MAXIMALLY SEPARATED AVERAGES PREDICTION FOR HIGH FIDELITY REVERSIBLE DATA HIDING

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1. Background

- ✓ Prediction-error histogram (PEH) sharpness (often estimated by how low PEH entropy is) is an important determinant of performance (embedding distortion minimization) of prediction-error expansion based reversible data hiding (RDH).
- ✓ Common approaches for low entropy PEH generation in RDH are:

Pixel sorting (PS): use smooth pixels for PEH generation

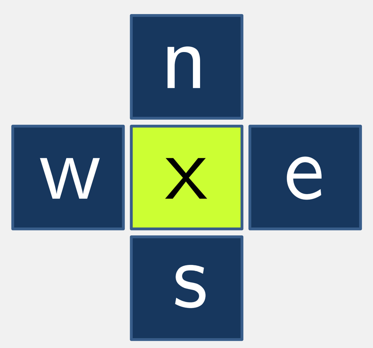
Pixel pairing (PP): pair up correlated pixels for sharper 2D PEH generation

Better Prediction: improve prediction accuracy to obtain sharper PEH

- ✓ Some recent RDH schemes including [2], [3] have utilized PS and PP simultaneously to achieve high performance.
- ✓ To perform PS and flexible PP, such schemes limit the prediction context to the 4-neighbour pixels and use rhombus 4-neighbour average) predictor (introduced in [1]).
- ✓ Predictors better than rhombus exist (e.g., [4]), but cannot be easily used with the 4-neighbour prediction context.

Motivation: To design a sharp-PEH-generating predictor that can be used together with pixel pairing and pixel sorting to achieve high RDH performance.

2. Maximally Separated Averages (MSA) Predictor



4-neighbour prediction context

Step 1: Compute the set of two-neighbour averages

$$S=\left\{\left\lfloor\frac{n+s}{2}\right\rfloor,\left\lfloor\frac{w+e}{2}\right\rfloor,\left\lfloor\frac{n+e}{2}\right\rfloor,\left\lfloor\frac{e+s}{2}\right\rfloor,\left\lfloor\frac{s+w}{2}\right\rfloor,\left\lfloor\frac{w+n}{2}\right\rfloor\right\}$$

Step 2: Compute the values:

$v_L = \min S$ and

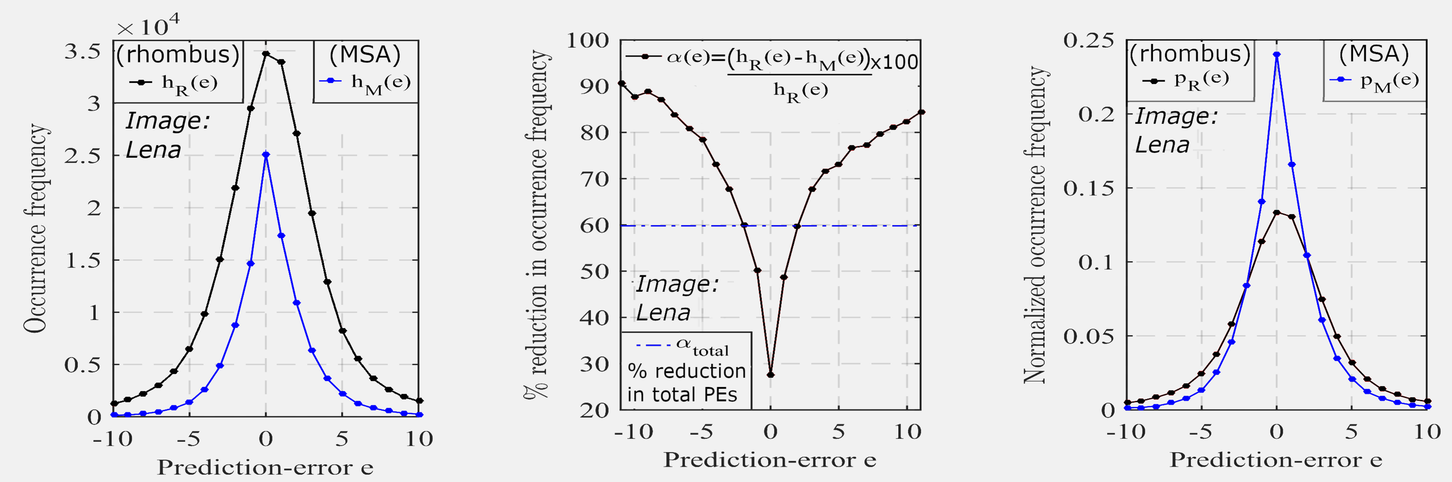
$v_H = \max S$

Step 3: Compute prediction value

Cases	Prediction value
$x \geq v_H$	v_H
$x < v_L$	v_L
$v_L \leq x < v_H$	Unpredictable Pixel Location (UPL)

Using the 4 neighbour pixels, 11 ($^4C_2 + {}^4C_3 + {}^4C_4$) averages can be computed. Among these, the two most separated averages are from the set S as the two-neighbour averages have the lowest common neighbours (either 0 or 1) . Hence, we call max S and min S as the maximally separated averages.

Reduction in PEH entropy due to UPLs



Un-normalized PEH | % reduction in PE | Normalized PEH

After PEH generation using non-UPLs, it can be observed that $h_R(e)>h_M(e)$. As |e| increases from 0, change in $h_R(e)$ >> change in $h_R(e)$-$h_M(e)$. Hence, % reduction of PE in MSA w.r.t rhombus, α(e), increases (except a few local inconsistencies) with increase in |e|. Let α_{total} = % reduction in total PEs in MSA w.r.t rhombus. If $\alpha(e)<\alpha_{total}$ ($\alpha(e)>\alpha_{total}$) then $p_M(e)>p_R(e)$ ($p_M(e)<p_R(e)$). Hence, PEH entropy decreases due to exclusion of UPLs.

The two maximally separated averages are chosen in step 2 to maximize the number of UPLs for high PEH entropy reduction.

3. Results

Performance gain by using our MSA predictor in [1],[2],[3]

- ✓ Performance (embedding distortion) is evaluated by PSNR between marked & cover images.
- ✓ [1] is a popular benchmark RDH scheme that employs pixel sorting and rhombus predictor.
- ✓ [2], [3] are state-of-the-art RDH schemes based on rhombus predictor, pixel pairing & sorting.

PSNR gains (dB) in schemes (averaged over payloads ranging from 1kbits to max embedding capacity with steps of 1kbits)

	USC-SIPI test images						
	Lena	Baboon	F16	Barbara	Lake	Boat	Average
[1]	1.29	1.16	1.41	1.36	0.74	1.16	1.187
[2]	1.08	1.02	1.15	1.29	0.50	0.94	0.997
[3]	0.92	0.83	0.64	1.04	0.46	0.83	0.787

Increase in PEH sharpness i.e. decrease in PEH entropy

PEH entropy	Lena	Baboon	F16	Barbara	Lake	Boat
Rhombus predictor	4.108	5.967	3.864	5.111	4.963	4.811
MSA predictor	**3.415**	**5.313**	**2.612**	4.337	**4.314**	**4.094**
Predictor of [4]	3.939	5.696	3.722	**4.040**	4.869	4.432

4. Conclusion

High prediction-error histogram sharpness

- ✓ Better than rhombus predictor and comparable to the highly efficient predictor of [4].

Flexible choice of prediction contexts

- ✓ Compatible with the 4-neigbour prediction context and extendable to any other context.

Simultaneous usage with pixel pairing and pixel sorting

- ✓ Further performance improvement can be achieved in high performance RDH schemes employing pixel pairing and pixel sorting by using the proposed MSA predictor.

References

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2) B. Ou, X. Li, Y. Zhao, R. Ni, and Y.-Q. Shi, **"Pairwise prediction-error expansion for efficient reversible data hiding,"** *IEEE Trans. Image Process.*, vol. 22, no. 12, pp. 5010–5021, 2013.
3) B. Ou, X. Li, W. Zhang, and Y. Zhao, **"Improving pairwise pee via hybrid-dimensional histogram generation and adaptive mapping selection,"** *IEEE Trans. Circuits Syst. Video Techn.*, to be published, doi:10.1109/TCSVT.2018.2859792.
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