

# **Basics I**

CSE 40537/60537 Biometrics

**Daniel Moreira**  
Spring 2020



# Today you will...

*Get to know*

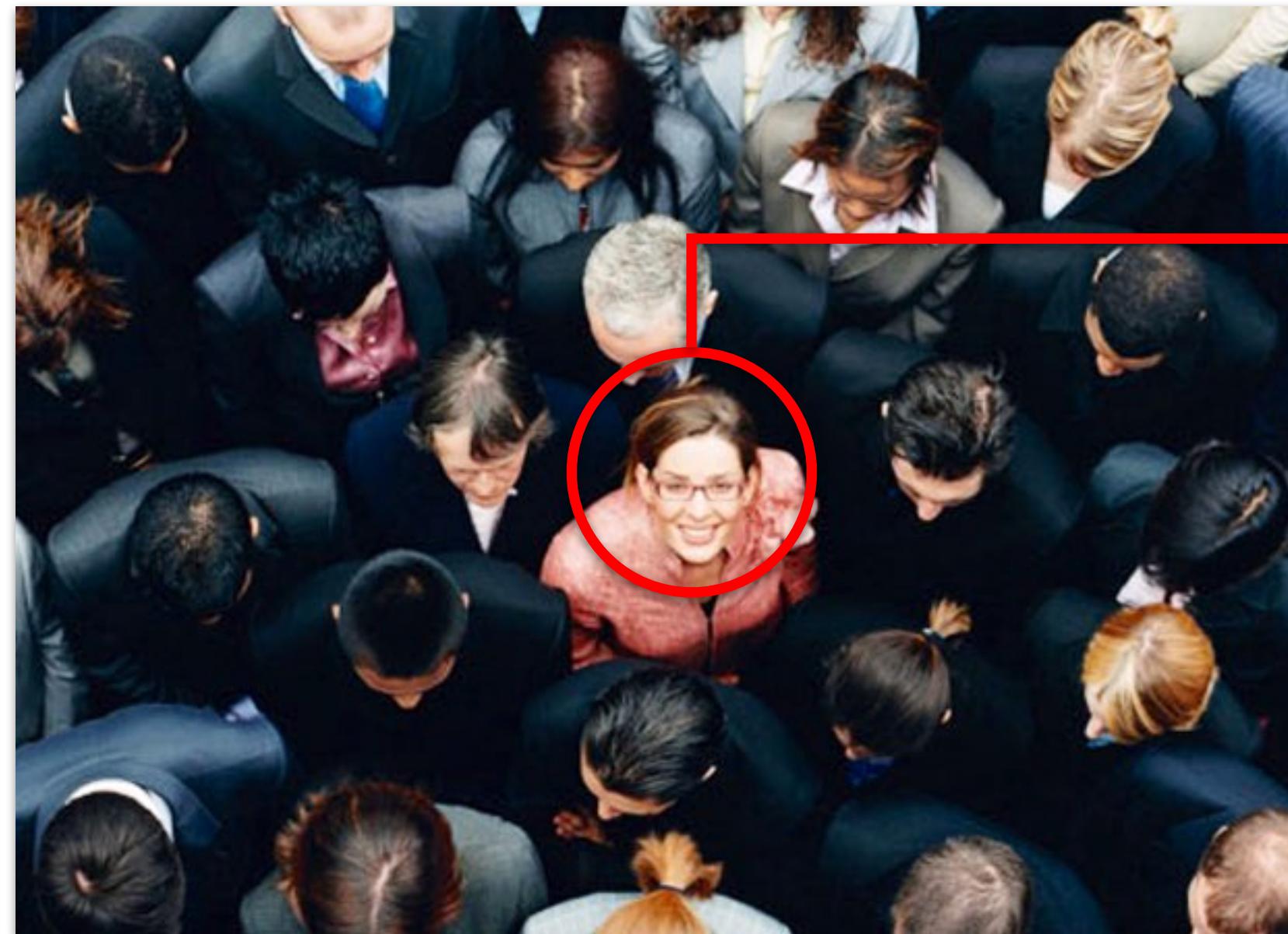
What Biometrics is.

Reasons to use Biometrics.

Biometric traits.

How Biometric systems look like.

# 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.

# What is Biometrics?



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

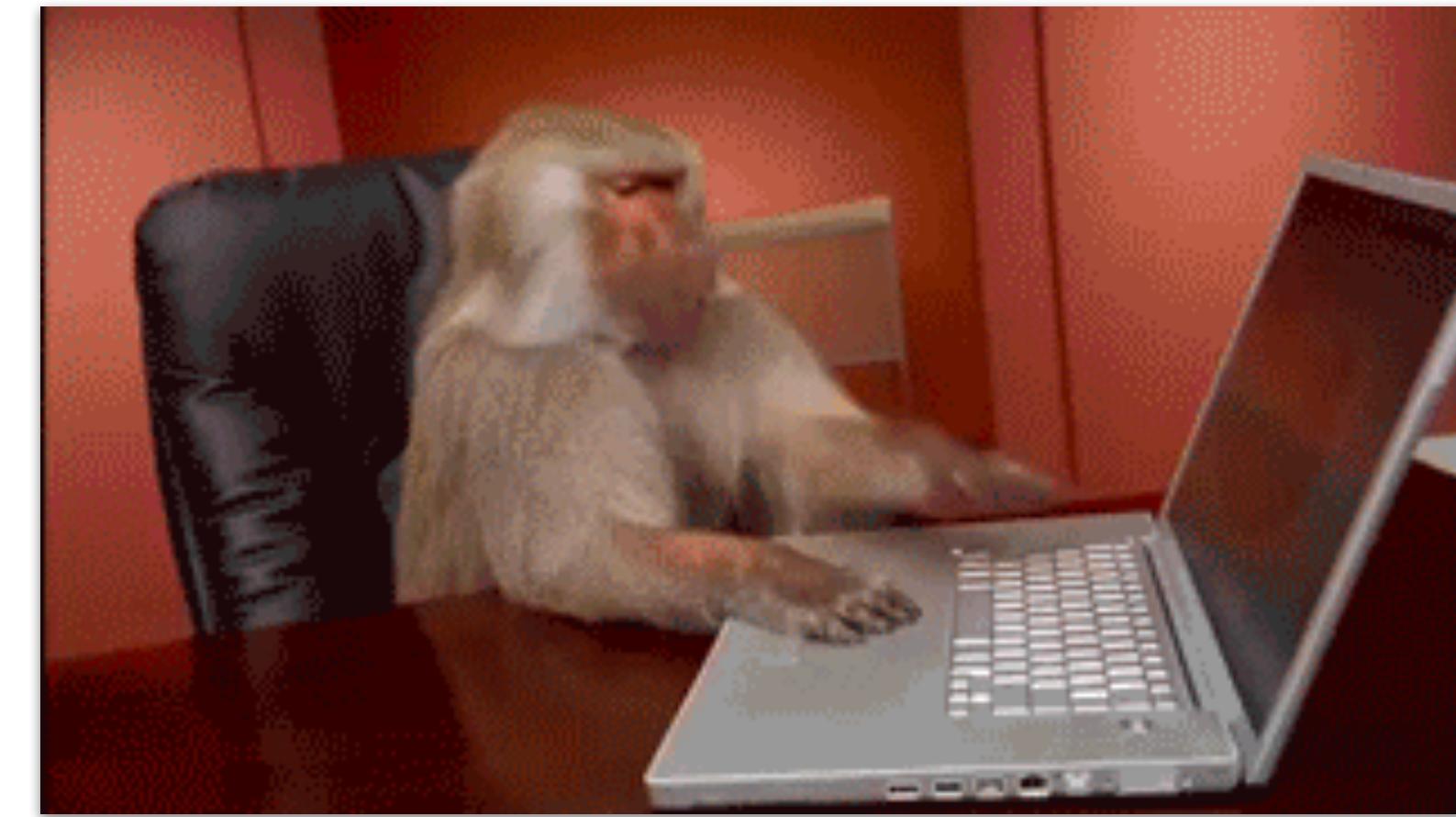
We'll focus on **software solutions**  
rather than hardware.

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

# What is Biometrics?

## Why computers?

- High throughput
- Repeatability
- Predictability
- Accountability

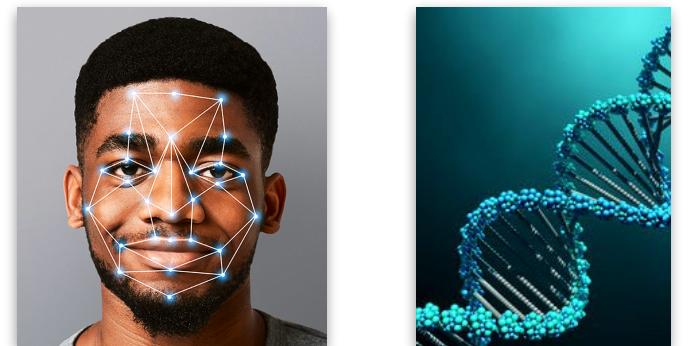


# What is Biometrics?

Identity verification through:



A unique trait  
of yours.



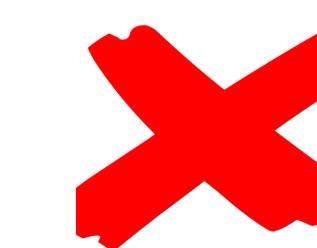
physical      chemical



behavioral



Not something  
you have.



Not something  
you know.



# Why use Biometrics?

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

Jan 6, 2020 | [Chris Burt](#)

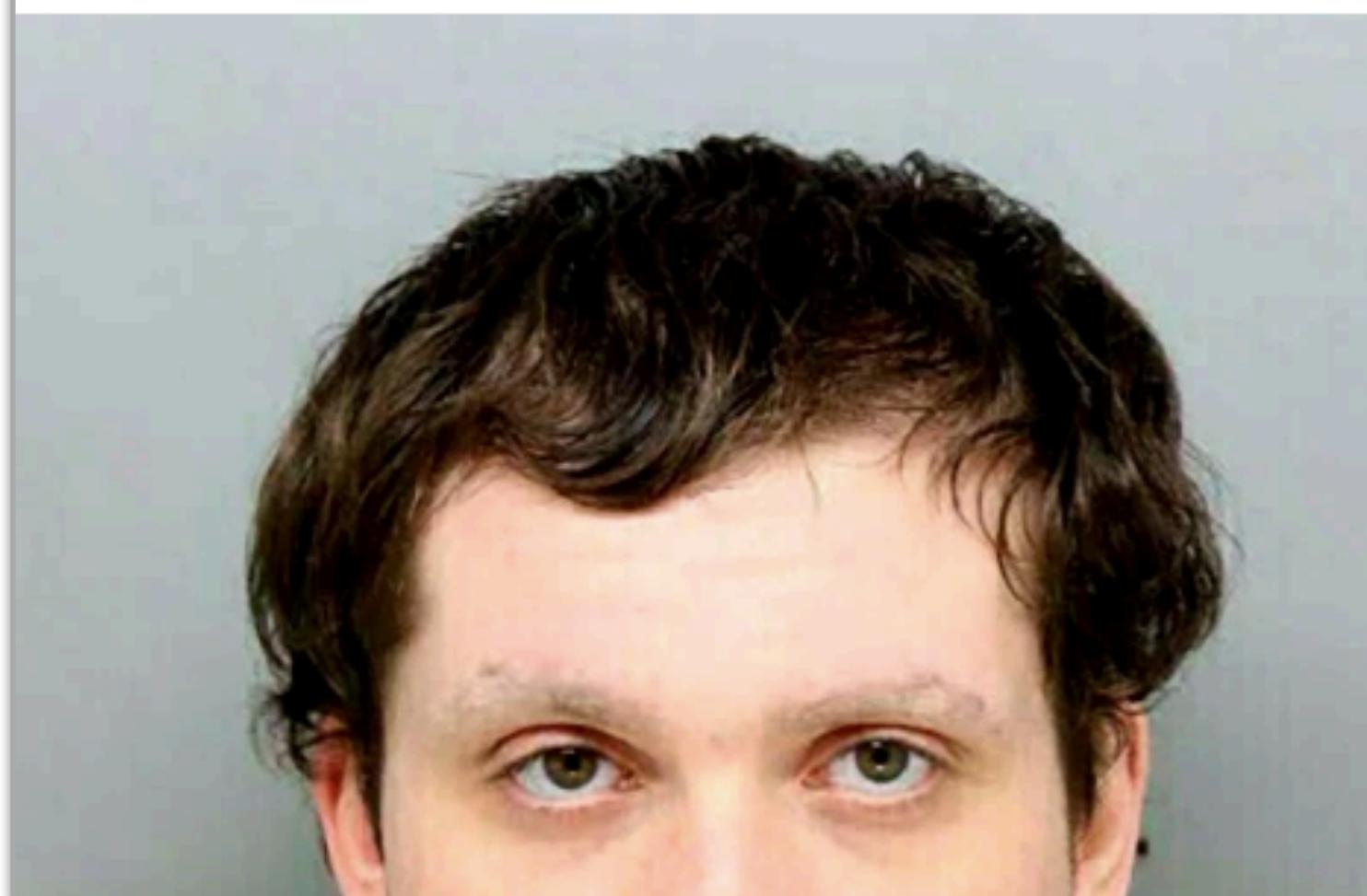
CATEGORIES [Biometrics News](#) | [Financial Services](#)



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>

# Why use Biometrics?



A mugshot of Brian Rini, a man with dark hair and blue eyes, looking directly at the camera against a plain grey background.

TIME

SUBSCRIBE

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/>

# Why use Biometrics?

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

BBC | Sign in | News | Sport | Reel | Worklife | Travel | Future | M

## NEWS

Home | Video | World | US & Canada | UK | Business | Tech | Science | Stories | Entertainment

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**Doctor 'used silicone fingers' to sign in for colleagues**

⌚ 12 March 2013

f | Share



<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!

= WIRED

SUBSCRIBE



Experience that new-car feeling.

ANDY GREENBERG SECURITY 11.14.2017 07:00 AM

## Watch a 10-Year-Old's Face Unlock His Mom's iPhone X

Yes, twins can unlock each other's iPhones. But kids accessing their parents' devices raises different concerns.



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

# Why use Biometrics?

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

The screenshot shows a news article from Reuters. At the top, the Reuters logo is on the left, followed by navigation links: Business, Markets, World, Politics, TV, More, and an American flag icon. Below this is a black header bar with three colored circles (orange, red, green) and a 'Learn more' button. The main title 'The man in the plastic mask: Brazil inmate busted in brazen jailbreak' is displayed prominently. Below the title, it says 'WORLD NEWS AUGUST 5, 2019 / 8:47 AM / 5 MONTHS AGO'. At the bottom, there's a '3 MIN READ' indicator and social sharing icons for Twitter and Facebook.



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>

# Why use Biometrics?

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

The New York Times

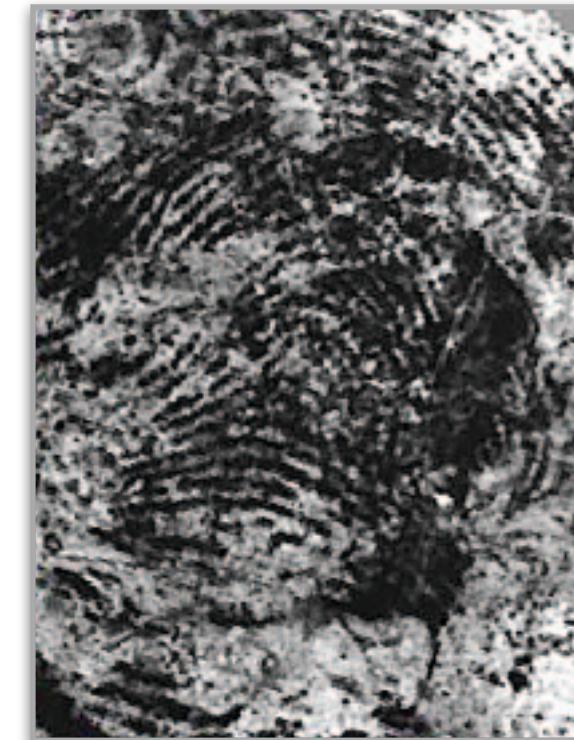
## ***Report Faults F.B.I.'s Fingerprint Scrutiny in Arrest of Lawyer***

By David Stout

Nov. 17, 2004

f    t    e-mail    share    bookmark

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



latent  
fingerprint

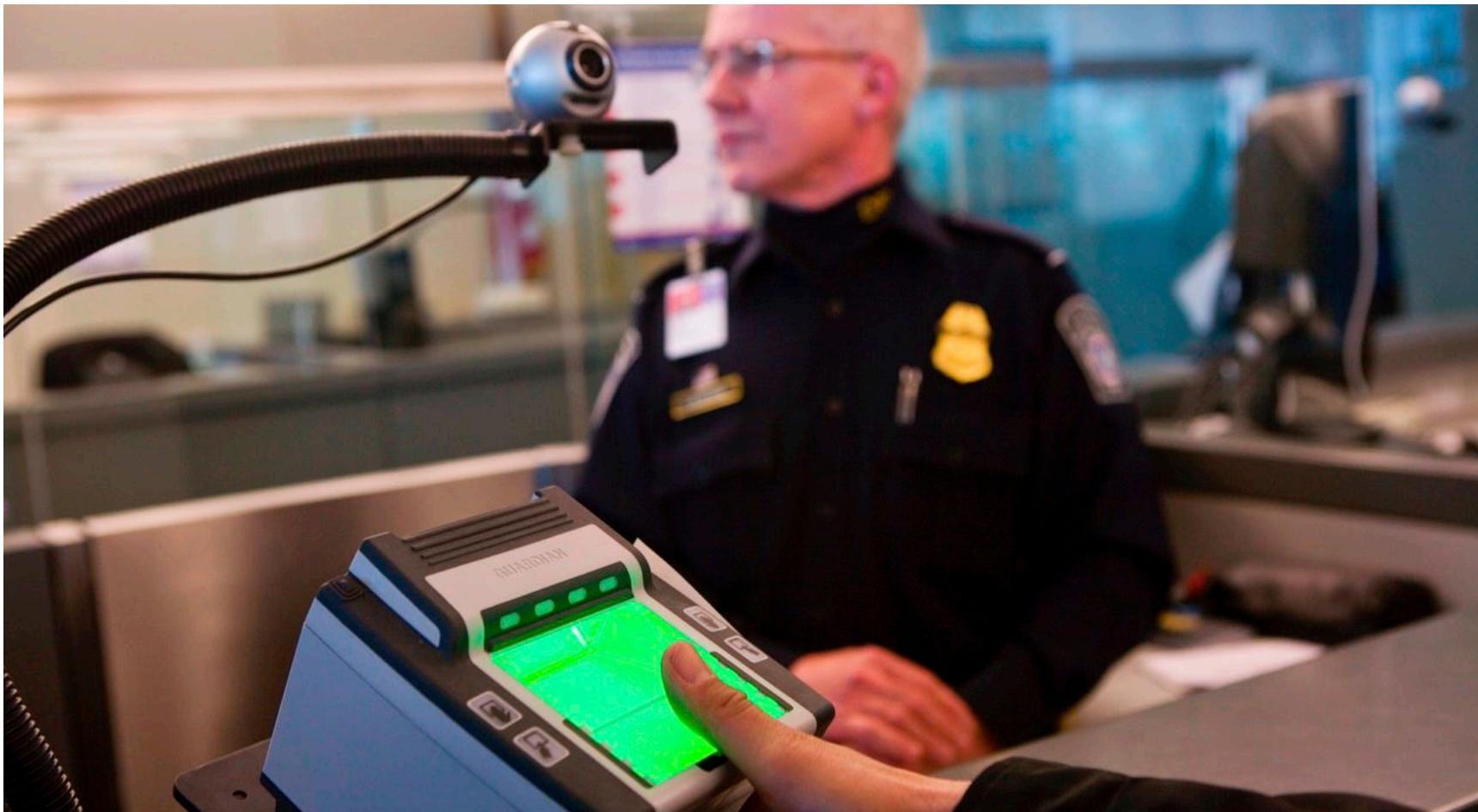


collected  
fingerprint

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.

# Biometrics Use

**Biometrics is a reality**



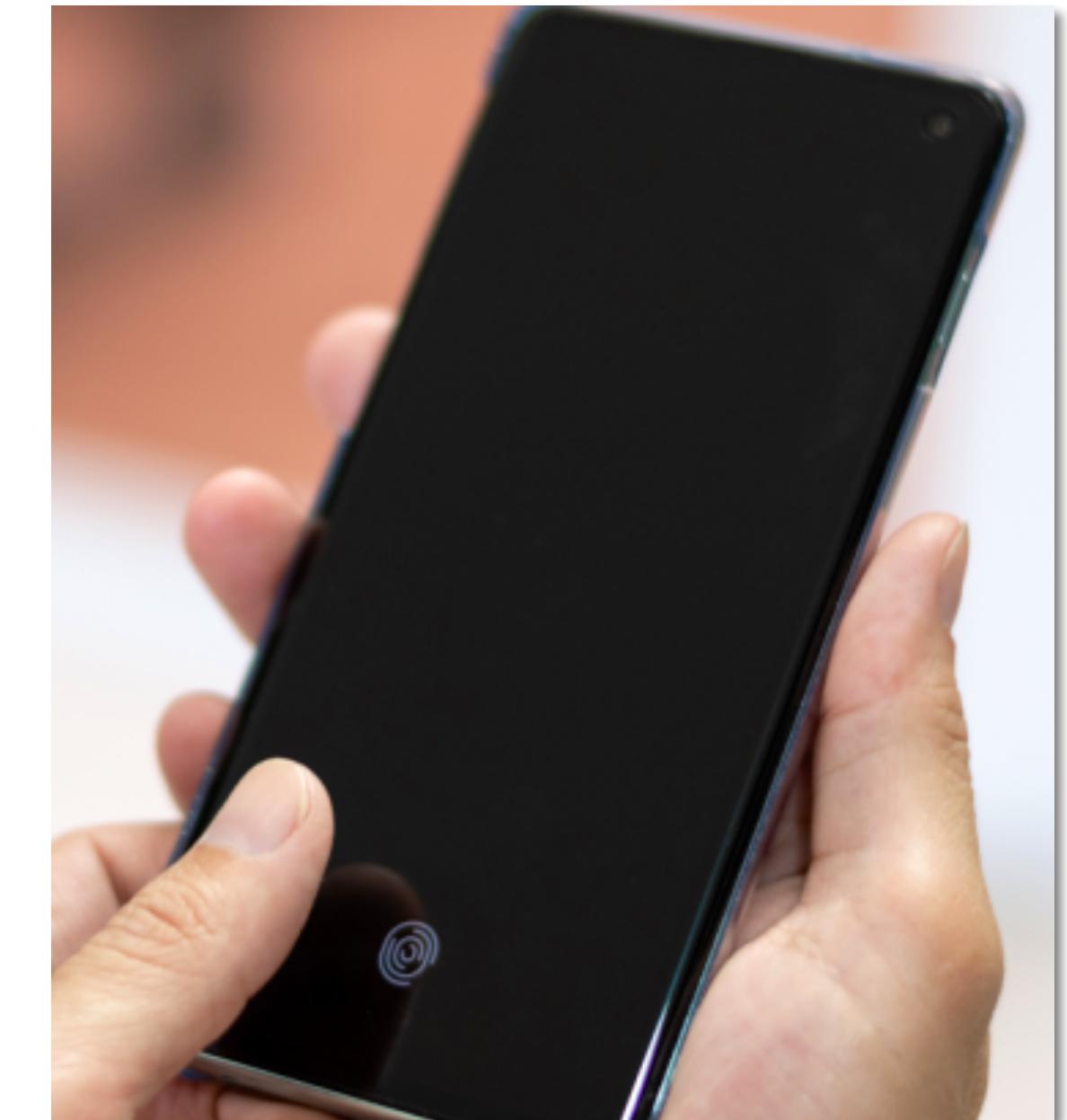
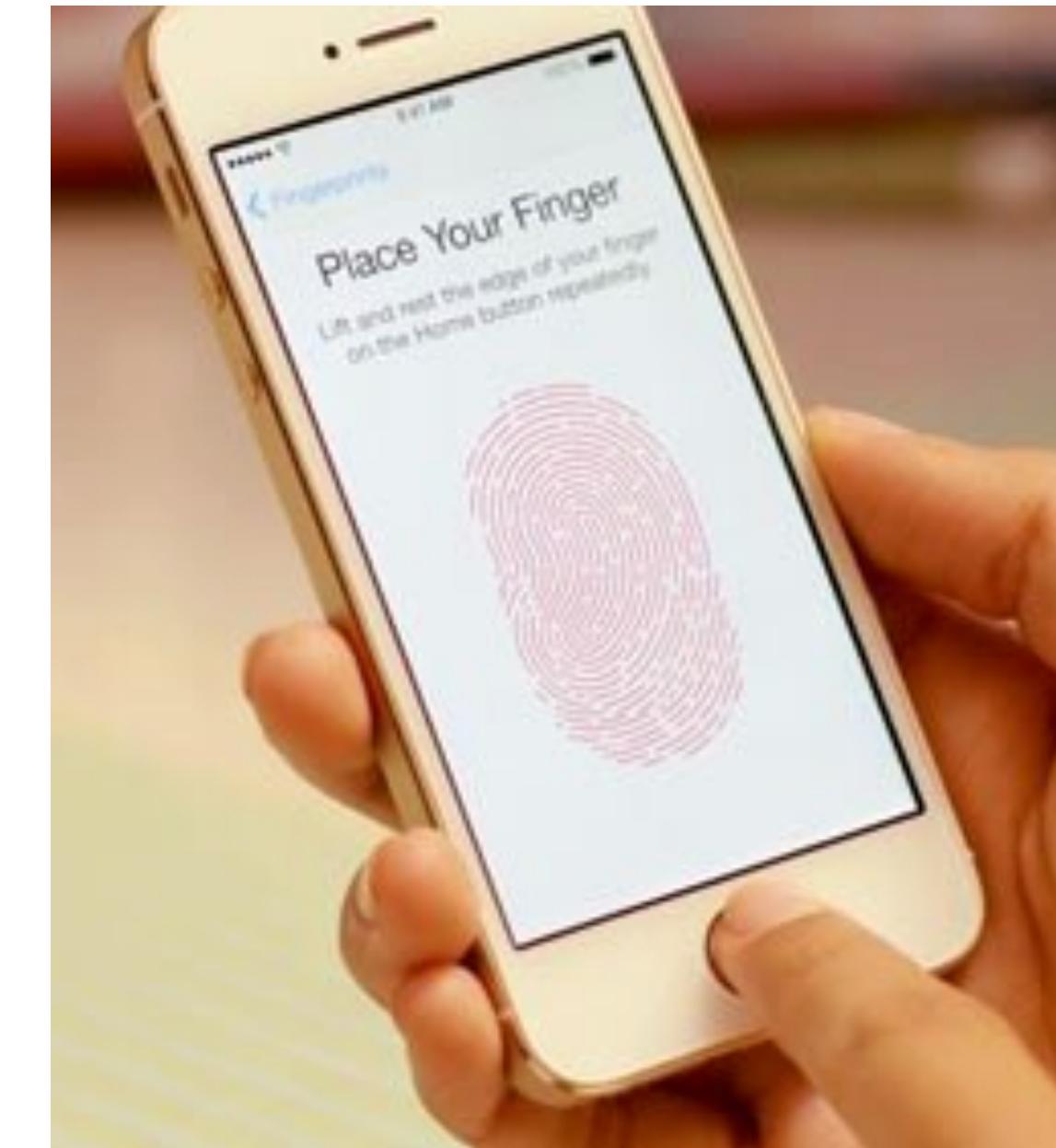
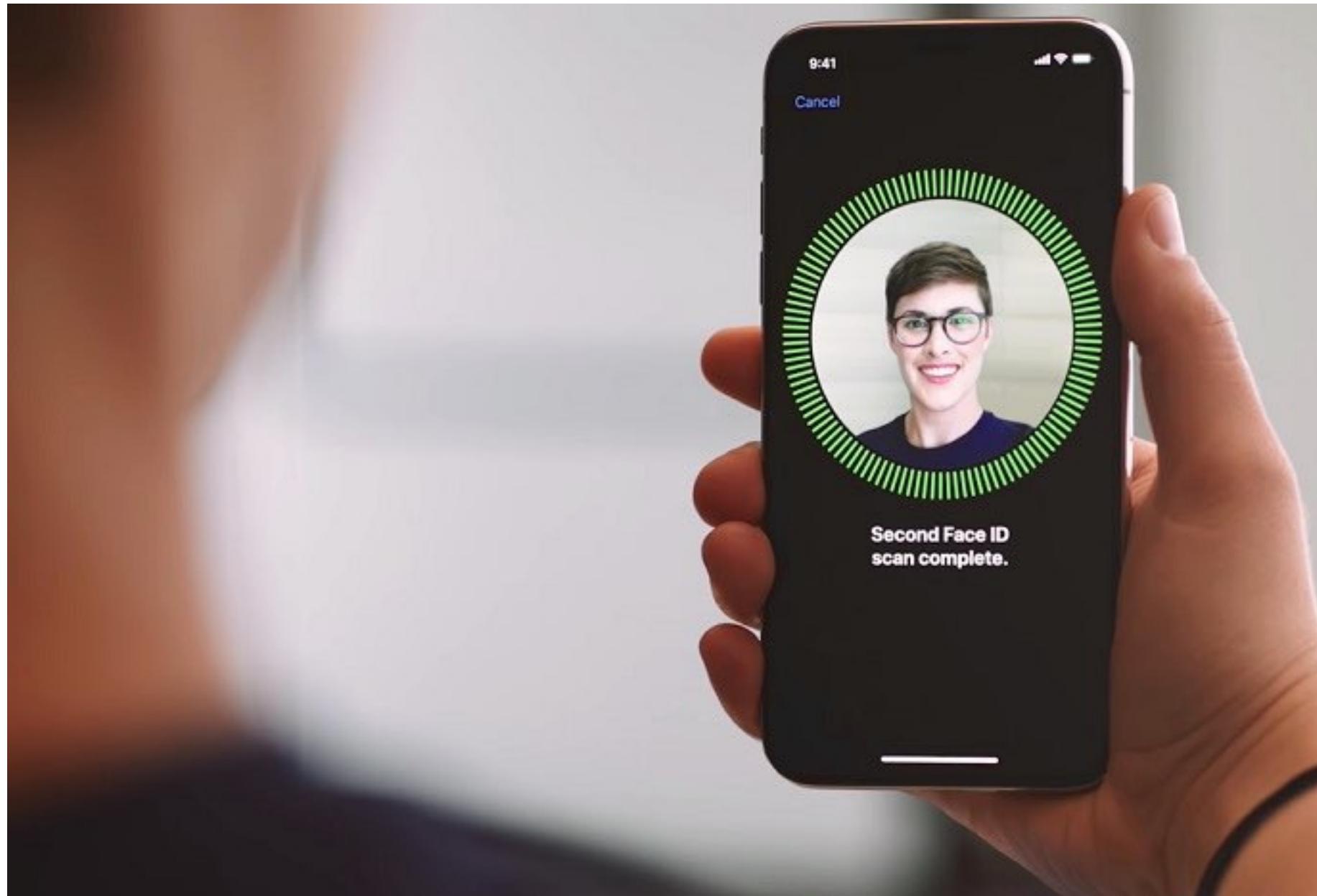
border patrol



entertainment

# Biometrics Use

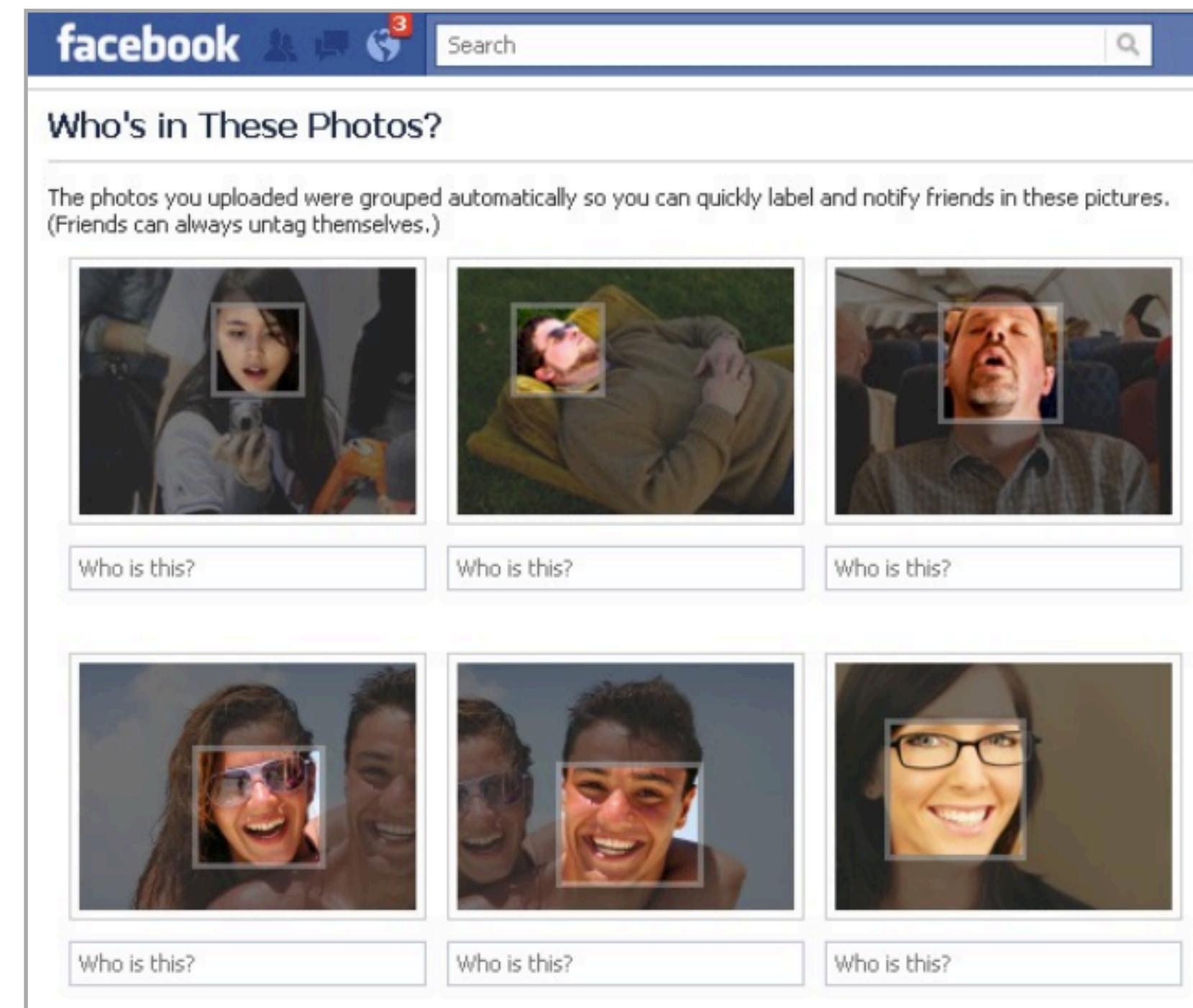
**Biometrics is a reality**



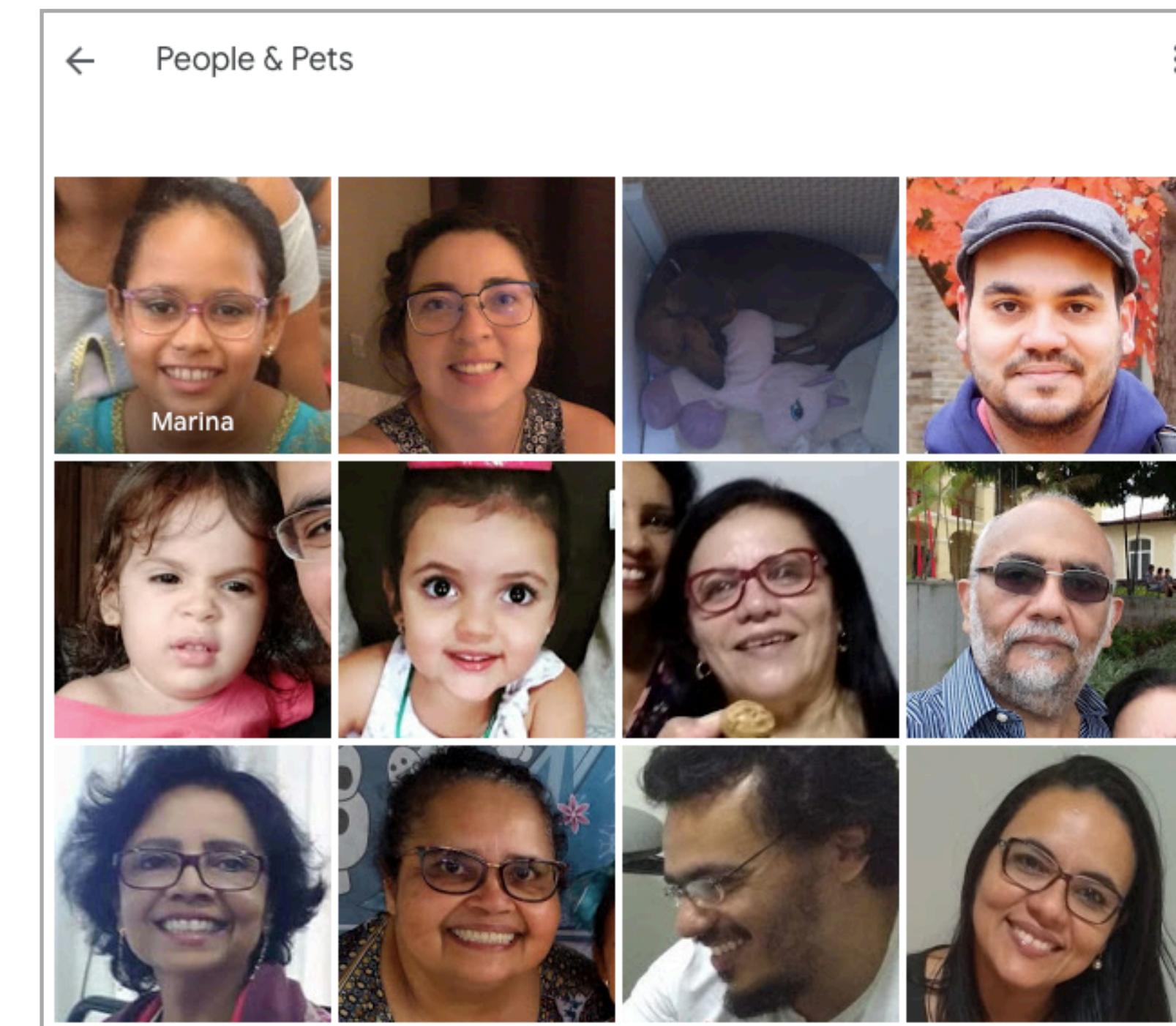
personal devices

# 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.

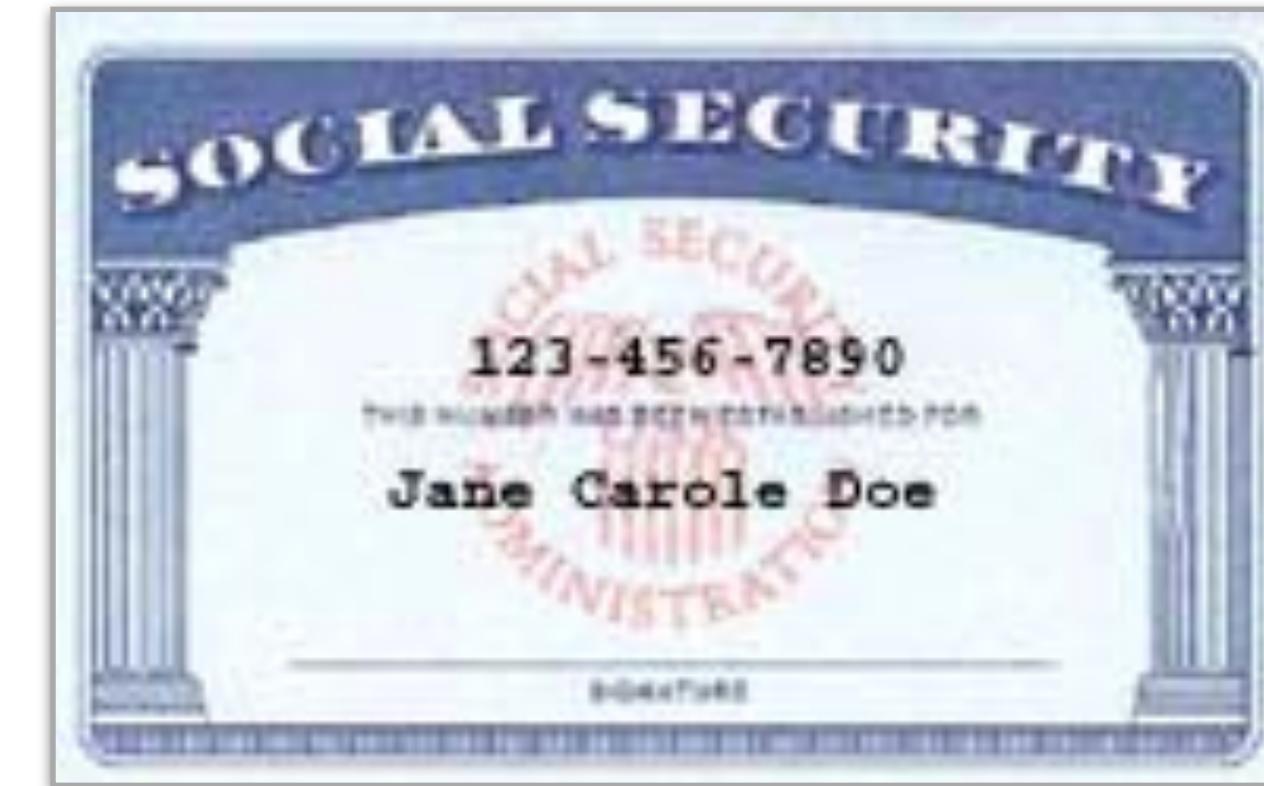


civil rights

# 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>

# Biometrics Abuse

## Segregating Profiling

The screenshot shows a news article from Hindustan Times. At the top, the website's logo 'hindustantimes' is displayed in blue and black. To its right are links for 'Sign In', 'Saturday, Jan 11, 2020 | New Delhi 16°C', and 'e-paper'. Below the logo is a navigation bar with 'discover' and various categories like 'india cities opinion world cricket entertainment election trending videos tech •••'. A search bar is also present. The main headline reads 'Linking benefits for AIDS patients to Aadhaar triggers privacy concerns'. A sub-headline states: 'Many patients are avoiding going to hospitals and ATR centres fearing mandatory submission of their Aadhaar number could lead to disclosure of their identity, inviting social stigma.' A small note at the bottom left indicates the article was updated on April 3, 2017.

[https://www.hindustantimes.com/bhopal/  
linking-benefits-for-aids-patients-to-aadhaar-  
triggers-privacy-concerns/story-  
iR6HB8RmqPDAwkX2Oj5EJ.html](https://www.hindustantimes.com/bhopal/linking-benefits-for-aids-patients-to-aadhaar-triggers-privacy-concerns/story-iR6HB8RmqPDAwkX2Oj5EJ.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

f t m r b 341

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

# Biometrics Abuse

## Data Leakage



The screenshot shows a news article from Tribune India. At the top left is a navigation bar with a home icon and the word 'NATION'. Below it, in red text, is 'TRIBUNE INVESTIGATION — SECURITY BREACH'. The main title of the article is 'Rs 500, 10 minutes, and you have access to billion Aadhaar details'. A subtext below the title reads: 'JALANDHAR: It was only last November that the UIDAI asserted that &ldquo;Aadhaar data is fully safe and secure and there has been no data leak or breach at UIDAI.' At the bottom of the article, it says 'Posted: Jan 04, 2018 02:07 AM (IST) Updated: 2 years ago' and shows 103612 views, 0 comments, 0 likes, and 0 dislikes.

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

# Biometrics Abuse

## Compromised biometric data

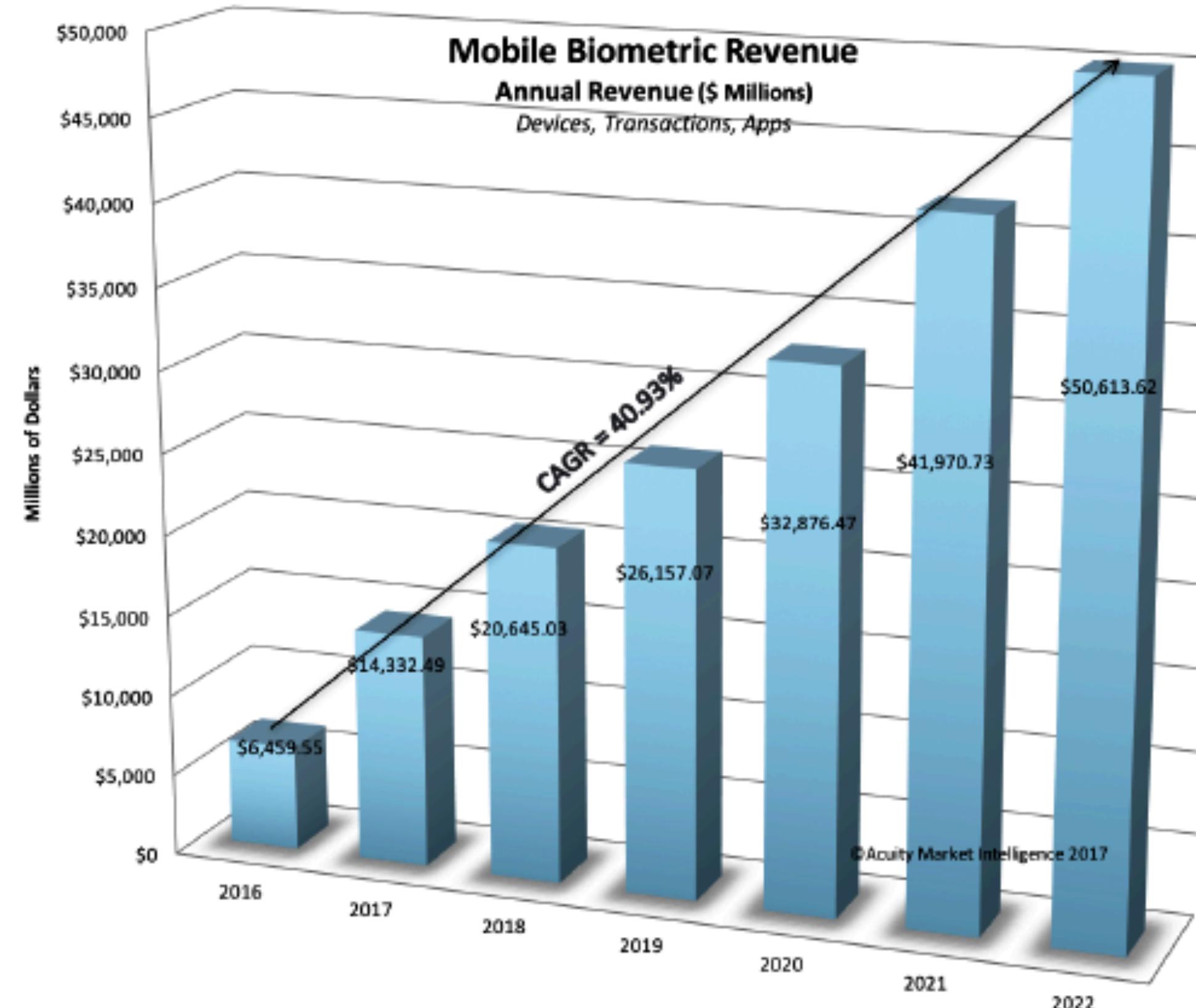
People cannot change their biometric data in response to a leak.  
Irreversible for whole lifetime.



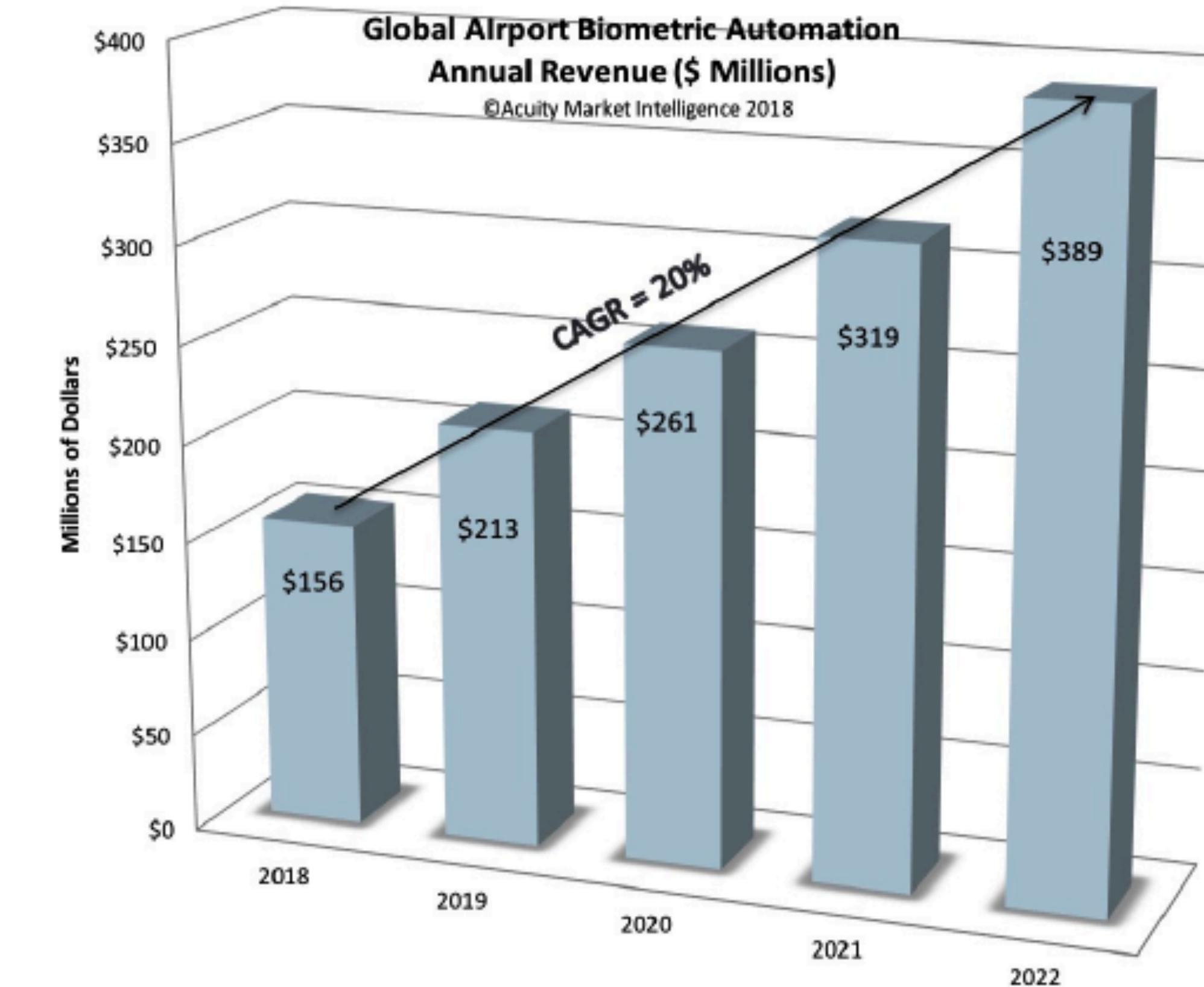
Please, don't.

# Biometrics Appeal

2017 Forecast



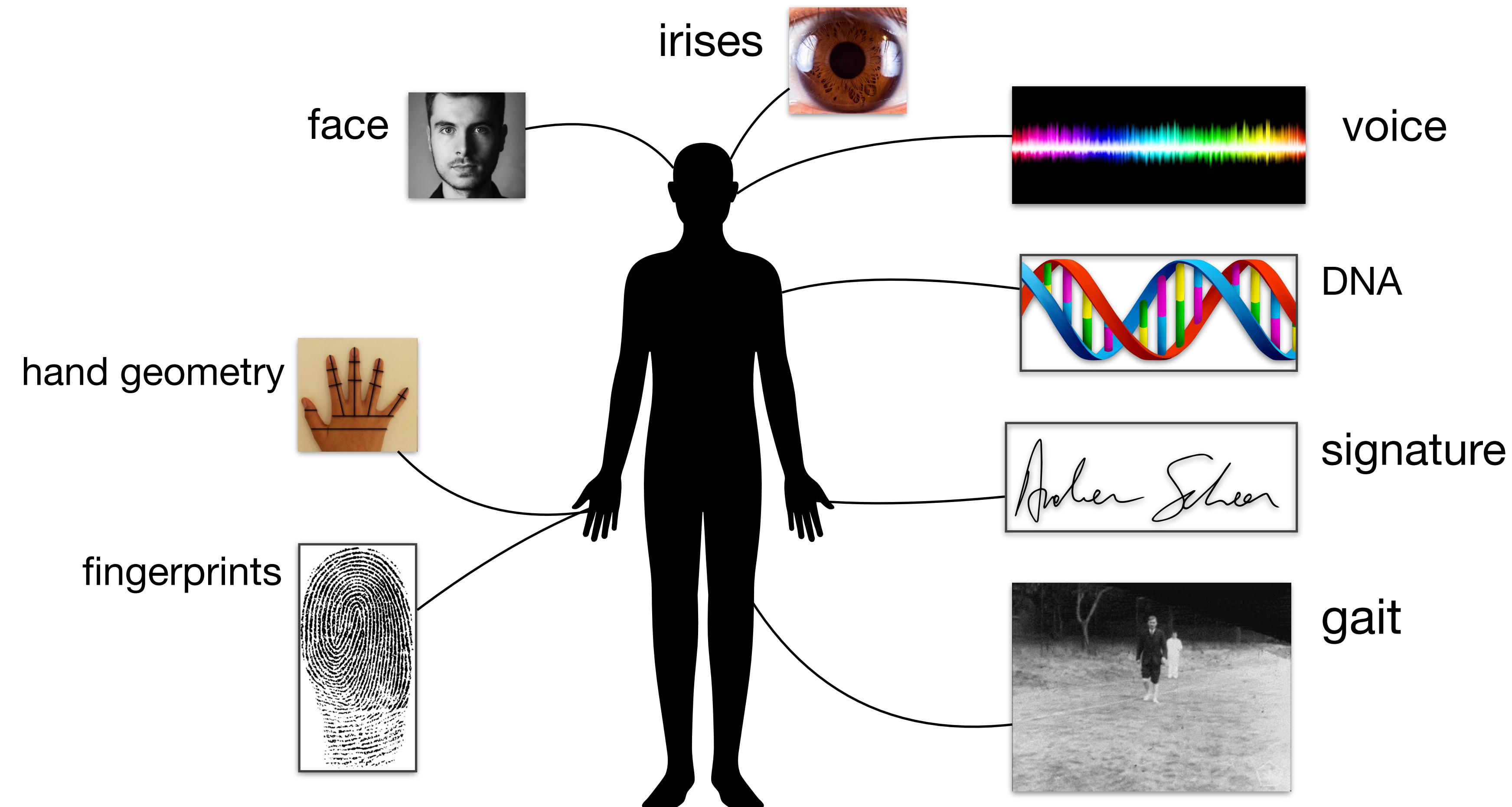
2019 Forecast



Source: Acuity Market Intelligence (<https://www.acuitymi.com/>)

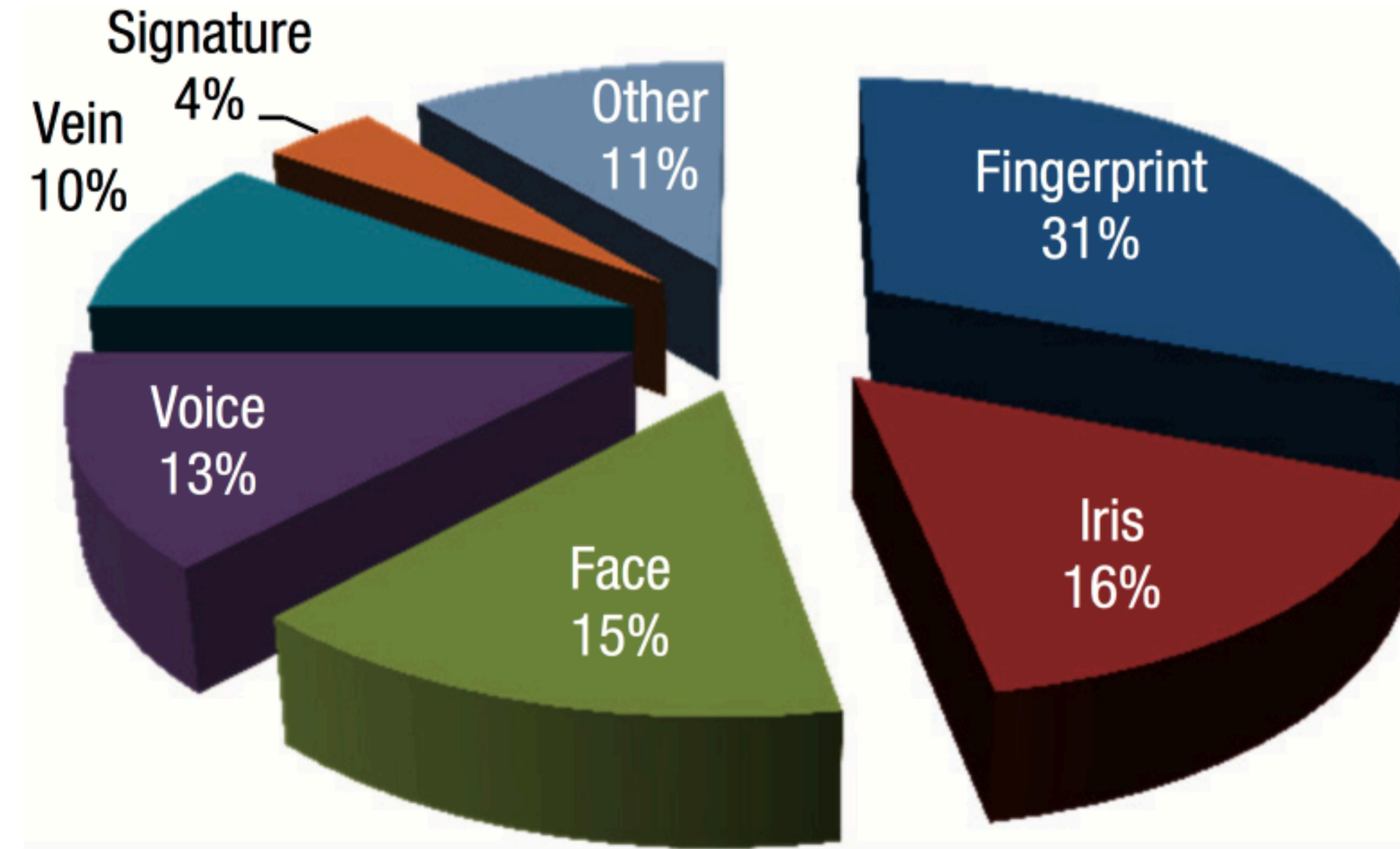
CAGR: Compound Annual Growth Rate

# Biometric Traits



# 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>

# 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 screenshot shows the BuzzFeed News homepage with a red 'TRENDING' button. The main headline is 'This Man Failed A Paternity Test Due To His Vanished Twin's DNA'. Below the headline is a summary: 'DNA researchers report a father failed a paternity test because the genes in his saliva differ from his sperm's. One in eight people might possess such "chimeric" genes caused by a twin lost in the womb.' The author is Dan Vergano, a BuzzFeed News Reporter, and the post was made on October 24, 2015, at 10:16 a.m. ET.

<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?



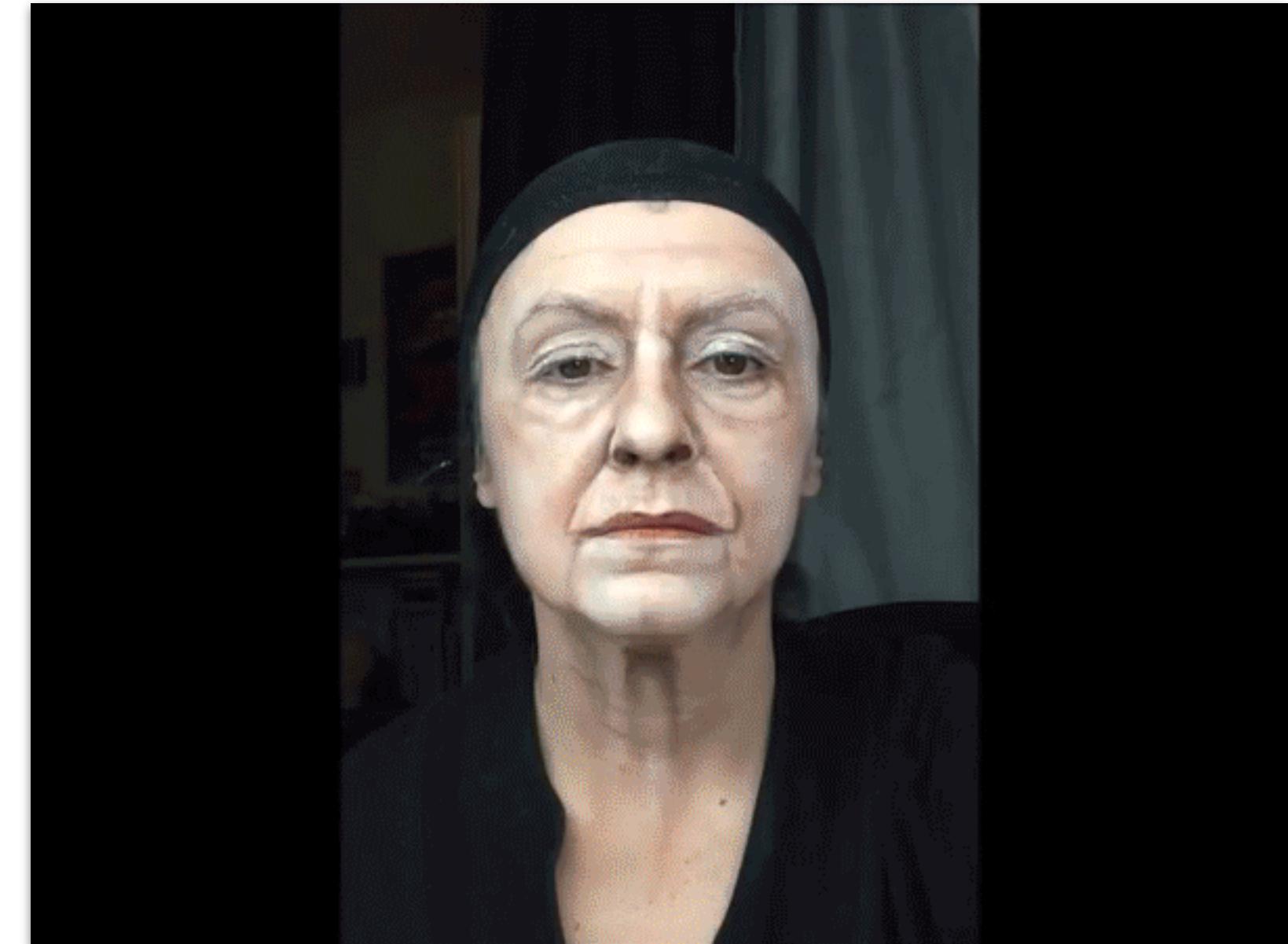
# Biometric Traits

**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>

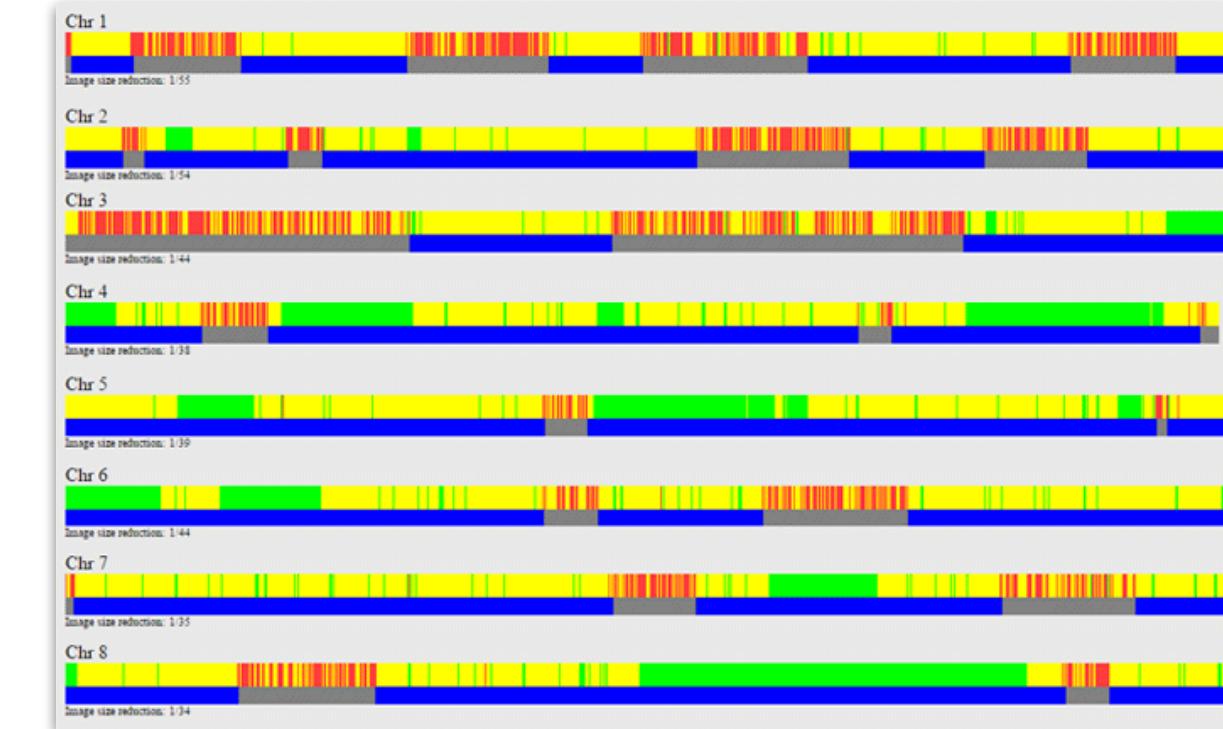
# Biometric Traits

**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?



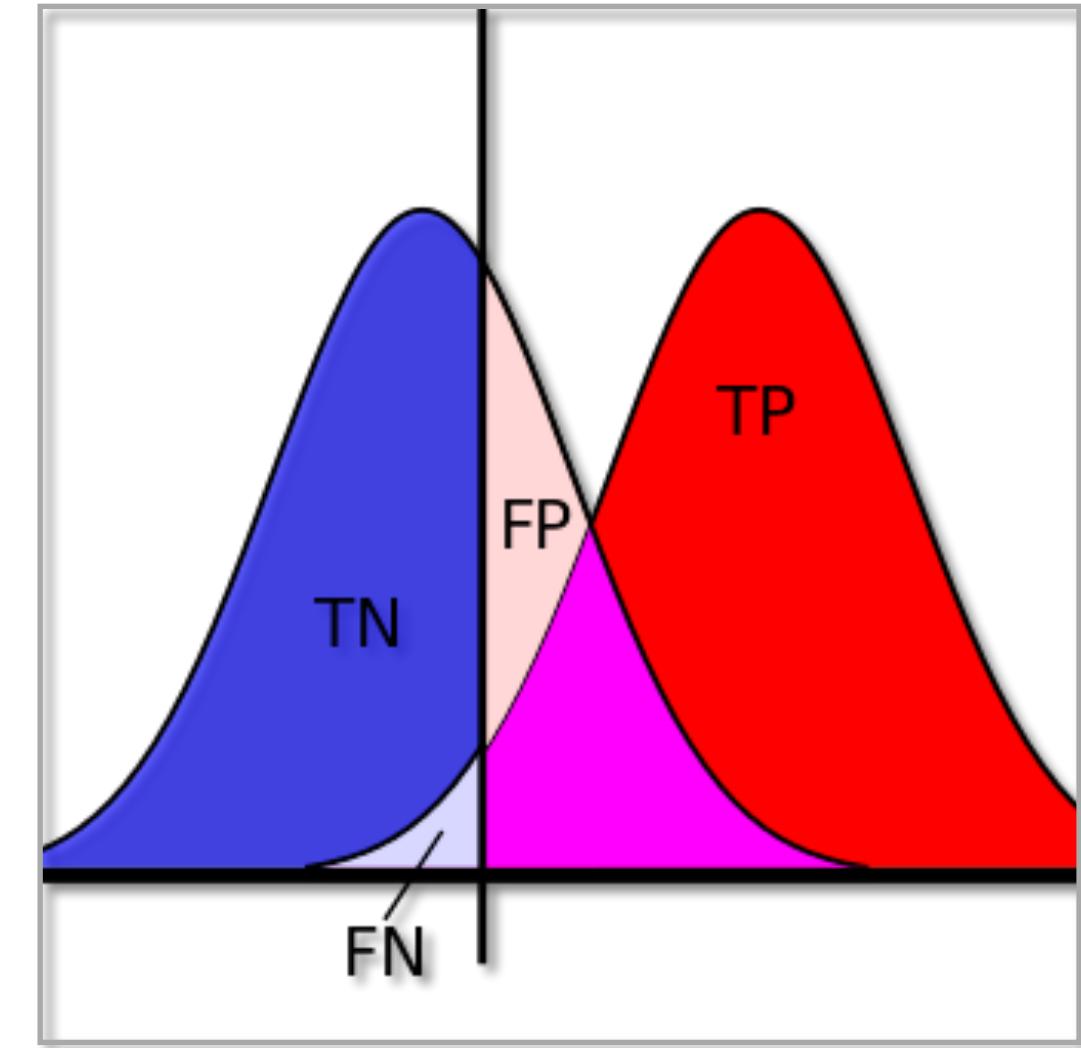
# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

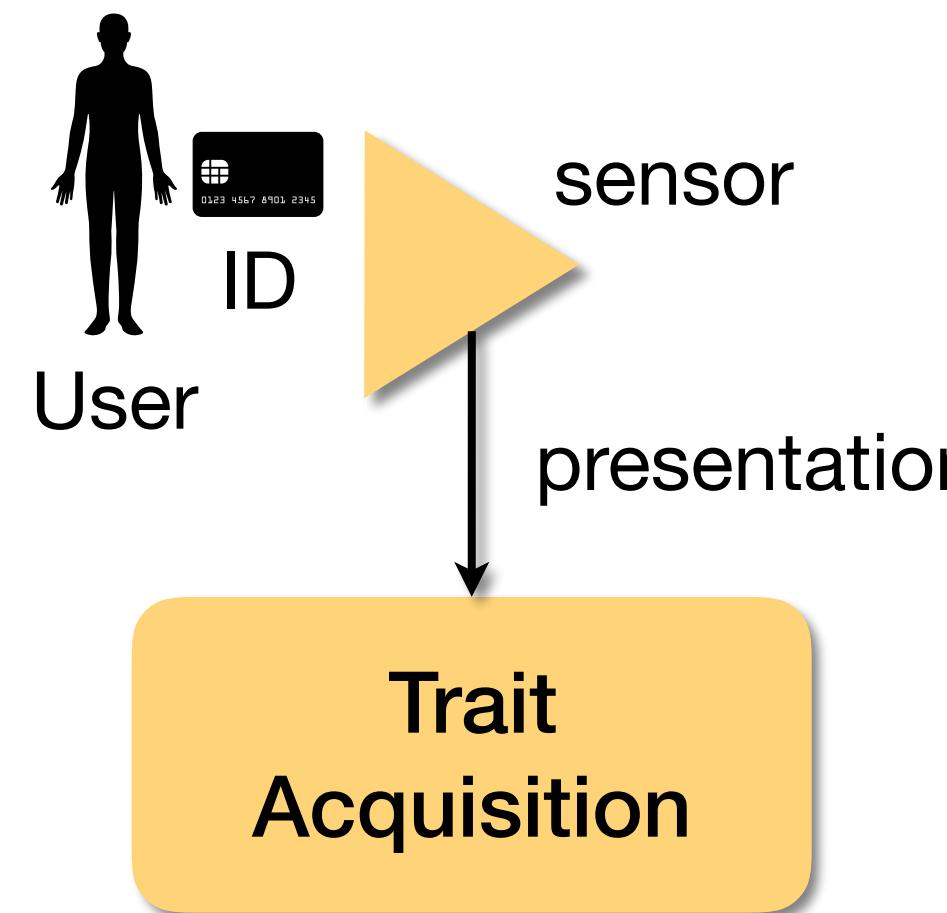
**Performance (8/8)**

How good is the trait quantitatively according to objective **metrics**?  
(we'll see them soon)



# Biometric Systems

## Enrollment



## Trait Acquisition

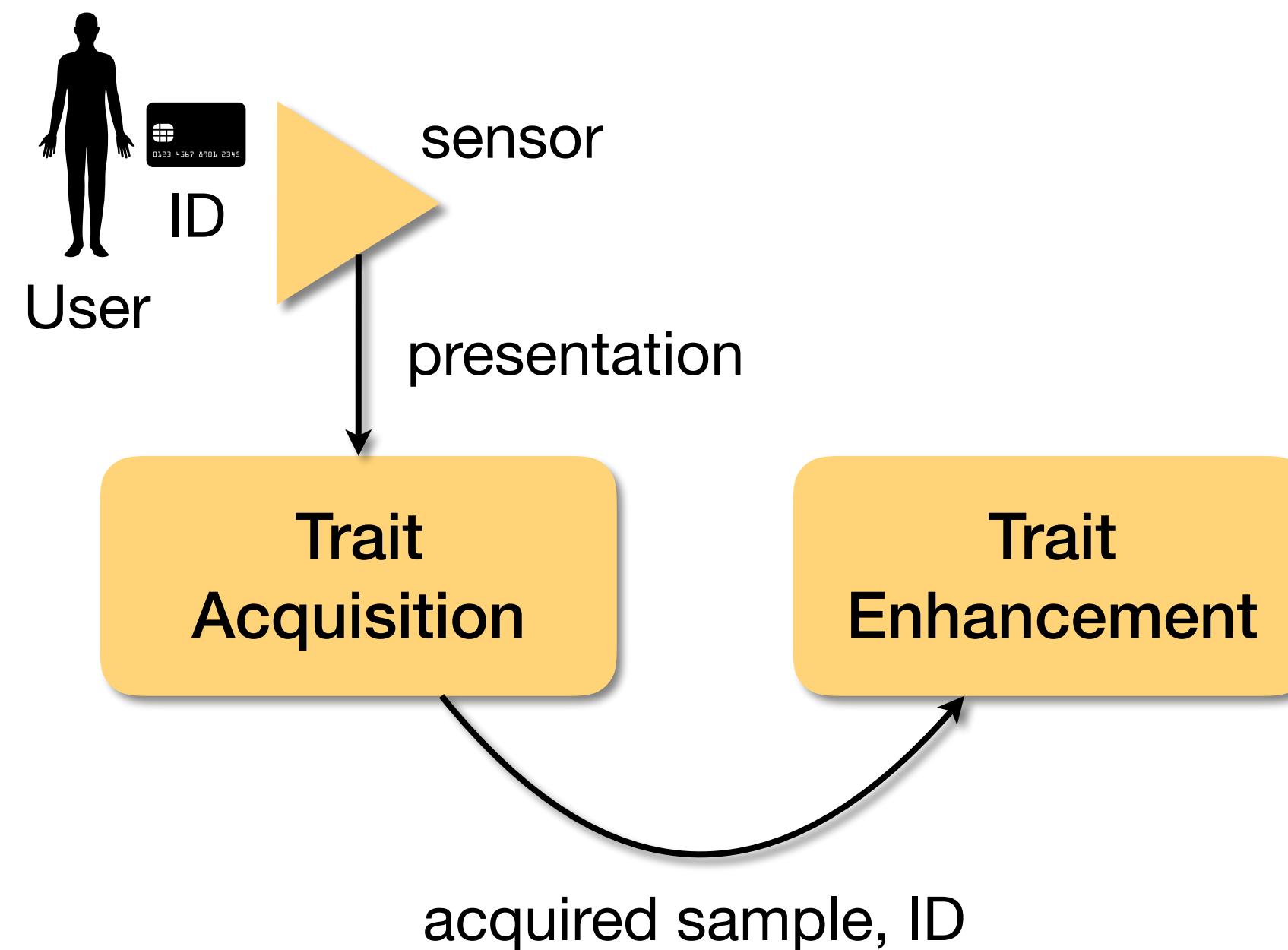
We'll have data-collection classes.  
We'll use real-world sensors.

## What to observe?

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

# Biometric Systems

## Enrollment



## Trait Enhancement

Noise removal.

Operations to keep only **essential** information (consider universality, uniqueness, permanence, circumvention, accountability, and performance).

Load irises

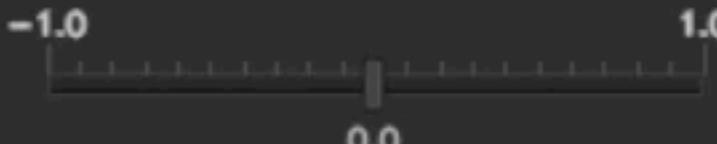
Load examination

Save examination

Save report

Quit program

**Brightness**



**Contrast**



**Sharpening**



**Segment iris**

**Brightness**



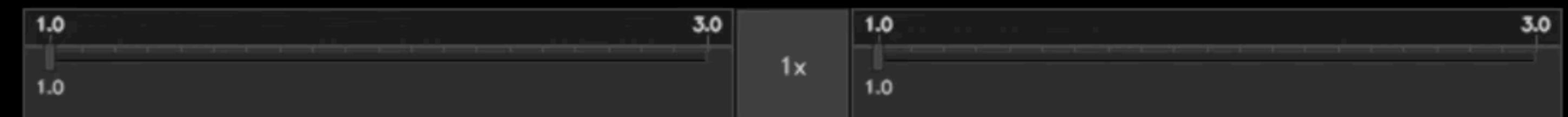
**Contrast**



**Sharpening**



**Segment iris**



### Human-Interpretable Features

<input checked="" type="checkbox"/> TSHEPII	<input type="checkbox"/> Show Matched		0		out of 0	<input checked="" type="checkbox"/> MSER	<input type="checkbox"/> Show Matched		0		out of 0
	<input type="checkbox"/> Show Unmatched		1		out of 0		<input type="checkbox"/> Show Unmatched		1		out of 0
<input checked="" type="checkbox"/> SURF	<input type="checkbox"/> Show Matched		0		out of 0	<input checked="" type="checkbox"/> SIFT	<input type="checkbox"/> Show Matched		0		out of 0
	<input type="checkbox"/> Show Unmatched		1		out of 0		<input type="checkbox"/> Show Unmatched		1		out of 0
<input checked="" type="checkbox"/> Crypts	<input type="checkbox"/> Show Matched		0		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**

thr: 0.4461

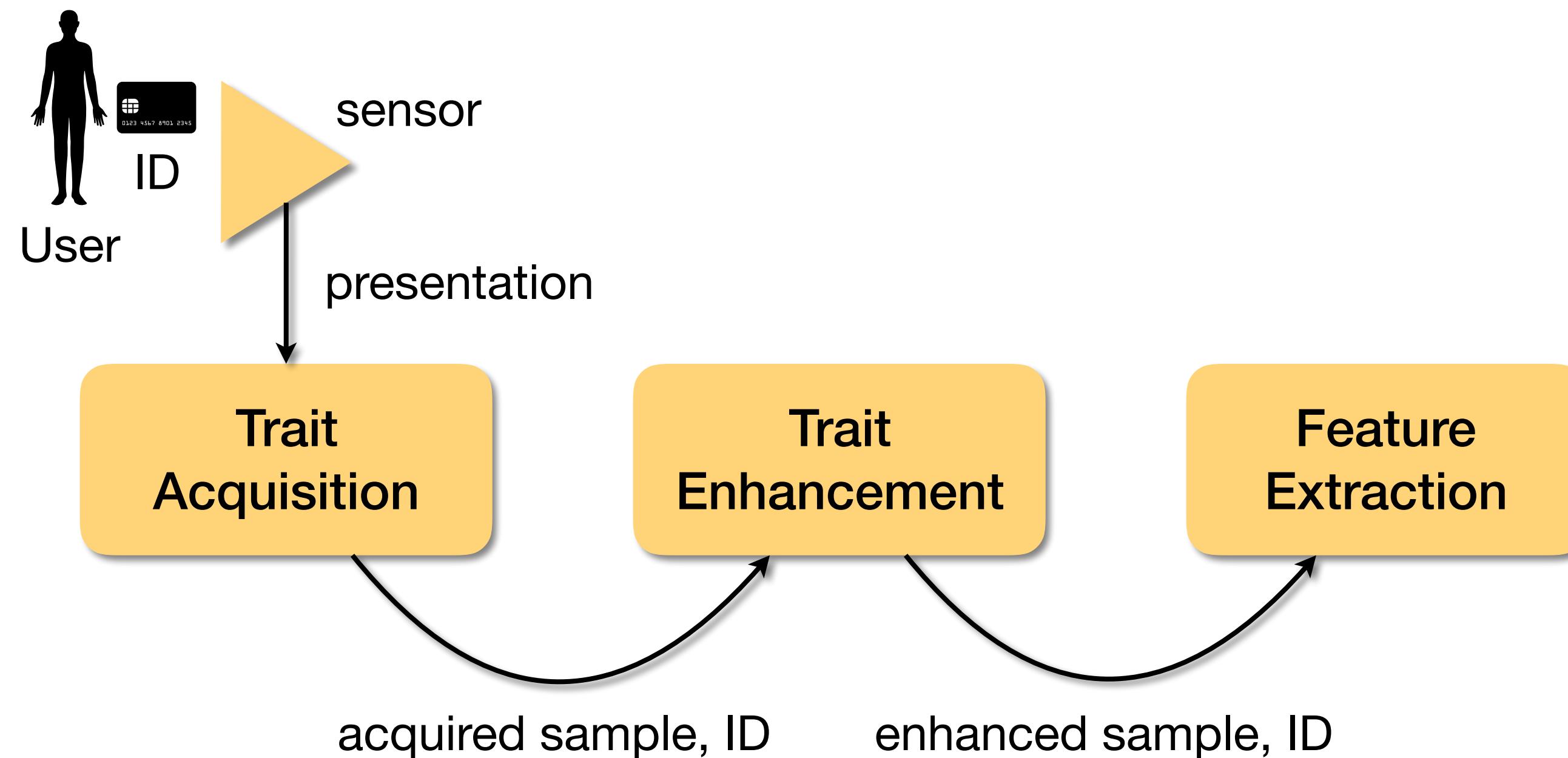
**BSIF Filters**

thr: 0.4216

### Global match score

# Biometric Systems

## Enrollment Modules



### Feature Extraction

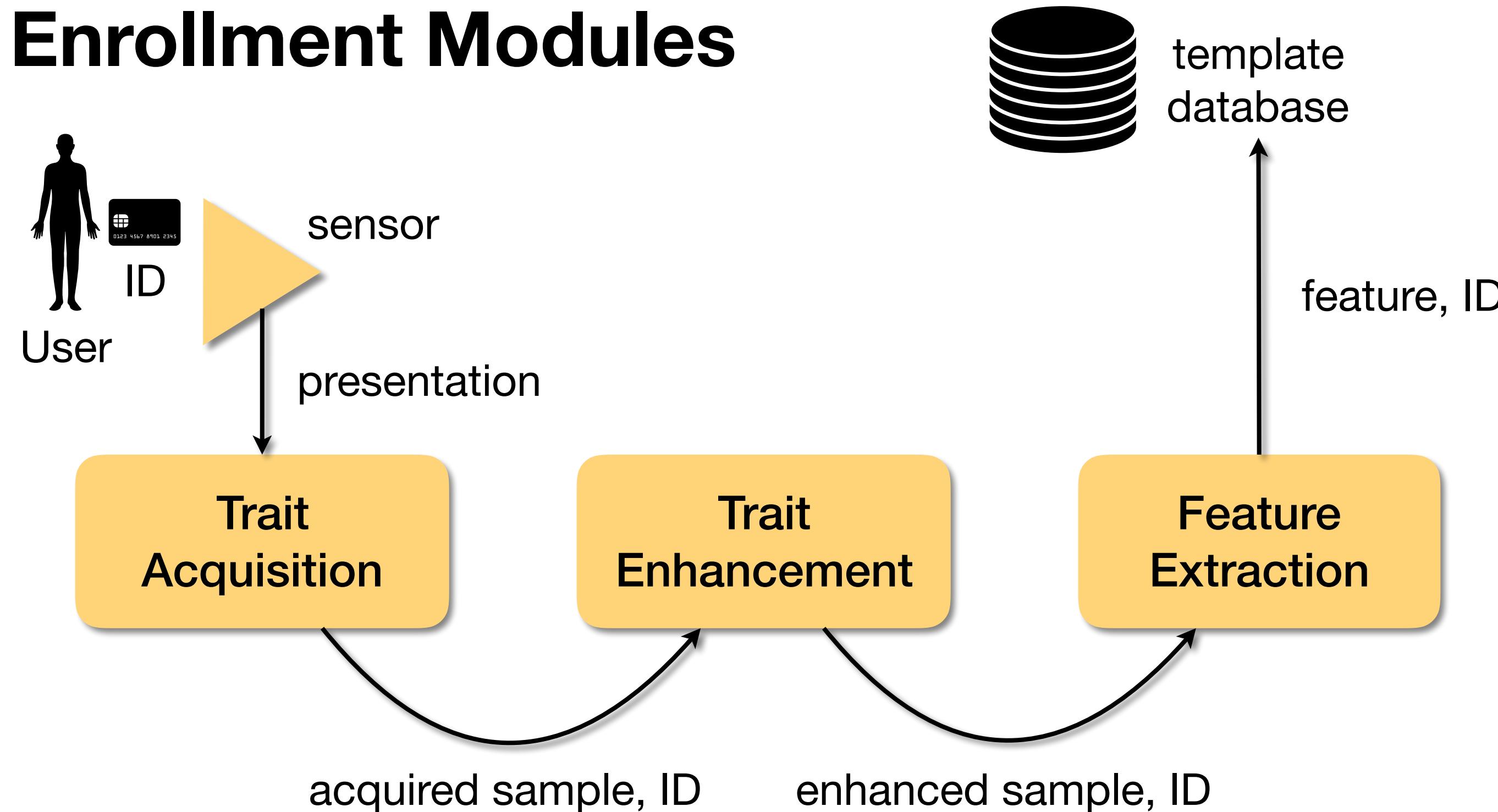
Compact but expressive digital representation of the trait.

### Types

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

# Biometric Systems

## Enrollment Modules

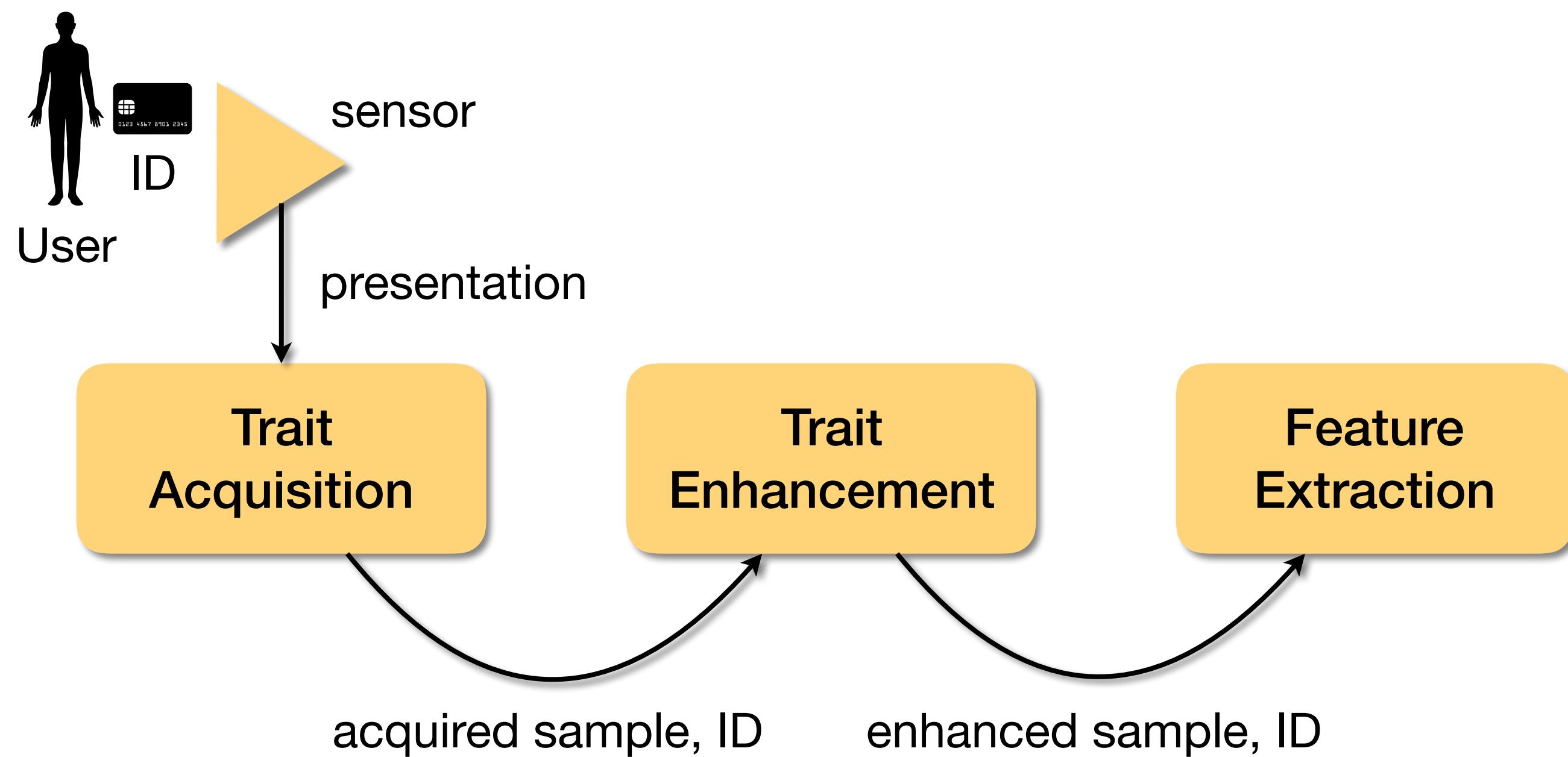


## Template Database

It inherits all the security and privacy issues from database systems. Be careful with invasions, leaks, etc.

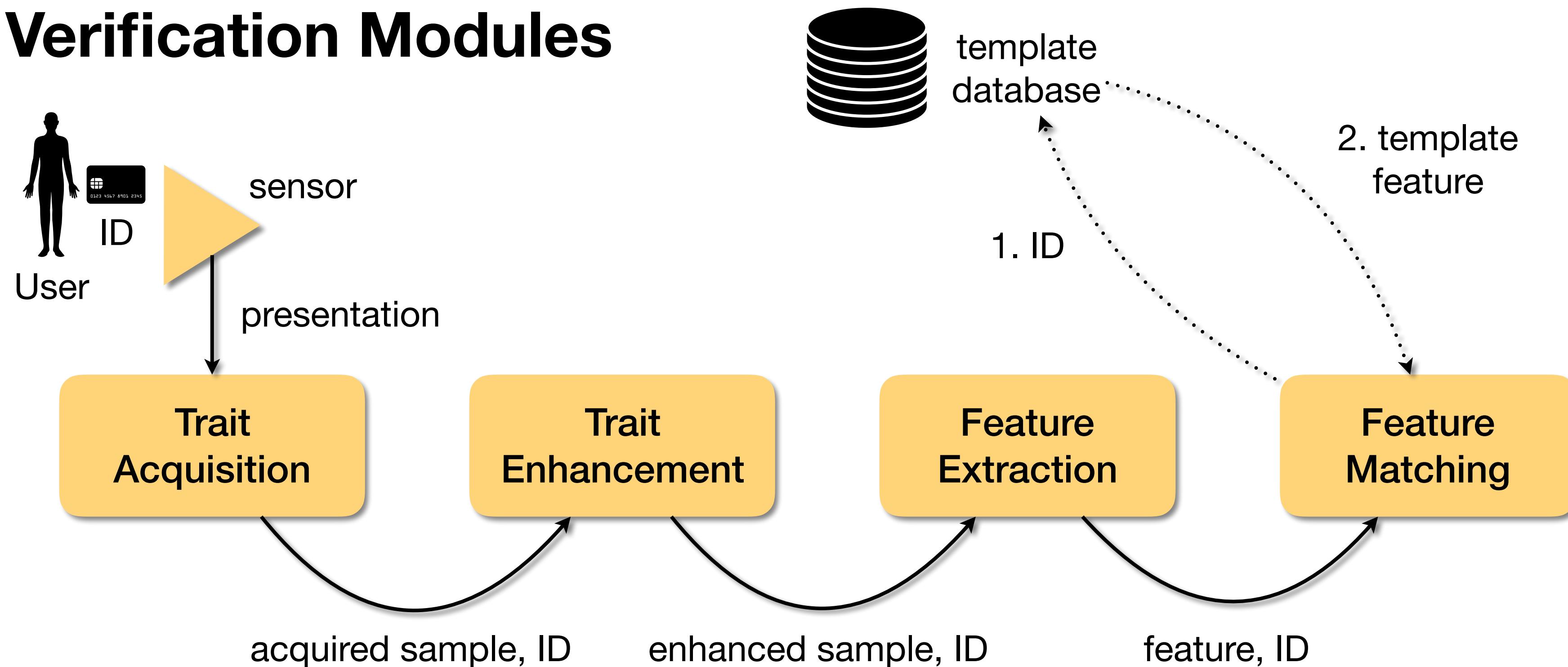
# Biometric Systems

## Verification Modules



# Biometric Systems

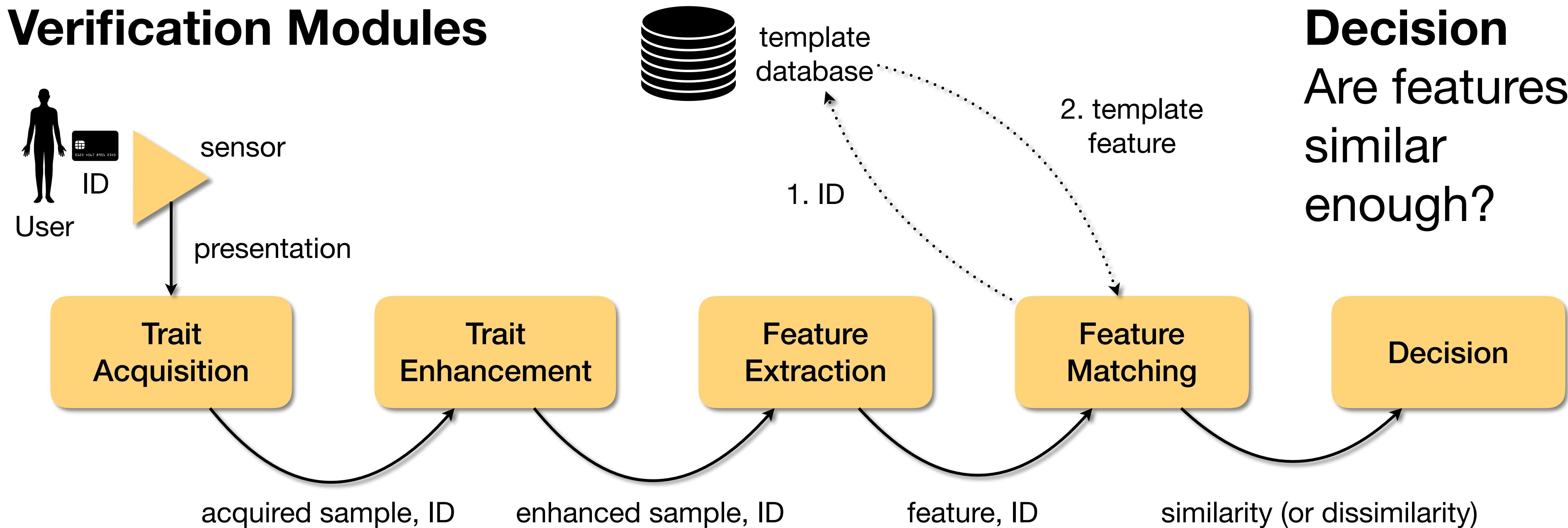
## Verification Modules



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

# Biometric Systems

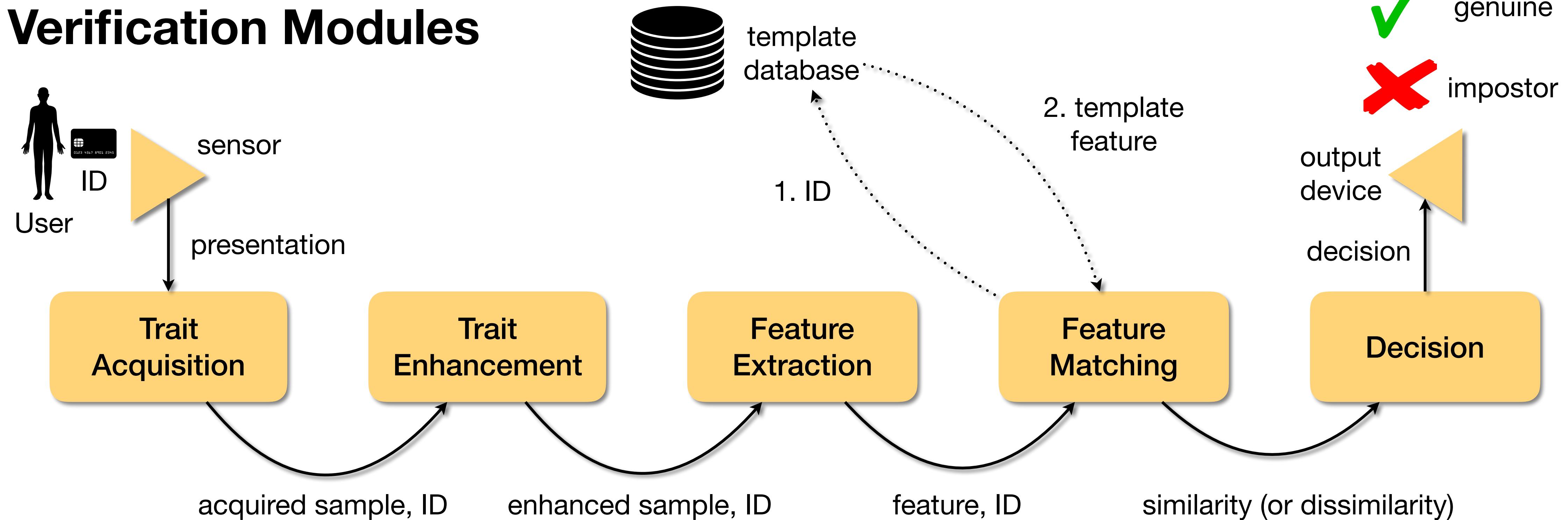
## Verification Modules



**Decision**  
Are features  
similar  
enough?

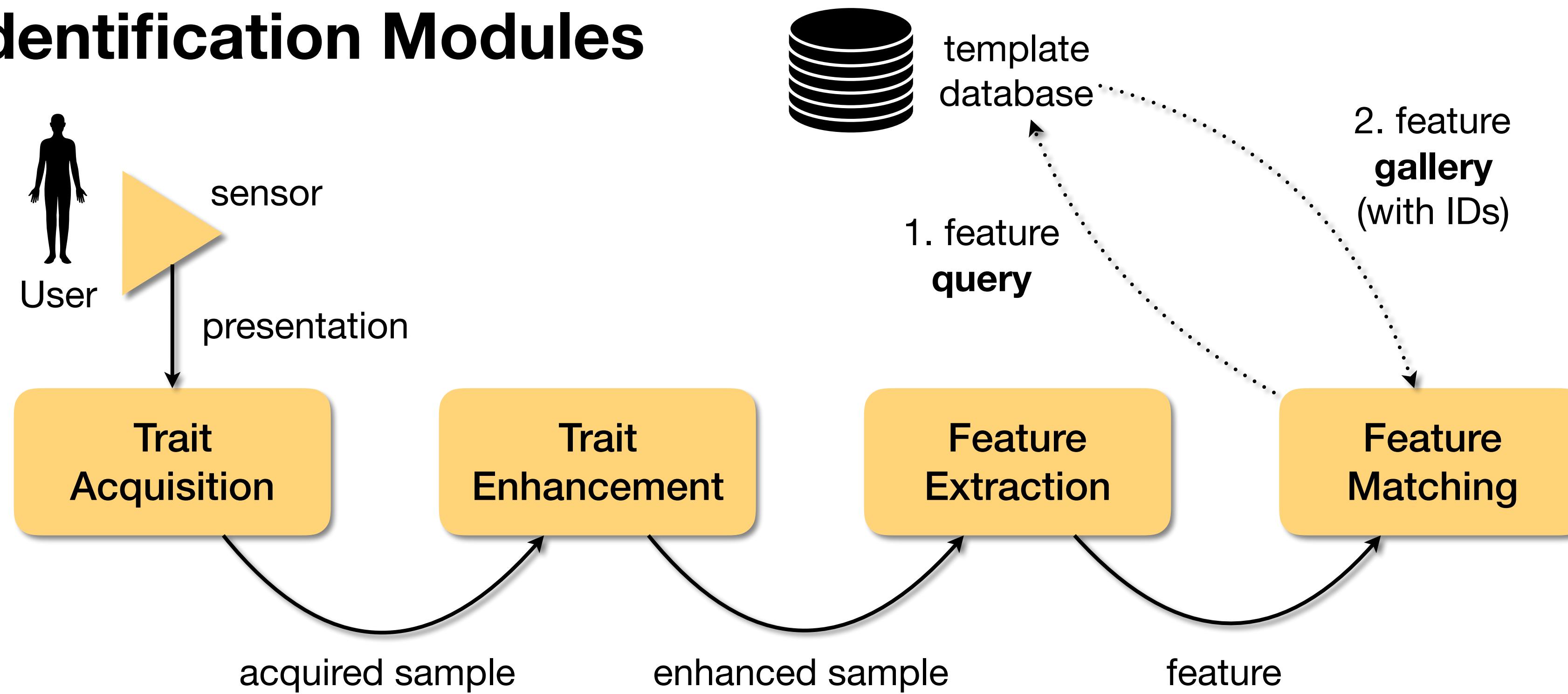
# Biometric Systems

## Verification Modules



# Biometric Systems

## Identification Modules



**Gallery**  
Closest template features to query.

# Biometric Systems

## Query and Gallery Example



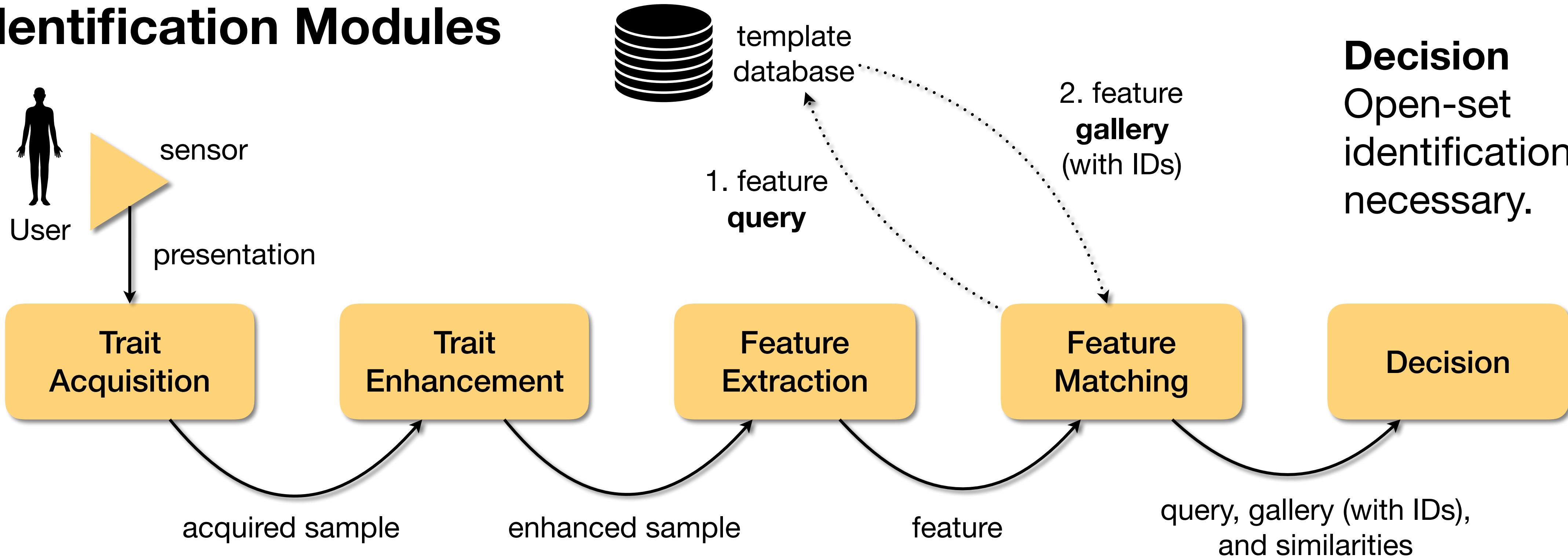
query



gallery

# Biometric Systems

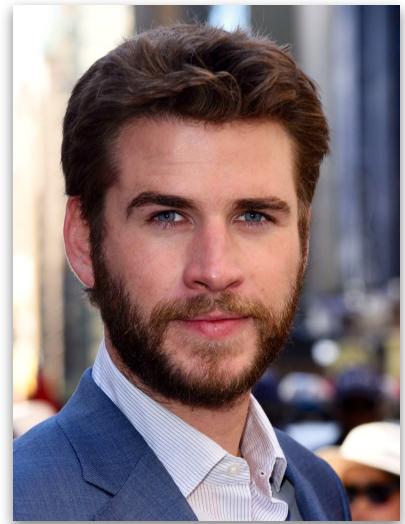
## Identification Modules



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

# Biometric Systems

## Open-set Identification



**Query**  
(Liam Hemsworth)

### Dataset



Robert  
Downey Jr.



Scarlet  
Johansson



Chris  
Evans



Mark  
Ruffalo

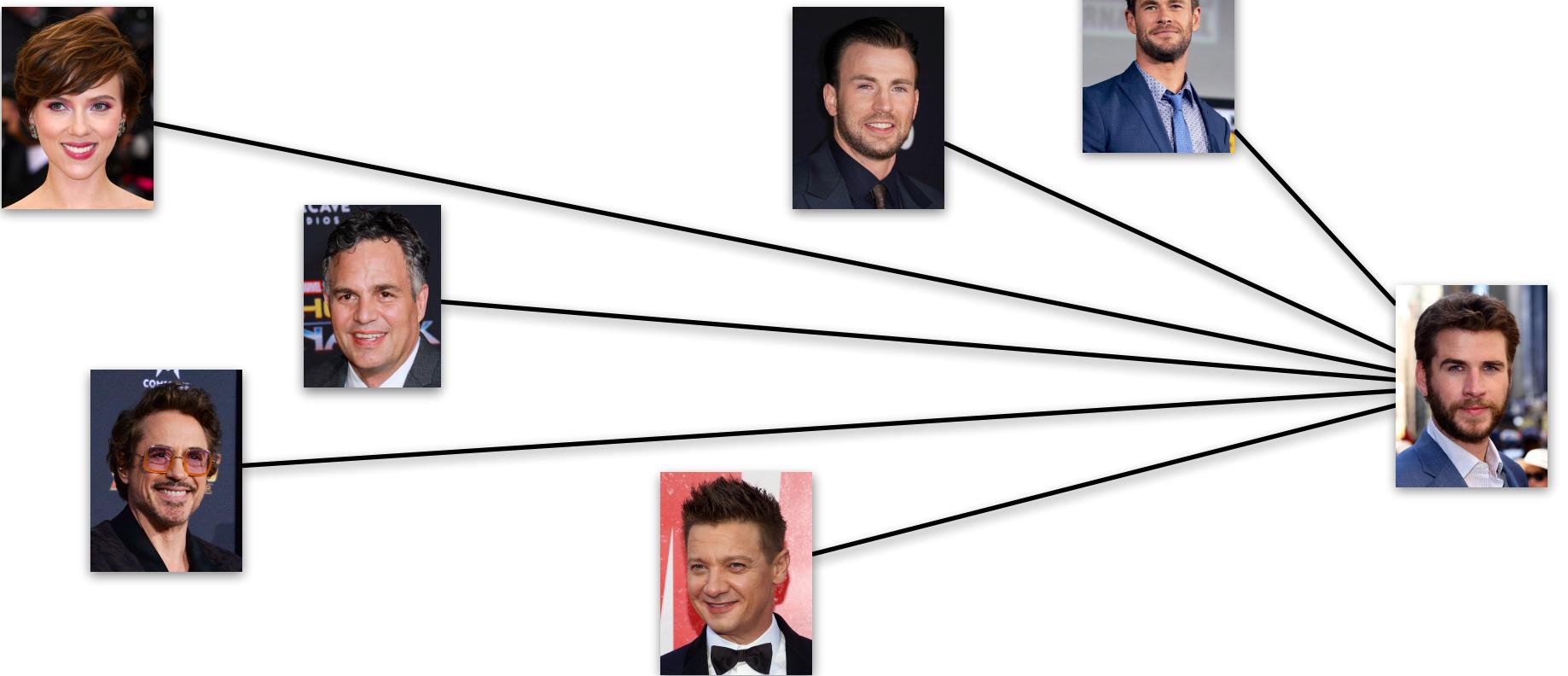


Chris  
Hemsworth



Jeremy  
Renner

### Feature Space



### Closet Set

#### Output

This is  
Chris Hemsworth!



### Open Set

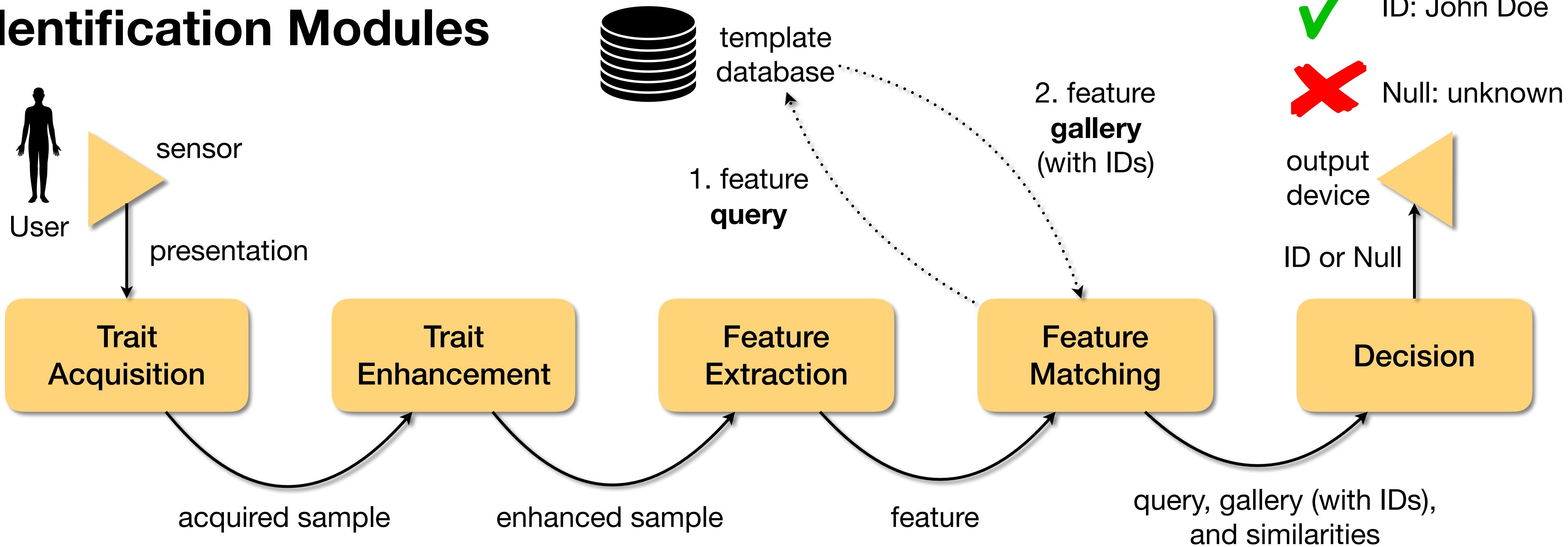
#### Output

I don't know  
this person!



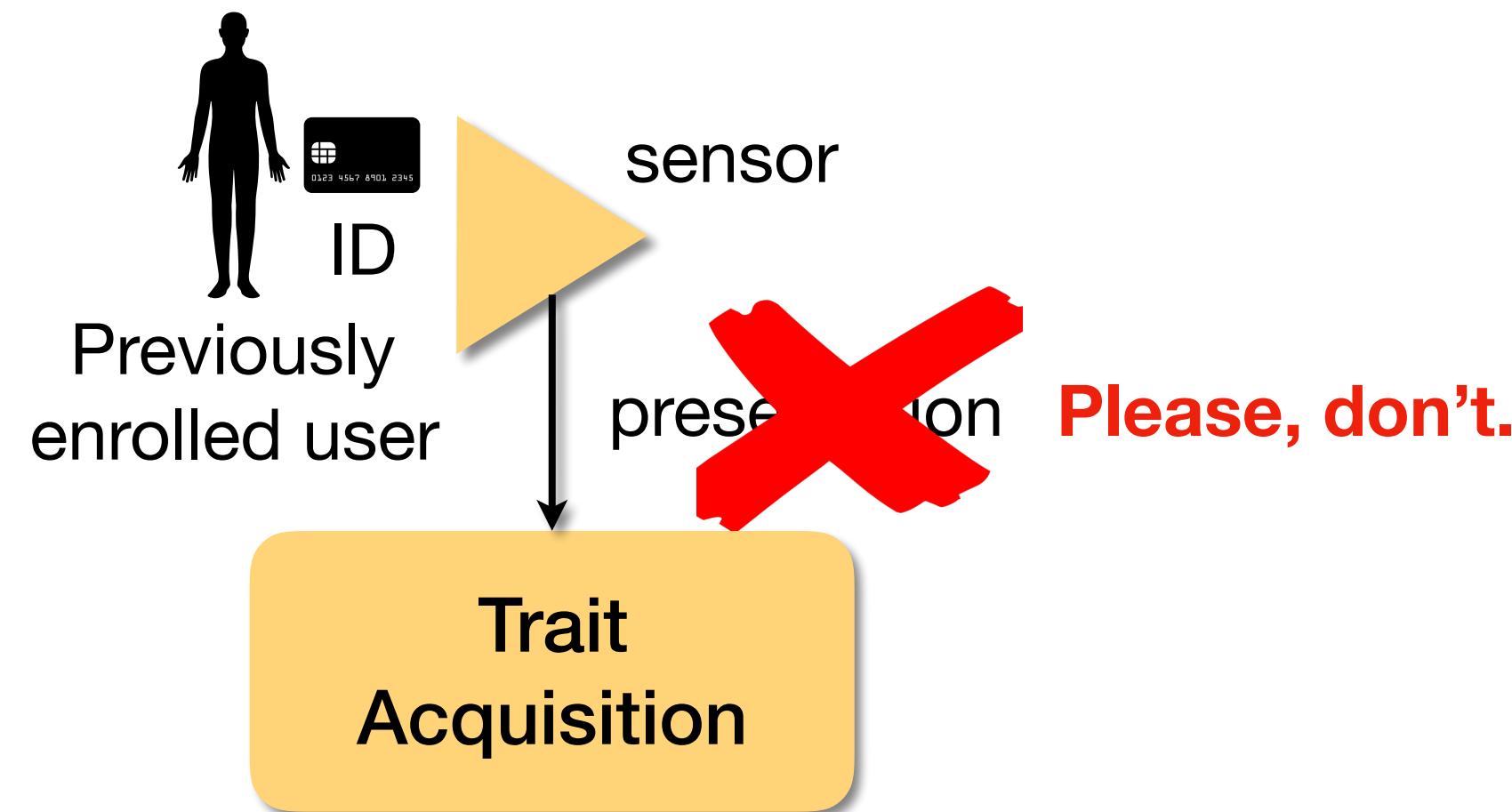
# Biometric Systems

## Identification Modules



# Biometric Systems

## Enrollment Revision

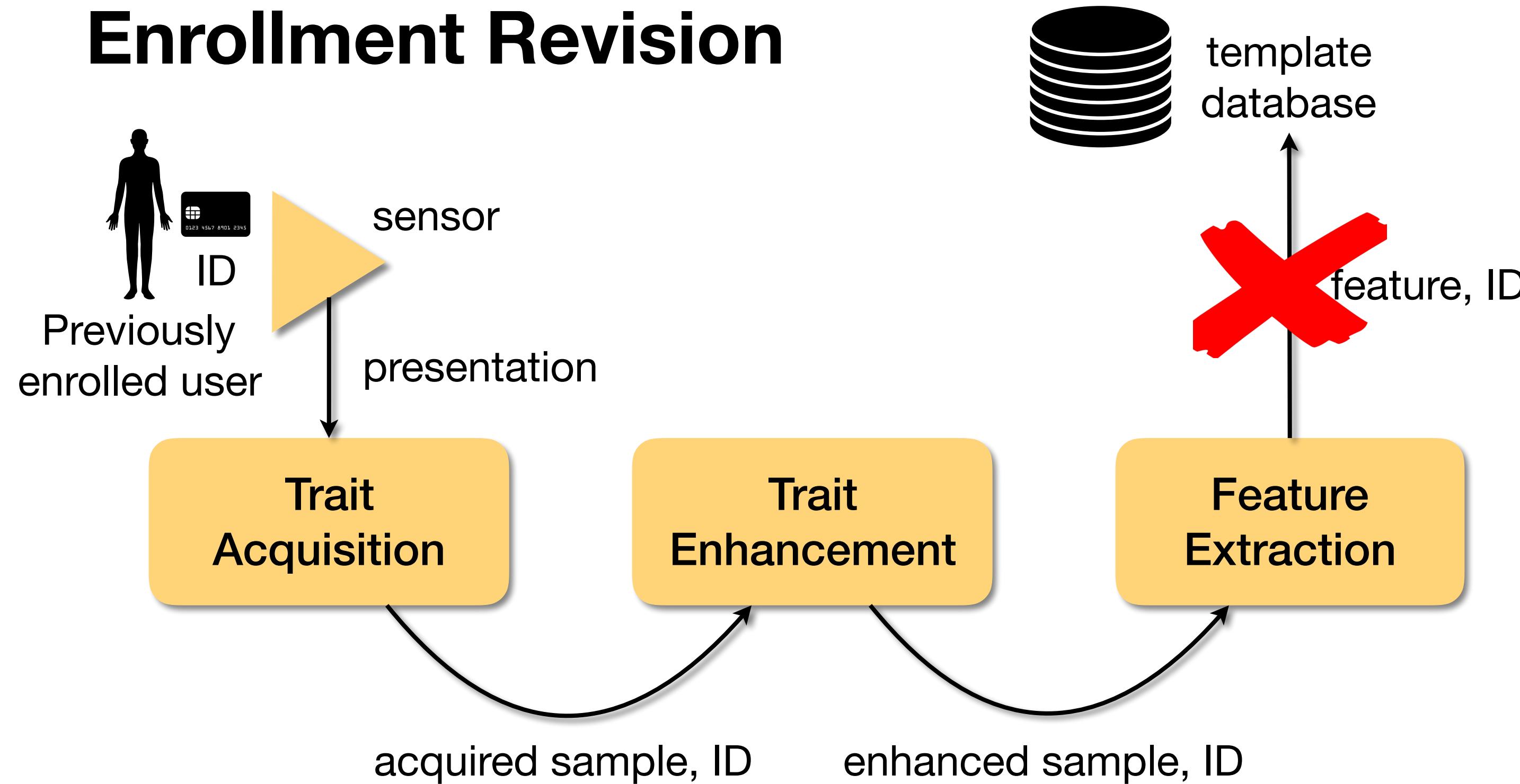


### Attended operation?

“I’m seeing here in my notes  
that you are already enrolled.”

# Biometric Systems

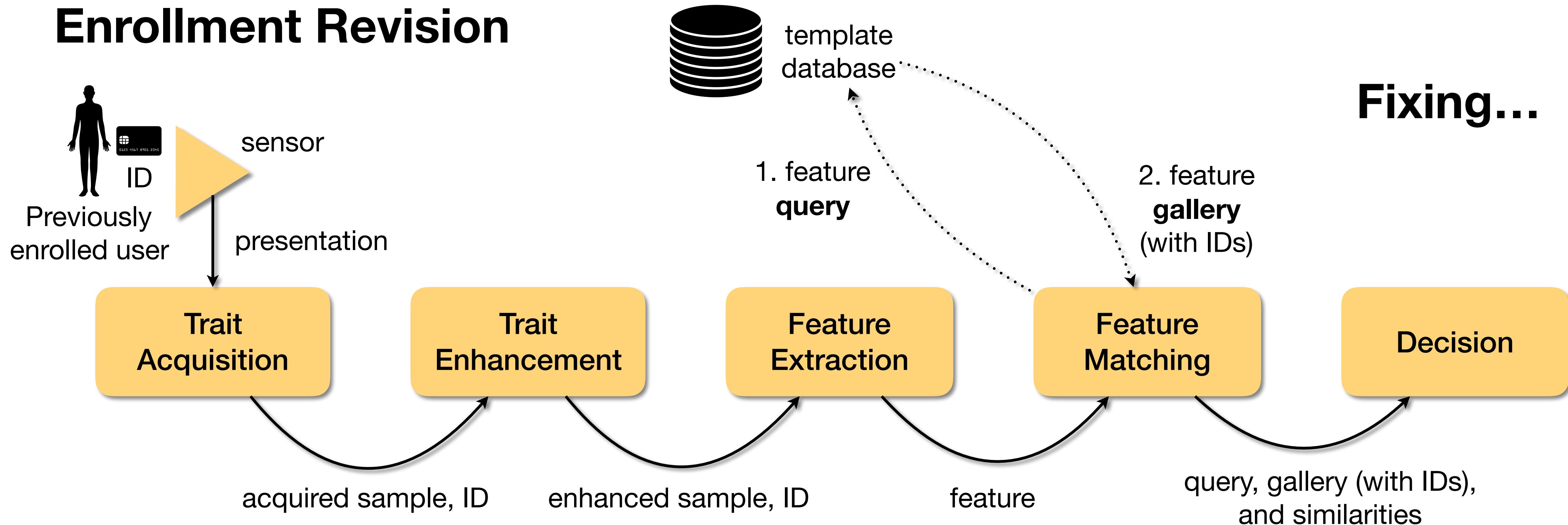
## Enrollment Revision



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

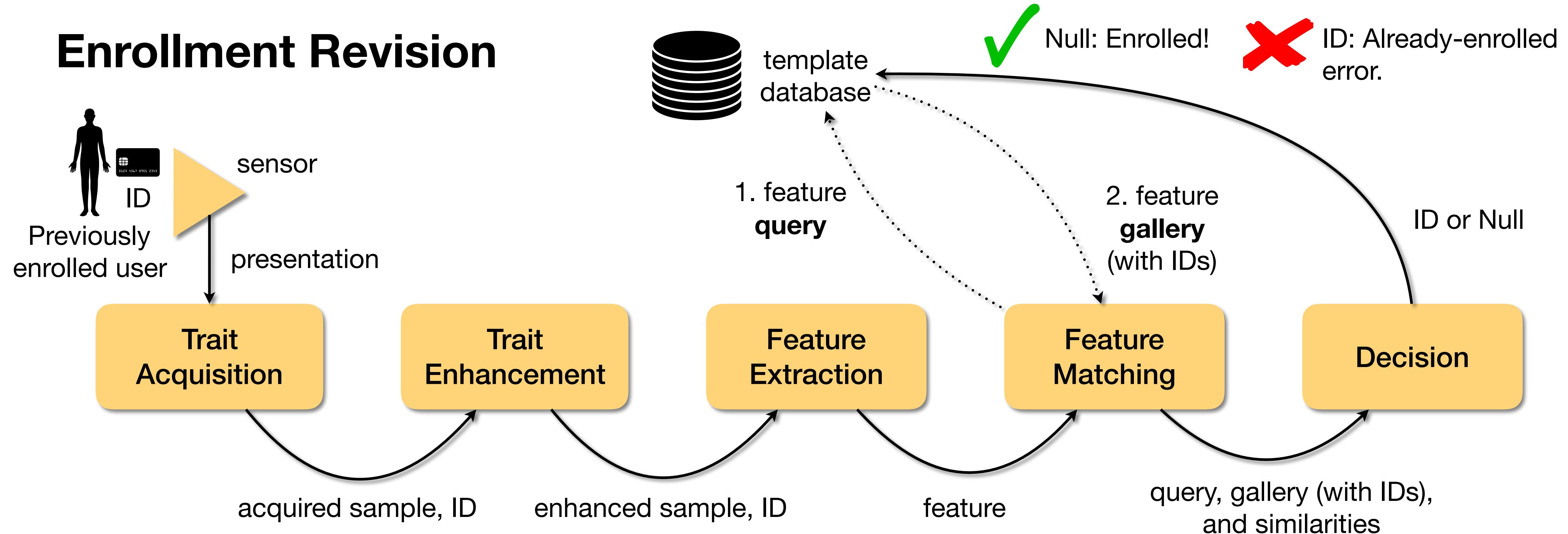
# Biometric Systems

## Enrollment Revision



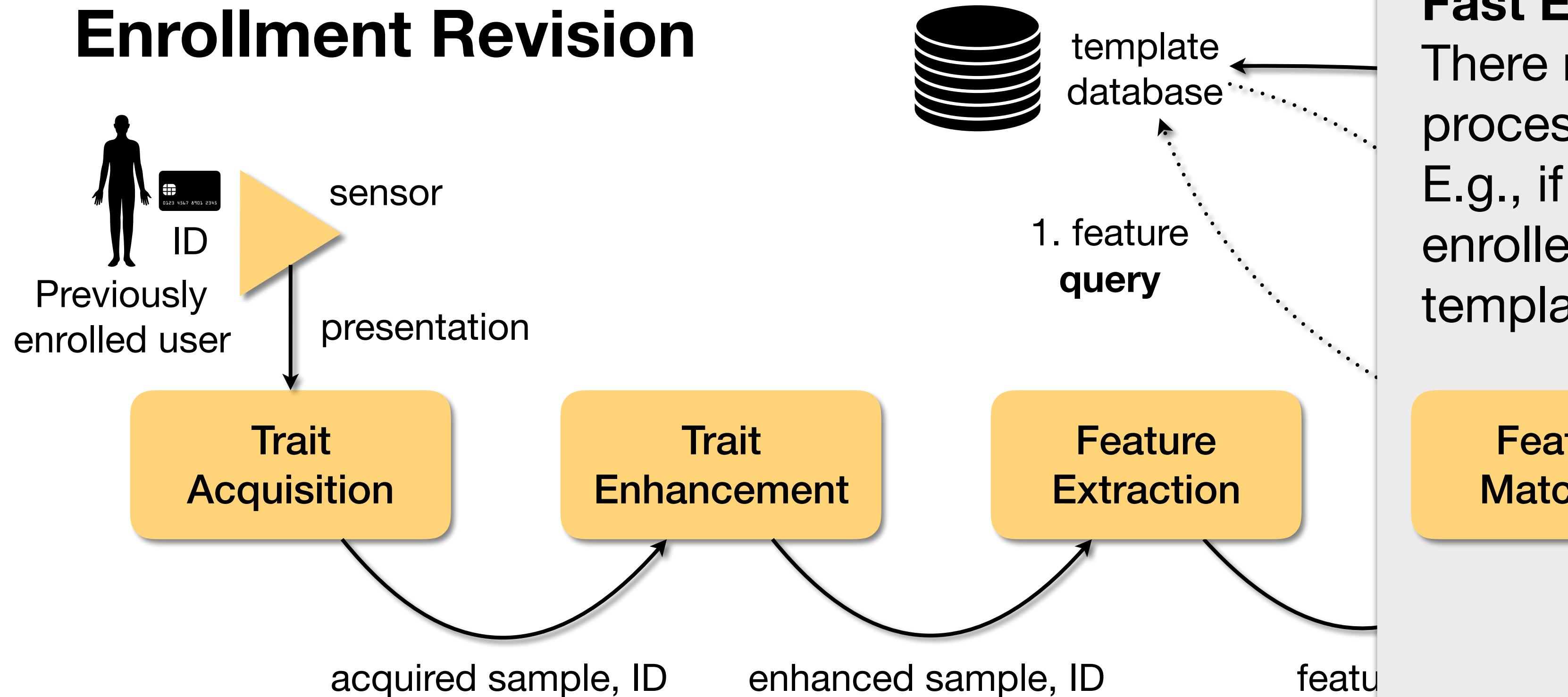
# Biometric Systems

## Enrollment Revision



# Biometric Systems

## Enrollment Revision

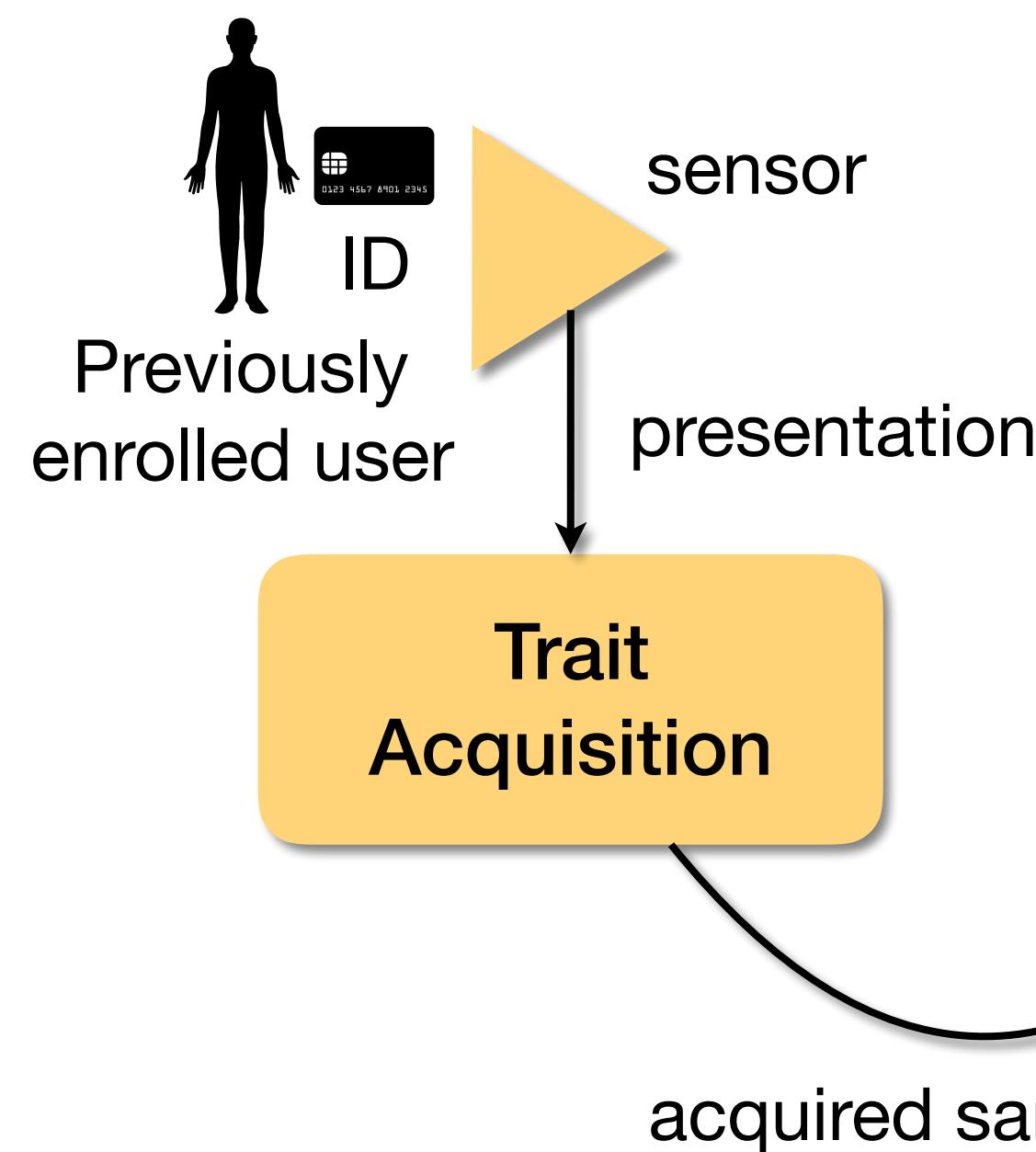


### Fast Enrollment

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

# Biometric Systems

## Enrollment Revision



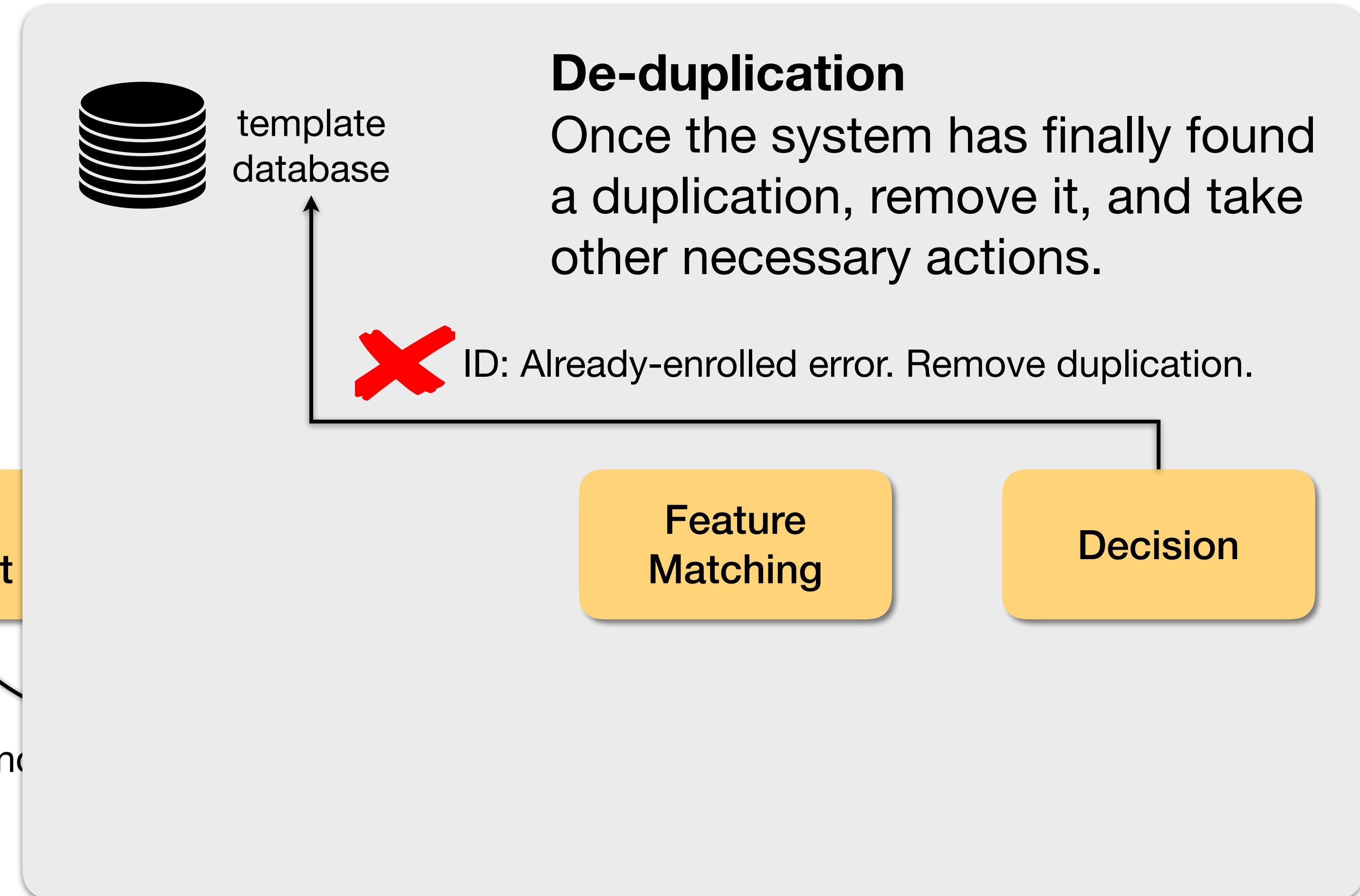
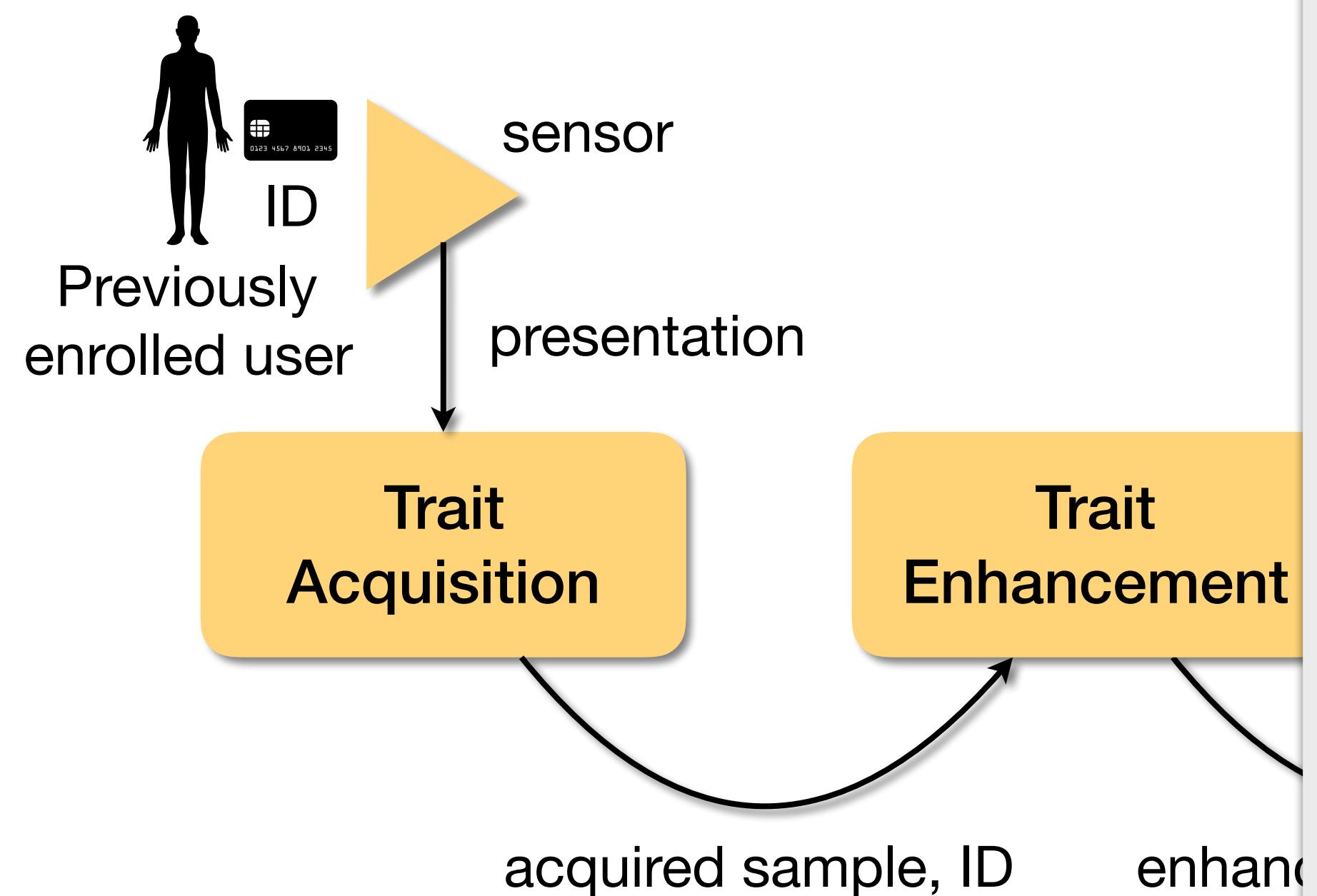
### Fast Enrollment

Possible solution: conclude enrollment after *Feature Extraction*.

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

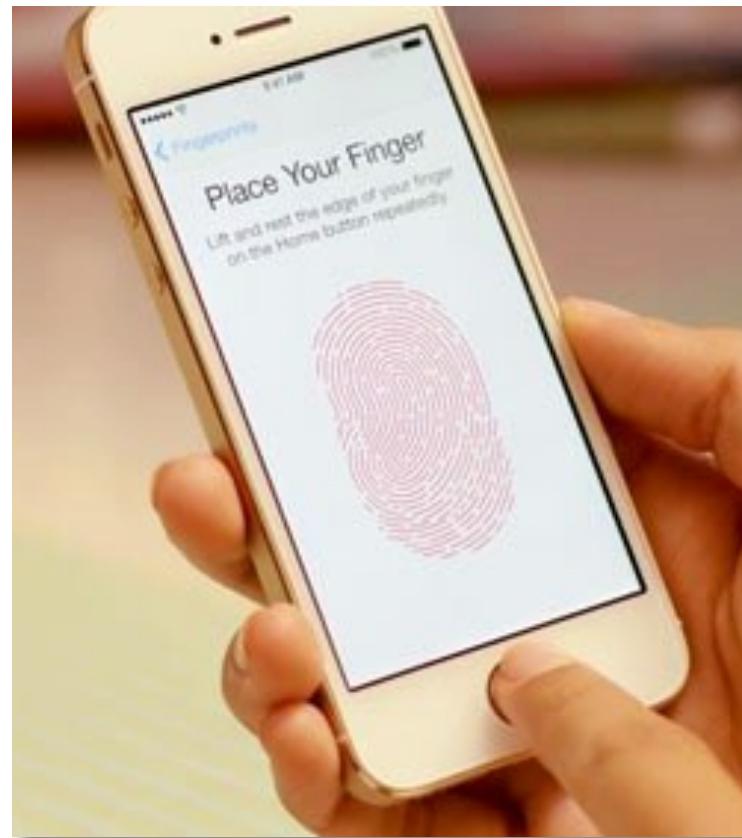
# Biometric Systems

## Enrollment Revision



# Biometric Systems

## Deployment



From all modules integrated within single chips...



To disperse modules independently deployed in diverse platforms.



# 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?



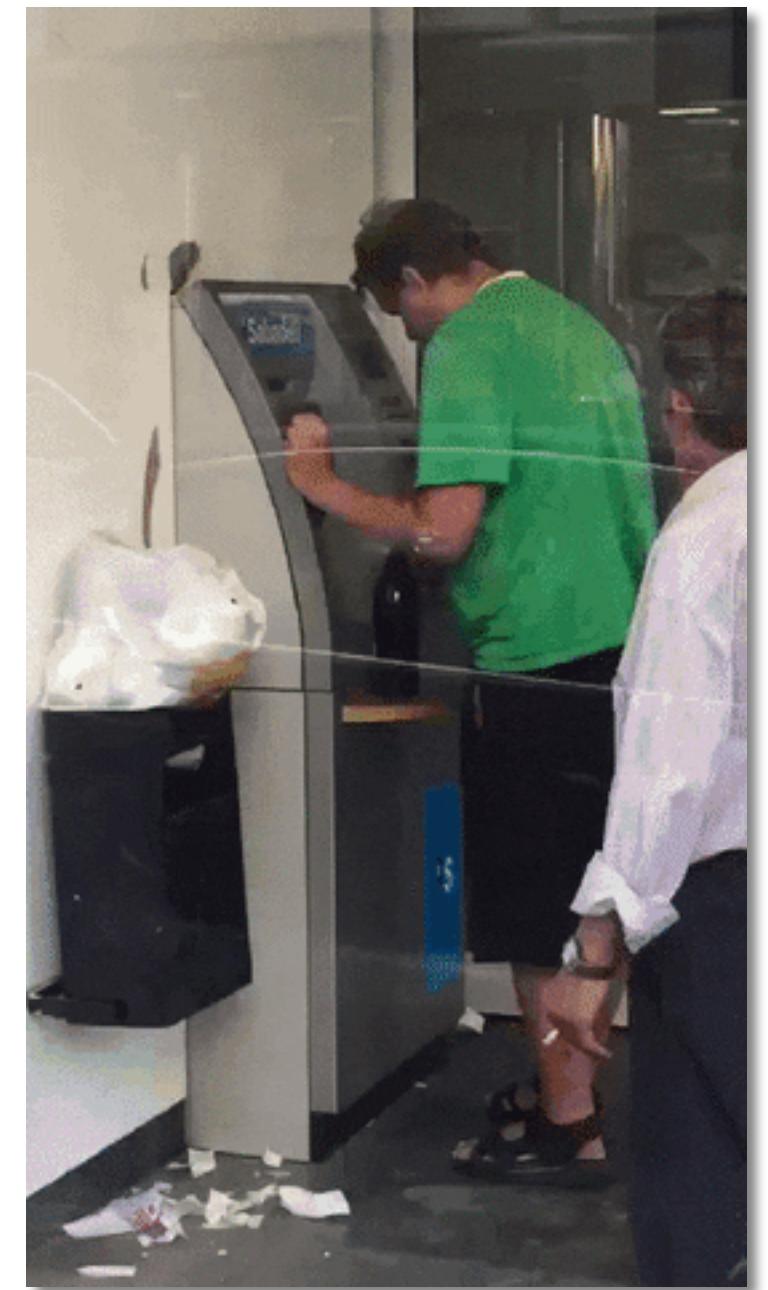
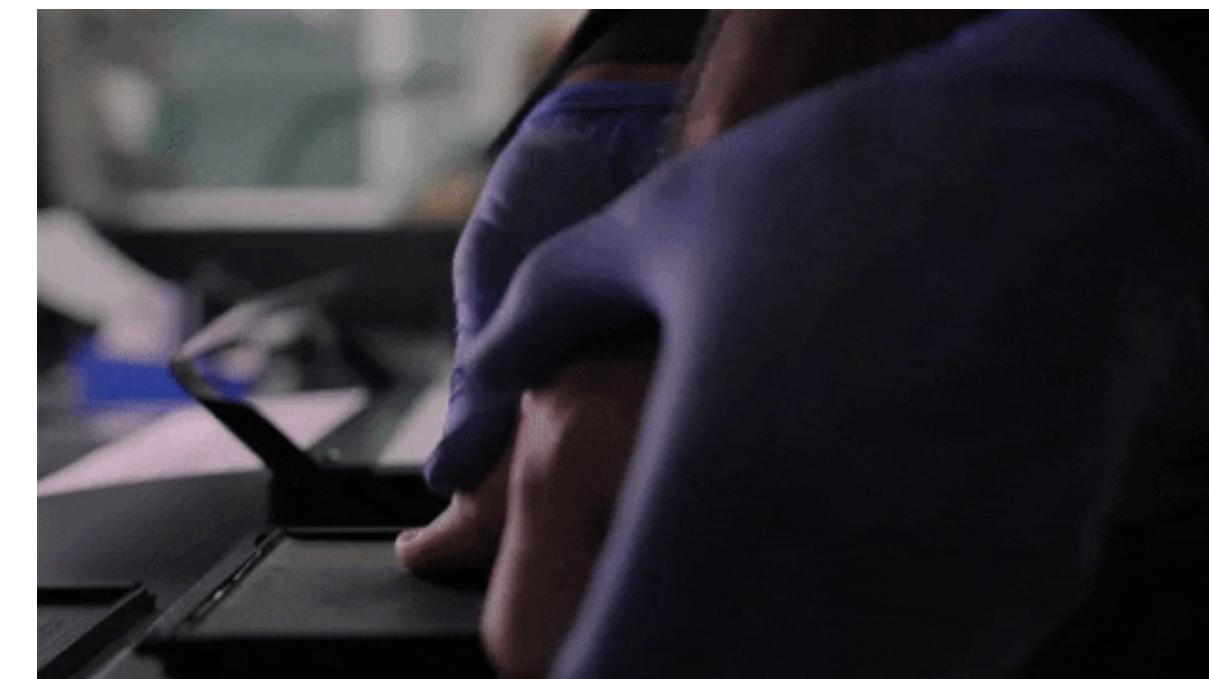
# Biometric Systems

## 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?



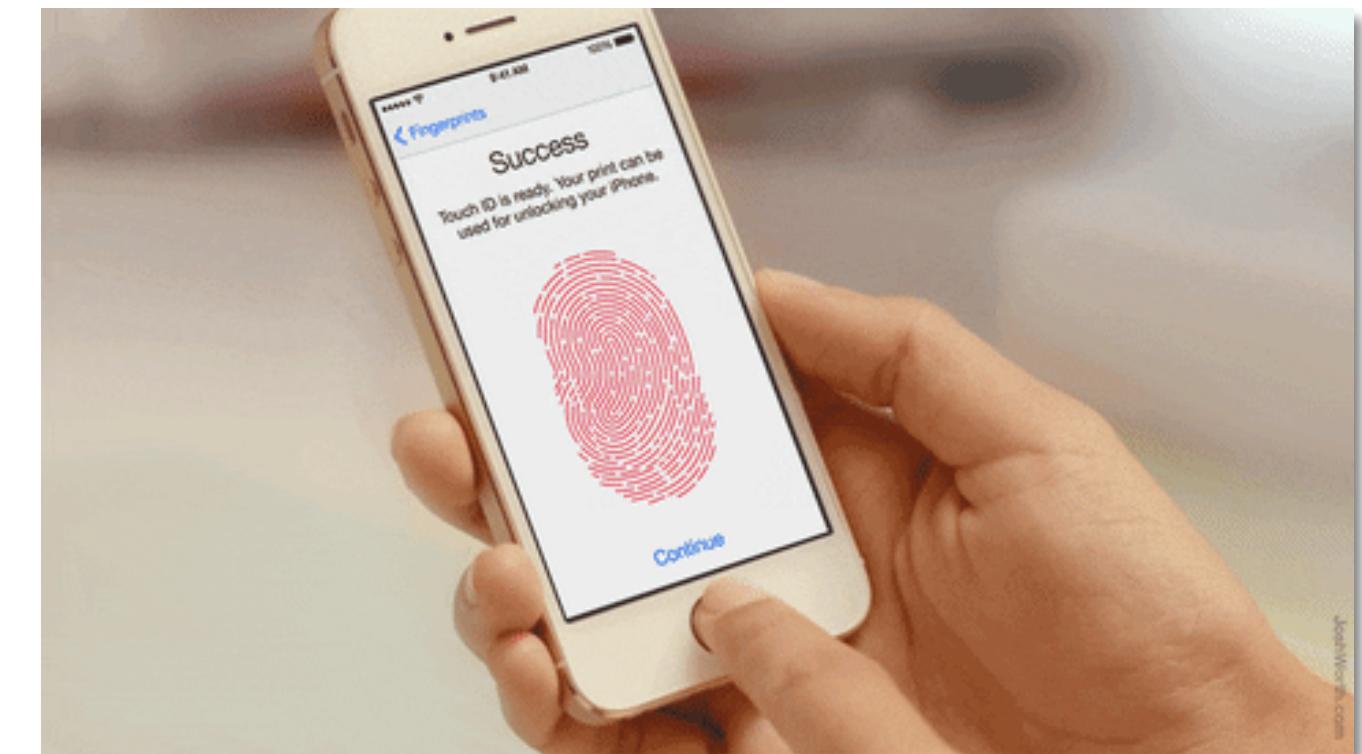
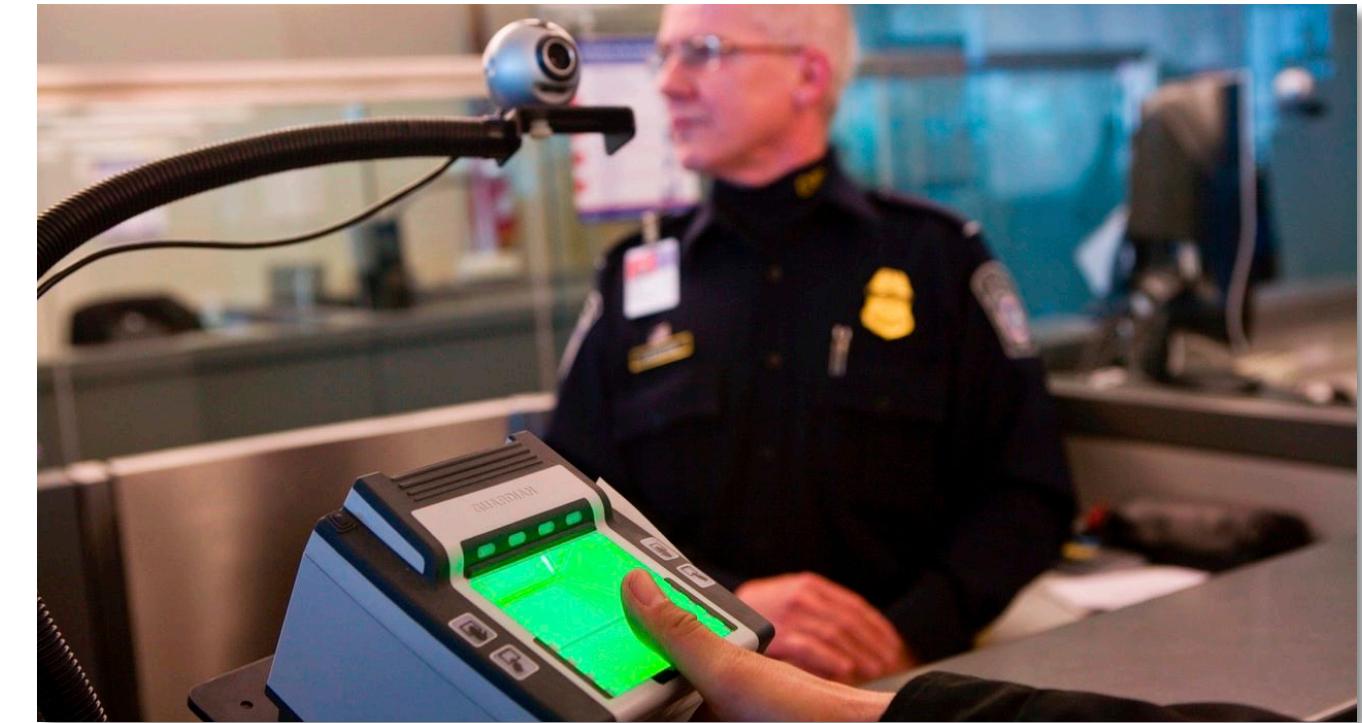
# Biometric Systems

## 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.



# Biometric Systems

## What do we want to avoid?

### **X Covert deployment**

Users must be aware of the Biometric system collecting their data.

Respect their privacy.



### **X No data confidentiality**

Collected data must be confidential. Avoid function creep.

### **X Unsafe system**

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

# S'up Next?

**Be happy**

Any issues? Please come and talk to me.

**More basics**

Biometric system errors,  
metrics and attacks.

