Deformable Multi-Scale Scheme For Biometric Personal Identification

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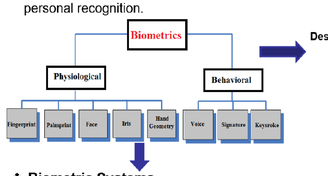
Introduction

Biometrics..... Something you are!

- Biometrics stands for measuring human's biological features for personal recognition.



Desirable properties

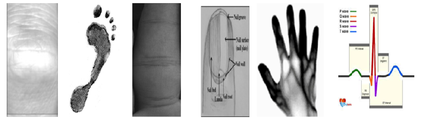
- Universality
- Uniqueness
- Permanence
- Collectivity
- Acceptability
- Circumvention
- Performance

Biometric Systems

- **Authentication Problem/ Verification :** One to One matching and decide using thresholding.
- **Identification Problem/ Recognition :** One to Many matching and best matching scores and corresponding subjects are reported.

Traits and Challenges

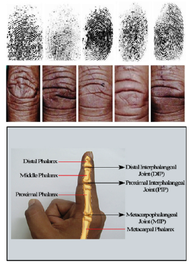
- **FACE**: Expression, Illumination, Pose, Occlusion, Ageing.
- **IRIS**: Occlusion, Specular reflection, User Co-operation, Difficult to acquire and Very expensive acquisition sensors.
- **FINGERPRINT**: Fail to acquire specially for cultivators and workers, low public acceptance as connected to criminals.
- **EAR**: Occlusion, Illumination.
- **Palmprint**: Illumination, rotation, translation
- **NEW TRAITS**: Nailbed, Knuckle pattern, Foot print, Vein Pattern etc.



Problem Statement

- Hand based biometric systems are in great demand. Hand properties: impression, geometry, veins, lines, texture
- Several hand biometric traits have been studied such as palm print, hand shape/geometry, palm vein, finger knuckle pattern, nail bed, fingerprint, finger geometry.
- Applications: immigration, border control, dormitory meal plan, time and attendance, ATM transaction etc.
- Capability to deal with low resolution (<100 dpi) features, economic and small size camera.
- Additional facility to acquire multiple features together.
- Invariant to Emotions, aging, non-intrusive, Lesser User Cooperation

Motivation



- **Finger Knuckle patterns:** refers to the curve shape skin patterns (highly rich lines and creases) lie over the finger dorsal surface specifically at finger joints.
- **Types:** Lower Minor Finger Knuckle; Major Finger Knuckle; Upper Minor Finger Knuckle

Pros of Finger Knuckle

- Unique and permanent among individuals.
- No obstruction, inexpensive sensors.
- Cultivators and workers have the equally good quality patterns as others.
- No risk of imposter attacks
- Invariant to emotions and other behavioral aspects

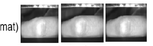
Cons of Finger Knuckle

- Less Benchmark Datasets

Ajay Kumar. "Importance of being unique from finger dorsal patterns: Exploring Minor Finger Knuckle Patterns in verifying Human Identities." IEEE transactions on information forensics and security 9.8 (2014): 1288-1298.

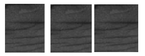
Finger Knuckle Image Databases

- **PolyU FKP Database:** Biometric Research Center at **Hong Kong Polytechnic University**.
  - Total Distinct Subjects = 165 (125 male/ 40 female)
  - 4 fingers per subject (LI,LM,RI,RM) = 165 x 4= 660 fingers
  - 12 images per subject = 660 x 12 (7920 images in BMP format)



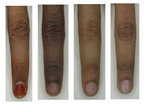
FKP Sample Database Images

- **IIT Delhi Finger Knuckle Image Database:** Biometrics Research Laboratory at IIT Delhi.
  - Total Distinct Subjects = 158
  - 5 images per subject = Total 790 images in BMP format
  - Age Group= 16-55



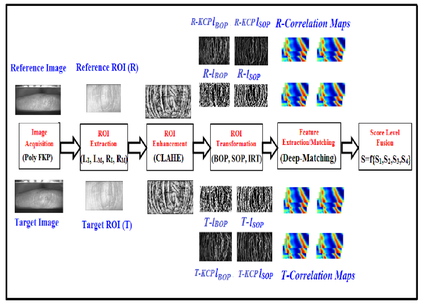
FKI Sample Database Images

- **PolyU Contactless Finger Knuckle Image Database:**
  - Images = Middle Finger Dorsal
  - 5 images per subject= 2515 (BMP format)
  - Total Subjects = 503
  - Age Group= 88% of the subjects are younger than 30 years

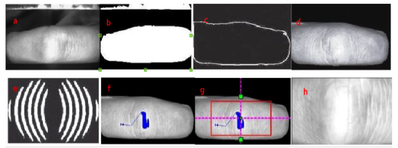


FKI Sample Dataset Images

Proposed Architecture



ROI Extraction and Enhancement



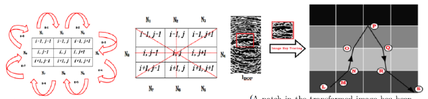
(FKP ROI extraction)

(a) Original, (b) Binary Sample, (c) Boundary, (d) FKP area, (e) Knuckle filter, (f) Filter response, (g) Localized ROI (h) Final ROI.

(Proposed Image Enhancement for FKP images (Difference between Additive Vs Multiplicative noise)

(a) I_{ROI} (b) Steady Ill. (c) En. (Additive) (d) En. (Multi.) (e) De-noised

Finger Knuckle Image Transformations



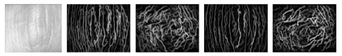
(Neighborhood pattern considered for image transformation)

(A patch in the transformed image has been enlarged to explain Image Ray Tracing)

(a) BOP Pattern (b) SOP Pattern (c) Image Ray Transform

(a) I_R (b) I_{BOP} (c) I_{BOP} (d) I_{SOP} (e) I_{SOP}

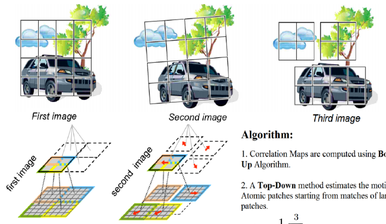
(BOP and SOP based Image Transformation and Encoding Schemes)



(a) I_R (b) KCP_{BOP} (c) KCP_{BOP} (d) KCP_{SOP} (e) KCP_{SOP}

(Image Ray Transformation based Transformation)

Deep Matching Methodology



Algorithm:

1. Correlation Maps are computed using **Bottom-Up** Algorithm.
2. A **Top-Down** method estimates the motion of Atomic patches starting from matches of large patches.

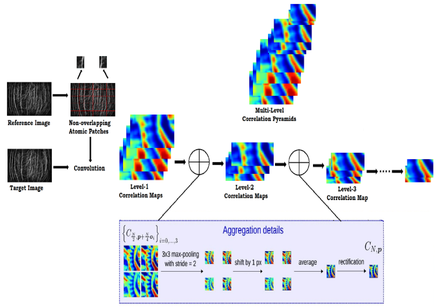
- We allow each subpatch to move:
  - independently
  - in a limited range depending on its size
- fast to compute using convolution and max-pooling

$$\mathrm{sim}(\mathbf{R},\mathbf{R}') = \frac{1}{4}\sum_{i=0}^{3} \max_{p_i} \mathrm{sim}\left(\mathbf{R}_i, \mathbf{R}'_i(p_i)\right)$$

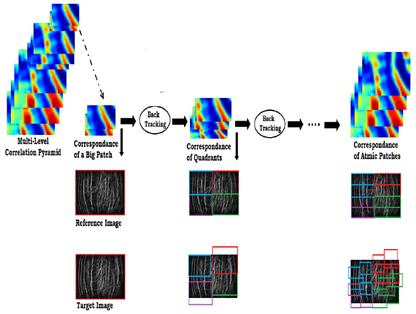
$$C_{N,\mathbf{p}}(\mathbf{p}') = \frac{1}{4}\sum_{i=0}^{3} \max_{\mathbf{m}' \in \theta_i} C_{\frac{N}{2},\mathbf{p}+s_{N,i}}(\mathbf{m}')$$

*Revaud Jerome, et al. "Deepmatching: Hierarchical deformable dense matching." International Journal of Computer Vision 120.3 (2016): 300-323.

FKI - Deep Matching (Bottom Up)



FKI - Deep Matching (Top Down)

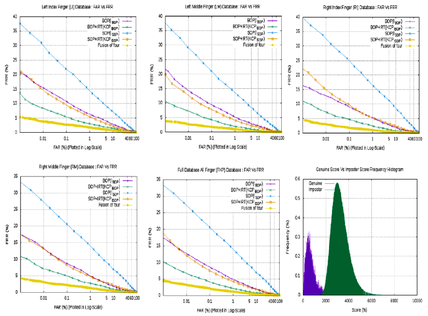


Parametrization

Table: Description and nature of parameters

Parameter	Default value	Description	Operating Range	Nature
		ROI Extraction		
Threshold	0.8	Otsu generated	0.3-0.9	High
c	0.01	The curvature term	0.0-0.04	Low
d	30	Distance between two gabor (Empirical)	0-50	Moderate
f	0.75	Fraction to binarize the response	0.45-0.95	High
		CLAHE		
f_{scale}	0.5	Scaling down	0.4-0.6	Moderate
Block Size	10 × 10	Blocking, selected empirically	(8 × 8)-(16 × 16)	Low
		GOP/SOP		
Sobel Kernel	9 × 9	Blocking to compute gradient (for thick features)	(3 × 3)-(11 × 11)	High
		DeepMatching		
Patch Size	4 × 4	Atomic Patch size	2 × 2-16 × 16	Low
Maxpooling	3 × 3	Max-pooling with a stride of 2	(3×3)-(9×9)	Low
Rectification	1.4	Gamma correction power factor	1-2	Moderate
Rotation	-26° to +26°	Rotational Invariance	-30° to +30°	High

ROC based Performance Analysis



Comparative Performance Analysis

Comparative Analysis over FKP Database

	Full FKP db		Left Index		Left Middle		Right Index		Right Middle	
Algorithm	EER	(%)CRR	EER	(%)CRR	EER	(%)CRR	EER	(%)CRR	EER	(%)CRR
Compcode [28]	1.386	-	1.884	-	1.883	-	1.445	-	1.175	-
BOCV [8]	1.833	-	2.202	-	2.299	-	1.892	-	1.647	-
ImCompcode+MapCode[30]	1.210	-	1.610	-	1.650	-	1.326	-	1.097	-
MonCode [7]	1.201	-	1.544	-	1.698	-	1.605	-	1.244	-
MtexCode [7]	1.816	-	2.077	-	2.078	-	2.115	-	2.055	-
MonCode and MtexCode [7]	1.0481	-	1.328	-	1.453	-	1.247	-	1.063	-
DeepMatching I^{GOP}	2.12	99.34	2.88	98.67	2.02	99.64	2.15	99.59	2.36	98.91
DeepMatching I^{SOP}	3.67	98.66	4.67	98.21	3.99	98.98	3.71	98.86	3.96	99.01
DeepMatching I^{SOP}	3.11	98.42	3.98	98.43	3.64	98.99	3.98	99.11	3.70	98.64
DeepMatching I^{SOP}	7.63	96.61	8.91	96.01	7.34	96.01	9.32	94.01	7.96	98.98
DeepMatching Proposed Fusion	**0.98**	99.10	**1.21**	99.03	**1.13**	100	**1.18**	100	**0.96**	99.33

Timing Analysis

Stage	Knuckle (ms)
ROI Extraction	198
I_{BOP} and I_{SOP} Generation	14.96 × 2 = 29.92
KCP_{BOP} and KCP_{SOP} Generation	141.6 × 2 = 283.2
I_{BOP} and I_{SOP} Matching	56.4 × 2 = 112.8
KCP_{BOP} and KCP_{SOP} Matching	65.3 × 2 = 130.6
Fusion of all codes	2.3
Total Single Matching Time	**756.82**

Inferences

- A biometric system is proposed that can be suitable to enable financial inclusion of rural community, based on score level fusion of multiple FKP features.
- Samples are transformed using novel BOP, SOP, IRT schemes to obtain robust image representations and are matched using a hierarchical Deep-Matching.
- The PolyU FKP benchmark data-set has been used for performance evaluation and as compared with other state of art methods have achieved superior results.
- In future work, we will try to incorporate Minor Finger Knuckle Patterns and will test our algorithm on more challenging Finger knuckle Image Datasets.