Face Anti-spoofing Based on Dynamic Color Texture Analysis Using Local Directional Number Pattern

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Motivation

- Texture-based methods
  color LBP[1], color texture[2]
- Motion-based Methods
  LBP-TOP[3], multi-scale BSIF-TOP and LPQ-TOP[4]
- Methods Based on Other Cues
  image quality analysis[5], depth based CNN[6]

[1] Zinelabidine Boulkenafet, Jukka Komulainen, and Abdenour Hadid. "Face anti-spoofing based on color texture analysis". In: *International Conference on Image Processing* (2015), pp. 2636–2640.

[2] Zinelabidine Boulkenafet, Jukka Komulainen, and Abdenour Hadid. "Face spoofing detection using colour texture analysis". In: *IEEE Transactions on Information Forensics and Security* 11.8 (2016), pp. 1818–1830.

[3] Tiago de Freitas Pereira et al. "Face liveness detection using dynamic texture". In: *EURASIP Journal on Image and Video Processing* 2014.1 (2014), p. 2.

[4] Shervin Rahimzadeh Arashloo, Josef Kittler, and William Christmas. "Face spoofing detection based on multiple descriptor fusion using multiscale dynamic binarized statistical image features". In: *IEEE Transactions on Information Forensics and Security* 10.11 (2015), pp. 2396–2407.

[5] Javier Galbally and Sébastien Marcel. "Face anti-spoofing based on general image quality assessment". In: *International Conference on Pattern Recognition* (2014), pp. 1173–1178.

[6] Yousef Atoum et al. "Face anti-spoofing using patch and depth-based CNNs". In: *International Joint Conference on Biometrics* (2017), pp. 319–328.

Motivation

- Texture is widely used in anti-spoofing methods.
- Motion is also useful for discriminating fake faces from real ones.
- Color information is also discriminative in term of face anti-spoofing.
- Local directional number pattern (LDN) has shown excellent performance on several visual tasks such as face recognition and expression recognition.
- The probabilistic collaborative representation based classifier (ProCRC) has been confirmed to be effective in term of image classification.

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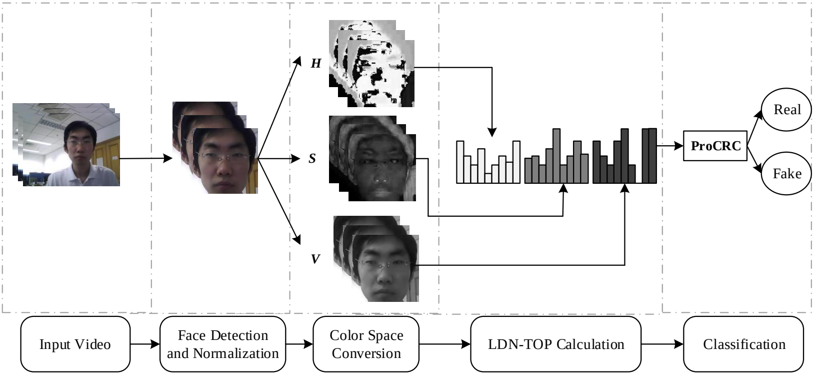
Face Anti-spoofing Flowchart



Local Directional Number Pattern

- Calculate eight edge response images

$$I^k = I * M^k, \quad k = 0, 1, \cdots, 7. \tag{1}$$

- Select two directional numbers with the maximum and minimum edge responses

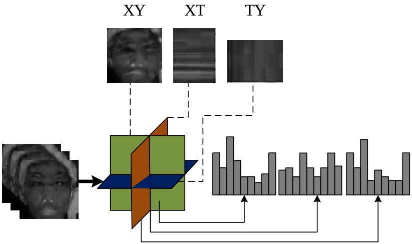
$$i^*(x, y) = \arg\max_i I^i(x, y), \quad i = 0, 1, \cdots, 7. \tag{2}$$

$$j^*(x, y) = \arg\min_j I^j(x, y), \quad j = 0, 1, \cdots, 7. \tag{3}$$

- Calculate LDN code

$$\mathrm{LDN}(x, y) = 8 \times i^*(x, y) + j^*(x, y). \tag{4}$$

Extention to LDN-TOP



- Final color LDN-TOP feature vector

$$F = [f_1, \cdots, f_i, \cdots, f_L] \quad (5)$$

- LDN-TOP feature vector of $i - th$ color channel

$$f_i = [H_i^{XY}, H_i^{XT}, H_i^{TY}] \quad (6)$$

- LDN feature vector of each plane

$$H^{plane} = \prod_{j=1}^{N} \prod_{k=1}^{n} h_{j,k} \quad (7)$$

ProCRC Classifier

- Objective function

$$\arg\min_{\alpha}(\lambda \|\alpha\|_2^2 + \|y - X\alpha\|_2^2 + \gamma \sum_{k=1}^{K} \|X\alpha - X_k\alpha_k\|_2^2) \quad (8)$$

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Datasets

- CASIA

Low / Normal / High

Real | Warped Photo | Cut Photo | Video

Datasets

- Replay-Attack

Real HD Video Mobile Photo Mobile Video HD Photo

Datasets

- UVAD

Effectiveness of different color spaces

- Performance of single color space on CASIA

Operator	Gray		RGB		HSV		YCbCr	
	EER	AUC	EER	AUC	EER	AUC	EER	AUC
LDN-TOP$_{[0.3,0.6,0.9]}$	15.56	90.28	12.22	93.90	6.30	98.48	10.00	96.85
LDN-TOP$_{[0.5,1.0,1.5]}$	15.56	90.64	12.22	95.44	5.19	99.23	9.63	96.89
LDN-TOP$_{[1.0,1.3,1.6]}$	14.81	93.84	8.89	97.35	3.70	99.36	6.30	98.74
LDN-TOP$_{[1.0,1.5,2.0]}$	15.56	92.72	8.89	96.83	4.44	99.18	7.78	98.21

- Performance of color space combinations on CASIA

Operator	RGB+HSV		RGB+YCbCr		HSV+YCbCr	
	EER	AUC	EER	AUC	EER	AUC
LDN-TOP$_{[0.3,0.6,0.9]}$	6.67	98.10	7.78	97.72	4.81	99.40
LDN-TOP$_{[0.5,1.0,1.5]}$	5.93	98.81	7.78	98.14	5.56	99.42
LDN-TOP$_{[1.0,1.3,1.6]}$	3.33	99.47	4.44	99.24	2.22	99.76
LDN-TOP$_{[1.0,1.5,2.0]}$	3.33	99.33	5.56	99.09	3.33	99.73

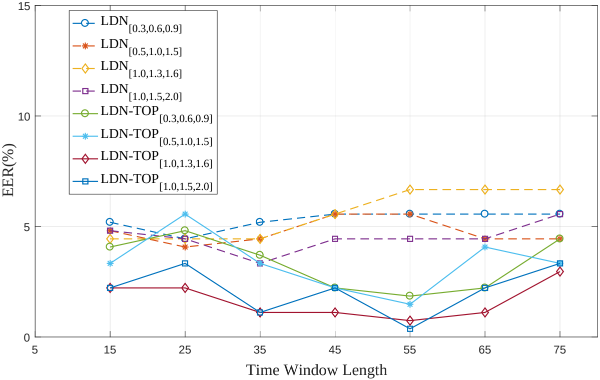
Effectiveness of ProCRC

- Performance of different classifiers on CASIA

Operator	SVM-HIK		SVM-Linear		ProCRC	
	EER	AUC	EER	AUC	EER	AUC
LDN-TOP$_{[0.3,0.6,0.9]}$	4.44	99.13	5.56	98.67	4.81	99.40
LDN-TOP$_{[0.5,1.0,1.5]}$	3.33	99.26	5.56	99.04	5.56	99.42
LDN-TOP$_{[1.0,1.3,1.6]}$	2.59	99.27	4.44	99.35	2.22	99.76
LDN-TOP$_{[1.0,1.5,2.0]}$	2.22	99.34	4.44	99.34	3.33	99.73

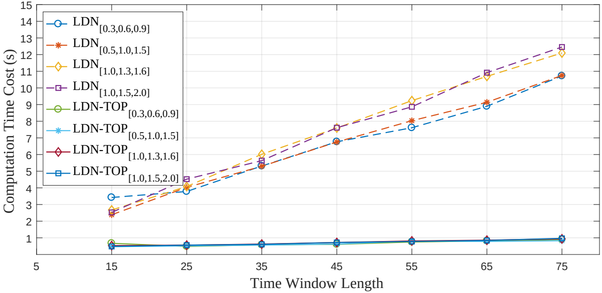
Comparison between LDN and LDN-TOP

- Evaluation of Time Window Length



Comparison between LDN and LDN-TOP

- Efficiency



Comparison with the state of the arts

- Performance comparison on CASIA and Replay-Attack

	Method	CASIA	Replay-Attack
		EER	HTER
Hand-Crafted Features	CASIA Baseline [11]	17	–
	LBP-TOP [5]	10	7.6
	Color Texture Markov [16]	8	4.4
	MBSIF-TOP + MLPQ-TOP [6]	7.2	1.0
	CVLBC [7]	6.48	0.75
	Colour LBP [15]	6.2	2.9
	Scale Space Texture [14]	4.2	3.1
	Colour Texture [3]	3.2	3.5
	Guided Scale Texture [25]	2.53	3.13
Deep Learning	CNN-Stacking [26]	6.7	0.38
	Attention CNN [27]	3.145	**0**
	Patch & Depth based CNN [20]	2.67	0.72
	LBP Network [28]	2.5	1.3
	Deep LBP [29]	2.3	0.9
	3D Virtual Synthesis [30]	2.22	0.63
	3D CNN [31]	1.4	1.2
	Ours	**0.37**	3.13

Comparison with the state of the arts

- Performance comparison on UVAD

Method	UVAD		
	FAR	FRR	HTER
Visual Codebooks [17]	44.73	15.00	29.87
Visual Rhythm [12]	44.52	11.67	28.09
FFT + LDP-TOP [32]	7.38	40.00	23.69
IQA [33]	36.80	9.20	23.00
DDGL [9]	–	–	16.50
Ours	**3.33**	**8.13**	**5.73**

Comparison with the state of the arts

- Cross-database performance comparison

	Method	C → R[1]	R → C[2]	Average
Hand-Crafted Features	LBP-TOP [5]	49.7	60.6	55.2
	Guided Scale Texture [25]	48.4	40.3	44.4
	Color LBP [15]	47.0	39.6	43.3
	Visual Codebooks [17]	34.4	50.0	42.2
	CLNF [36]	33.7	49.3	41.5
	Videolet [37]	35.4	44.6	40.0
	Color Texture Markov [16]	32.3	45.9	39.1
	IQA [33]	38.1	39.0	38.6
	Colour Texture [3]	30.3	37.7	34.0
Deep Learning	Noise Modeling [38]	28.5	41.1	34.8
	Attention CNN [27]	30.0	33.4	31.7
	CNN-Stacking [26]	**20.6**	40.4	30.5
	Auxiliary [21]	27.6	28.4	28.0
	GFA-CNN [39]	21.4	34.3	27.9
	DDGL [9]	22.8	**27.4**	**25.1**
	Ours	38.8	42.9	40.9

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Conclusions

- The combination of HSV and YCbCr achieved the best results.
- The ProCRC outperformed the SVM classifiers.
- Our method achieved the best performance on CASIA with EER and UVAD with HTER. And our method also showed the competitive results on the Replay-Attack database.

Thank you!