Global median filtering forensic method based on Pearson parameter statistics

CNN Based Detector

Pearson Parameter ‘$\mathcal{K}$’

Pearson system of distributions is characterised by the parameter κ which is defined as the polynomial ratio of skewness and kurtosis.

Skewness(S) and Kurtosis(K)

Here. μ2, μ3 and μ4 are second, third and fourth centralised moments, respectively.

$$S=\mu_3/\mu_2^{3/2} \text{ and } K=\mu_4/\mu_2^2.$$

Derivation of Parameter $\mathcal{K}$

Generation of unimodal probability distributions can be achieved by solving the differential equation

$$\frac{1}{g(x)}\frac{\mathrm{d}g(x)}{\mathrm{d}x} = \frac{x+a}{c_0 + c_1 x + c_2 x^2} \qquad (2)$$

where $g(x)$ is the probability density function (pdf) and a, c_0, c_1 and c_2 are constant parameters.

Equation Generated

$$\frac{1}{g(x)}\frac{dg(x)}{dx} = -\frac{x + \left((\sqrt{\mu_2}S(K+3))/2(5K - 6S^2 - 9)\right)}{\left(\left((2K - 3S^2 - 6)x^2 + \sqrt{\mu_2}S(K+3)x + \mu_2(4K - 3S^2)\right)/2(5K - 6S^2 - 9)\right)}$$

Final Equation

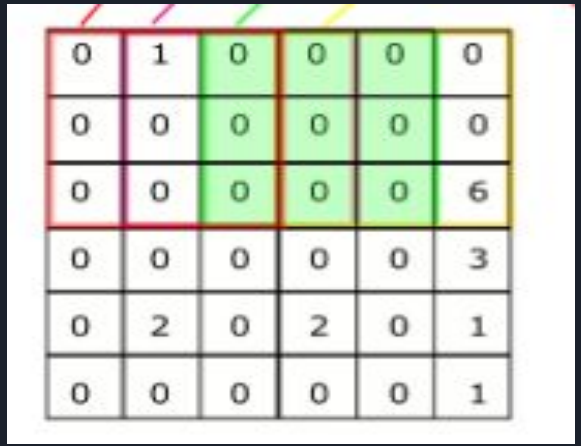
$$\kappa = \frac{c_1^2}{4c_0c_2} = \frac{S^2(K+3)^2}{4(4K-3S^2)(2K-3S^2-6)}$$

Streaking Effect.

The extent of dependence varies with the size of the window used and the distance between pixels. This effect is known as streaking effect.

SRV(Single Residual Value)

A block with single residual value referred to as SRV block.



0	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	6
0	0	0	0	0	3
0	2	0	2	0	1
0	0	0	0	0	1

a

b

0	0	0	0	0	0
3	7	2	0	0	0
0	0	0	7	8	3
0	0	0	0	9	0
0	0	0	0	5	0
2	4	4	2	6	1

Highlighted red block with residual values

-0.756	-0.358	-0.382	-0.310	-0.756	-0.358	-0.117	-0.091	...
κ^1_{org3}	κ^2_{org3}	κ^3_{org3}	κ^4_{org3}	κ^5_{org3}	κ^6_{org3}	κ^7_{org3}	κ^8_{org3}	
κ_{SRV}	-1.531	-0.043	-0.020	-0.244	-0.244	-0.123	-0.232	
κ^9_{org3}	κ^{10}_{org3}	κ^{11}_{org3}	κ^{12}_{org3}	κ^{13}_{org3}	κ^{14}_{org3}	κ^{15}_{org3}	κ^{16}_{org3}	

κ_{org3}

c

d

e

0	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	6
0	0	0	0	0	3
0	2	0	2	0	1
0	0	0	0	0	1

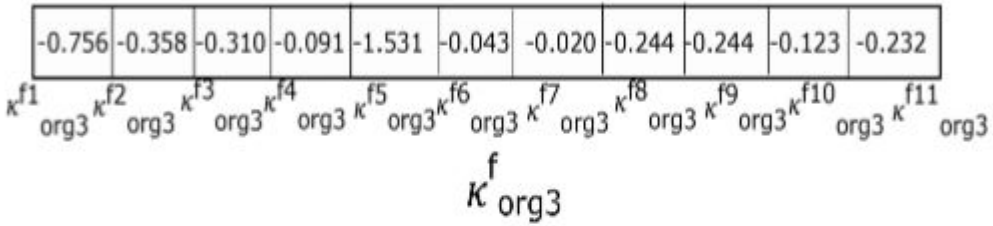
Highlighted red block with residual values

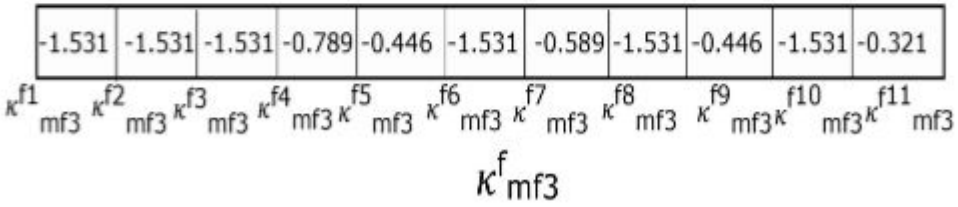
-1.531	-1.531	κ_{SRV}	-1.531	κ_{SRV}	κ_{SRV}	κ_{SRV}	-0.789	...
κ^1_{mf3}	κ^2_{mf3}	κ^3_{mf3}	κ^4_{mf3}	κ^5_{mf3}	κ^6_{mf3}	κ^7_{mf3}	κ^8_{mf3}	
-1.531	-0.446	-1.531	-0.589	-1.531	-0.446	-1.531	-0.321	
κ^9_{mf3}	κ^{10}_{mf3}	κ^{11}_{mf3}	κ^{12}_{mf3}	κ^{13}_{mf3}	κ^{14}_{mf3}	κ^{15}_{mf3}	κ^{16}_{mf3}	

κ_{mf3}

f

(a) Original image from BOWS2 [28] database,
(b) MFR of Fig. 1*a*,
(c) κ vector formation from an example block of Fig. 1*b*,
(d) Median filtered image with window size 3×3,
(e) MFR of Fig. 1*d*,
(f) κ vector formation from an example block of Fig. 1*e*. For better visualisation, original image MFR and median filtered image MFR are displayed log compressed


-0.756 -0.358 -0.310 -0.091 -1.531 -0.043 -0.020 -0.244 -0.244 -0.123 -0.232
κ^{f1}_{org3} κ^{f2}_{org3} κ^{f3}_{org3} κ^{f4}_{org3} κ^{f5}_{org3} κ^{f6}_{org3} κ^{f7}_{org3} κ^{f8}_{org3} κ^{f9}_{org3} κ^{f10}_{org3} κ^{f11}_{org3}
κ^{f}_{org3}

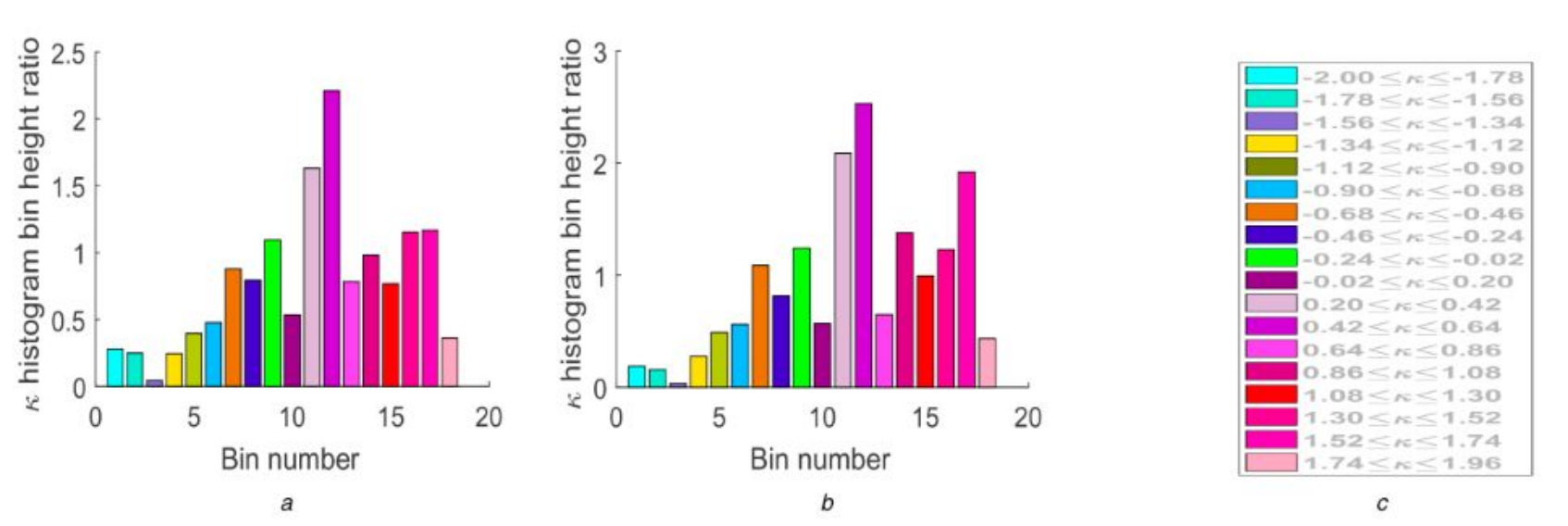

-1.531 -1.531 -1.531 -0.789 -0.446 -1.531 -0.589 -1.531 -0.446 -1.531 -0.321
κ^{f1}_{mf3} κ^{f2}_{mf3} κ^{f3}_{mf3} κ^{f4}_{mf3} κ^{f5}_{mf3} κ^{f6}_{mf3} κ^{f7}_{mf3} κ^{f8}_{mf3} κ^{f9}_{mf3} κ^{f10}_{mf3} κ^{f11}_{mf3}
κ^{f}_{mf3}

κ analysis of distinct residual values in blocks

- Streaking effect is responsible for decrease in number of distinct residual values in sliding blocks after median filtering

Nr	Orignal Image	MFR of median filtered image(s=3)	MFR of median filtered image(s=5)
1	1.56	40.24	51.37
2	3.99	33.70	30.01
3	7.76	15.19	11.66
4	9.04	7.24	5.02
5	9.37	2.58	1.48
6	11.38	0.81	0.36
7	15.40	0.20	0.07
8	20.63	0.028	0.009
9	20.85	0.002	0.0007

Average percentage (%) of distinct residual value blocks in the UCID database original images MFR (ORG_IMG_MFR) and median filtered images (s = 3 and s = 5) MFRs (MF3_IMG_MFR and MF5_IMG_MFR)



(a) Original image MFRs to corresponding 3x3 median filtered images MFRs
(b) Original image MFRs to corresponding 5x5 median filtered images MFRs
(c) κ range for different color blocks

Novel Feature Set

23 Distinguishing Features

- κ histogram bin height
- Moments of block κ distribution
- Count of SRV blocks

κ histogram bin height

- κ histogram bin height are utilised as intrinsic fingerprints

$$HBH_k = [h_i] \qquad 1 <= i <= 18 \qquad and \qquad i \in \mathbb{Z}^+$$

h_i denotes the ith bin of the κ vector histogram

Representation of h_i

$$h_i = \sum_{j=1}^{N_b} \Psi(\kappa, x_i, w_i)$$

where

$$\Psi(\kappa, x_i, w_i) = \begin{cases} 1 & (x_i - \frac{w_i}{2}) \leq \kappa \leq (x_i + \frac{w_i}{2}) \\ 0 & otherwise \end{cases}$$

N_b Total number of non-SRV blocks

x_i Center of *ith* bin in κ histogram

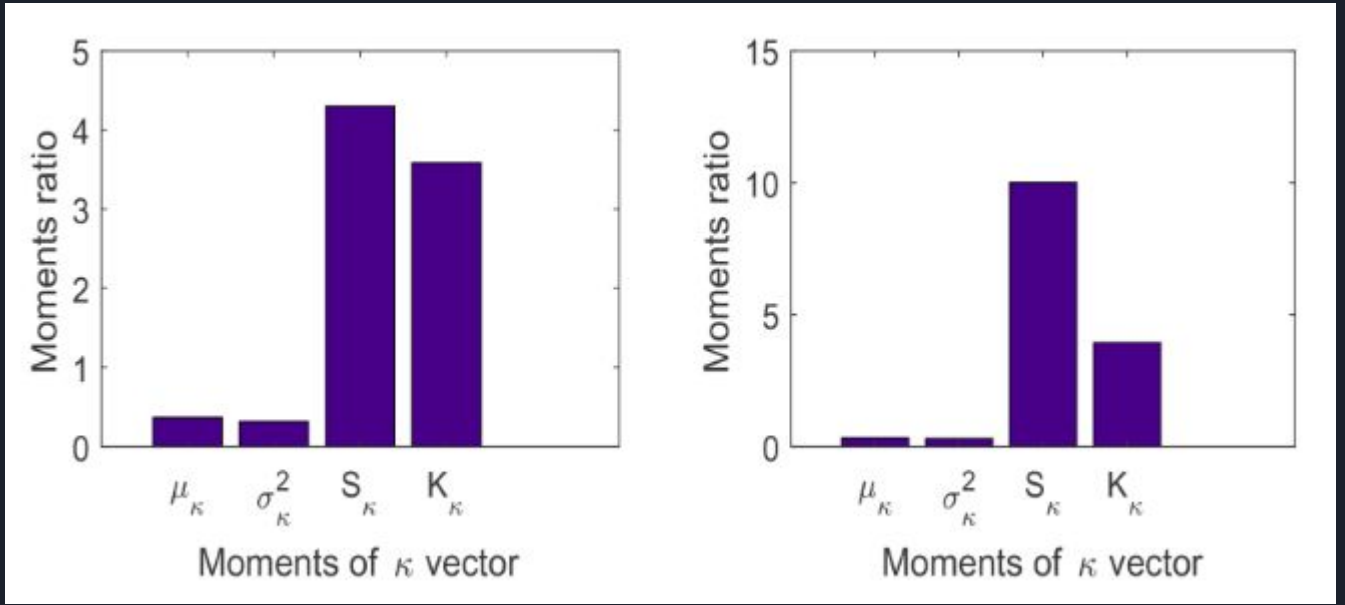
w_i Width of the *ith* bin in κ histogram

Moments of block $\boldsymbol{\kappa}$ distribution

$$MOM_\kappa = [\mu_\kappa, \sigma_\kappa^2, S_k, K_k]$$

where μ_κ , σ_κ^2 , S_k , K_k denote mean , variance , skewness and kurtosis of $\boldsymbol{\kappa}$ vector

Bar plots of the ratio of average of the first four moments



κ^f_{org3} and κ^f_{mf3}

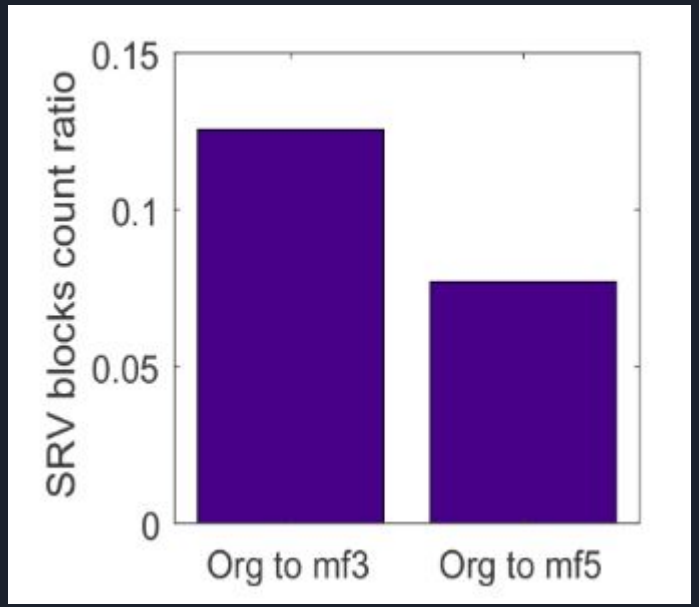
κ^f_{org3} and κ^f_{mf5}

Count of SRV Block

$$C_{SRV} = \sum_{k=1}^{B} \phi(r_p^k, r_q^k)$$

Where *B* denotes number of SRV blocks in image MFR and

$$\phi(r_p^k, r_q^k) = \begin{cases} 1 & r_p^k = r_q^k \ \forall \ p, q \\ 0 & otherwise \end{cases}$$



Ratio of the average of SRV block count , 3x3 median filtered to original , 5x5 median filtered MFR

Composite Feature Set

$$F_k^{23} = [HBH_k, MOM_k, C_{SRV}]$$