HIGH-ORDER LOCAL NORMAL DERIVATIVE PATTERN (LNDP) FOR 3D FACE RECOGNITION

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METHODS CATEGORIZATION

Face recognition: global and local feature-based Methods
Local descriptors:
prominent points, patches or regions of the face to handle facial expression, occlusion, and missing data

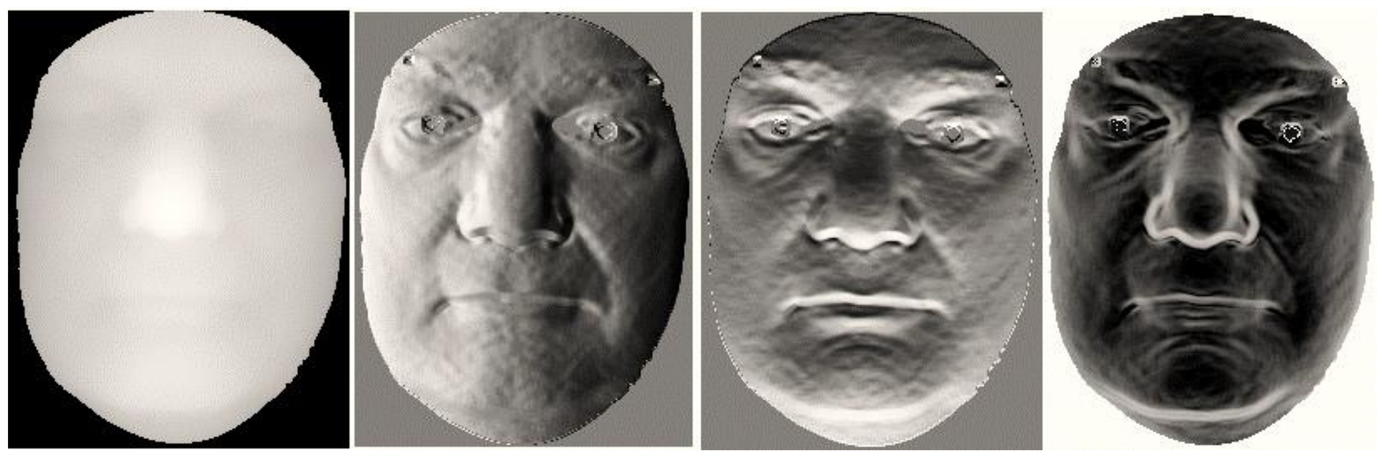
PRE-PROCESSING

- Remove spike and noises using median filter
- Hole filling by fitting square surface
- Nose detection by curvature-based method, and region of interest (ROI) cropping
- Pose correction (the iterative closest point (ICP))

SURFACE NORMAL

$P = [p_1, p_2, ..., p_n]^T, p_i \in R^3 \quad p_i = [p_{ix}, p_{iy}, p_{iz}]^T$

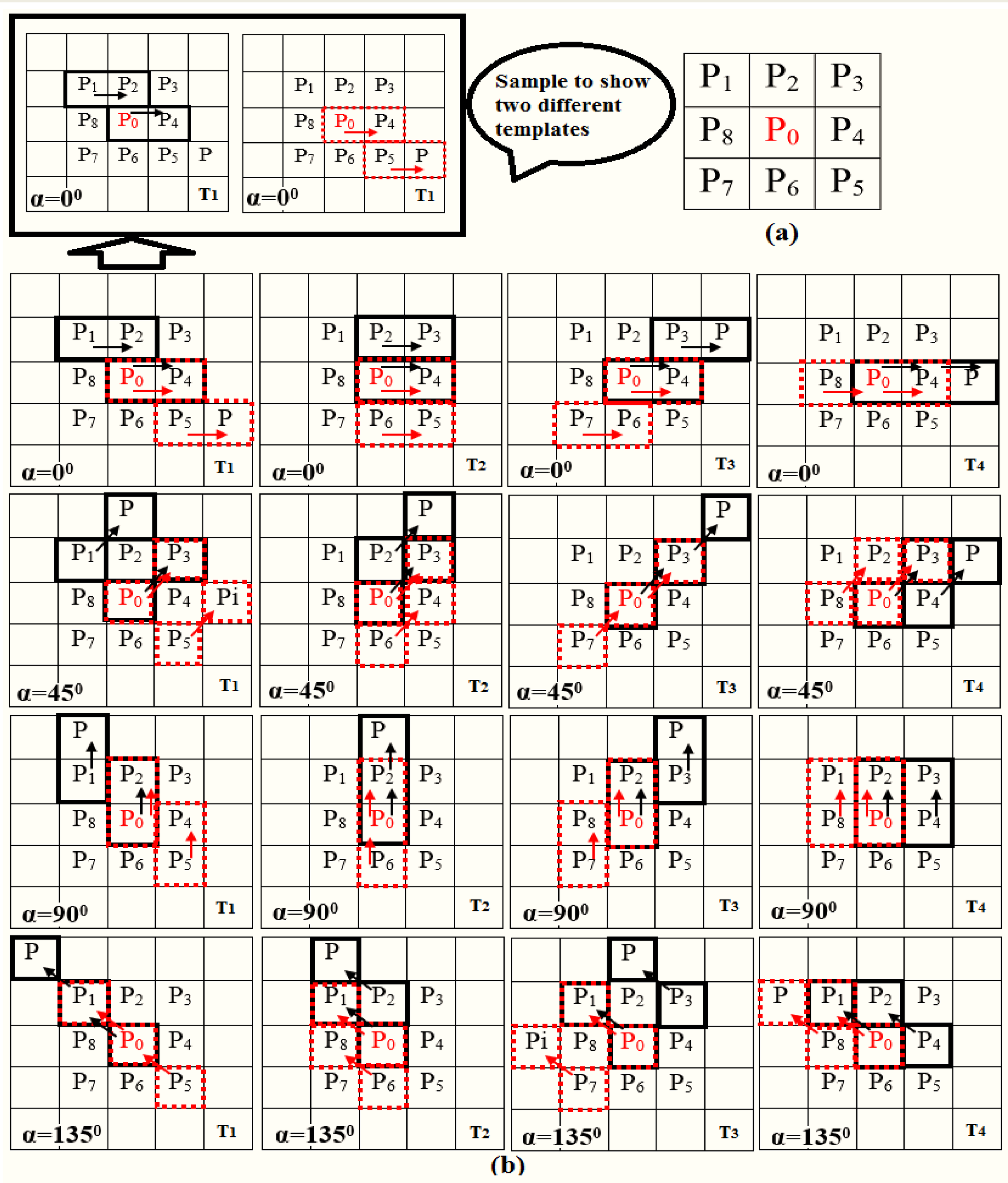
$n_i = [n_{ix}, n_{iy}, n_{iz}]^T Q_i = [q_{i1}, q_{i2}, ..., q_{il}]^T \; minA(p_i, Q_i, n_i)$



Range image, normal component x, normal component y, and normal component z

LOCAL DERIVATIVE PATTERN

LDP: encoding directional pattern features



(a) 8-neighborhood around P0
(b) 32 templates for α= 0, 45, 90, 135
The black and dashed red lines represent two different templates:
T1(i =1, 5), T2(i =2, 6), T3(i =3, 7), and T4(i =4, 8)

PROPOSED LNDP

Algorithm 1 n^{th}-order LNDP

Input: 3D face data P

for each point in P **do**
  Calculate normal components (N_x, N_y, and N_z)
end for
for each N **do**
  Divide into 10×8 patches
end for
for $alpha = 0°, 45°, 90°, 135°$ **do**
  for each patch **do**
    for each pixel in patch of N **do**
      Apply Equation (★)
    end for
    Encode $LNDP$ using Equation (★★)
    Histogram construction
  end for
  Concatenate the histogram for different patches
end for
Concatenate the histogram for different α
return $HLNDP_x^n, HLNDP_y^n, HLNDP_z^n$

The decimal value of the descriptor:

$$LNDP_\alpha^n(P_0) = \sum_{l=1}^{L} LNDP_\alpha^n(P_0) \times 2^{l-1} \quad ★★$$

Similarity:

$$S(H_G, H_Q) = \sum_{i=1}^{C} min(H_G(i), H_Q(i))$$

For a normal component the first-order derivatives:

$N'_{0°}(P_0) = N(P_0) - N(P_4) \quad N'_{90°}(P_0) = N(P_0) - N(P_2)$

$N'_{45°}(P_0) = N(P_0) - N(P_3) \quad N'_{135°}(P_0) = N(P_0) - N(P_1)$

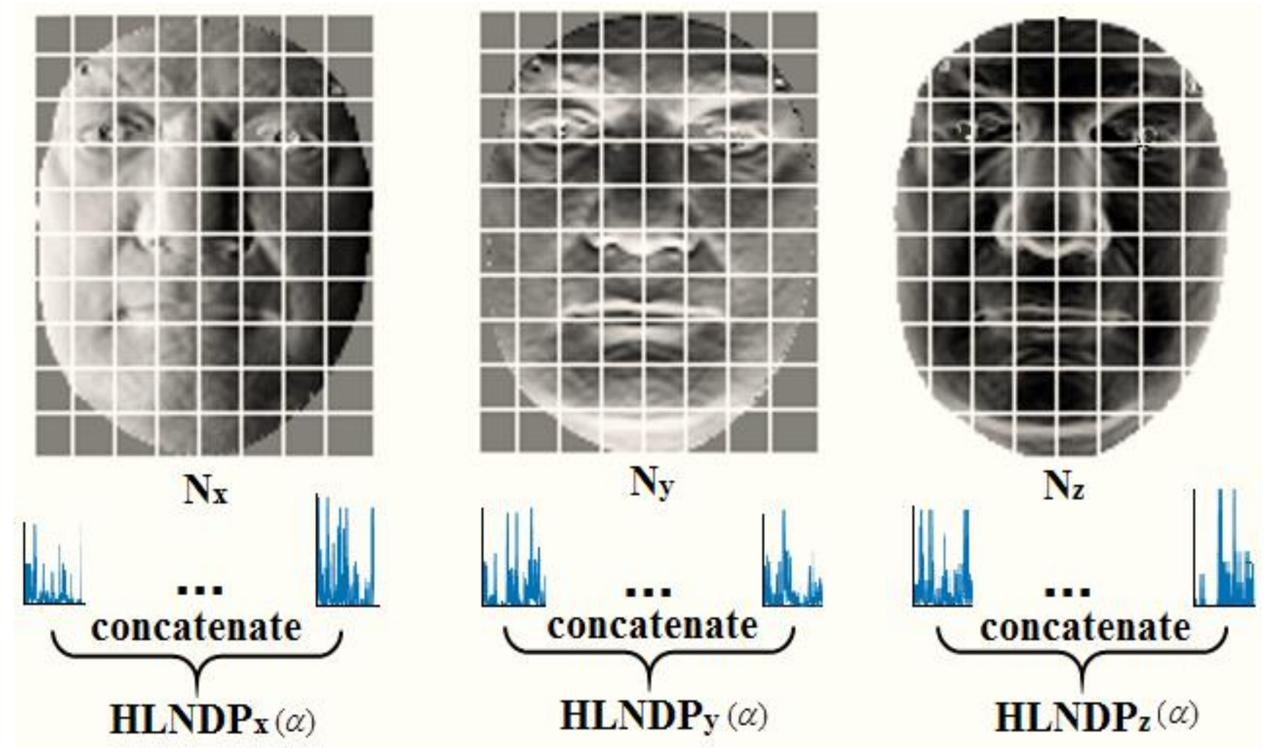
The second-order normal local derivative pattern:

$$LNDP_\alpha^2(P_0) = (f(N'_\alpha(P_0), N'_\alpha(P_1)), f(N'_\alpha(P_0), N'_\alpha(P_2))..., f(N'_\alpha(P_0), N'_\alpha(P_8)))$$

Binary coding function $f(N'_\alpha(P_0), N'_\alpha(P_i))$
is equal to 0 if $N'_\alpha(P_0).N'_\alpha(P_i) > 0$
and equal to 1 if $N'_\alpha(P_0).N'_\alpha(P_i) <= 0.$

nth- order of LNDP:

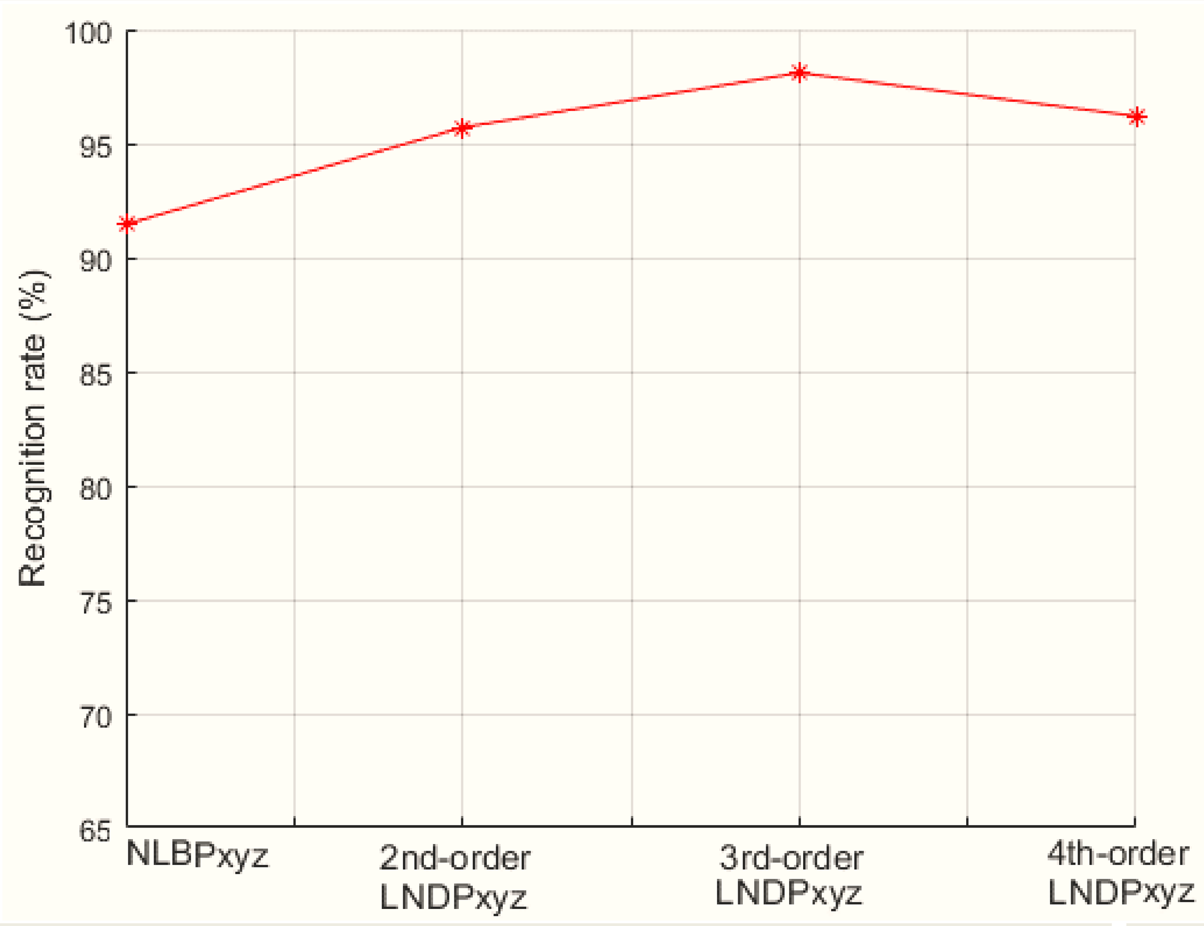
$$LNDP_\alpha^n(P_0) = (f(N_\alpha^{n-1}(P_0), N_\alpha^{n-1}(P_1)), f(N_\alpha^{n-1}(P_0), N_\alpha^{n-1}(P_2))..., f(N_\alpha^{n-1}(P_0), N_\alpha^{n-1}(P_8))) \quad ★$$



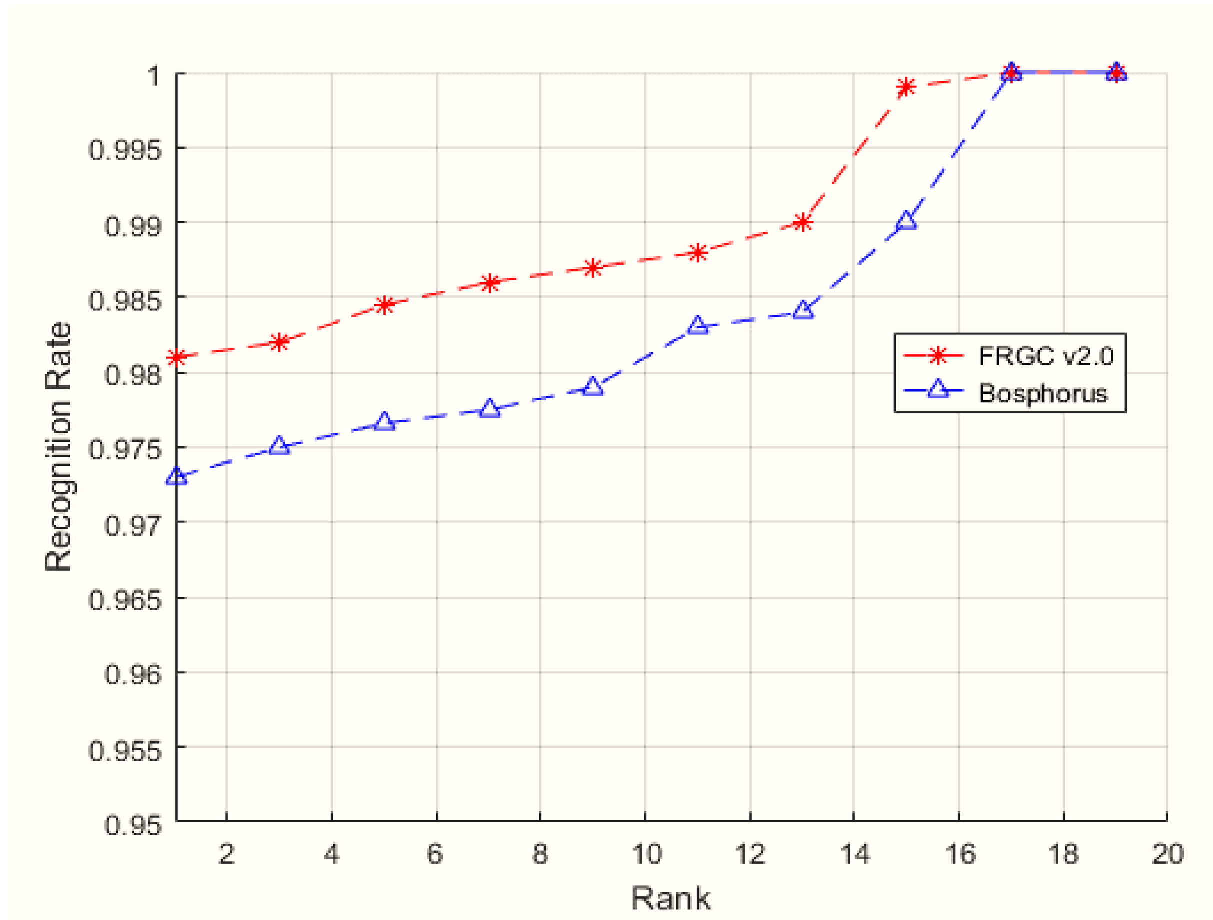
HLNDP for x, y, and z facial normal components

EXPERIMENTAL RESULTS

Different orders on FRGC v2.0 DB



CMC (score-level fusion third-order LNDP)



Comparison of LBP, LDP, and LNDP

Descriptor	RR1 (FRGC v2.0)
$DepthLBP$	86.2%
$DLDP^3$	89.08%
$LNDP_x^3$	92.53%
$LNDP_y^3$	91.18%
$LNDP_z^3$	96.04%
$LNDP_{xyz}^3$	**98.1%**

Comparison of LBP-based methods

Methods	RR1 (FRGC v2.0)	RR1 (Bosphorus)
MS-eLBPDFs [1]	97.6%	97%
V-LBP [2]	94.89% (900/150)	-
MSMC-LNP [3]	96.3%	95.4% (2797/105)
DLBP [4]	90%	90%
Region-based-eLBP [5]	97.8%	-
$LNDP_{xyz}^3$	**98.1%**	**97.3%**

Conclusion

- High-order LNDP (more detailed distinct information from the 3D facial image) is proposed.
- The score-level fusion (LNDPx, LNDPy, and LNDPz) is applied.
- The algorithm is training free and computationally efficient.
- The proposed descriptor can be used in 3D object recognition as well.

References

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[2] H. Tang, B. Yin, Y. Sun, and Y. Hu, "3D face recognition using local binary patterns," Signal Processing, vol. 93, no. 8, pp. 2190–2198, 2013.
[3] H. Li, D. Huang, J.-M. Morvan, L. Chen, and Y. Wang, "Expression-robust 3D face recognition via weighted sparse representation of multi-scale and multi-component local normal patterns," Neurocomputing, vol. 133, pp. 179–193, 2014.
[4] A. Aissaoui, J. Martinet, and C. Djeraba, "DLBP: A novel descriptor for depth image based face recognition," in IEEE International Conference on Image Processing (ICIP), 2014, pp. 298–302.
[5] S. Lv, F. Da, and X. Deng, "A 3D face recognition method using region-based extended local binary pattern," in IEEE International Conference on Image Processing (ICIP), 2015, pp. 3635–3639.