A Framework for Secure Cloud-Empowered Mobile Biometrics

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Outline

1. Introduction
2. Homomorphic LBP-based face recognition
3. A framework for secure cloud biometrics
4. System analysis
5. Conclusion

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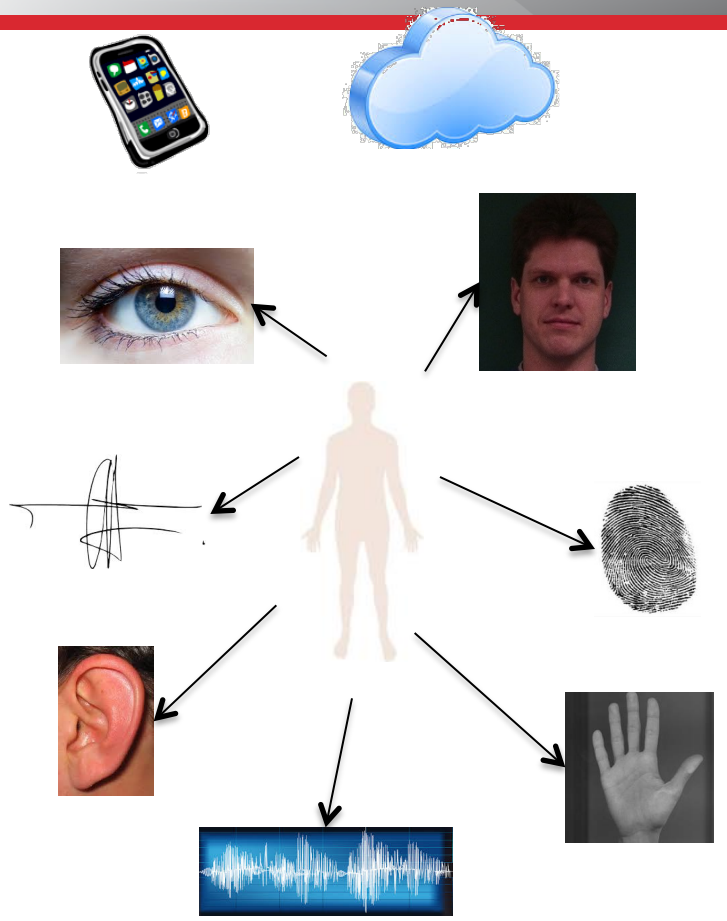
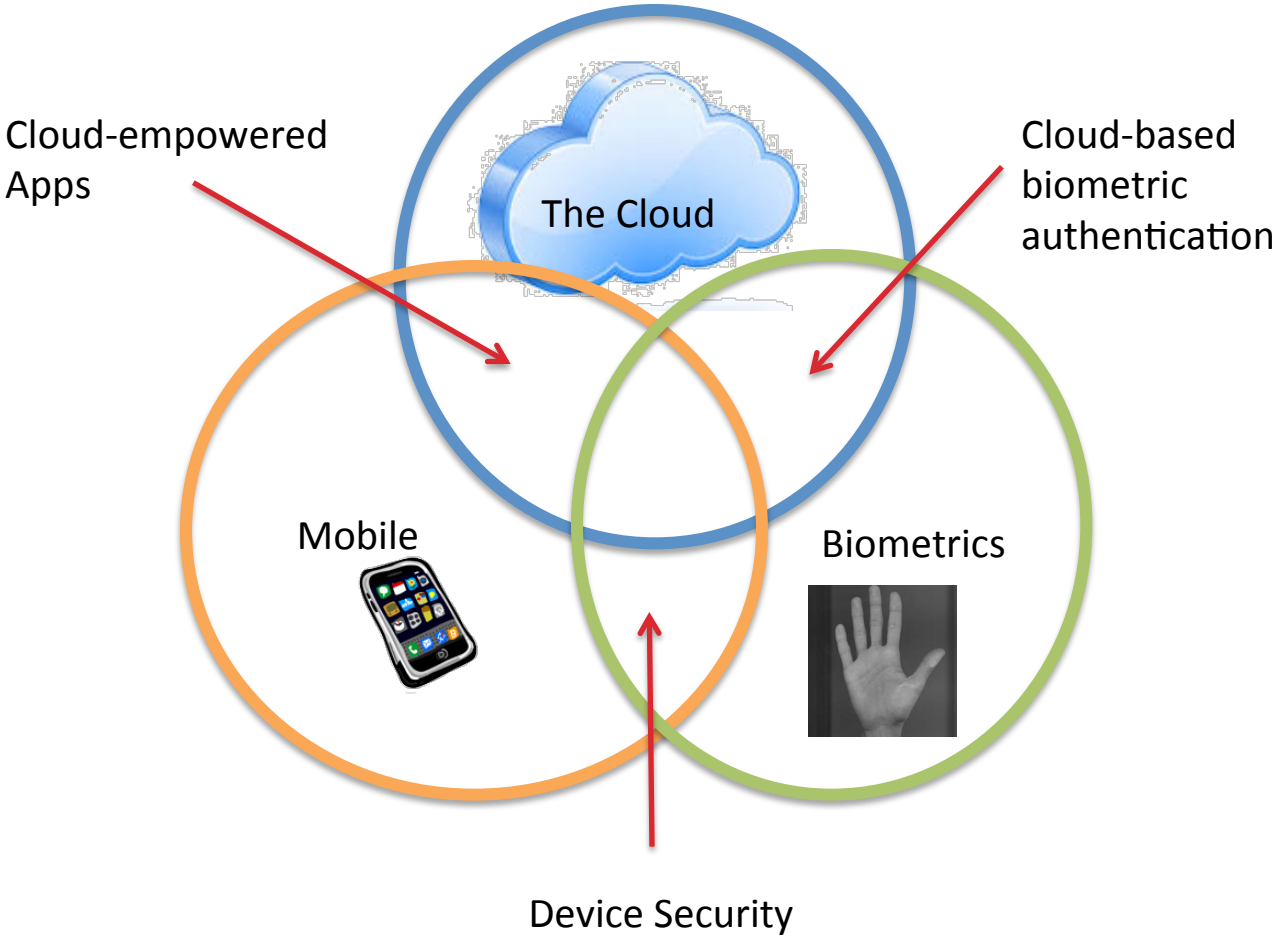
Introduction

- The cloud provides unbounded, cost-effective, and elastic computing resources.
- Biometrics can leverage the efficiency of the cloud.
- The cloud provides an opportunity to offload compute-intensive operations from the mobile device.
- Conversely, biometrics can help to make the cloud more secure.



Mobile + Cloud + Biometrics



The Cloud leveraging Biometrics

- Biometric authentication for cloud clients.
  - e.g., Cloud Iris Verification System (CIVS), Kesava, 2010, Correlation keystroke verification, Xi et al., 2011.
- Securing cloud data storage with biometrics.
  - Biocryptographic systems
  - Using biometrics for key generation: Fuzzy extractor.
  - Using biometrics for key binding: Fuzzy vault, Fuzzy commitment, Bipartite token.
- Authentication as a service (AaaS)
  - Outsource system authentication to the cloud.
  - Confederates access to a single sign-on.

Security threats

- Biometric dilemma threat
  - Attacker compromises a less secure system to obtain biometric data.
  - Then uses the biometric data to gain access to a secure, high-value system.
- Doppleganger threat
  - Attacker presents a large amount of biometric data, in the hopes of achieving a match.
  - Exploits non-zero False Accept Rates (FAR)
  - Analogous to a dictionary attack.
- Trust Issues
  - Who is allowed to enroll the users?

Biometrics leveraging the Cloud

- Using the cloud to store biometric data.
  - The cloud is a cost effective and elastic way to store and share data.
  - Need to preserve privacy of biometric data while in the cloud, and during transfer to/from the cloud.
  - Potential to support access from different entities under different policies.
  - Laws may dictate where the data is stored.
  - Potential to share biometric data among research organizations.
- Using the cloud to perform biometric computations
  - Rapid analytics: e.g., identification through parallelization.
  - "Big data" biometrics using Hadoop, ZooKeeper, and Accumulo.
- Biometrics as a service
  - Allow access to different algorithms provided by different service providers and/or developers.
  - Upload the algorithm, not the biometric.

Literature review

- A Hadoop-based prototype for using the cloud for biometric identification is proposed in [3], but it does not describe biometric database security.
- Fingerprint authentication and storage of cancelable biometrics in the cloud is proposed in [7]. However, in this work matching is performed locally.
- A privacy-preserving biometric identification scheme is proposed in [10]. However, it does not offer a solution to minimize the damage resulting from a compromised biometric database.
- Secure authentication of mobile cloud users using a fingerprint image (using a mobile device camera) is proposed in [12], but data security is not addressed in this work.

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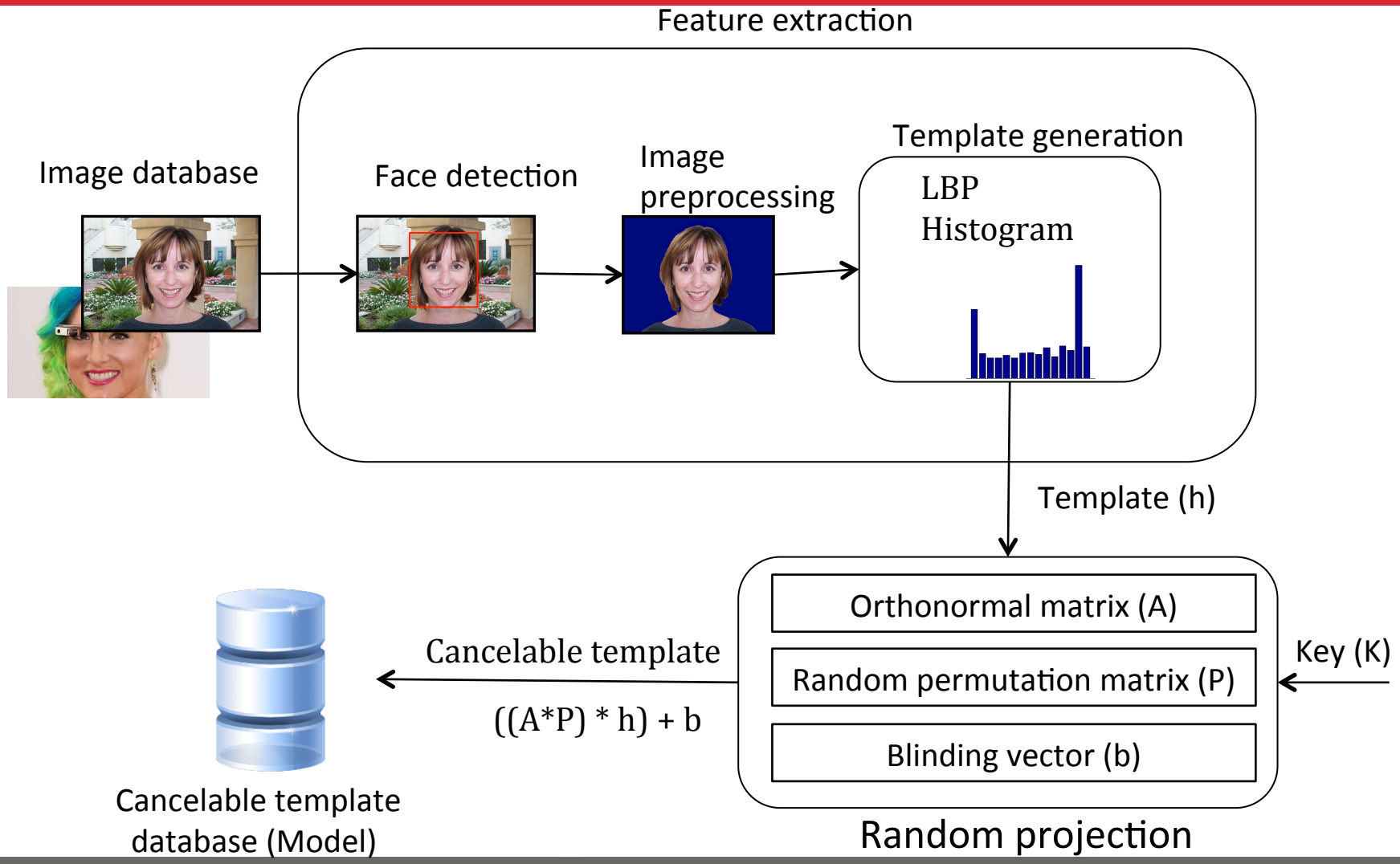
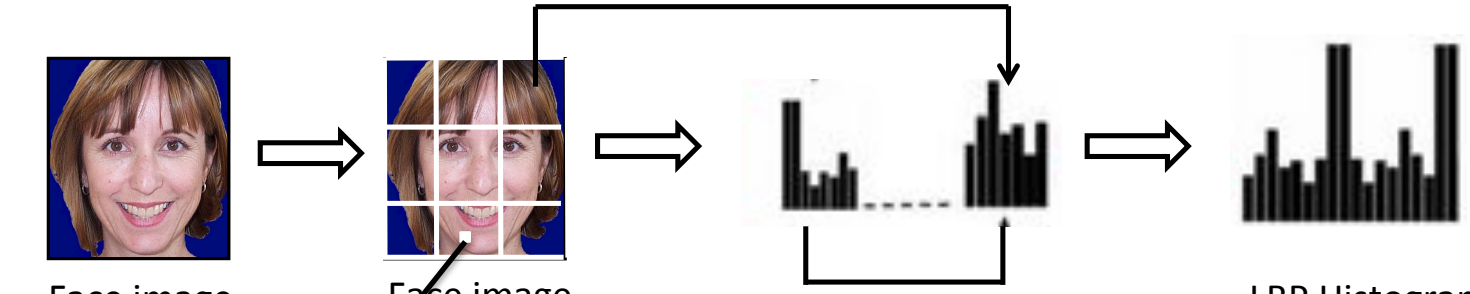
Motivation and Goals

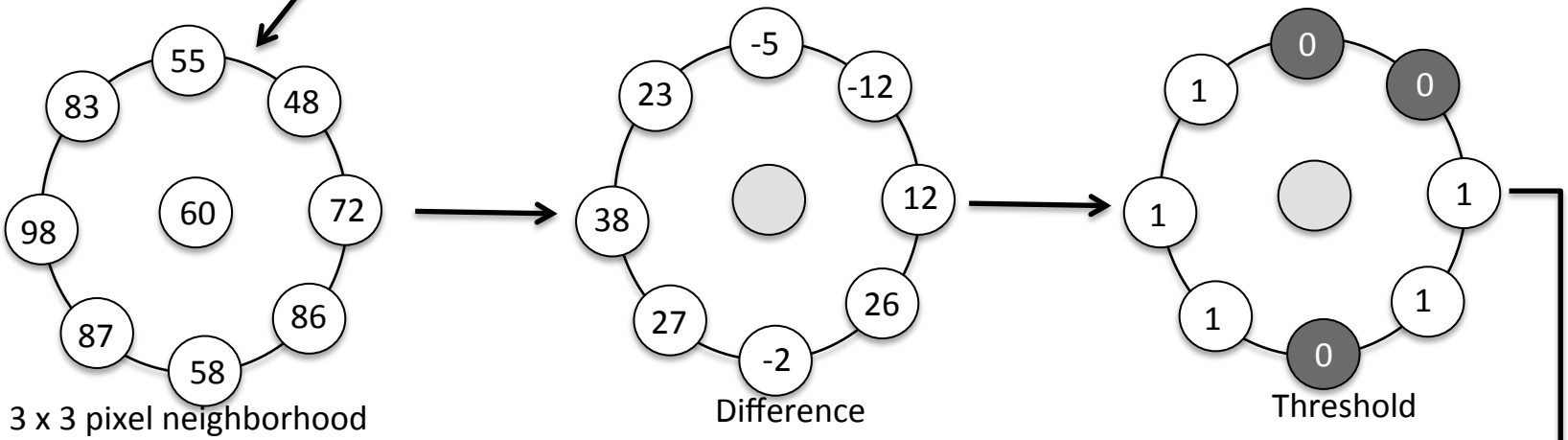
- There is a need to know when and how to best leverage cloud computing for biometric applications.
- There is also a need to characterize the risks and benefits of using cloud computing for biometric systems.
- Goal: To demonstrate the ability to leverage CC services for mobile biometrics, while still maintaining the privacy of the underlying biometric database.
- Developed a proof of concept demo featuring:
  - Facial recognition based on the LBP algorithm.
  - Homomorphic templates to protect privacy of individual's biometrics.

Enrollment – Secure model generation



Local Binary Patterns (LBP)-based template generation





$236 = (2^7*1 + 2^6*1 + 2^5*1 + 2^4*0 + 2^3*1 + 2^2*1 + 2^1*0 + 2^0*0)$ ← $(11101100)_2$

Template generation contd.,

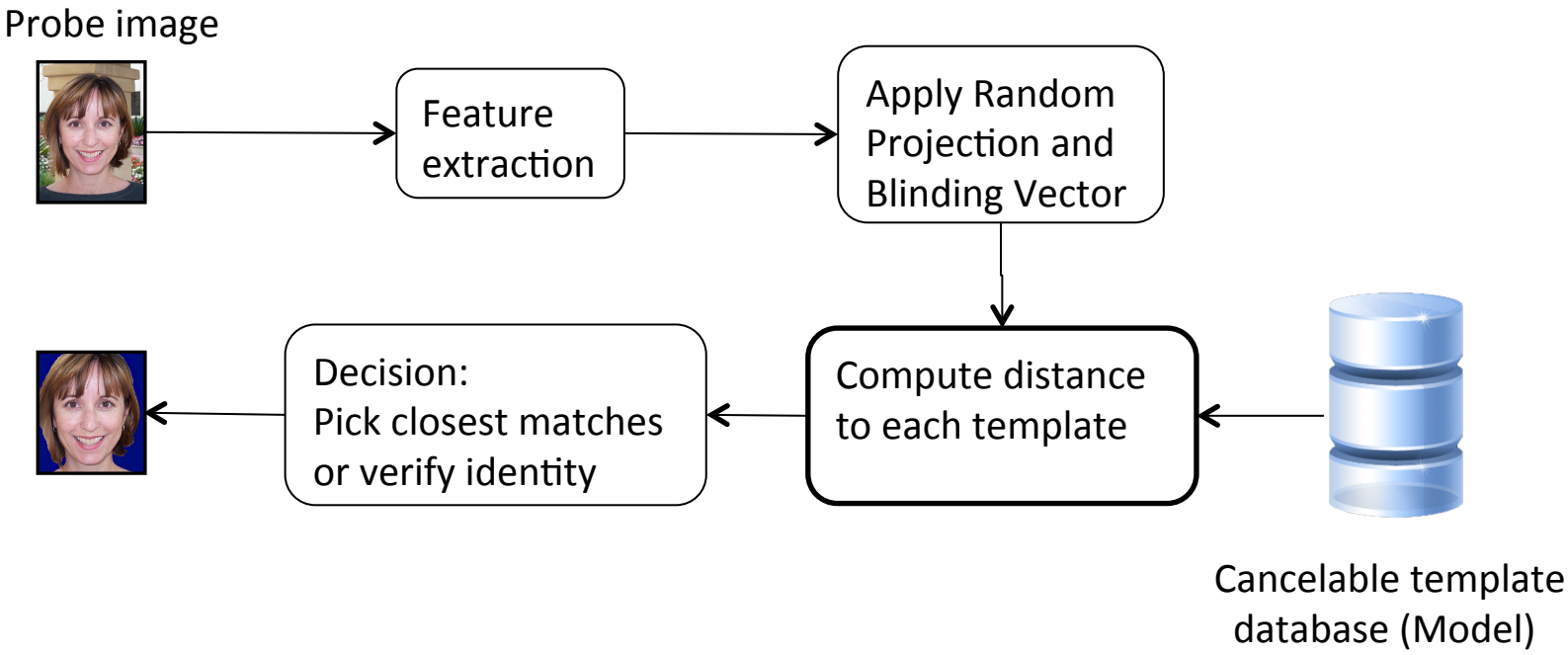
- **Uniform LBP**
  - e.g. 01110000, 11001111 ➔ at most 2 bitwise transitions
  - Each uniform pattern a separate label.
  - All non uniform patterns have a single label.
  - Total labels: P (P − 1) + 3; P = # neighbors

Template generation contd.,

- **Cancelable template generation:** cancelable template for template, h is generated using,
  - an l x l orthonormal matrix, A.
  - (for additional security, an l x l *secret permutation matrix, P* and a length l *blinding vector, b).*

$$y = \left(AP\right)h + b = Qh + b$$

Face recognition



Transformed template matching

- For a transformed probe template, z = Qx+b, and a transformed gallery template y_j, Euclidean distance is

$$d_j^2 = \left\| z - y_j \right\|$$

- Distance between templates before and after transformation is preserved because of orthogonal nature of matrix Q.
- The closest image $\hat{I}_j$

$$j = \arg\min_j \left\{ d_j \right\}$$

- Identification
  - The subject corresponding to the closest template.
  - A ranked list of matches can be provided to the user.

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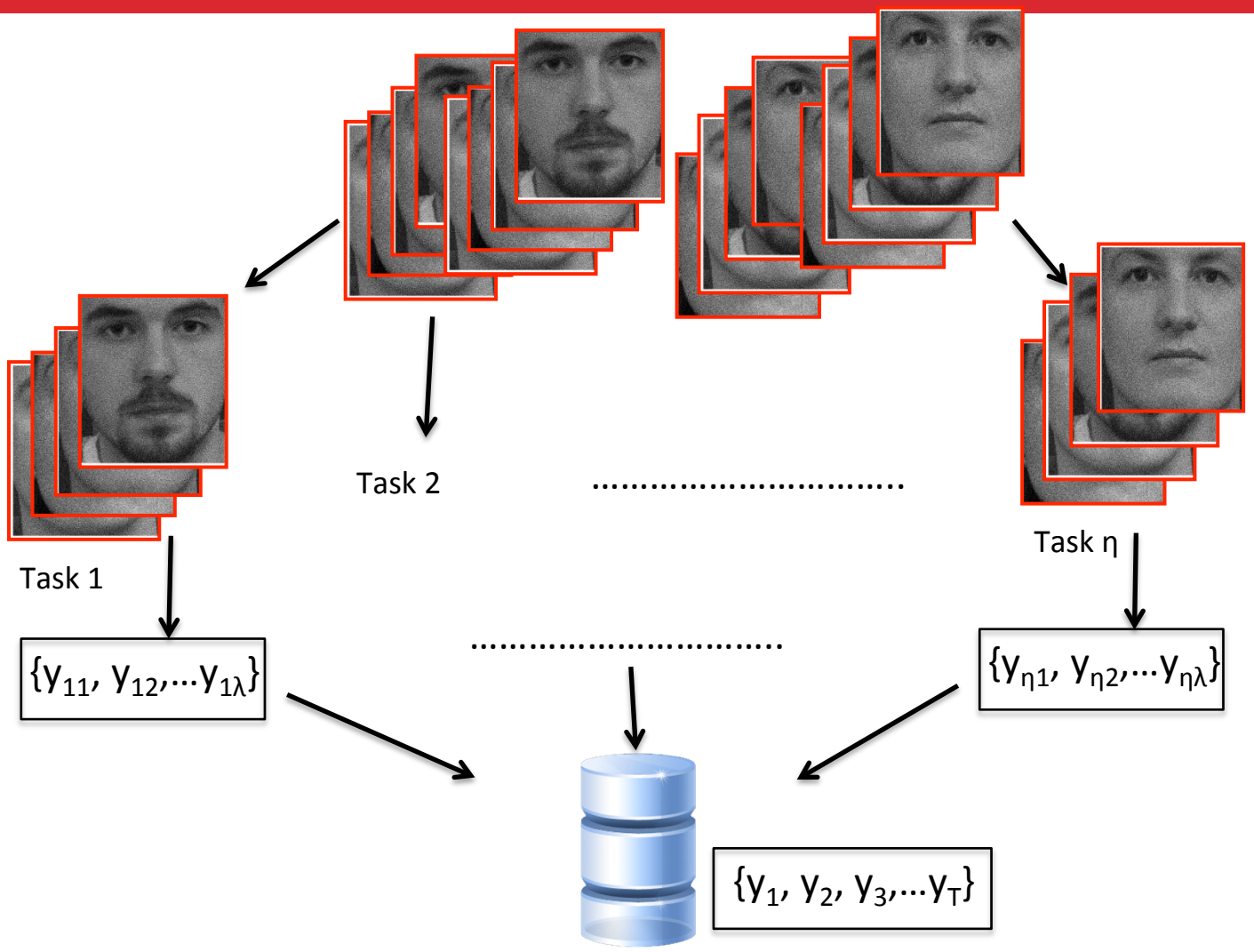
Parallel biometric template generation



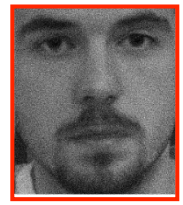
1. Face images database

2. Task division

3. Generate cancelable templates

4. Cancelable template data model

Parallel distance matching



Probe image

Cancelable template, z

Model

$(z, \{y_1, y_2, y_3, \ldots y_T\})$

$(z, \{y_{11}, y_{12}, \ldots y_{1\lambda}\})$

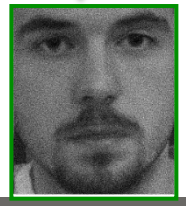
Task 1

$(z, \{y_{\eta 1}, y_{\eta 2}, \ldots y_{\eta\lambda}\})$

Task η

$\{d_{11}, d_{12}, \ldots d_{1\lambda}\})$

$\{d_{\eta 1}, d_{\eta 2}, \ldots d_{\eta\lambda}\}$



1. Preprocessing

2. Task division

3. Calculate distance

4. Establish identity

System framework

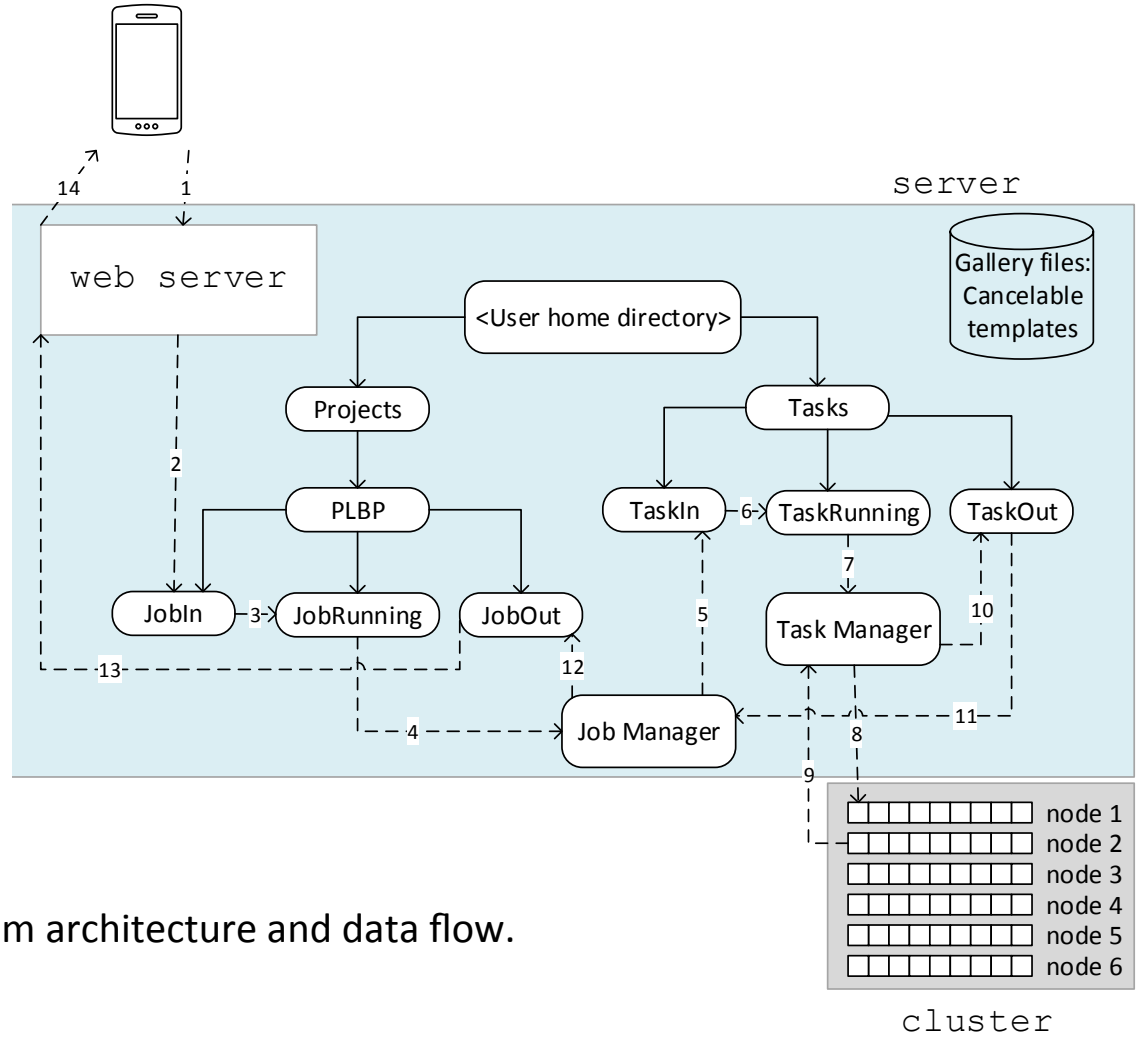


Figure: System architecture and data flow.

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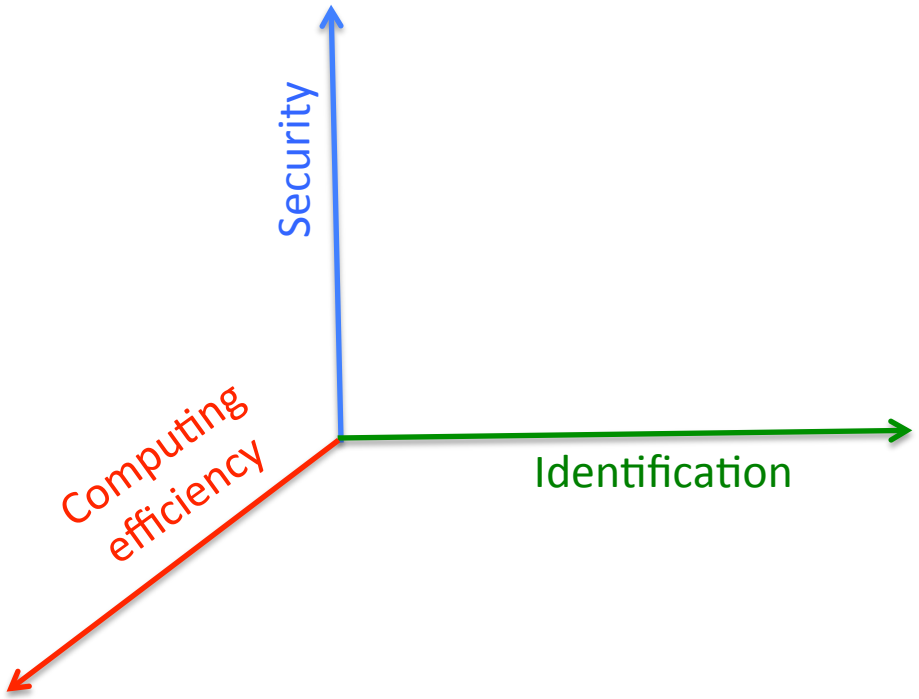
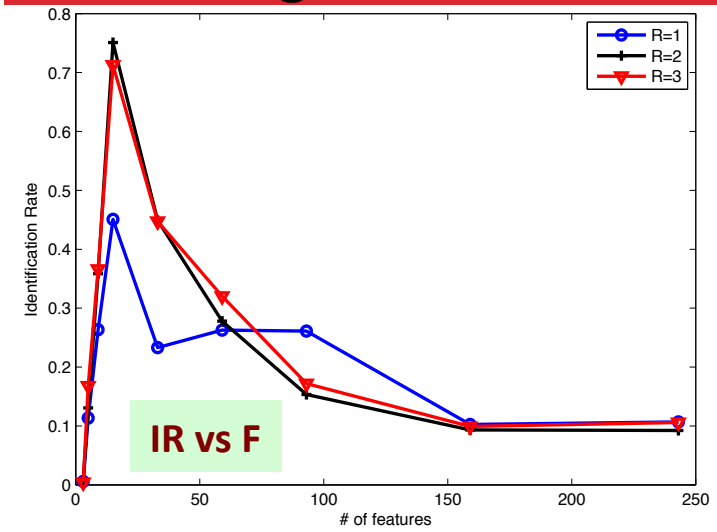
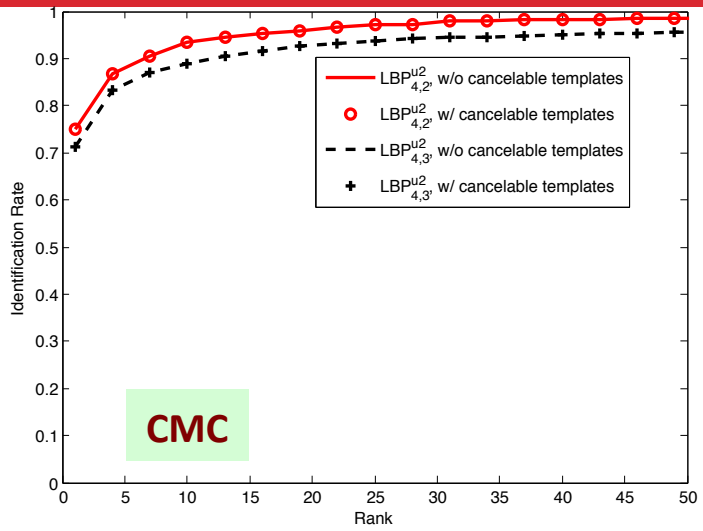
System analysis

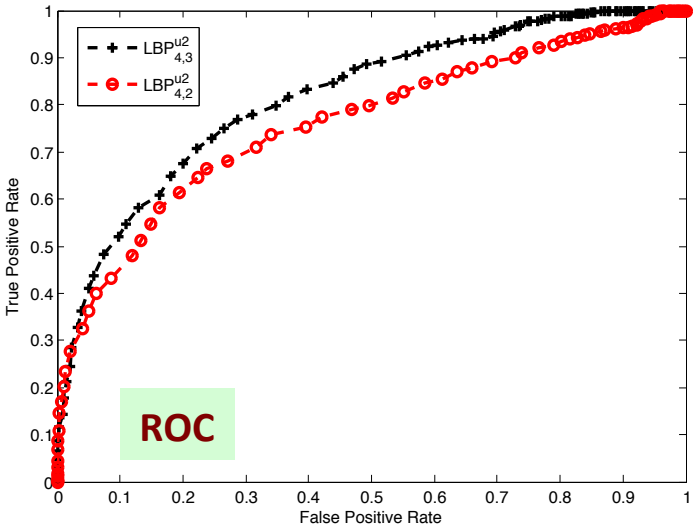


Identification system analysis -XM2VTS database and uniform LBP algorithm





Cumulative match characteristic (CMC)

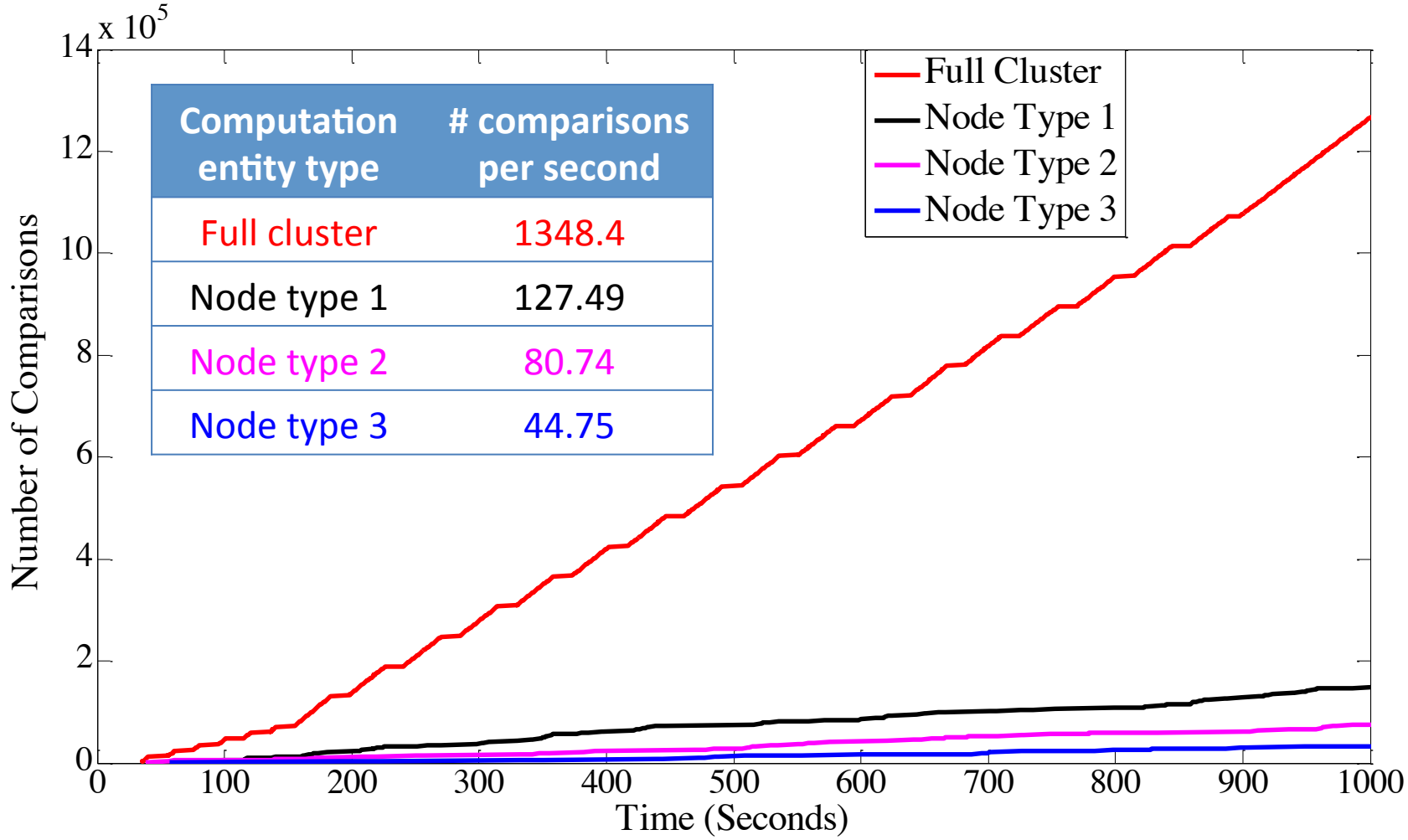


--Best LBP parameters (P,R) are found through experimentation.

--Use of cancelable templates does not noticeably degrade the matching performance

Computational performance

Computation entity type	# comparisons per second
Full cluster	1348.4
Node type 1	127.49
Node type 2	80.74
Node type 3	44.75



Security assessment

- A single key is used to create the cancelable templates.
  - The key is kept secure by generating a hash value using bcrypt.
  - The key cannot be derived from the templates.
- Vulnerabilities if key is compromised
  - If the key is known, the native template could be derived.
  - However, original picture gallery is not compromised.
  - The key should be periodically changed to prevent its compromise.
- Steps to take if templates are compromised.
  - Just need to change the key and generate new templates.
- Matched images stored in user's cache.
  - Should be periodically cleared and/or encrypted.

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Conclusion and Observations

- By leveraging cloud services, biometric operations can be parallelized to improve the system performance computationally.
- Secure storage of massive biometric data on the cloud is possible using biometric template protection techniques.
  - An approach for generating cancelable templates allows templates to be fully revocable with negligible loss on matching accuracy.
- Multiple mobile devices can be supported by interfacing through a mobile-friendly web application

Future work

- Address scalability issues.
- Formulate key-management and access policies.
- Reduce latency through improved implementation.
- Integrate improved identification algorithms.
- Extend to other modes and other applications.

Thank you for your attention.

Questions?

References

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