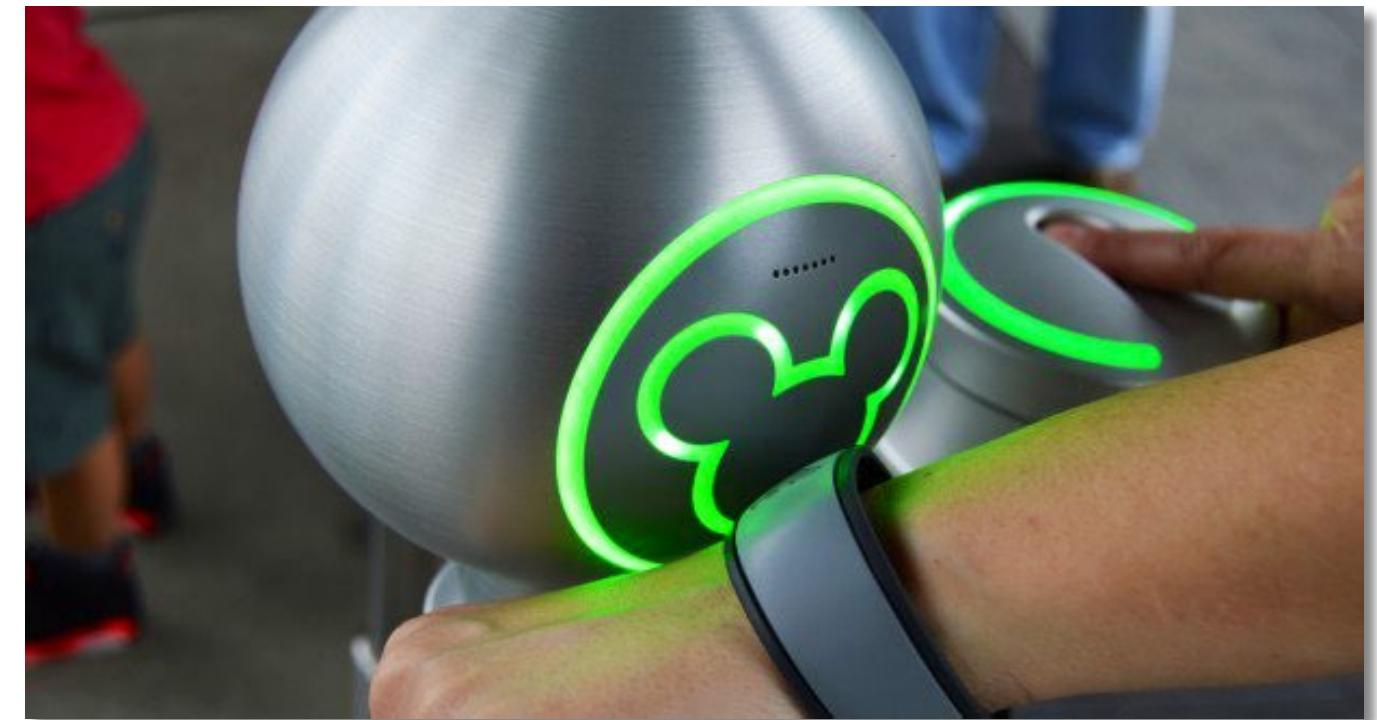
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# Biometric Systems

**What do we want to consider?**
Things to consider when designing
a Biometrics system, besides trait.

**Cooperative or
non-cooperative users? (1/5)**
Do users want to be identified?

Don't appeal to covert deployment.

# Biometric Systems

**What do we want to consider?**
Things to consider when designing a Biometrics system, besides trait.

**Habituated or non-habituated users? (2/5)**
Do users interact with the system frequently or sporadically?
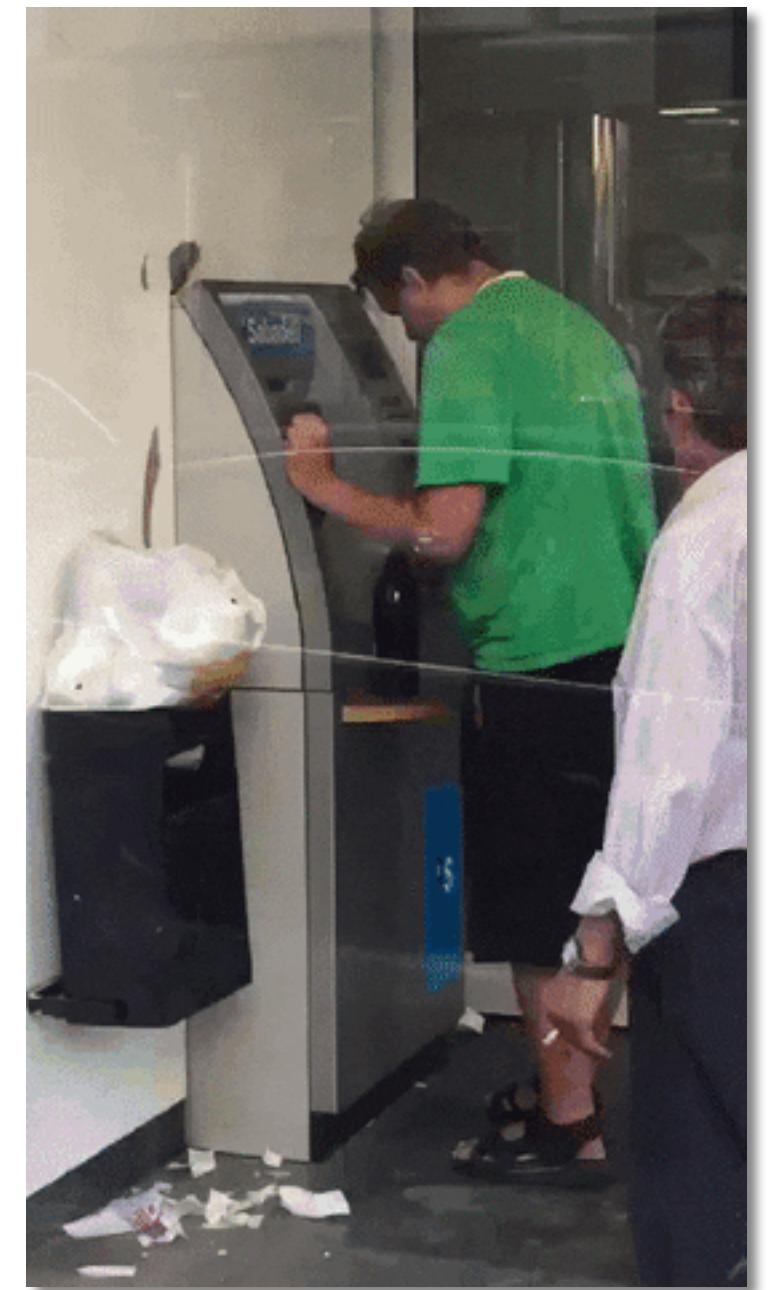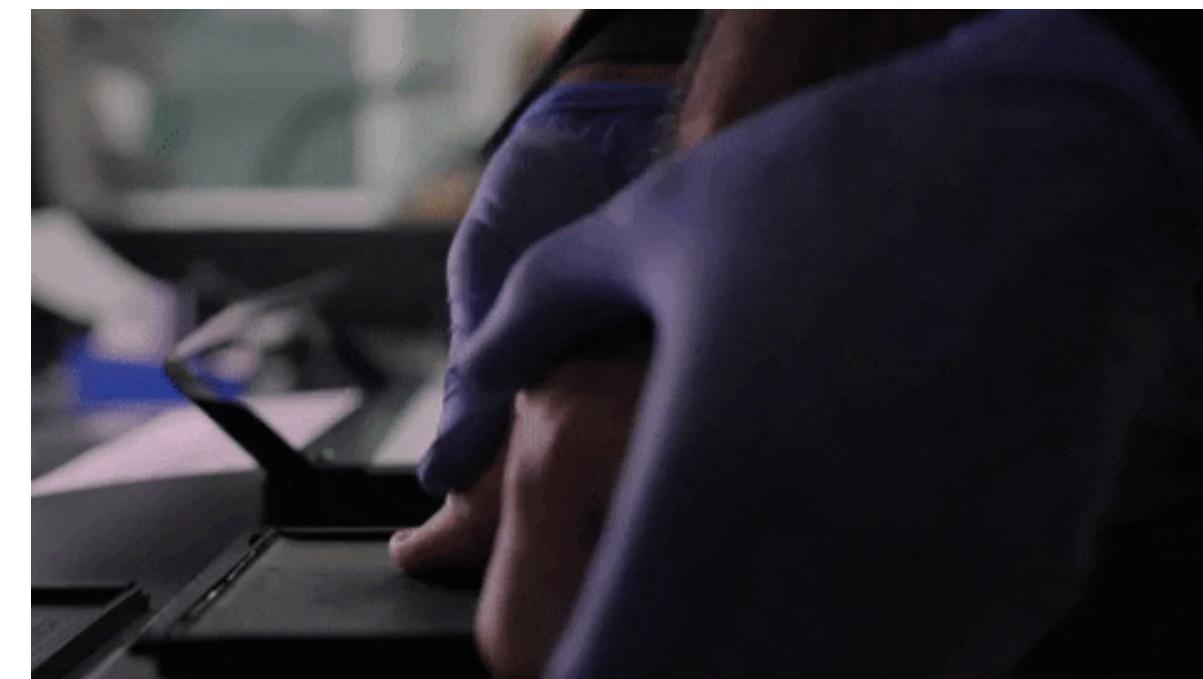
# Biometric Systems

**What do we want to consider?**
Things to consider when designing
a Biometrics system, besides trait.

**Attended or
unattended operation? (3/5)**
Will somebody be
helping users?
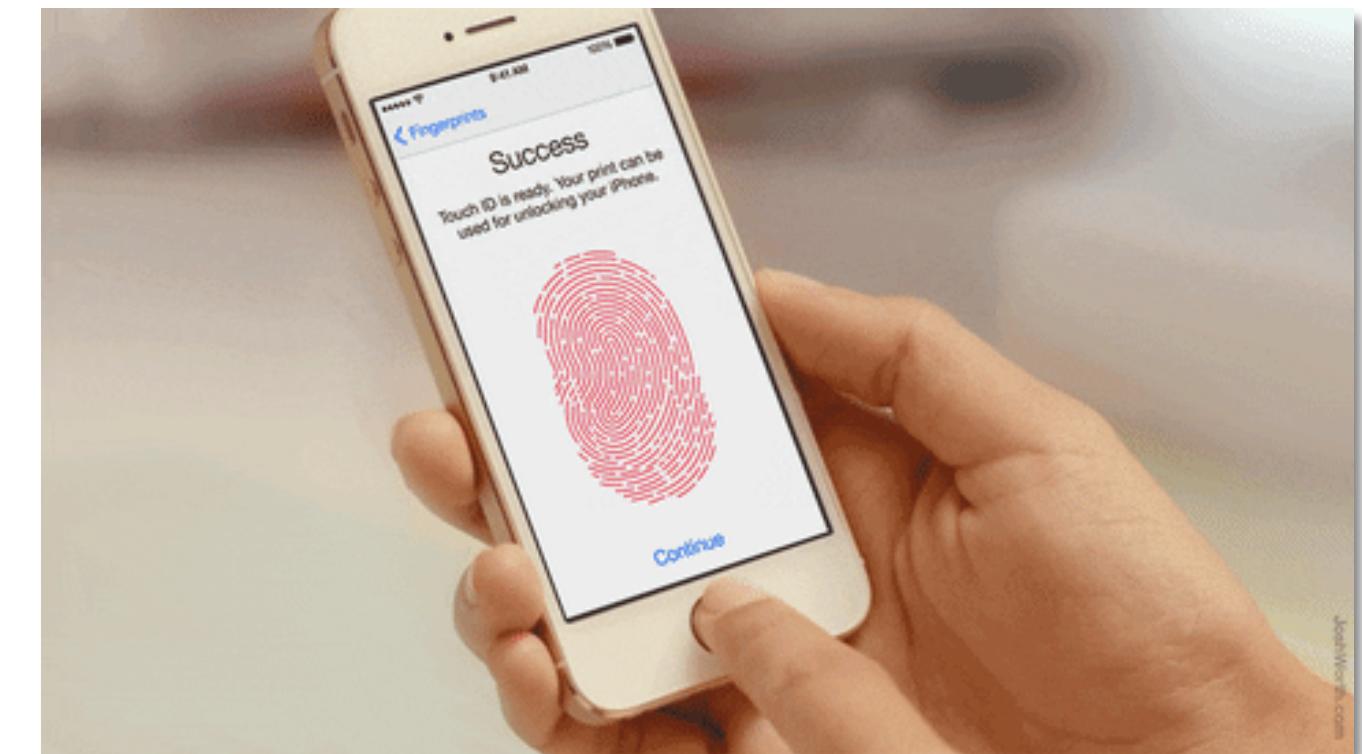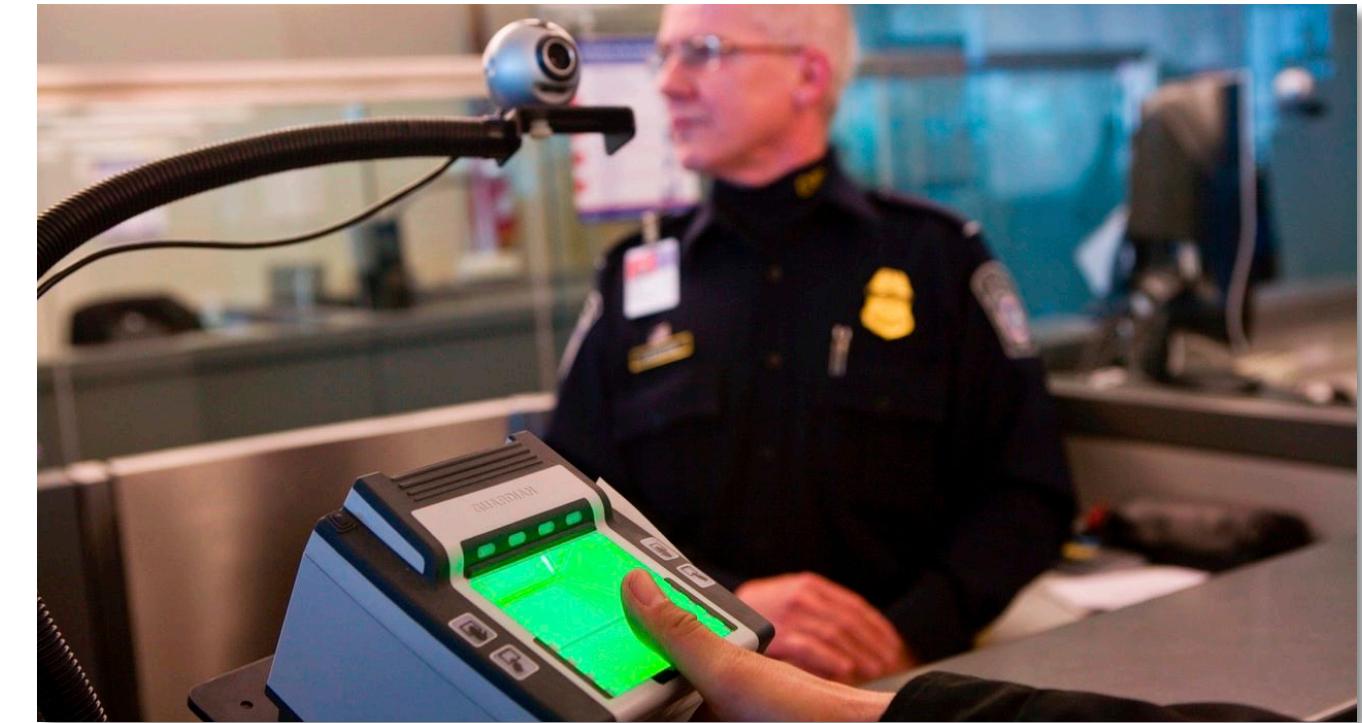
# Biometric Systems

**What do we want to consider?**
Things to consider when designing a Biometrics system, besides trait.

**Controlled or uncontrolled environment? (4/5)**
How do the environmental conditions change?
(temperature, illumination, etc.)

# Biometric Systems

**What do we want to consider?**
Things to consider when designing a Biometrics system, besides trait.

**What are the computational requirements? (5/5)**
Consider memory footprint, processing time, response time, and system availability.



THIS IS SO SLOW

# Biometric Systems

**What do we want to avoid?**

❌**Covert deployment**
Users must be aware of the Biometric system collecting their data.
Respect their privacy.



❌**No data confidentiality**
Collected data must be confidential. Avoid function creep.

❌**Unsafe system**
We will get to know threats (attacks) that may harm a system's integrity.

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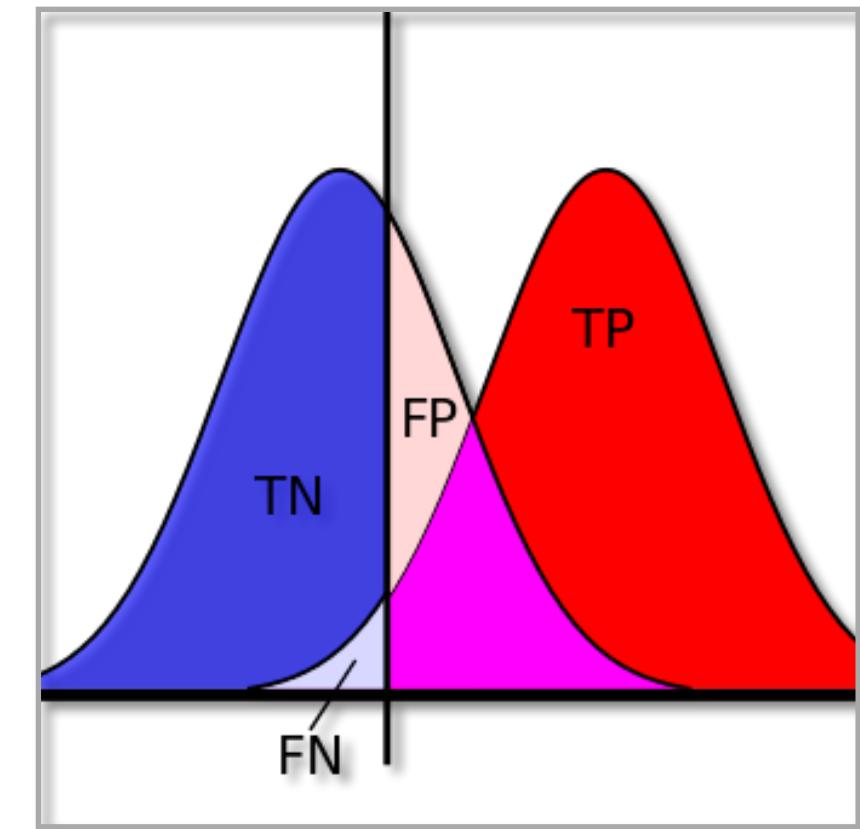
# S'up Next?

**Be happy**
Any issues? Please come and talk to me.

**More basics**
Biometric system errors, metrics and attacks.





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