BIOMETRICS UNDER ATTACKS

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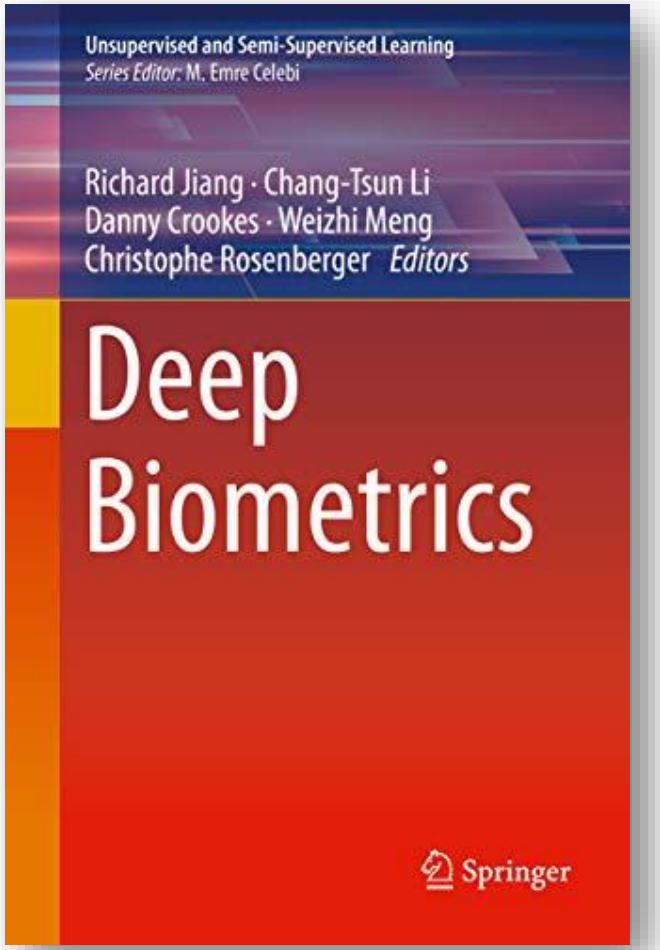
WHO AM I?

Christophe ROSENBERGER

- ❑ Full professor in Computer Science at ENSICAEN - FRANCE
- ❑ Cybersecurity researcher in the GREYC research lab
  - ✓ Biometrics (since 2005)
  - ✓ Digital forensics (since 2021)
- ❑ Reviewer in charge of the evaluation/monitoring of the SERICS foundation (2022-2026)



SERICS
SECURITY AND RIGHTS IN THE CYBERSPACE

https://rosenberger.ensicaen.fr/

PLAN

- ❑ Motivations
- ❑ Presentation & injection attack (active)
- ❑ Template attack (passive)
- ❑ Backdoor & adversarial attack (active)
- ❑ Conclusion

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BIOMETRICS

Automatic identification of an individual or verification of its identity by using morphological or behavioral characteristics

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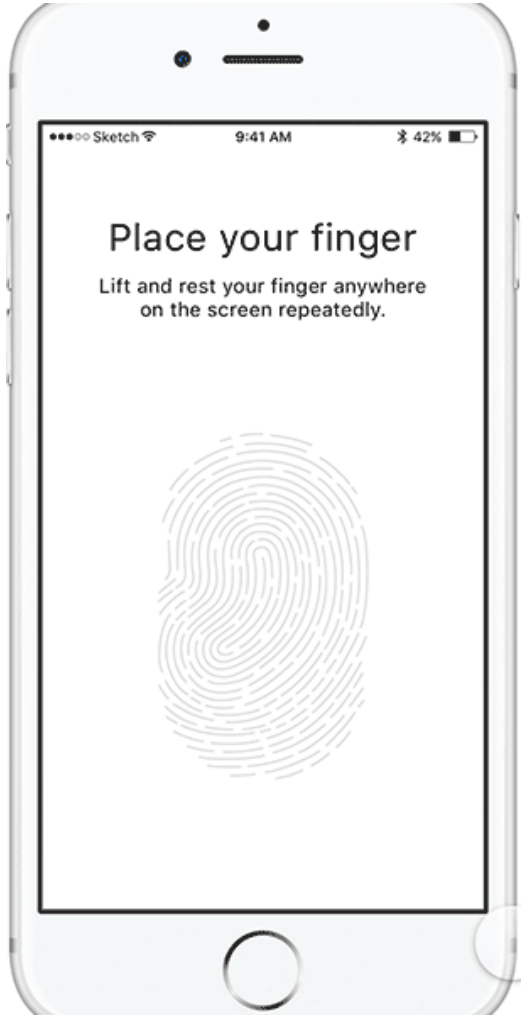
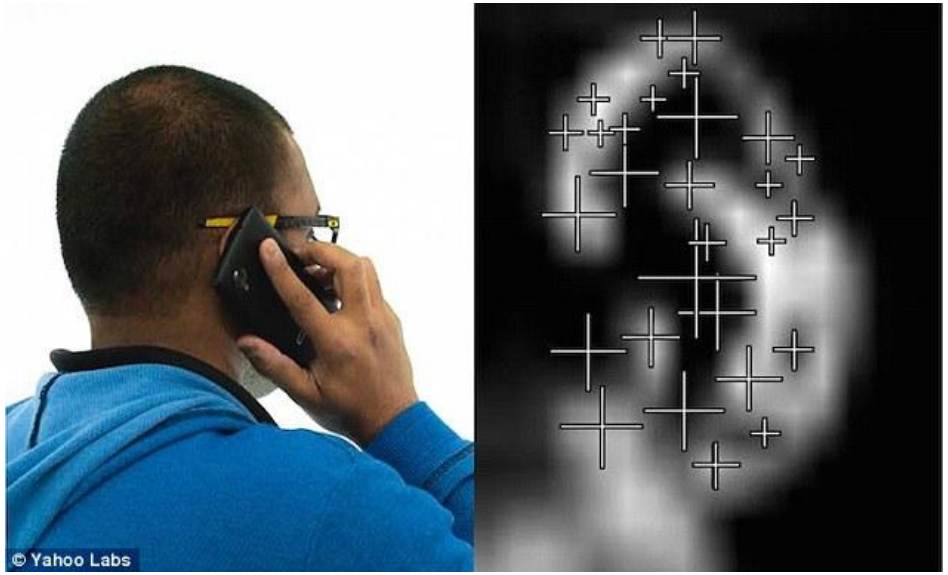
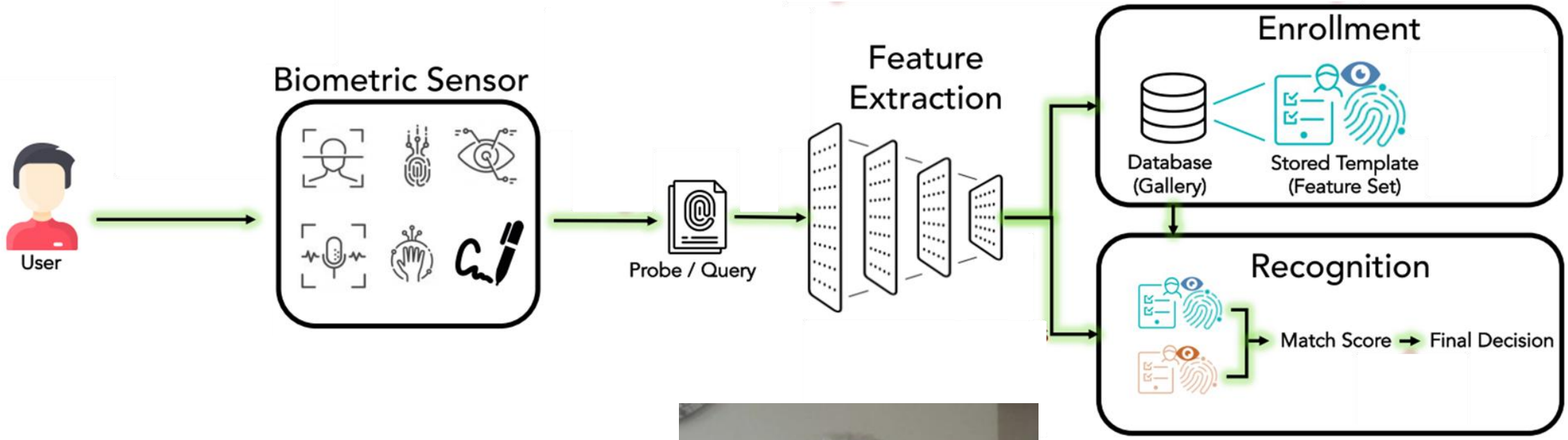
APPLICATIONS





BIOMETRIC SYSTEM



Artificial Intelligence, a key component:

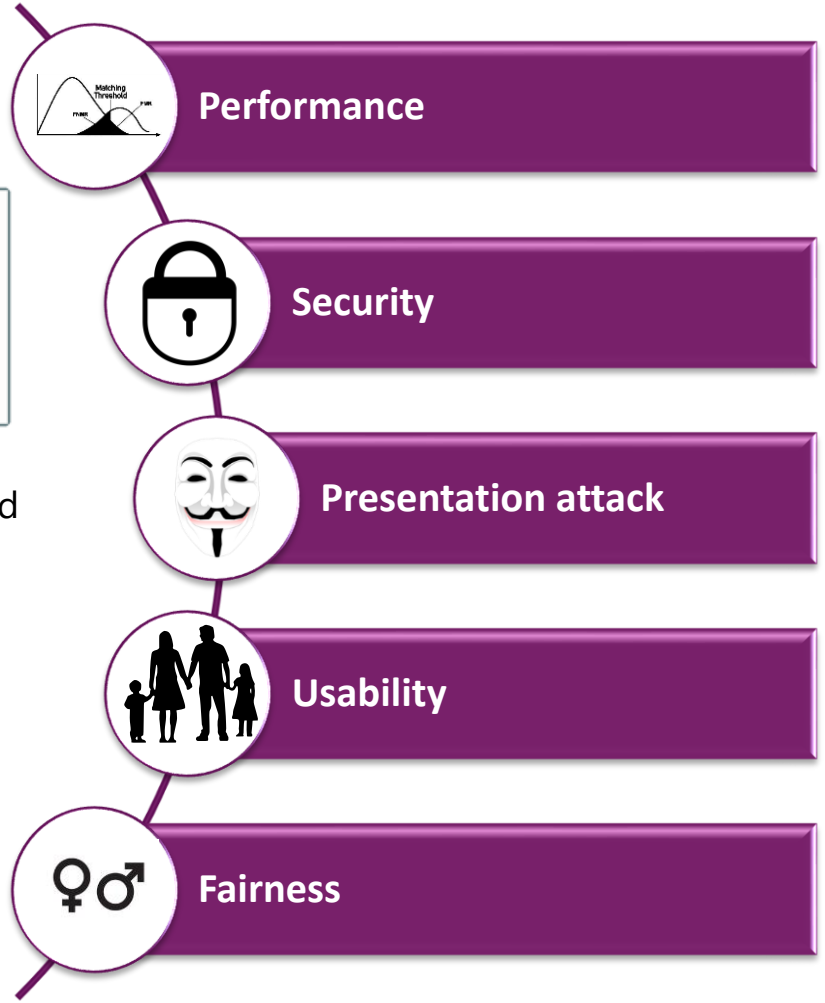
- ❑ Preprocessing (e.g. face detection)
- ❑ Efficient feature extraction
- ❑ Simple and fast comparison

CERTIFICATION

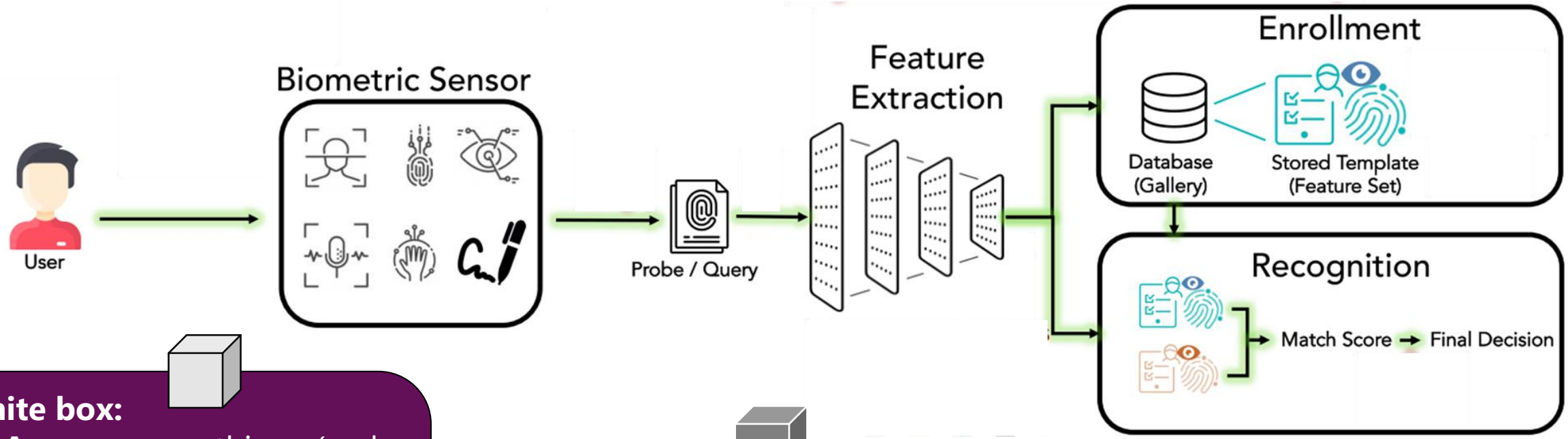
A product certification ensures that the system can be trusted to work accurately, even under challenging circumstances.

- Biometric security
- Biometric component
- ISO 19795-1
  ISO 30107-3
- Biometric system on card (BSOC)
- NIST/NVLAP
- Biometric system on card (VBSS)

- Requirements defined by an international authority of stakeholders from industry, government, and subject matter experts ;
- Tests done by an independent accredited laboratory ;
- Attacks are useful for testing biometric systems.



THREAT MODEL

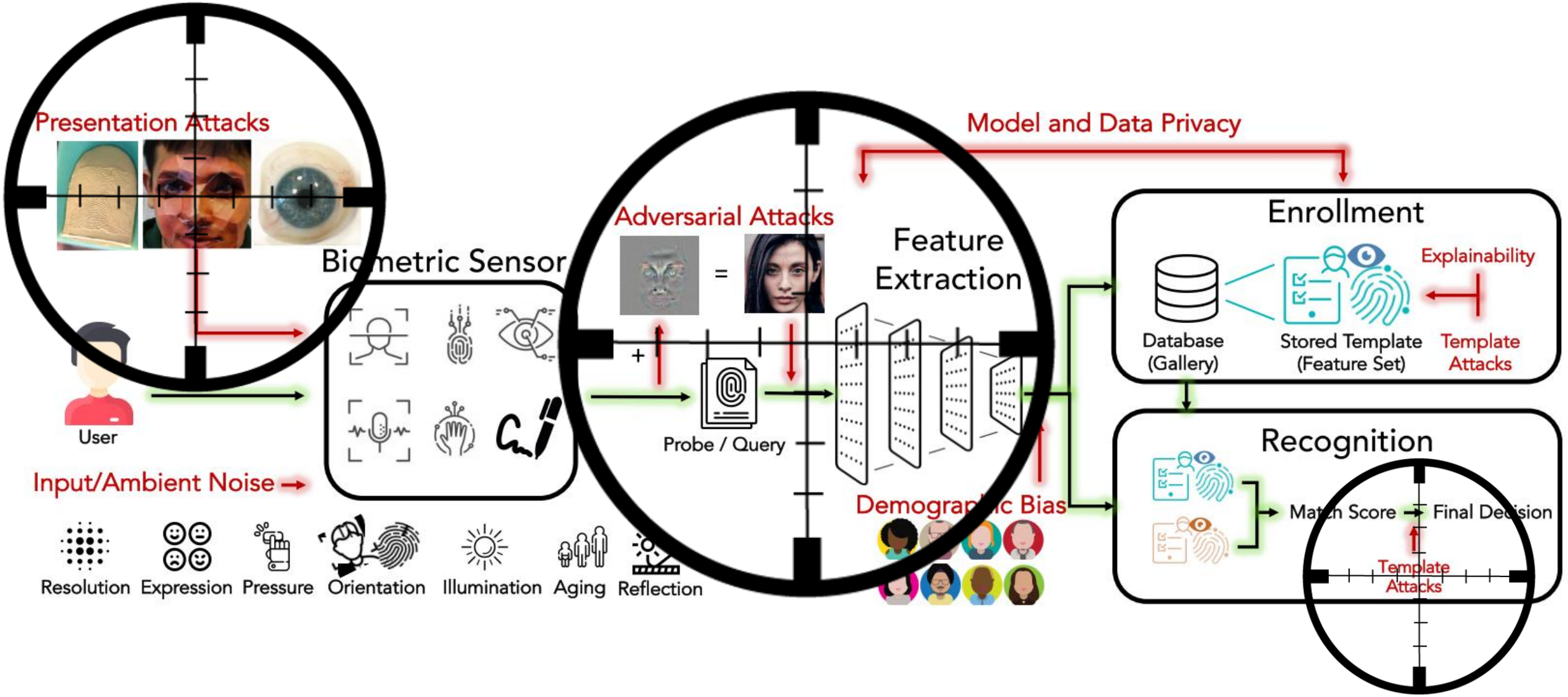


White box:
- ❑ **Access:** everything (code, coefficients, score…)
- ❑ **Realism:** no (except If a BSP uses available deep models on Internet)
- ❑ **Difficulty**: easy

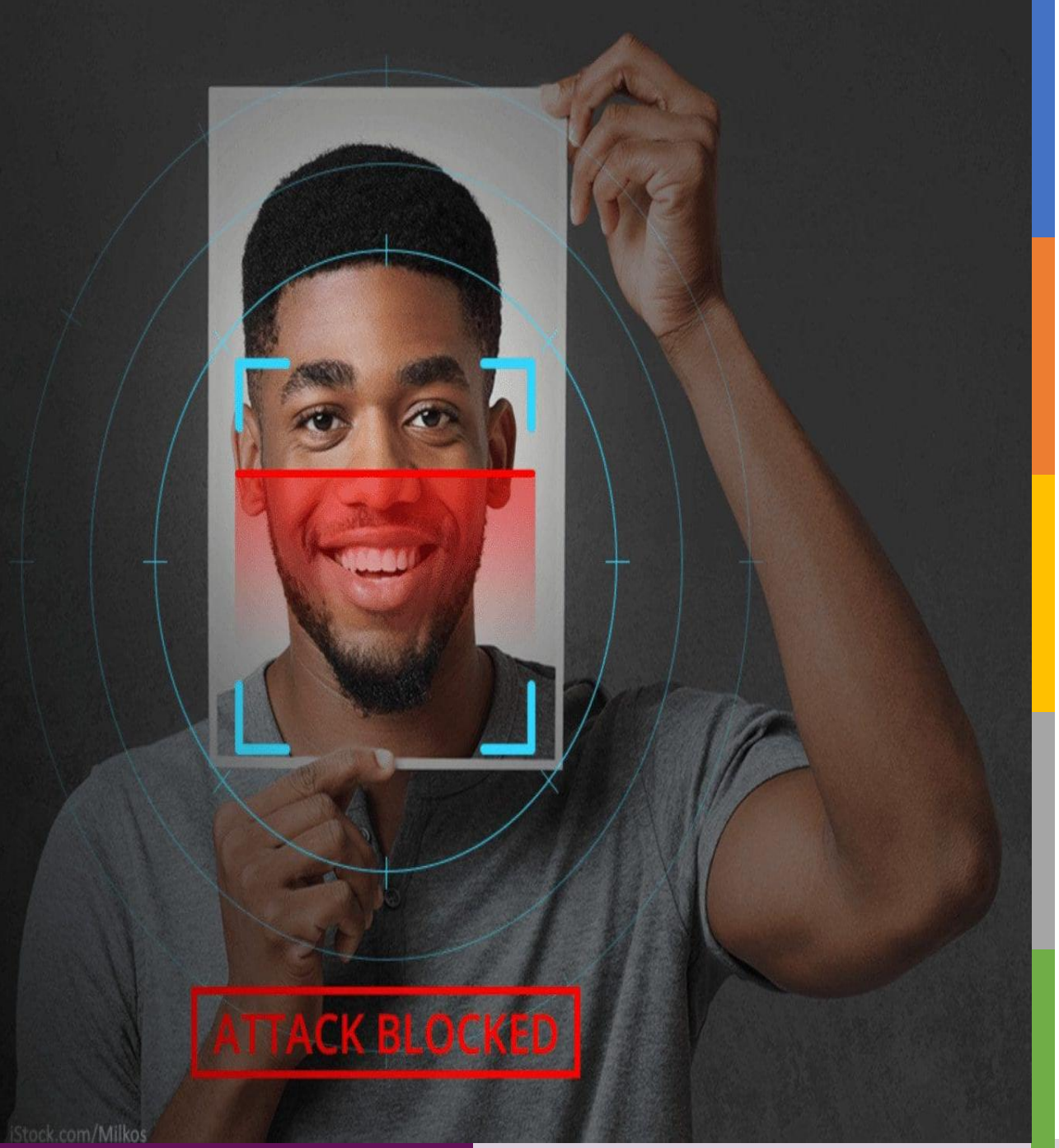
Gray box:
- ❑ **Access:** few information (score, decision)
- ❑ **Realism:** yes (certification)
- ❑ **Difficulty**: average

Black box:
- ❑ **Access:** only decision
- ❑ **Realism:** yes (daily life)
- ❑ **Difficulty**: high

TRENDS IN BIOMETRICS



Jain, A. K., Deb, D., & Engelsma, J. J. (2021). Biometrics: Trust but verify. *IEEE Transactions on Biometrics, Behavior, and Identity Science*, *4*(3), 303-323.



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PRESENTATION & INJECTION ATTACKS

Avoiding the good functioning of a biometric system through the capture

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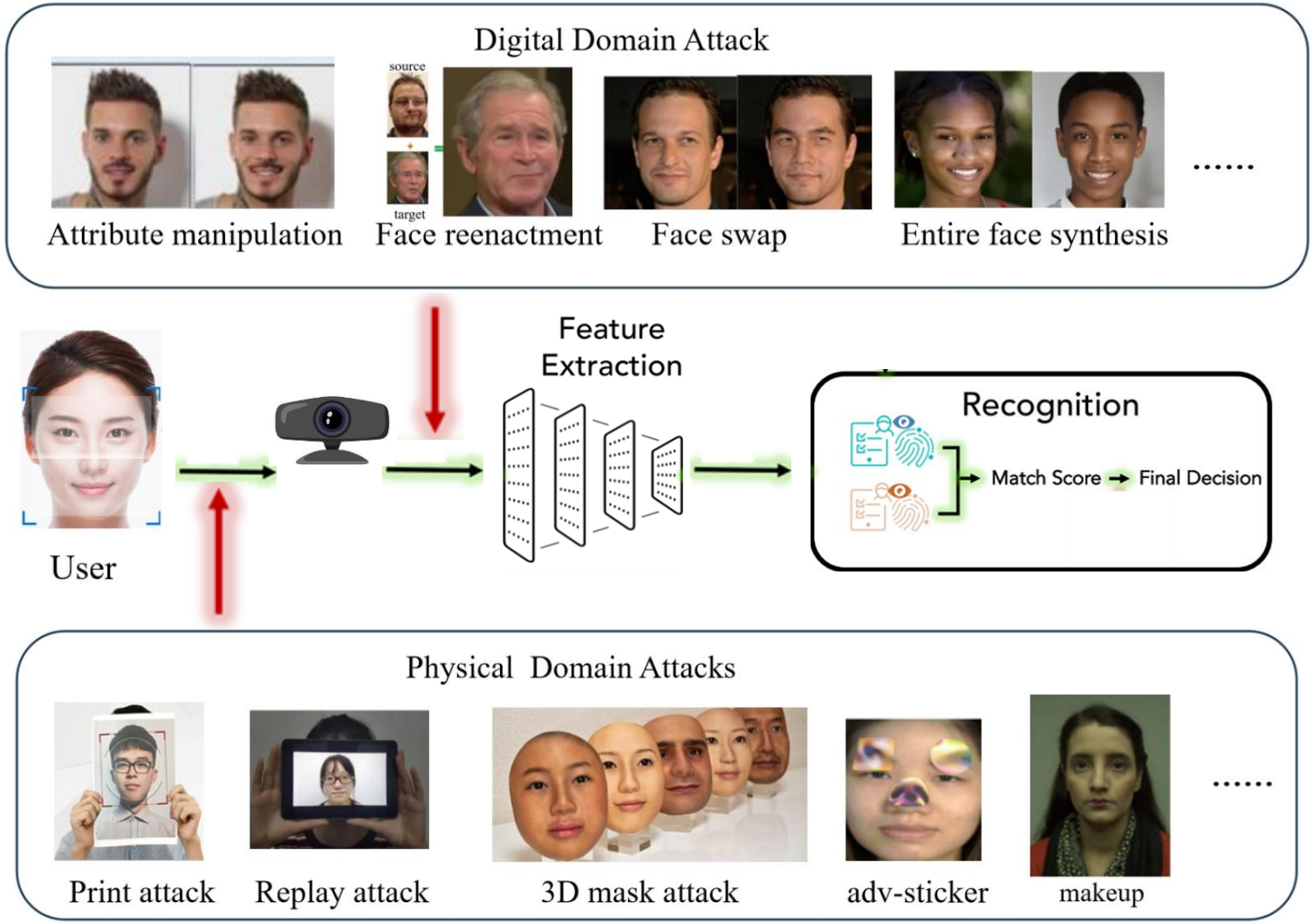
PRESENTATION/INJECTION ATTACKS



Two categories:

- **Physical attack**
  Present to the sensor an altered content to the sensor.

- **Digital attack**
  Altering the multimedia content with AI injected to the device or though a link.

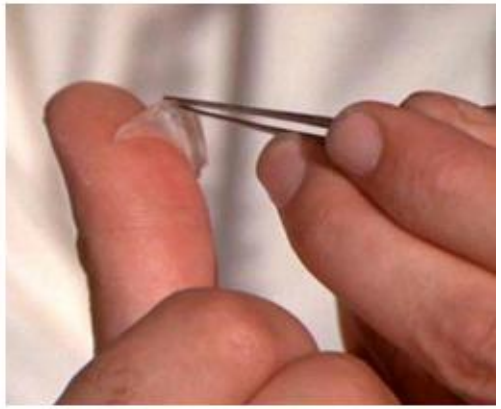
Günay Yılmaz, A., Turhal, U., & Nabiyev, V. (2023). Face presentation attack detection performances of facial regions with multi-block LBP features. *Multimedia Tools and Applications*, *82*(26), 40039-40063.

PRESENTATION ATTACKS

Definitions:

- **Presentation attack**
  Presentation to the biometric capture subsystem with the goal of interfering with the operation of the biometric system

- **Presentation Attack Instrument (PAI)**
  Biometric characteristic or object used in a presentation attack



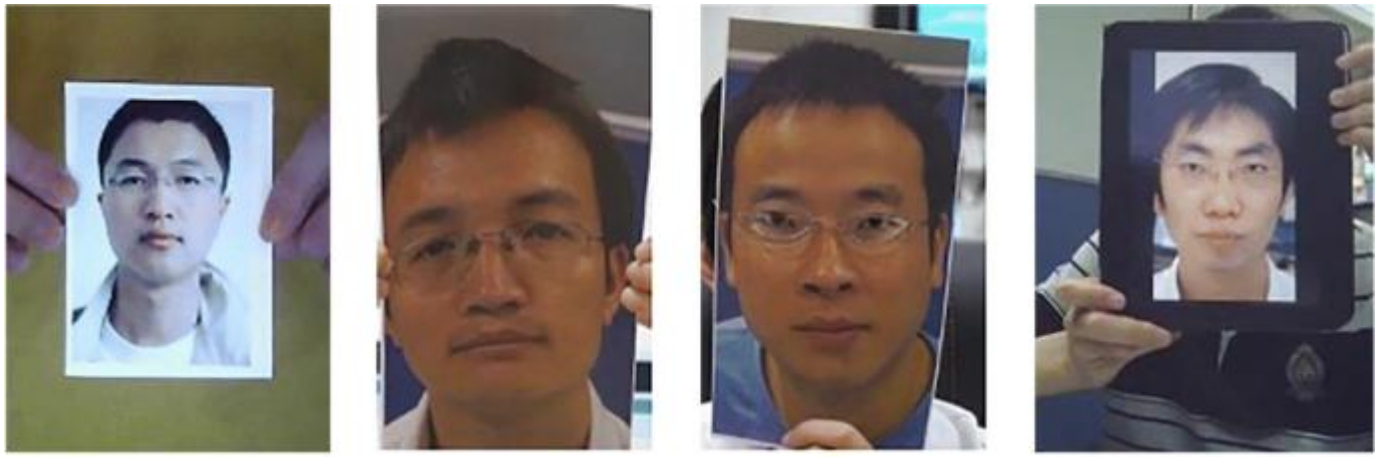
James Bond movie
Diamonds are forever (1971)

Objectives:

- **Identity concealer**
  Subversive biometric capture subject who attempts to avoid being matched to their own biometric reference

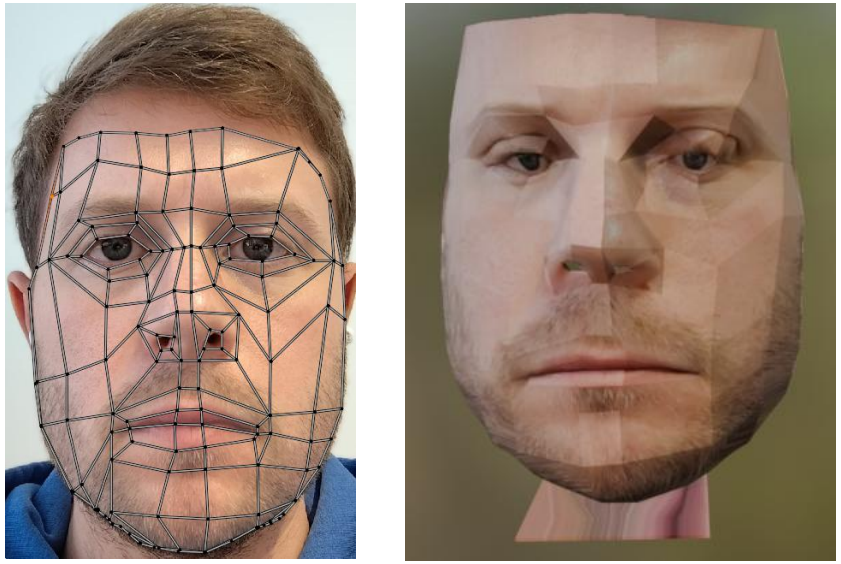
- **Identity impersonation**
  Attempt to be matched as another individual

FACE PRESENTATION ATTACKS (1/3)



Simple PAI

Makeup (@Paolo Ballesteros)



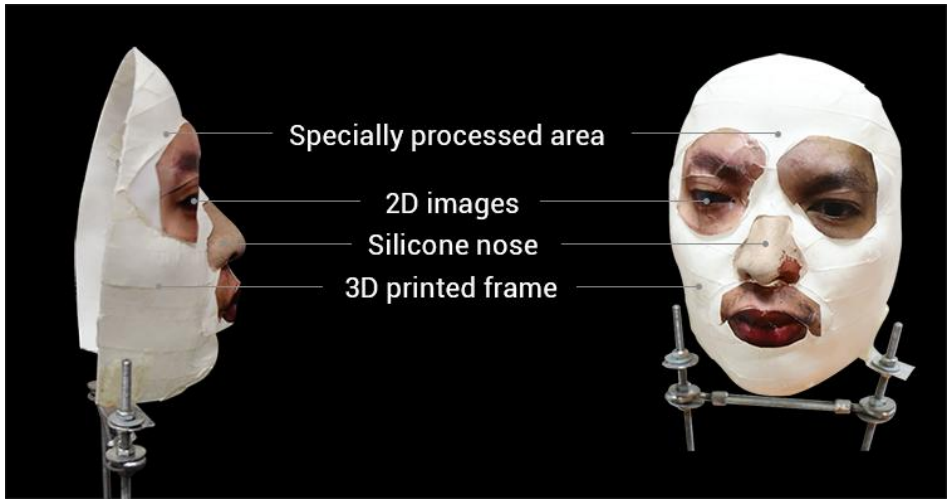
Papercut mask

DEMO 1

DEMO 2

Günay Yılmaz, A., Turhal, U., & Nabiyev, V. (2023). Face presentation attack detection performances of facial regions with multi-block LBP features. *Multimedia Tools and Applications*, *82*(26), 40039-40063.

FACE PRESENTATION ATTACKS (2/3)



3D spoof (FaceId attack)

3D scan

papercut

PVC (artist)

STUDIO JUNON

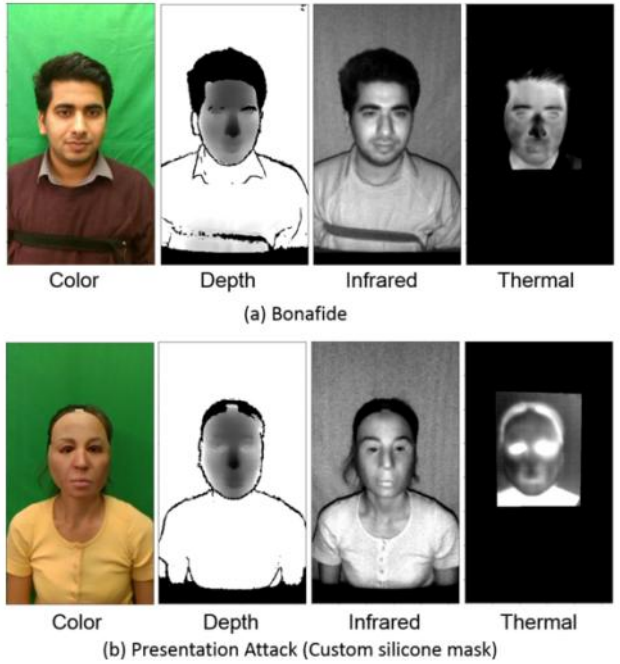
High quality mask

FACE PRESENTATION ATTACKS (3/3)

Deceased person

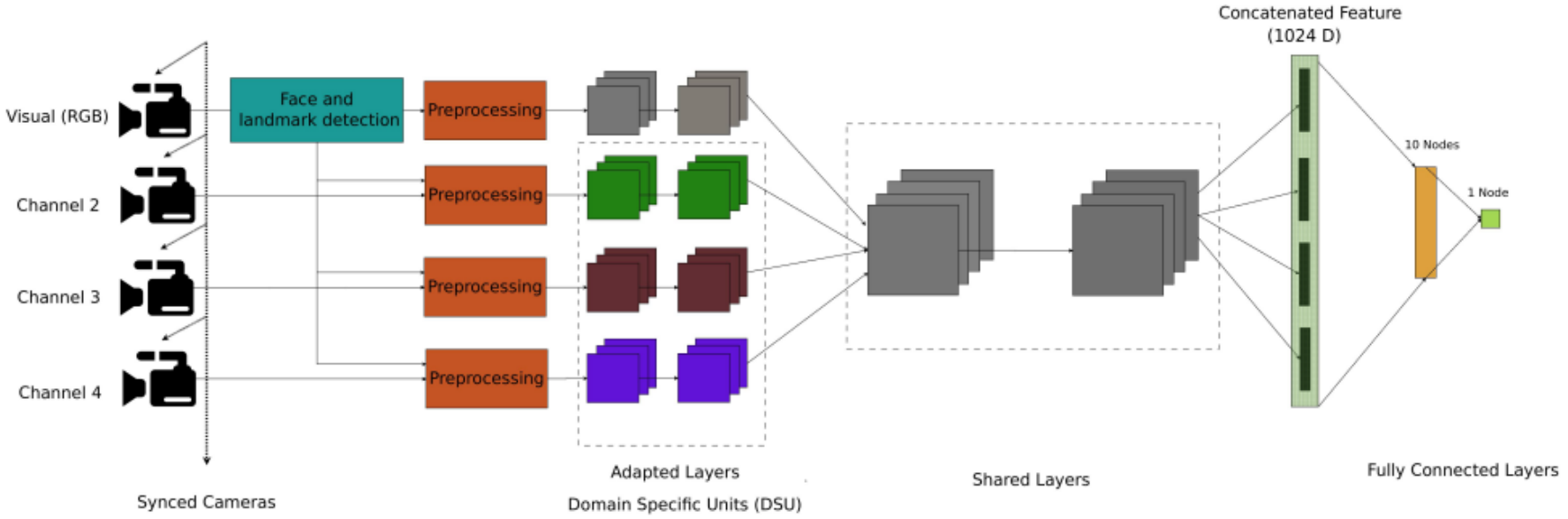
FACEPAD 3D

COUNTERMEASURE - PAD



Presentation Attack Detection (PAD)
Automated determination of a presentation attack

Two main components
- ❑ **Sensor:** RGB, 3D information, infrared, thermal…
- ❑ **AI:** deep models allowing to distinguish bona fide samples from an attack



George, A., Mostaani, Z., Geissenbuhler, D., Nikisins, O., Anjos, A., & Marcel, S. (2019). Biometric face presentation attack detection with multi-channel convolutional neural network. *IEEE transactions on information forensics and security*, *15*, 42-55.

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TEMPLATE ATTACKS

Security and privacy breaches from biometric templates

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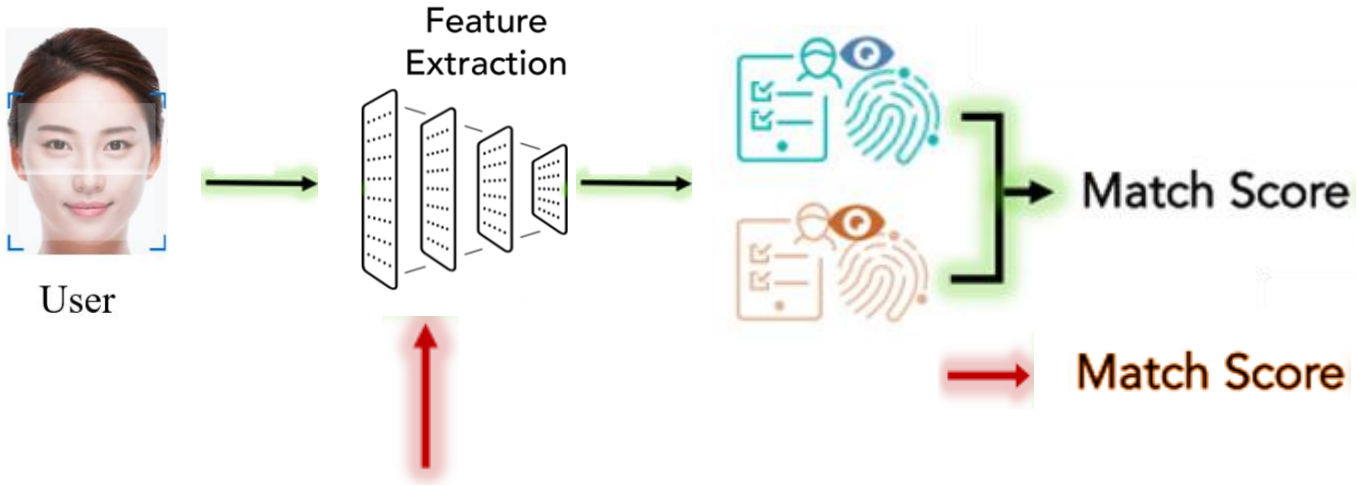
SIDE CHANNEL ATTACKS (SECURITY)



Minimizing the difference

Observing the biometric system:

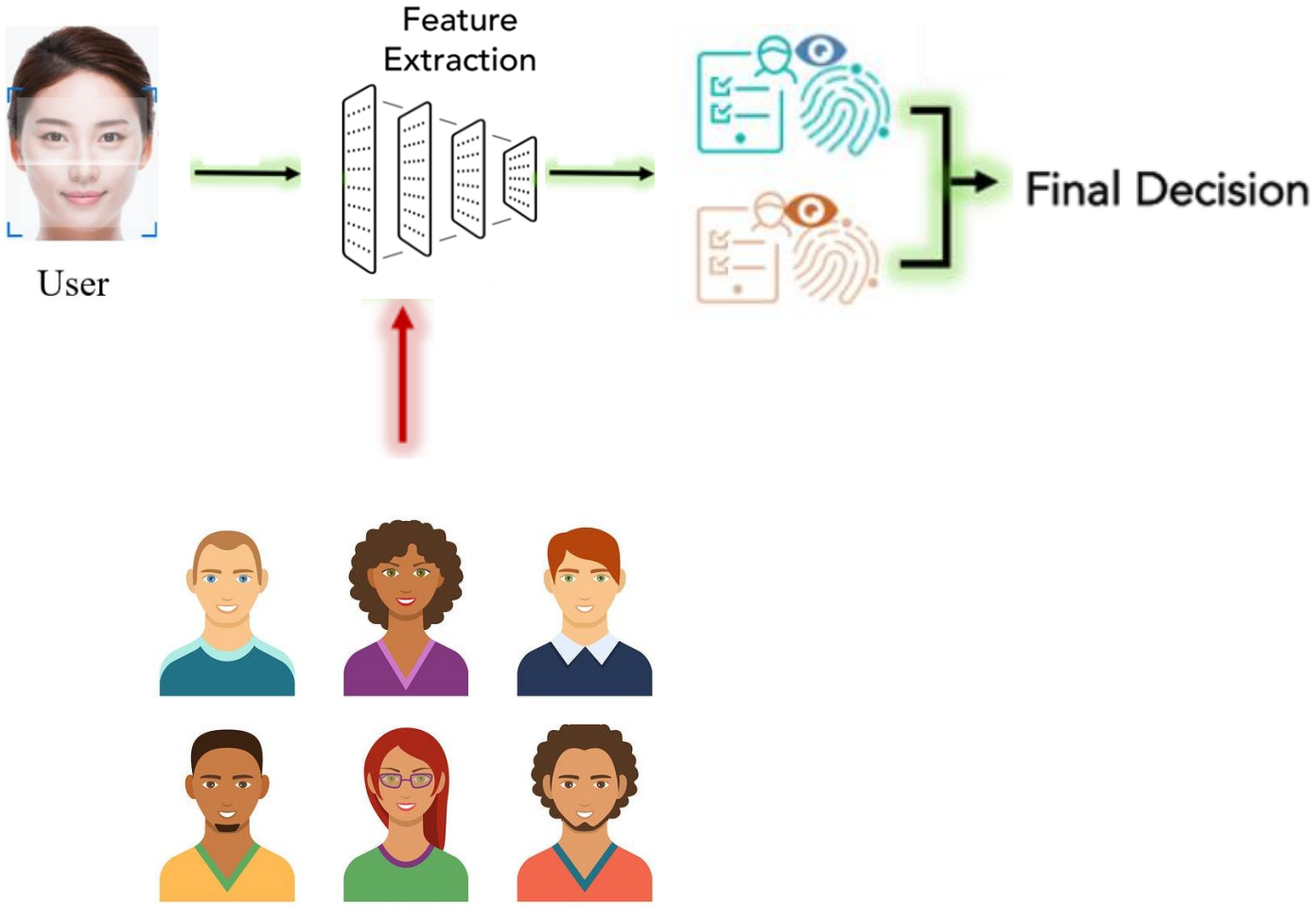
- ❑ White box: templates value

Possible inversion of the deep model to recover the reference template

- ❑ Gray box: match score

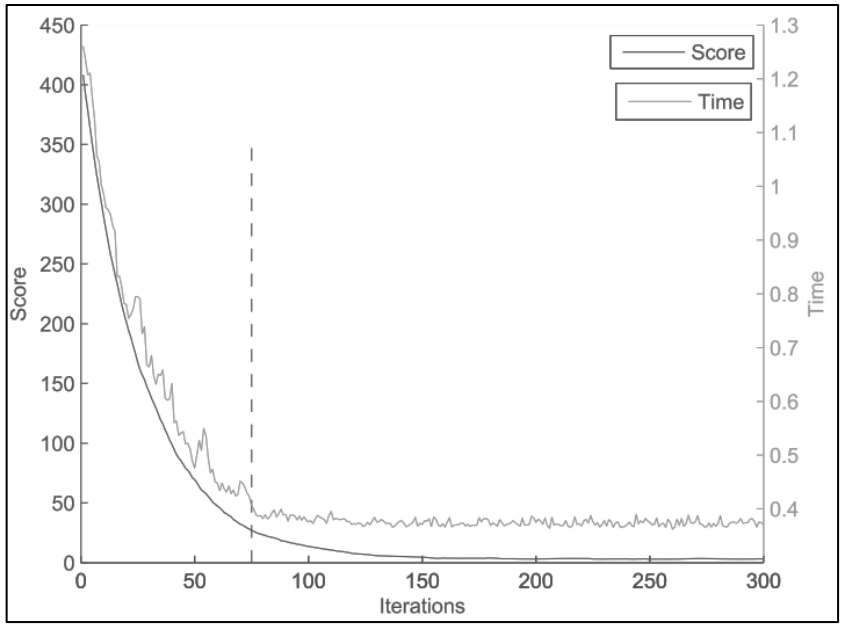
In industrial biometric systems (such as smartphones), the match score is never displayed (only the decision) for security reasons

SIDE CHANNEL ATTACKS (SECURITY)



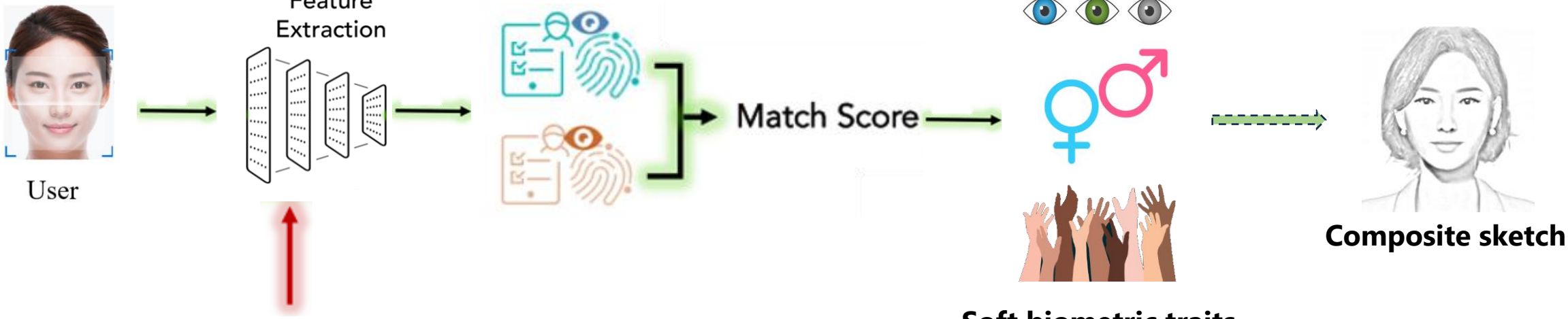
Black box systems: comparison time

Less relevant nowadays with AI



Galbally, Javier. "A new Foe in biometrics: A narrative review of side-channel attacks." Computers & Security 96 (2020).

DIFFERENTIAL PRIVACY



Observations of scores for different inputs

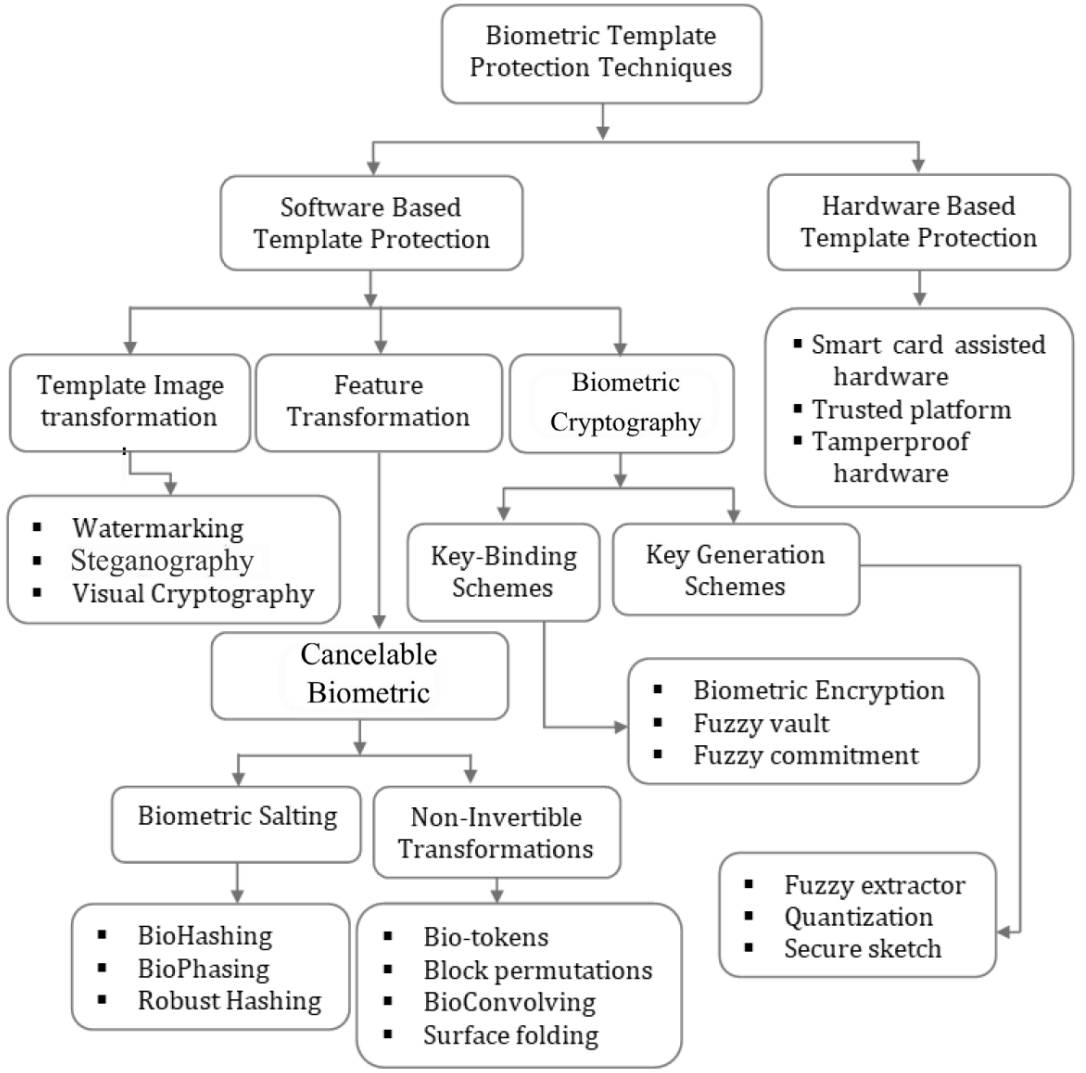
Privacy leakage analysis (certification context)

Carmen Licciardi, Francesco Buccafurri, Neily Sanon and Christophe Rosenberger, « Assessing Privacy Leakage in Biometric-Enabled Information Systems » submitted

COUNTERMEASURE - BTP

Biometric Template Protection (BTP):
Privacy Enhancing Technology (PET)

Taxonomy of existing approaches:
- ❑ Hardware solutions
- ❑ Software template protection



Sardar, A., Umer, S., Pero, C., & Nappi, M. (2020). A novel cancelable facehashing technique based on non-invertible transformation with encryption and decryption template. *IEEE Access*, *8*, 105263-105277.

COUNTERMEASURE - BTP

Cancelable biometrics:

Biometric data

Feature Extraction

Transformation

Secret or helper data (seed, password…)

BioCode

Expected properties:

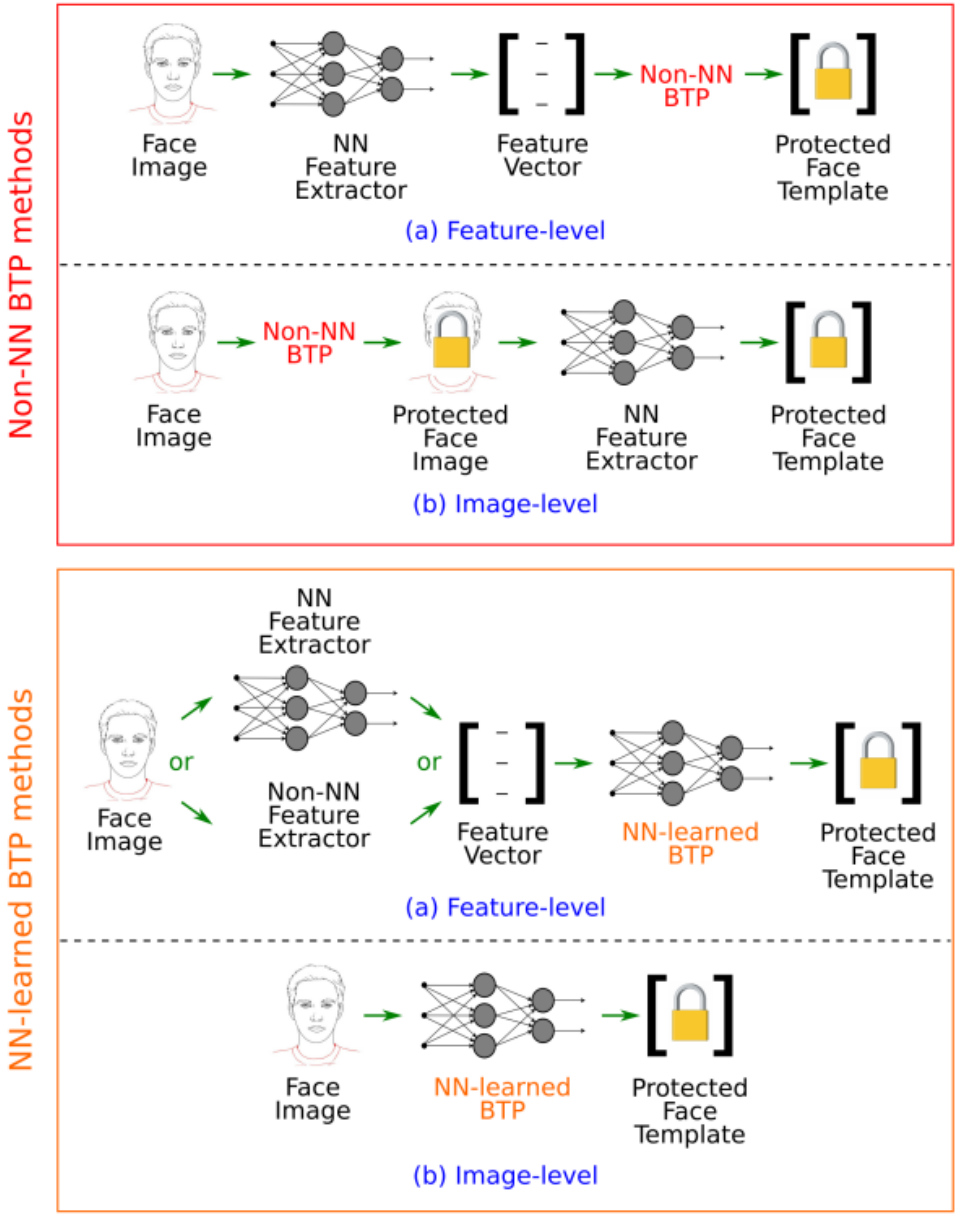
- **Verifiability**: it is possible to authenticate a user given a BioCode
- **Revocability**: it is possible to renew the BioCode in case of attack
- **Non invertibility or irreversability**: impossible to recover the raw biometric data given the BioCode and the Secret
- **Undistinguishability:** impossible to distinguish impostor BioCodes from legitimate ones with different Secrets
- **Unlikability**: no information leakage from different legitimate Biocodes

Lacharme Patrick, Cherrier Estelle and Rosenberger Christophe. Preimage attack on biohashing. In : *2013 International Conference on Security and Cryptography (SECRYPT)*. IEEE, 2013. p. 1-8.

COUNTERMEASURE - BTP

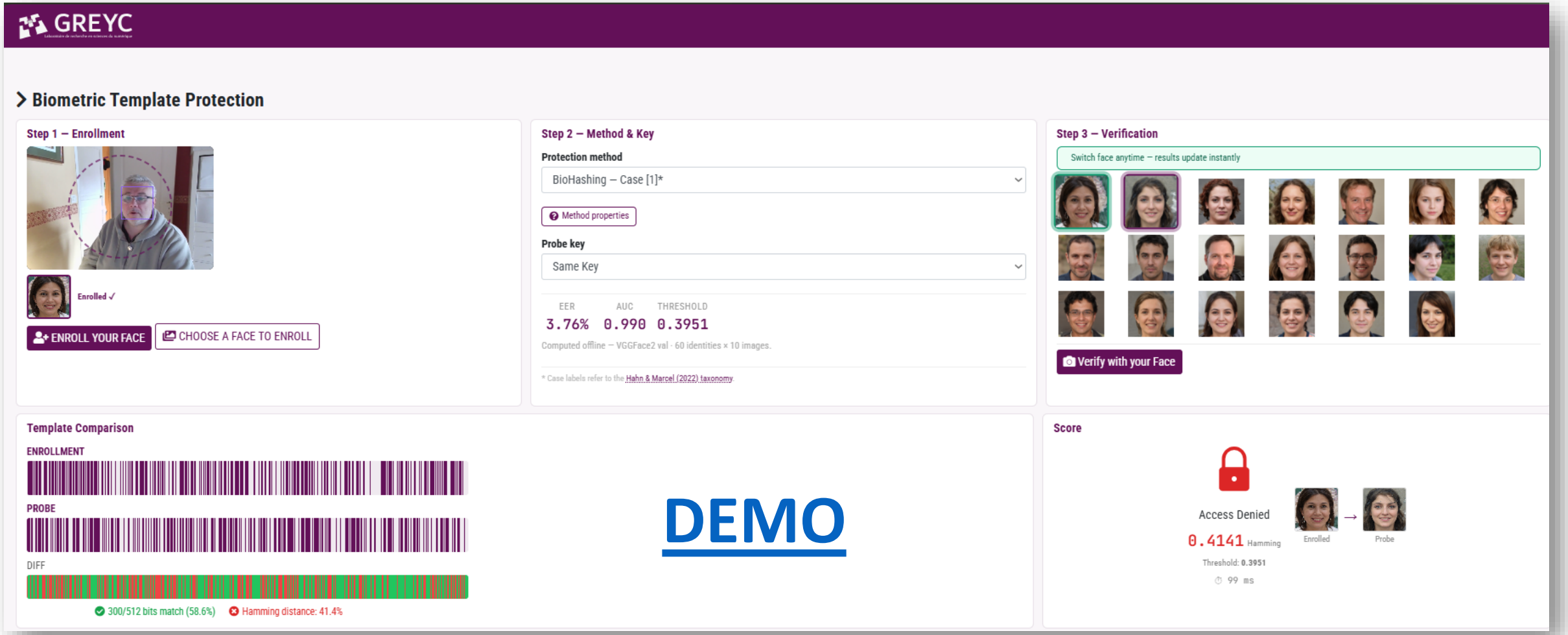
AI based BTP:

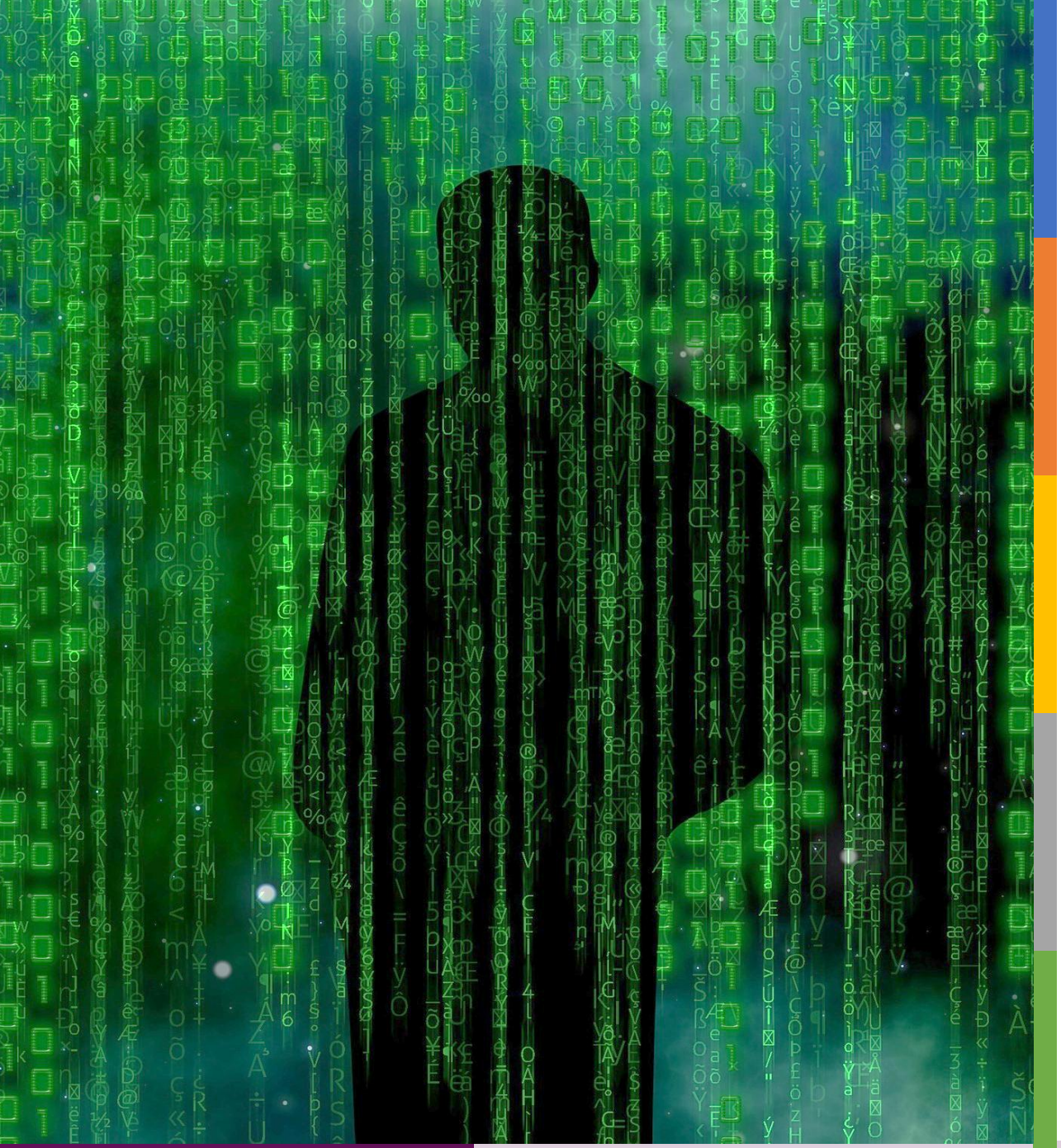
- ❑ Feature generation more efficient with AI
- ❑ Deep networks can learn encrypted data (homomorphic)
- ❑ Generation of secure biometric signatures



V. Krivokuca Hahn and S. Marcel, ‘‘Biometric template protection for neural-network-based face recognition systems: A survey of methods and evaluation techniques,’’ IEEE Transactions Information Forensics Security, vol. 18, pp. 639–666, 2023

COUNTERMEASURE - BTP





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BACKDOOR & ADVERSARIAL ATTACKS

Manipulation of deep models by deliberately feeding them deceptive data to cause incorrect or unintended behavior

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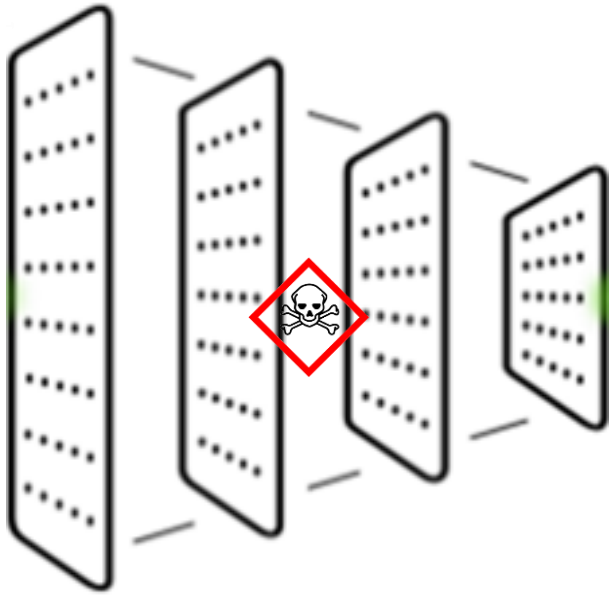
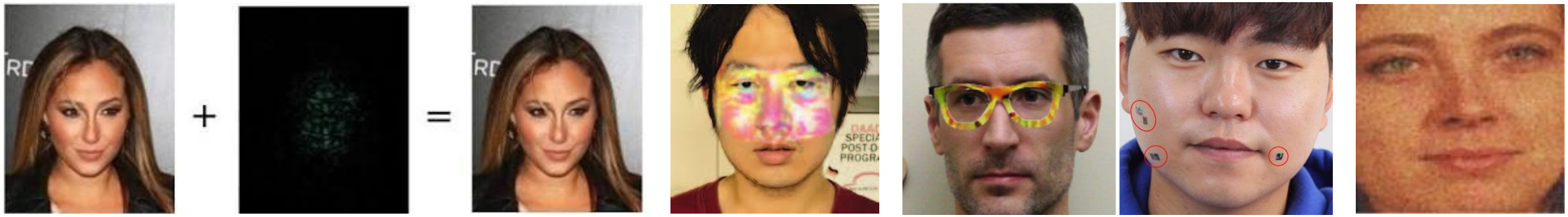
DATA POISONING



Deep models: Large use in biometrics for detection (i.e. face detection) and template extraction

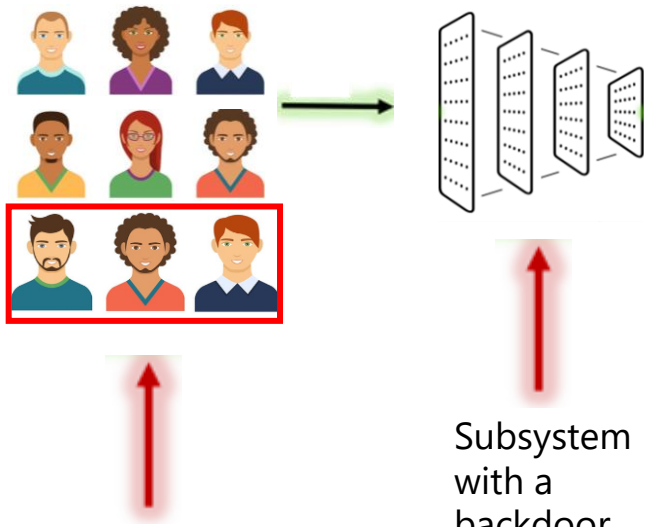
Principle:

- ❑ Alter an input image with a visible/invisible and physical/digital trigger
- ❑ During training (backdoor) or use (adversarial)
- ❑ Can be targeted to a specific user



Xu, Y., Raja, K., Ramachandra, R., & Busch, C. (2022). Adversarial attacks on face recognition systems. In *Handbook of Digital Face Manipulation and Detection: From DeepFakes to Morphing Attacks* (pp. 139-161). Cham: Springer International Publishing.

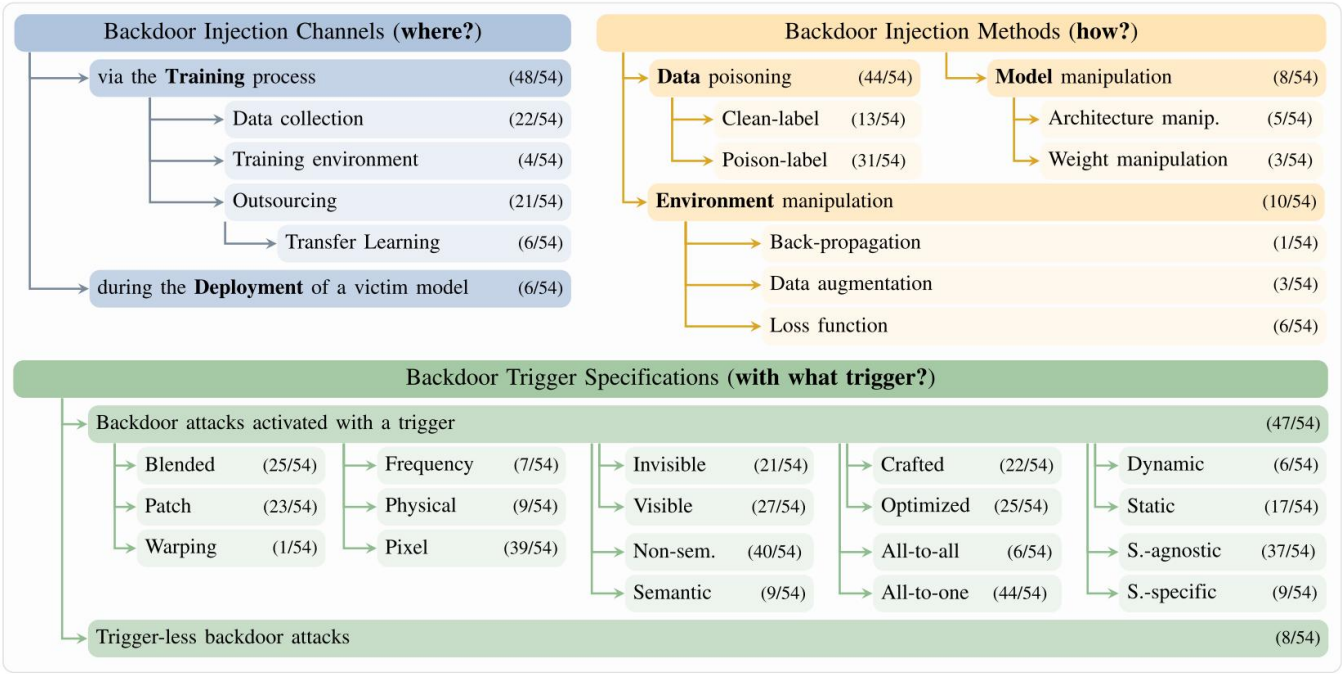
BACKDOOR ATTACK



Poisoned data in the training set

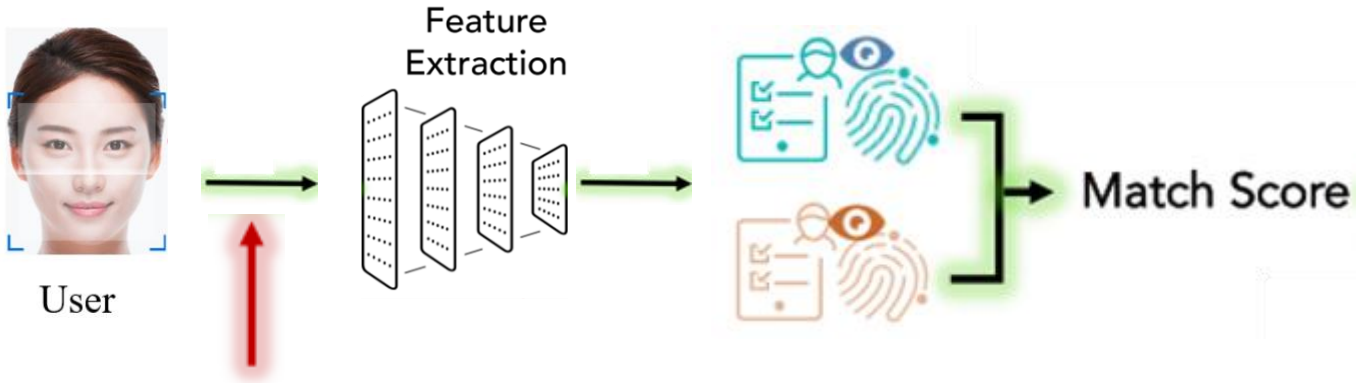
Subsystem with a backdoor

- Can be realized intentionally by the model owner or accidentally by using a subsystem with a backdoor (e.g. face detection) or poisoned data in the training set
- Difficult to identify and could be reused by commercial systems

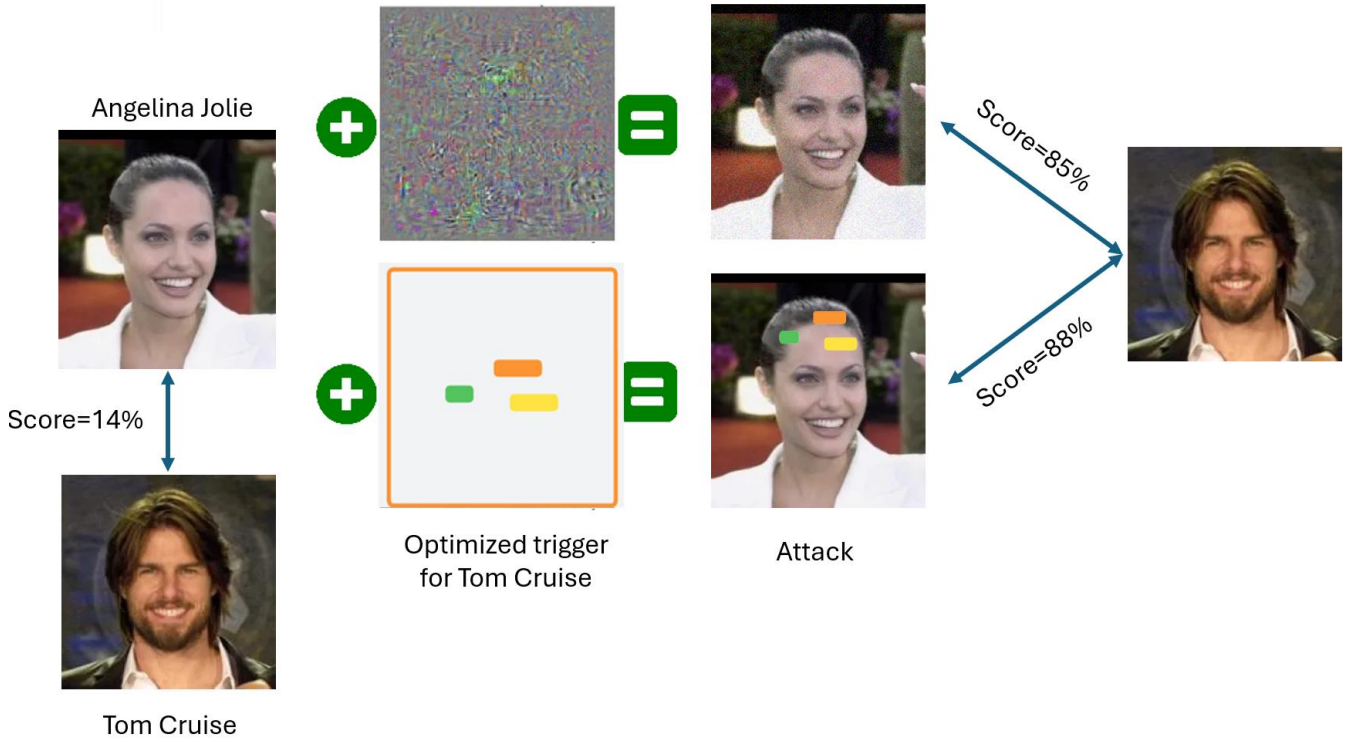


Le Roux, Q., Bourbao, E., Teglia, Y., & Kallas, K. (2024). A comprehensive survey on backdoor attacks and their defenses in face recognition systems. *IEEE Access*, *12*, 47433-47468.

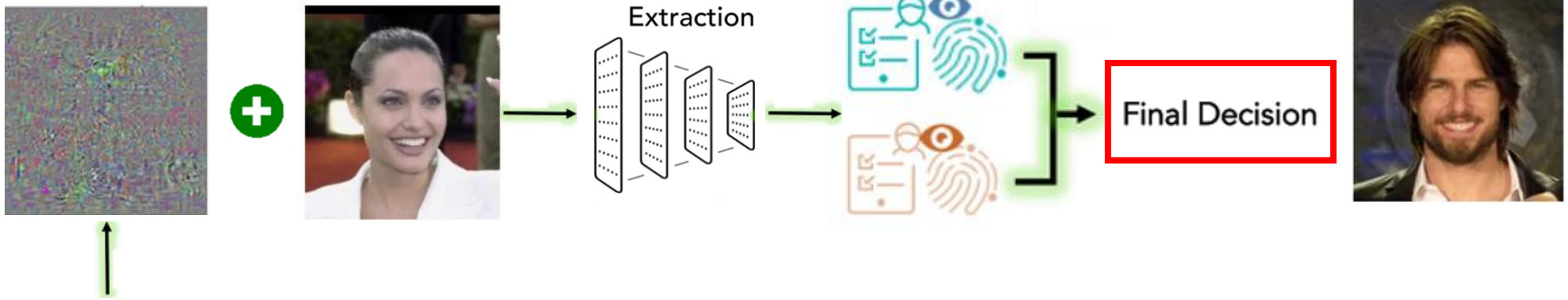
ADVERSARIAL ATTACK

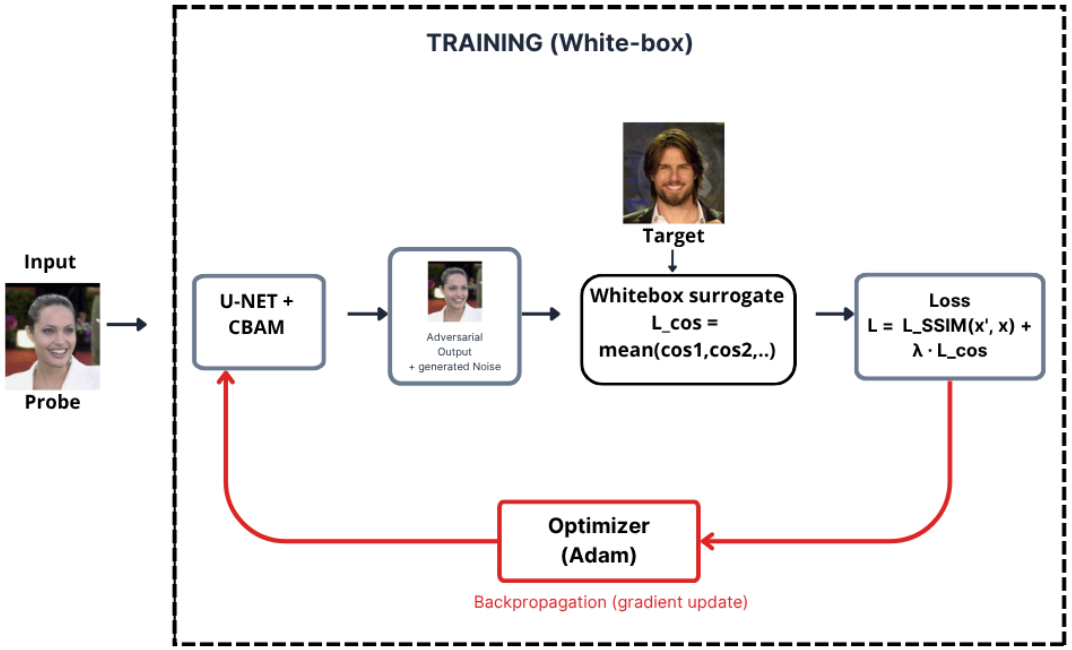


- Attack realized during the use of a biometric system (API)
- Alter the output (not be detected or recognized, impersonation..)



ADVERSARIAL ATTACK





Principle:

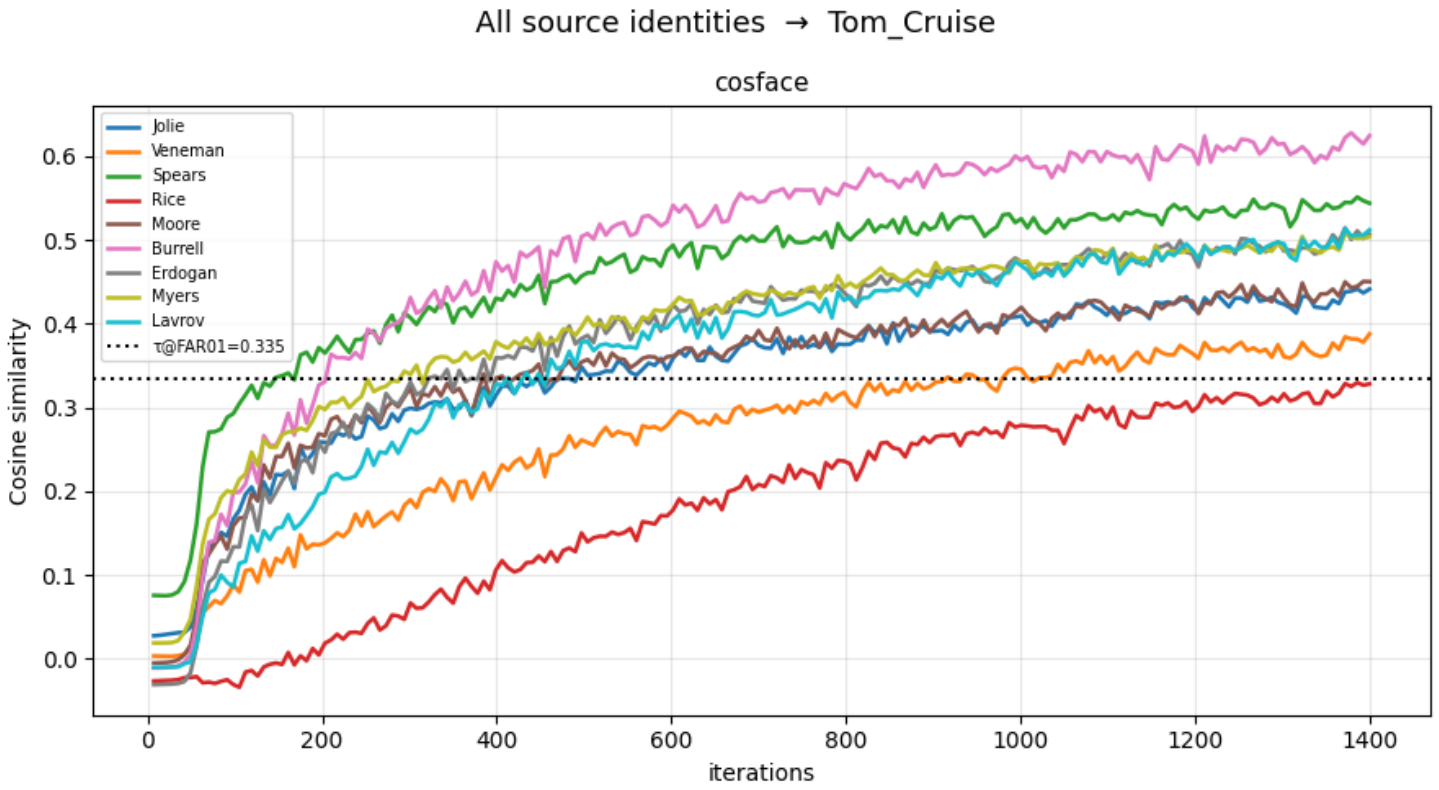
- ❑ Optimize the trigger on multiple white box models (to increase poison impact)
- ❑ Transfer the poison to a black box face recognition system

Dihia Slimana, Christophe Rosenberger, “Adversarial Attacks and Robustness Evaluation of Black Box Biometric Systems”, submitted

ADVERSARIAL ATTACK

Experiments:

- ❑ Impersonating Tom Cruise
- ❑ Trigger optimized with white box models (noise)



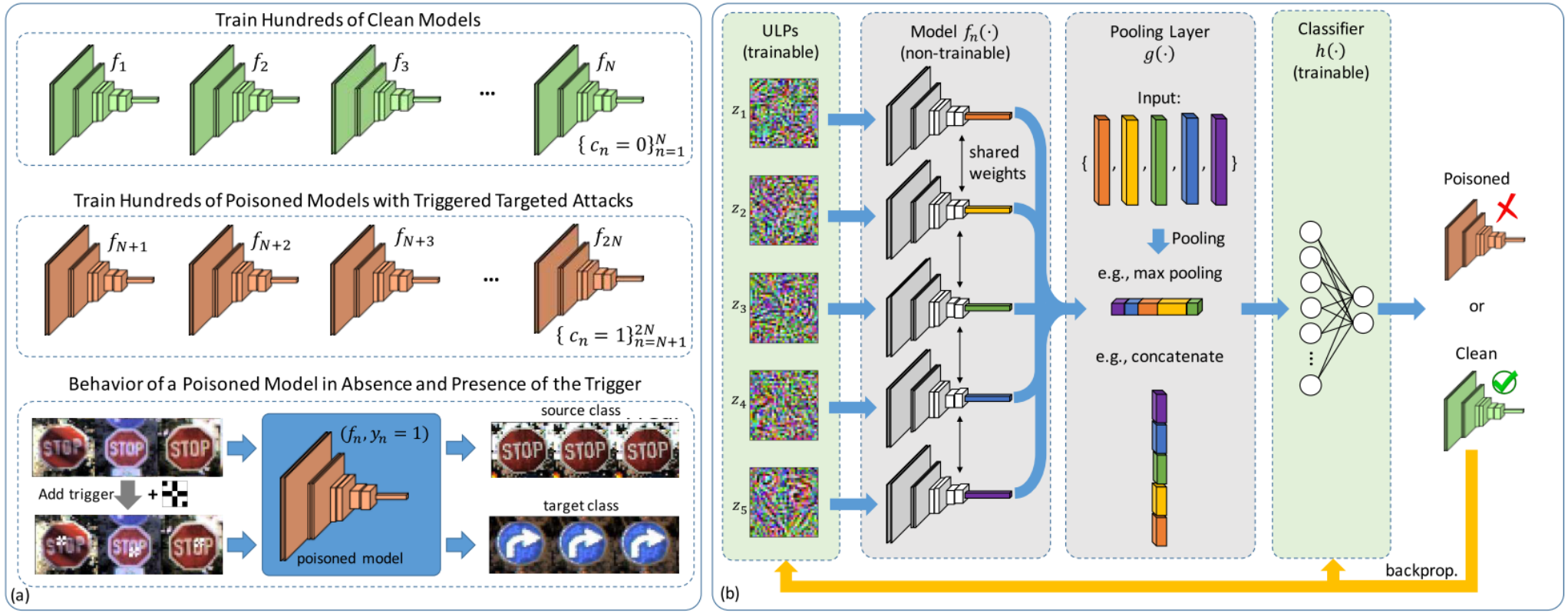
Tests on 4 commercial face recognition systems (Comparison between Angelina Jolie and Tom Cruise)

Context	C1	C2	C3	C4
Original	0	0 (1%)	0 (26%)	0
Poisoned	1	1 (86%)	1 (77%)	1

Dihia Slimana, Christophe Rosenberger, “Adversarial Attacks and Robustness Evaluation of Black Box Biometric Systems”, submitted

COUNTERMEASURE – BACKDOOR DETECTION

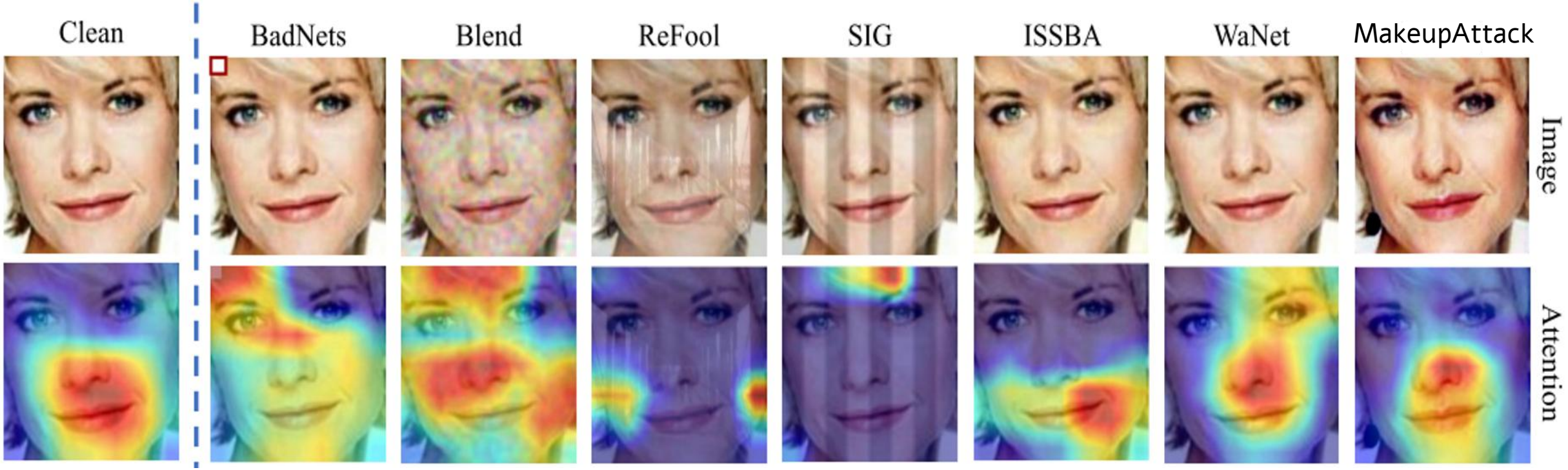
Detection of backdoor attacks: deep learning task



Kolouri, S., Saha, A., Pirsiavash, H., & Hoffmann, H. (2020). Universal litmus patterns: Revealing backdoor attacks in cnns. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 301-310).

COUNTERMEASURE – EXPLANATIONS

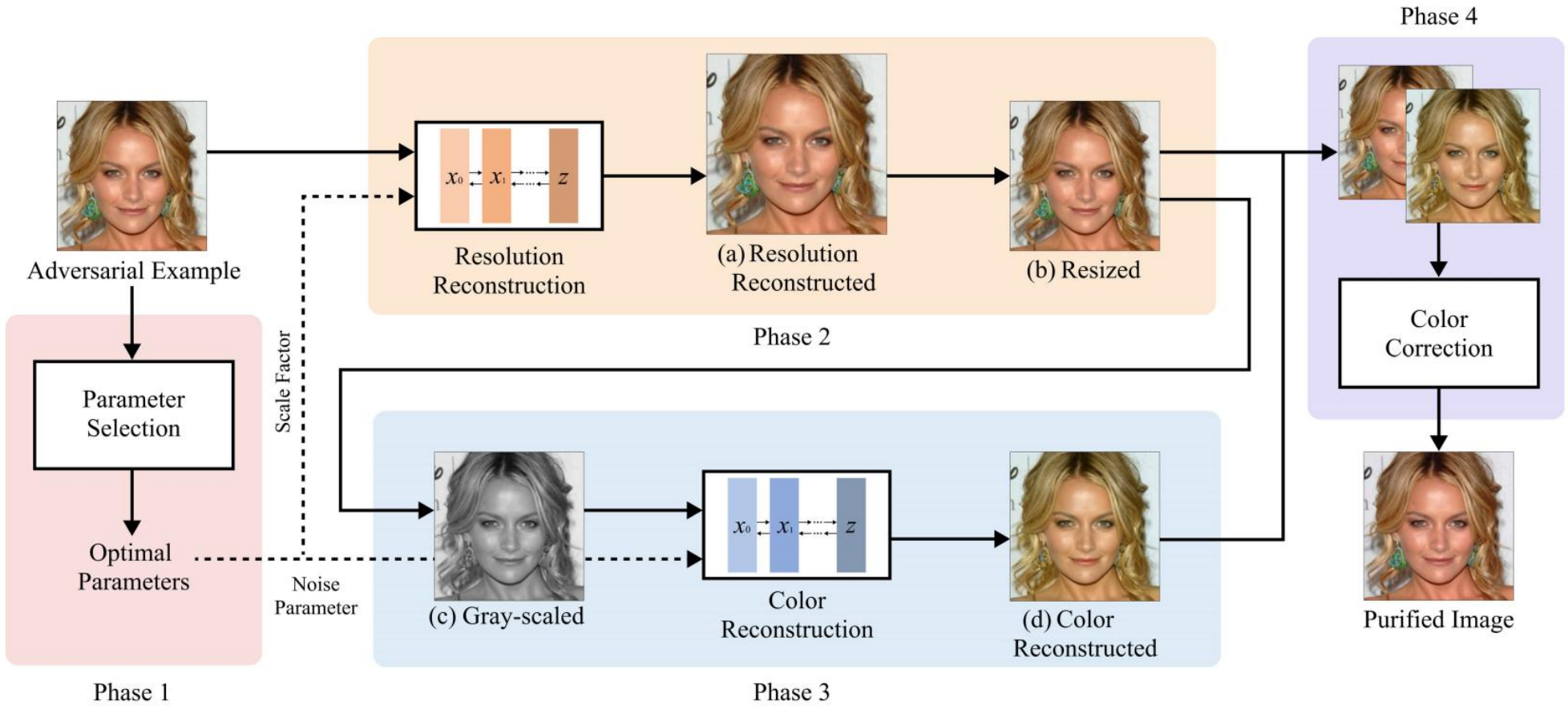
Adversarial & backdoor attacks: different impacts on the decision different than a clean input



Sun, M., Jing, L., Zhu, Z., & Wang, R. (2024). Makeupattack: Feature space black-box backdoor attack on face recognition via makeup transfer. *arXiv preprint arXiv:2408.12312*.

COUNTERMEASURE – PURIFICATION

Preprocessing input images: suppressing triggers



Lim, M. Y., Kim, S. Y., Jeon, M., & Lee, Y. K. (2025). FacePurifier: Enhancing Face Identification Robustness Against Adversarial Attacks via Two-Phase Image Restoration. *IEEE Access*, *13*, 215146-215159.

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CONCLUSION

Which are the hot topics (for me)?

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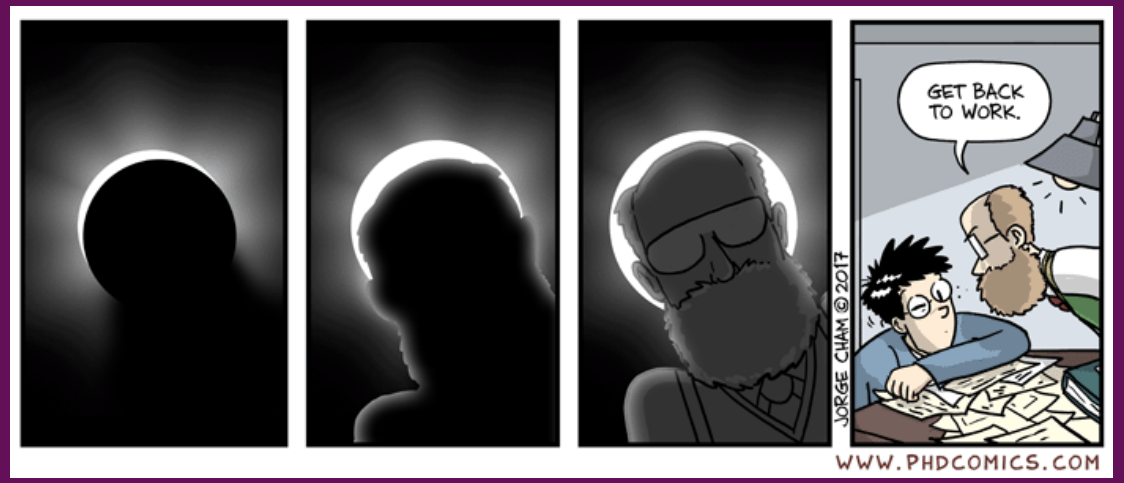
PERSPECTIVES

AI impacts on biometrics security and privacy:

- ❑ Certification of biometric systems is crucial
- ❑ Very few works on privacy testing on biometric systems
- ❑ How to detect backdoors and adversarial attacks in biometric systems?
- ❑ Authenticity of biometric data is challenging (deepfakes, modifications…)
- ❑ Is there still any black box system in biometrics?



QUESTIONS?

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