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Abstract—**In this letter, we propose an efficient one-nearest-neighbor classifier of texture via the contrast of local energy histograms of all the wavelet subbands between an input texture patch and each sample texture patch in a given training set. In particular, the contrast is realized with a discrepancy measure which is just a sum of symmetrized Kullback–Leibler divergences between the input and sample local energy histograms on all the wavelet subbands. It is demonstrated by various experiments that our proposed method obtains a satisfactory texture classification accuracy in comparison with several current state-of-the-art texture classification approaches.**

Index Terms—**Energy histogram, one-nearest-neighbor classifier, symmetrized Kullback–Leibler divergence (SKLD), texture classification, wavelet transform.**

I. IN ODUC ION

T E E [illegible] [1], [illegible] [1] [13], [illegible] [3] [7] [illegible] [1], [8] [12].

[illegible] [1] [7]. [illegible] C [illegible] G [illegible] G [illegible] D [illegible] (CGGD) [illegible] [3], B [illegible] Pr [illegible] (BP) [illegible] [5], [6], [illegible] H [illegible] (H) [4], G [illegible] G [illegible] D [illegible] (GΓD) [illegible] [7], [illegible]

In [illegible] [11], [12]. M [illegible] [1]. H [illegible]

[illegible] (LEH) [illegible]. In [illegible] K [illegible] L [illegible] LEH [illegible]. A [illegible]. I [illegible] II [illegible]. I [illegible] III. F [illegible] I [illegible].

II. P OPO ED E E CLA IFICA ION ME HOD

A. Local Energy Feature Extraction in Wavelet Domain

F [illegible] L- [illegible] $3L$ [illegible] $(B_1, B_2, \ldots, B_{3L})$ [illegible] B_{3L+1}. [illegible] (N [illegible]-1) [illegible] $S \times S$ [illegible] j- [illegible] $\Omega_i^j \times \Omega_i^j$ [illegible] i- [illegible]

$$E_{\mathrm{Loc}}^{i,j}(l,k) = \frac{1}{S^2}\sum_{u=1}^{S}\sum_{v=1}^{S}|w_{i,j}(l+u-1,k+v-1)| \quad (1)$$

[illegible] $1 \leq l,k \leq \Omega_i^j - S + 1$ [illegible] $w_{i,j}(m,n)$ [illegible] (m,n) [illegible] E_{Loc}^L [illegible] (1).

N [illegible]. On [illegible] i. [illegible] $E_{\mathrm{Loc}}^{i,j}$ [illegible] $1/2^i$ [illegible]. F [illegible] $1/4^L$ E_{Loc}^L [illegible]

M [illegible] D [illegible] 06, 2010; [illegible] J [illegible] 20, 2011; J [illegible] 26, 2011. D [illegible] F [illegible] 04, 2011; [illegible] F [illegible] 17, 2011. [illegible] N [illegible] F [illegible] C [illegible] 60771061. [illegible] Pr. H. [illegible]

[illegible] D [illegible] In [illegible] M [illegible] LMAM, P [illegible], B [illegible] 100871, C [illegible] [illegible] @ [illegible]

C [illegible] ://[illegible]

D [illegible] O [illegible] I [illegible] 10.1109/L P.2011.2111369

n . F r , n r - r n n r r r r n r r n n.

B. Local Energy Histogram (LEH)

1) Definition: G n r r n M n r r $E=(e_1,e_2,\ldots,e_M)$, r r n - n n r N_0 $e_{\max}<2^{N_0}$. L $\Delta_n=[2^a(n-1),2^a n)$, $n=1,2,\ldots,N$, r $N=2^{N_0-a}$ n $0\le a\le N_0$, n- n . N $[0,2^{N_0})=\bigcup_{n=1}^{N}\Delta_n$. I n n e_m, r n n r n_0 $(1\le n_0\le N)$ $e_m\in\Delta_{n_0}$. n n n r r (LEH) r n n $p(\Delta_n)=p_n=m_n/M$, r m_n n r n r r r n Δ_n. N n n r r n r n , n r n n- n n r r . H n , r r E $P=(p_1,p_2,\ldots,p_N)$, r rr LEH n r .

2) Discrepancy Measure: On LEH n r $P=(p_1,p_2,\ldots,p_N)$ n n n r r r n n , n r r - r n LEH r r . n r , LEH n r n . B - n n n r N_0 r n - r n n r , n r n n r n 2^{N_0}. N n- n a r n n r r n . $p_n=0$ r n n n r - n r r n n r n r , r η r p_{n^*}, r $n^*=\arg\max_n p_n$ n η n r n r $\eta=10^{-16}$. , $p'_n=p_n+\eta/(N-1)$ $n\neq n^*$, $p'_{n^*}=p_{n^*}-\eta$. I $\sum_{n=1}^{N}p'_n=\sum_{n=1}^{N}p_n=1$. F r r , LEH n r $P=(p_1,p_2,\ldots,p_N)$ n n r r n $P'=(p'_1,p'_2,\ldots,p'_N)$ n n. A - n r n r n r r n r K L r n (KLD) [4 . , n KLD n LEH H n Q

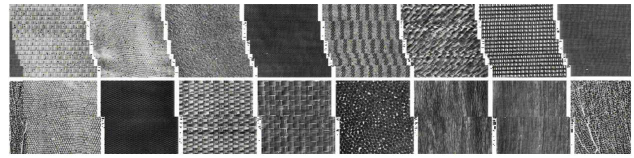
$$\mathrm{SKLD}(H,Q)=\sum_{n=1}^{N}p_n\log\left(\frac{p_n}{q_n}\right)+\sum_{n=1}^{N}q_n\log\left(\frac{q_n}{p_n}\right) \quad (2)$$

r p_n n q_n r LEH n r H n Q, r - .

G n I_1 n I_2, n n $3L+1$ n $(B_1^{I_1},B_2^{I_1},\ldots,B_{3L+1}^{I_1})$ n $(B_1^{I_2},B_2^{I_2},\ldots,B_{3L+1}^{I_2})$, r r n n n L- r n- r n , n n n r r n

$$TD=\sum_{i=1}^{3L+1}d_i=HD+d_{3L+1} \quad (3)$$

r $HD=\sum_{i=1}^{3L}d_i$, n $d_i=\mathrm{SKLD}(H_i^{I_1},Q_i^{I_2})$ KLD n LEH $H_i^{I_1}$ n $Q_i^{I_2}$ rr n n n $B_i^{I_1}$ n $B_i^{I_2}$, r r $i=1,2,\ldots,3L+1$. A



F . 1. n 80 Br r .

d_i n r r n n n $B_i^{I_1}$ n $B_i^{I_2}$, r r n n . I r TD n n n . N n n n , . ., HD, n r n r n n r r - n n n n . In n n, n r r n TD HD.

C. One-Nearest-Neighbor Classifier

r n r TD, n-n r -n r r r r r r n . I , n r nn n , r n n r nn r n r n n r nn . In , n n r n , r n r TD, n-n r -n r r r r n- r r n n n r n k-n r -n r r $k>1$ r r r n.

III. E PE IMEN AL E L

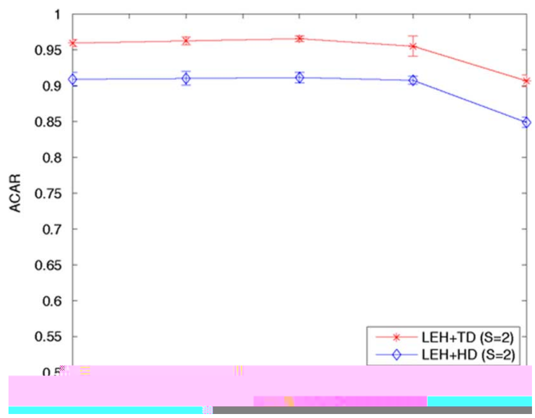
In n, r r n r rr n- r r r n , n - r rr n - - - r r n r n r r n r n r n .

In r n , 3- r n r D 1 (1) r n n r r n r 1 4 n r r n . r 3- r n r r . A r n r r N_0, r n $N_0=10$ n , , r n r n r , n n n r n 2^{10}. r r , $N_0=10$ n n r n . A r , r r n r n r N_0.

A. Classification Performance

r r r n n 80 r 640×640 (n -1, n 16 80 r n F . 1) r Br r [14 , n [17 .

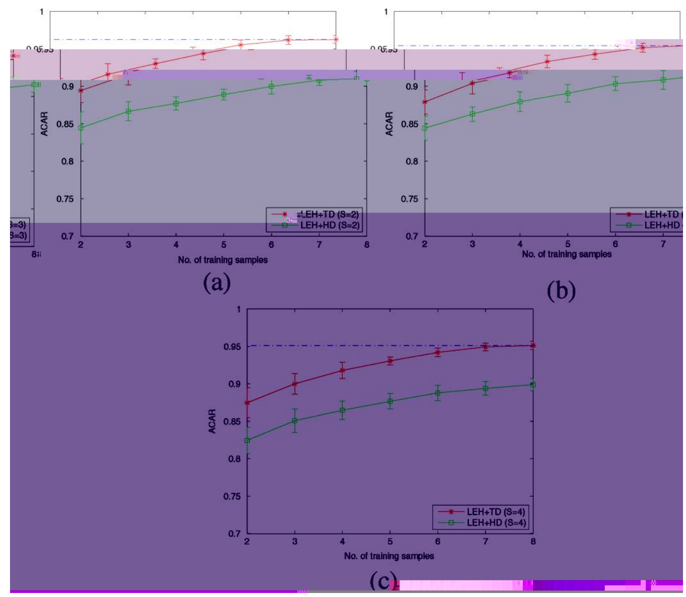
In r n n -1, n 16 160×160 n n r n , n r r 1280 . N_{tr} r nn r 80 n r r $N_{tr}=2,3,\ldots,8$. r n r r r n r n



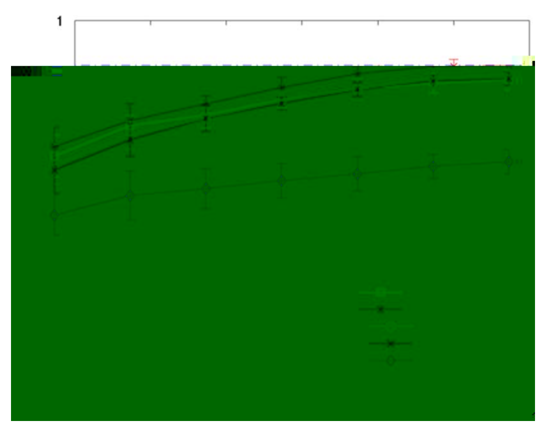
F . 2. r n r r LEH+ D (S =) n LEH+HD (S =) r n- n n r r n 8.

n r n r r (ACA) r r n r n n r n r n n N_{tr}.

F r , r r r r n r n r TD LEH+ D, n n -n r - n r r n LEH n r n - r HD (3) LEH+HD. F . 2 ACA LEH+ D n LEH+HD r n- n ($a = 0, 1, \ldots, 4$) n n r 2×2 (. ., S = 2) r n r n N_{tr} = 8. N r r r r n F . 2 n n - r r r r n n n r n r r r . Fr F . 2, n ACA LEH+ D n LEH+HD r n- n , a, n LEH+ D r- r LEH+HD 5.00% 6.00%, r - n r TD r r r n HD n n- n . In r , n r n n ACA $a = 0$ n $a = 4$ 5.00% 6.50%, n- n a n r n r n r . N a r r 3 0, r n n ACA n- n n . n r n , a r, r LEH n r r r n n r , n , ACA n r . H r, n r n r n n (. ., $a = 0$), nn r . In , r n n r r n nn n - r . r r , n n r n , n n- n $a = 1$ n r r . n n n n n r n n r r 2×2, 3×3 n 4×4 (, S = 2, 3, n 4). F . 3( ), ( ) n ( ) ACA (rr r r) LEH+ D n LEH+HD r n r r n n N_{tr} r n r , r . A n n, ACA LEH+ D n LEH+HD n r n n n r r n n n r n r . n LEH+ D r LEH+HD 4.00% 6.00% N_{tr} n n r , n r



F . 3. C n r r n LEH+ D n LEH+HD r n r r n n r n r :( ) S = ; ( ) $S = 3$; ( ) $S = 4$.



F . 4. C r n r r n r n r r n n .

TD r r r n HD. r r , n n r n n r n n n r n r .

n r r r r n , LEH+ D, - n r (BP) - n r [5], r rr BP M . F . 4 ACA r n r r n n , N_{tr}. I n r n r F . 4 ACA LEH+ D r n r n BP M n r n n- n r r n n . LEH+ D ($S = 2$) r r n LEH+ D ($S = 1$), LEH+ D ($S = 3$) n LEH+ D ($S = 4$) 1.00%, n r BP M 6.00% 8.00% r N_{tr}, n n r $S = 2$. M r, r LEH+ D ($S = 2$) G n r [17 (n GMM M) n $N_{tr} = 8$. ACA GMM M n LEH+ D ($S = 2$) r 93.44% n 96.25%, r .

ABLE I
HE ACA (%) AND C (IN ECOND) OF HE H EE ME HOD

	LEH+TD ($S = 2$)	CLBP_S	CLBP_S/M/C
ACAR	95.29	92.46	98.08
TTC	140.99	138.36	144.37

, LEH+ D ($S = 2$) r r GMM M 2.81%. A n r n LEH+ D r n r N_{tr} r 0.90%, r n r n r n BP M , 1.48%. In r r r n n r r LEH+ D r r n n r r n n , r r n r r LEH+ D.

B. Comparisons With the Other Existing Methods

In n, r LEH+ D ($S = 2$) n Br [14 111 640×640 r (-n -2), n r BP M n n n- n n n n (ICA) n r (n ICA M) [16 . E r n 25 128×128 n n- r n n, 10 r n n r n r n n n r n r n r n n . ACA LEH+ D ($S = 2$), BP M , n ICA M r 85.80%, 74.90%, n 80.7%, r n LEH+ D ($S = 2$) r r- r - - - r BP M n ICA M n n r Br .

r r r n r r LEH+ D ($S = 2$), r LEH+ D ($S = 2$) rr n n n r rn (CLBP), n CLBP n CLBP /M/C n [18 , n [15 30 512×512 r . r n n n r rn n [18 n [19 . O r r n n n [3 . r n r r n r n rn n . A r n r n n r n In ( ) C r (M) 5 CP (3.2 GH) n M n r n n. I r r ACA n r r n (C) . A n n, r r LEH+ D ($S = 2$) r r CLBP 2.83% CLBP /M/C r r r n LEH+ D ($S = 2$) 2.79%. ACA r r r n r r n r G n n [3, . ., 88.1%. A r C n rn , LEH+ D ($S = 2$) r n CLBP /M/C. r r, r r LEH+ D ($S = 2$) r rr n - - - r CLBP n CLBP /M/C r .

I . CONCL ION

n r r n r n r n r r n n n n r n r n r n n . n r n r n K L r n n n n n r r n n , n n n -n r -n r r . r r n n r r r n r r n r rr n - - - r r .

EFE ENCE

[1 . n n . n n, D- r n r n, IEEE Trans. Image Process., . 16, n . 11, . 2688 2696, N . 2007.

[2 M. N. D n M. r, - r r r n n r- G n n n K L r n , IEEE Trans. Image Process., . 11, n . 2, . 146 158, F . 2002.

[3 . K. C n C. . n , r r n n r r n r G n n , J. Math. Imag. Vis., . 29, n . 1, . 35 47, . 2007.

[4 L. L , C. . n , n . K. C , r n n r n r , IEEE Trans. Image Process., . 19, n . 5, . 1371 1378, M 2010.

[5 . K. C n C. . n , r r n r n n n r r n, IEEE Trans. Image Process., . 17, n . 8, . 1399 1405, A . 2008.

[6 M. H. P , C. . n , . K. C , n H. n , A n r n r n n n r r r , IEEE Trans. Image Process., . 15, n . 10, . 3078 3088, O . 2006.

[7 . K. C n C. . n , n r r n n n r G n n n n r r r , IEEE Trans. Image Process., . 19, n . 2, . 281 289, F . 2010.

[8 A. L n n J. F n, r n n r , IEEE Trans. Pattern Anal. Mach. Intell., . 15, n . 11, . 1186 1191, N . 1993.

[9 . n n J. H. H , F rn r r n: A r , IEEE Trans. Pattern Anal. Mach. Intell., . 21, n . 4, . 291 310, A r. 1999.

[10 M. n r, r n n n n r , IEEE Trans. Image Process., . 4, n . 11, . 1549 1560, N . 1995.

[11 G. r, P. n r , n D. . D r r r n r r r r n n, IEEE Trans. Image Process., . 8, n . 4, . 592 598, A r. 1999.

[12 . C. K n . J. K n , r n n n n n r n G n r , Pattern Recognit., . 40, n . 4, . 1207 1221, A r. 2007.

[13 . L n D. L. n , r n n r r , IEEE Trans. Image Process., . 12, n . 6, . 661 670, J n 2003.

[14 [On n . A : [On n . A : ://. . .n / r n n/ r . .

[15 [On n . A : [On n . A : :// . . . . / / r / n r / .

[16 H. L B n , A. G. D , n N. E. O'C nn r, L rn n r r n r n n r n, IEEE Trans. Circuits Syst. Video Technol., . 17, n . 3, . 286 297, M r. 2007.

[17 H. L n, . Gr , . , n . A , r n n n r n rn G n r , IEEE Trans. Image Process., . 19, n . 6, . 1548 1557, J n. 2010.

[18 . H. G , L. n , n D. n , A n r rn r r r r n, IEEE Trans. Image Process., . 19, n . 6, . 1657 1663, J n. 2010.

[19 . H. G , L. n , n D. n , n n r n r n n LBP r n (LBP) n , Pattern Recognit., . 43, n . 3, . 706 719, M r. 2010.