



BINARY FINGERPRINT FEATURE VECTOR REPRESENTATION

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TURBINE WORKSHOP 2011



Motivations of the work.

- joint work with Mélanie Favre & Julien Bringer (Morpho)
- **Problematic:**
 - Variability of fingerprint acquisition
 - Classical fingerprint comparison approach is geometrical
- **Goal:**
 - Postpone as many calculus as possible during the feature extraction process
 - Have a comparison between 2 templates as simple as possible (XOR, AND,...)
- **What for:**
 - to be combined with template protection techniques (Secure sketches, Comparison embedded in the encrypted domain)

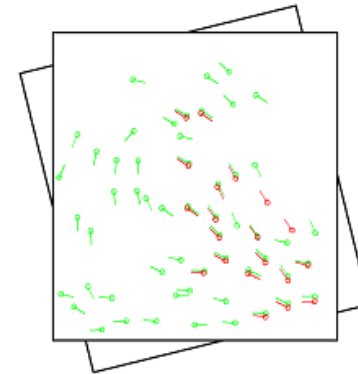
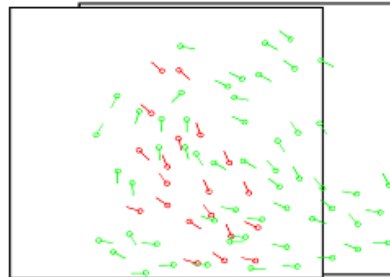
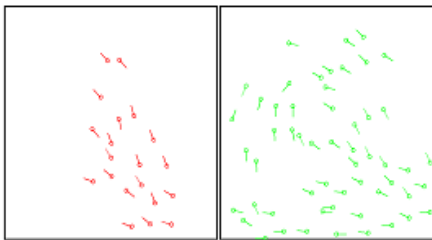


Classical fingerprint comparison.

■ How fingerprint are classically matched?

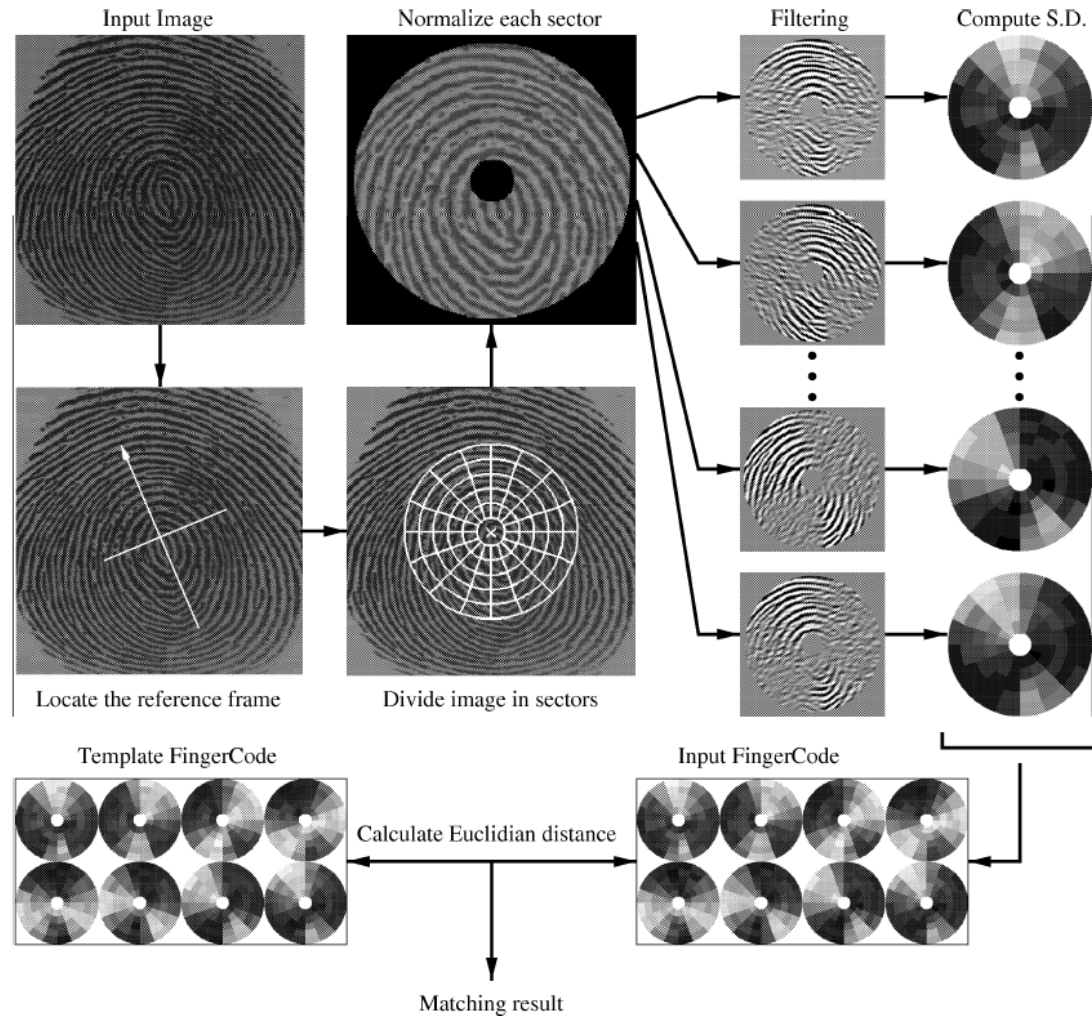
- Input: a set of minutiae.
- Output: a score.

■ Classical approach: Find the best translation which over impose the best the two clouds of minutiae and then build a score with the paired minutiae



Global information approach: Fingercodes.

- **FingerCode: A filterbank for fingerprint representation and matching:** A. Jain, S. Prabhakar, L. Hong, S. Pankanti
- **Idea: defining a fingerprint by its directional field around the core**



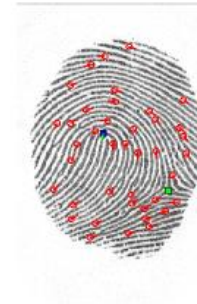
Local information approach: Spectral Minutiae.

Complex Spectral Minutiae Representation for Fingerprint Recognition,

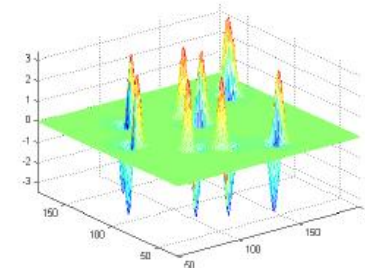
H. Xu, R. Veldhuis

Idea:

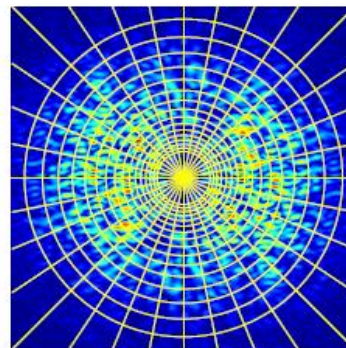
- Code the minutiae of a fingerprint as a gaussian (or other type of functions)
- 2D Fourier transform (to get translation invariance)
- log polar representation



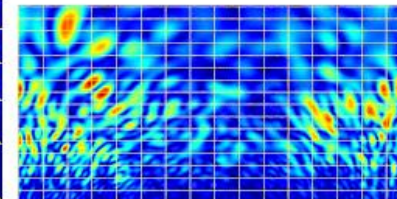
(a)



(b)



(c)



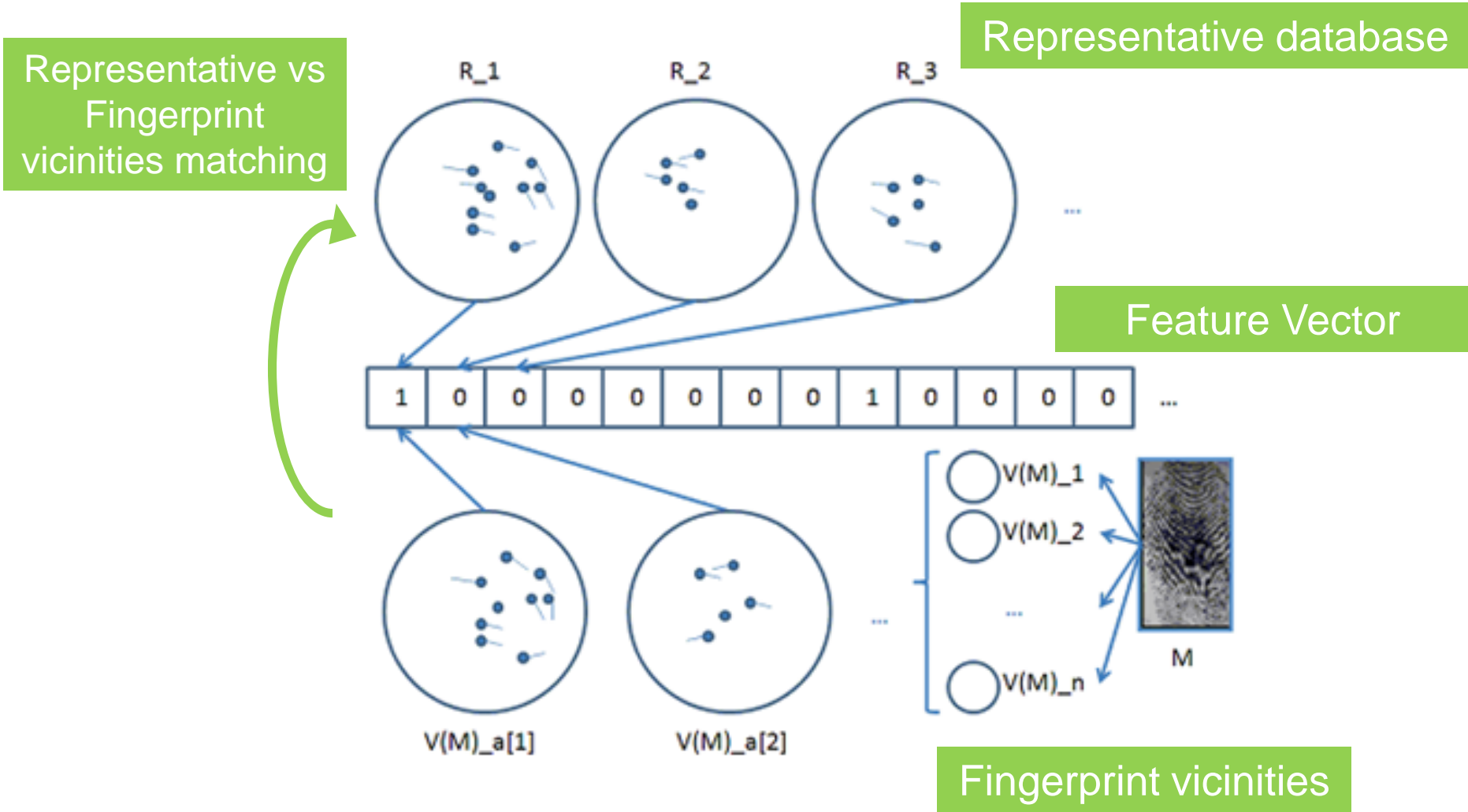
(d)

Constraints

- Matching as simple as possible (the major part of the calculation should be done during the encoding)
- Minutiae based methods (both for performances and internal Turbine inter operability constraints)
- No registration needed (No absolute alignment required)



General Overview.

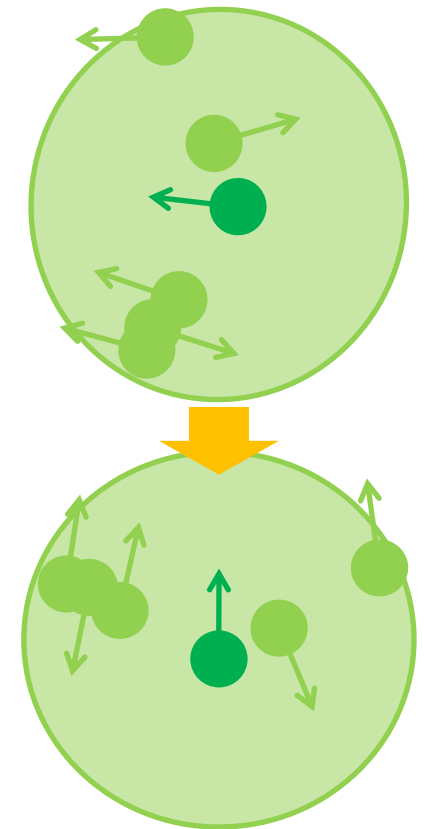
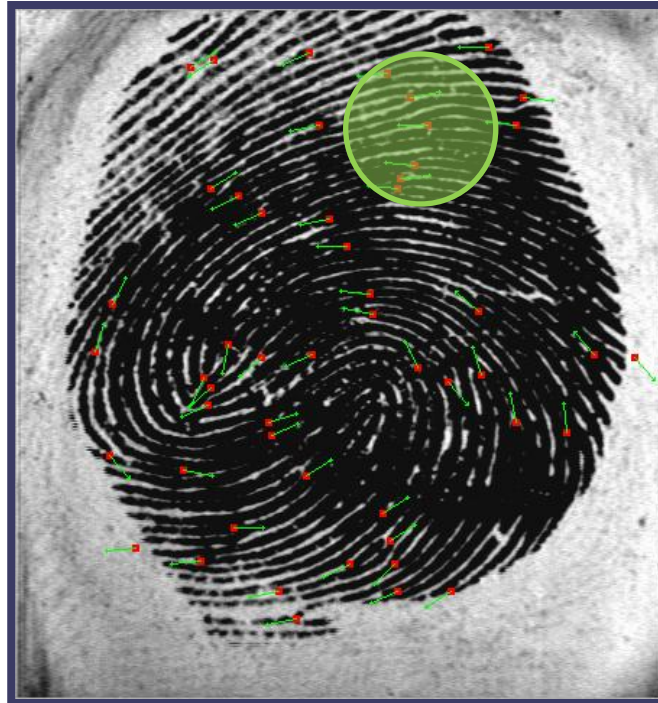


Minutiae vicinities.

- A fingerprint would be defined by its similarity between its minutiae vicinities and a set of representative vicinities

- **Fingerprint Vicinities extraction**

- Set of minutiae at most at a given distance D from a given minutia (called central minutia).
- Absolute coordinate system defined by the central minutia.

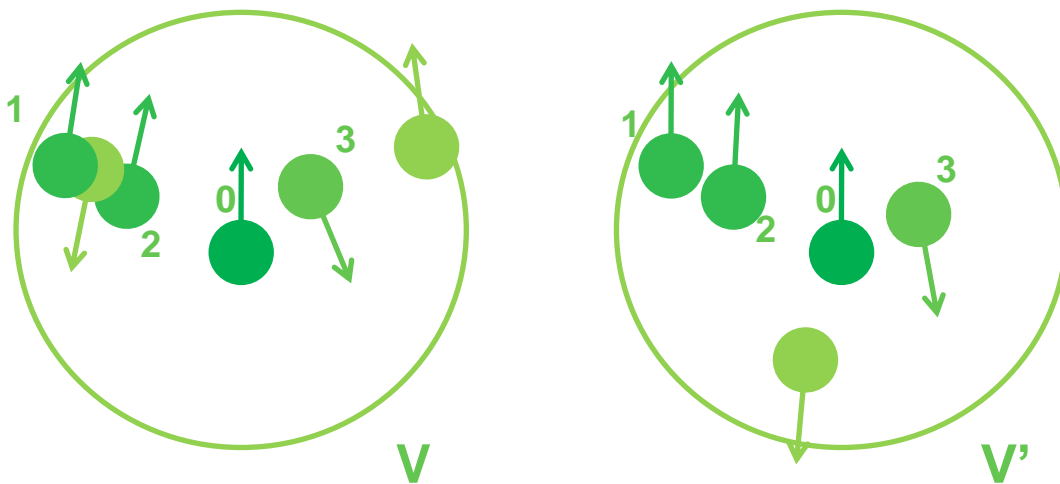


Comparison between vicinities.

■ Lets 2 vicinities $V = \{p_1, \dots, p_{l_V}\}$ and $V' = \{q_1, \dots, q_{l_{V'}}\}$

- As the vicinities are already in a absolute coordinate system, a pairing score between minutiae of V and V' can be easily defined

$$\mu(p_i, q_j) = e^{-\frac{(x_{p_i} - x_{q_j})^2}{\sigma_x^2}} e^{-\frac{(y_{p_i} - y_{q_j})^2}{\sigma_y^2}} e^{-\frac{(\theta_{p_i} - \theta_{q_j})^2}{\sigma_\theta^2}}$$



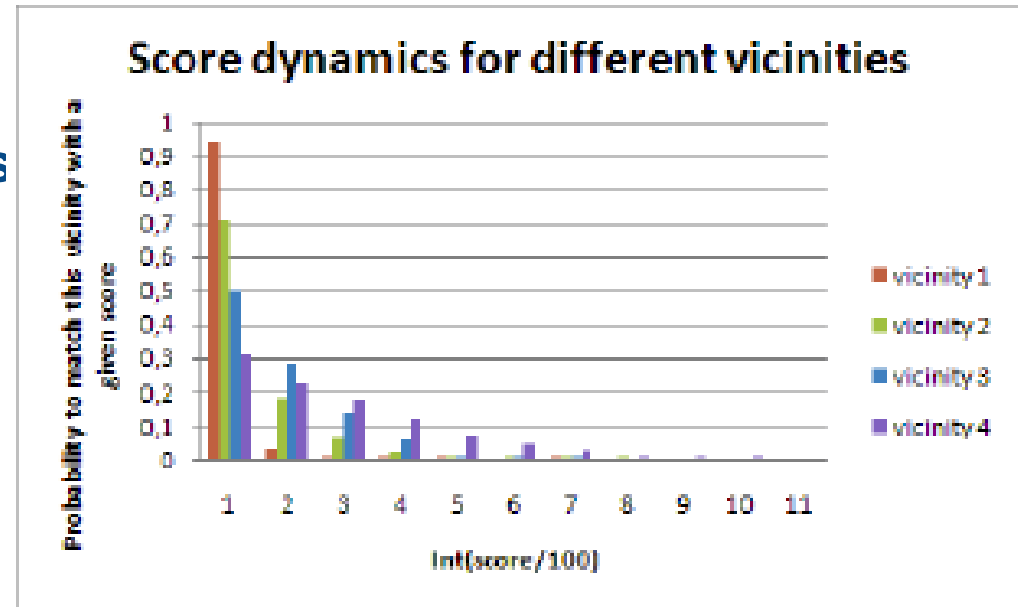
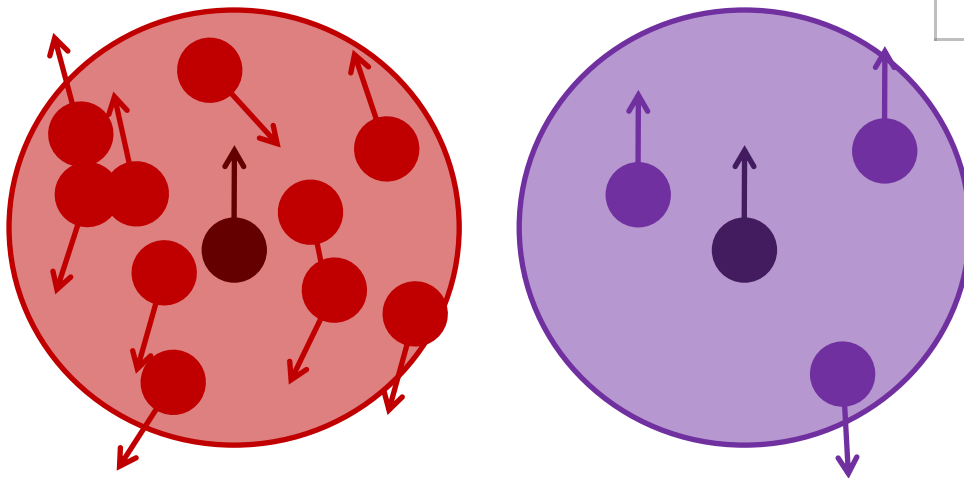
- The global matching between 2 vicinities: **classical global pairing problem** (Munkres algorithm).
- **Non associated minutiae penalize** the global pairing score between vicinities

Vicinities representative database.

- **Goal: Span as accurately as possible the space of all possible vicinities in the « world of fingerprint »**
 - Start with a large external fingerprint database
 - Extract all the vicinities of the fingerprint in the database
 - The radius D of the vicinities can be seen as a trade-off between performances and the number N of vicinities needed to span densely the space of all existing vicinities.
- **Problematic: how to densely represent the space of vicinities while remaining small enough?**

Discriminative power of representative vicinities.

- **Normalisation of the matching scores of representative vicinities**
 - ✓ High/Low curvature area
 - ✓ Dense/Sparse vicinities
- **R_i compared with another set of representative vicinities to build each score histograms**





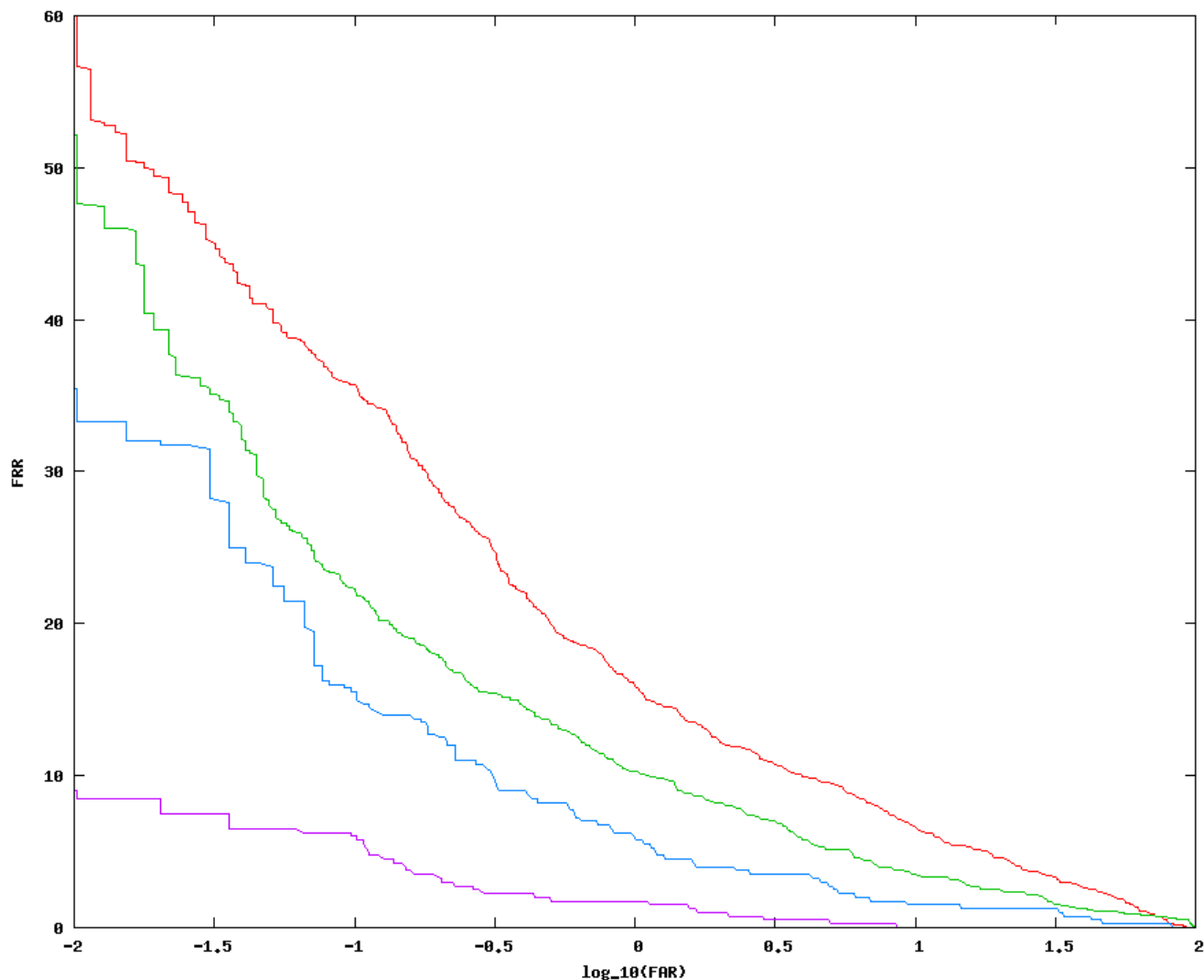
Binarization & Comparison of Feature Vectors

- Histograms are used to determine binarization thresholds so that each component of the vector has a probability of p to be a 1.
- Comparison of 2 Feature Vectors: straightforward
 - AND between the 2 Features vectors.
 - Normalization using the Hamming weight of each Feature Vector

$$Sc(FV(\mathcal{M}), FV(\mathcal{M}')) = \frac{\sum_{i=1}^N (FV(\mathcal{M})_i \text{ AND } FV(\mathcal{M}')_i)}{K + \min(\sum_{i=1}^N FV(\mathcal{M})_i, \sum_{i=1}^N FV(\mathcal{M}')_i)}$$

- Multi Acquisition scenarios: Simple and give the opportunity to keep the same size for the Feature Vector

Performances.



- FVC2000-DB2. Mono-acquisition scénario.**
- FVC2002-DB2. Mono-acquisition scénario.**
- FVC2000-DB2. Multi-acquisition scénario. (Enroll 4, Verif 1)**
- FVC2002-DB2. Multi-acquisition scénario. (Enroll 4, Verif 1)**
- Additional tests on various internal DB.**

Additional information

- Use of additional information to add « global coherency » to the feature vector.

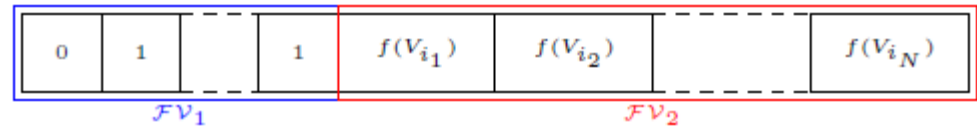


Figure 4. Binarized feature vector

- **Encoding**

- ✓ Classical Feature Vector
- ✓ Properties on the FP of the vicinities which match the best with the representative

- **Matching**

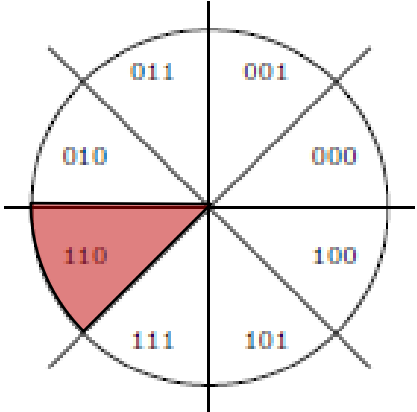
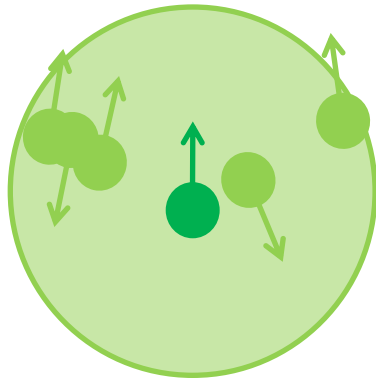
- ✓ Remain globally as simple as possible
- ✓ Distance between local descriptor δ_i should be simple too (Hamming distance)

$$s = \frac{\sum_{i=1}^N (\mathcal{FV}_1(\mathcal{M}) \wedge \mathcal{FV}_1(\mathcal{M}')) \times g(\delta_i)}{K + \min(\sum_{i=1}^N \mathcal{FV}_1(\mathcal{M}), \sum_{i=1}^N \mathcal{FV}_1(\mathcal{M}'))}$$

$$\delta_i = d(\mathcal{FV}_2(\mathcal{M})_i, \mathcal{FV}_2(\mathcal{M}')_i)$$

Additional information

- Additional information as the **absolute position or orientation** to add « global coherency » to the feature vector.
 - Fingerprint roughly correctly oriented.
 - Quantization of the additional information.



	00	10	11	01
00				
10				
11				
01				

Angle as Additional Information

How to use the angle of the central Minutiae?

- Quantization of the additional information.
- Constraint to keep the comparison simple (Gray code)
- Matching $\text{HW}(\text{H}(\theta_a) \otimes \text{H}(\theta_b))$

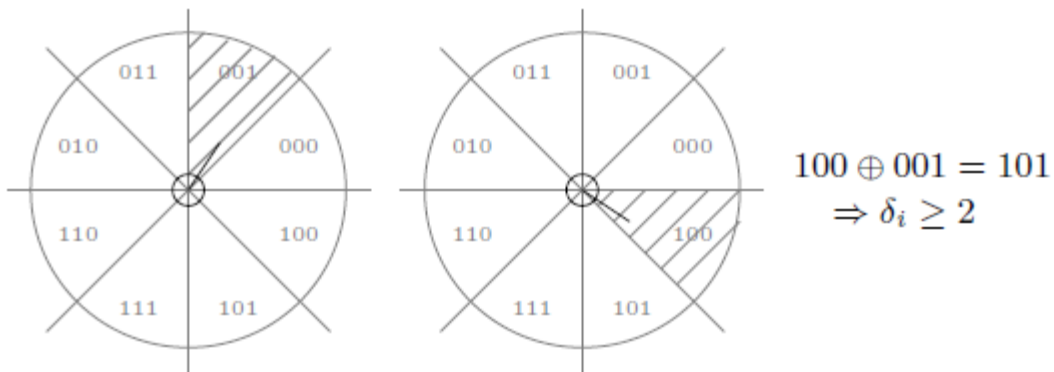
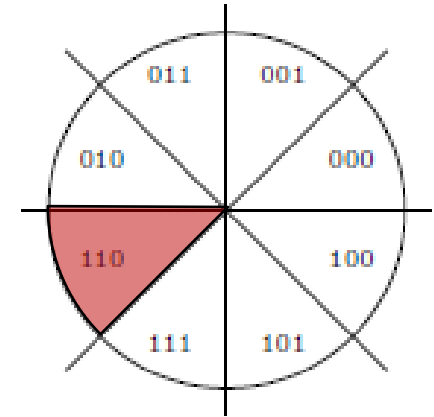
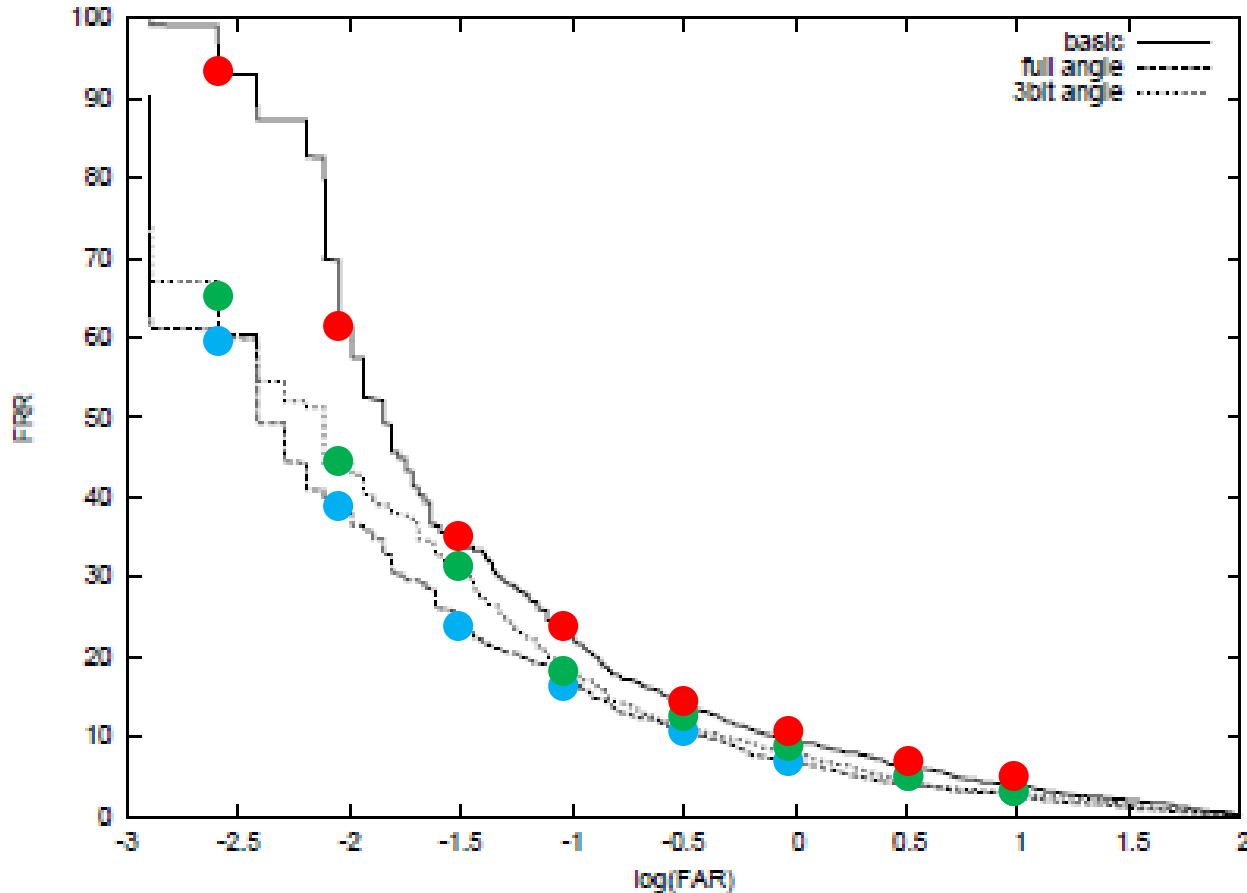


Figure 9. Angle difference evaluation using a Gray code

Performances.



- FVC2000–DB2.**
Mono-acquisition
scénario.
- FVC2000–DB2.**
Mono-acquisition
scénario. Angle 3bits
- FVC2000–DB2.**
Mono-acquisition
scénario. Angle Full

Bringer, J. and Despiegel, V., Binary feature vector Fingerprint representation from minutiae vicinities, BTAS'10. (2010).

Bringer, J. Despiegel, V. and Favre, M. Adding Localization Information in a Fingerprint Binary Feature Vector Representation, SPIE'11. (2011).

Conclusion.

■ New method to convert fingerprint to given size Feature Vector.

➤ Advantages

- ✓ Self aligned.
- ✓ Multi-acquisition straight-forward.
- ✓ Comparison as simple as possible. (the heavy computations done during FV construction)

➤ Proof of concept. Loads of work could be done to improve each step of the FV construction (representative DB selection, binarization)

➤ technique conceived within TURBINE.

■ Secure access control approach.

➤ Possibility to build a filtering technique based on this approach for a secure access control.

- ✓ To be presented later by Julien Bringer

➤ One demonstrator of Turbine project.

Thank you

