IMPROVED PAIRWISE PIXEL-VALUE-ORDERING FOR HIGH-FIDELITY REVERSIBLE DATA HIDING

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Introduction

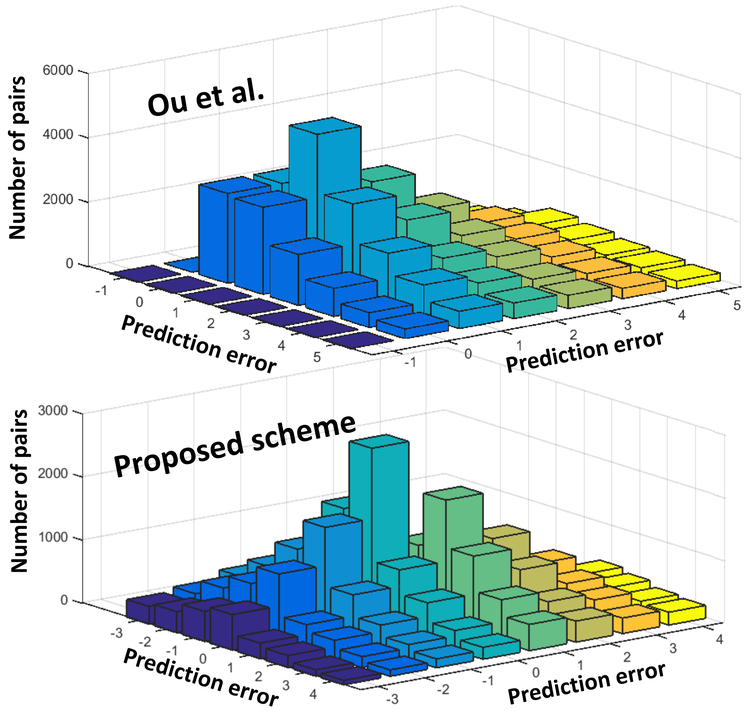
A new approach which improves the reversible data hiding framework of Ou et al.*

Original features:

- improved difference equations;
- streamlined pair classification and embedding;
- embedding parameters determined by linear programming.

Proposed scheme

- divide the image into equally sized blocks;
- split the blocks into three groups based on the t_1, t_2 complexity thresholds;
- **use pairwise IPVO on smooth blocks:**
  - sort the pixel values, $x_{(1)} \le x_{(2)} \le \ldots \le x_{(n)}$;
  - select $x_{(1)}, x_{(2)}, x_{(n-1)}$ and $x_{(n)}$ as host pixels;
  - select $x_{(3)}$ and $x_{(n-2)}$ as reference pixels;
  - compute the corresponding difference values;
  - pair the host pixels as (x_{u1}, x_{v1}) and (x_{u2}, x_{v2}) based on their original positions in the block;
  - embed the pairs using the streamlined embedding equations.
- **use classic IPVO on slightly noisy blocks:**
  - sort the pixel values, $x_{(1)} \le x_{(2)} \le \ldots \le x_{(n)}$;
  - select $x_{(1)}$ and $x_{(n)}$ as host pixels;
  - select $x_{(2)}$ and $x_{(n-1)}$ as reference pixels;
  - embed the host pixels based on their corresponding difference values.
- **noisy blocks remain unchanged.**



Linear programming model

- determine t_1, t_2 and the block size b_1 for the desired capacity C;
- pairwise IPVO offers a capacity of $C_{p1}(t_1, b_1)$ and a distortion of $D_{p1}(t_1, b_1)$;
- classic PVO offers $C_{p2}(t_2, b_2)$ and $D_{p2}(t_2, b_2)$;
- the total capacity/distortion is:

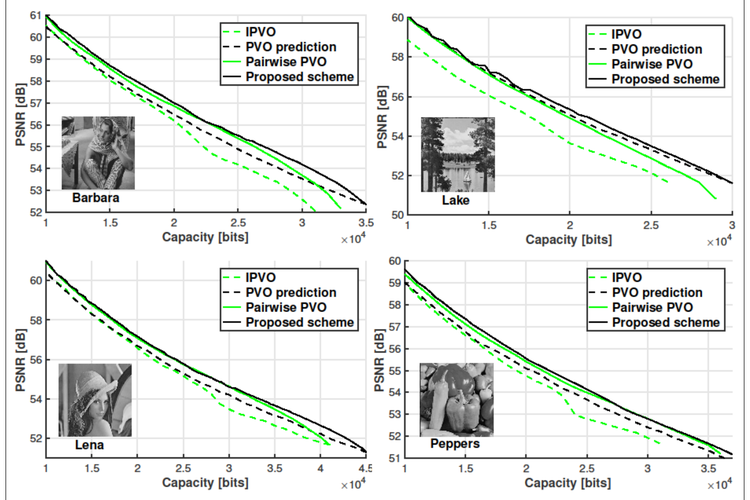
$$C_{p\ t_1,t_2,b_1,b_2} = C_{p1}(t_1, b_1) + C_{p2}(t_2, b_2) - C_{p2}(t_1, b_2)$$
$$D_{p\ t_1,t_2,b_1,b_2} = D_{p1}(t_1, b_1) + D_{p2}(t_2, b_2) - D_{p2}(t_1, b_2)$$

Objective function:

$$F = \arg \min_{t_1,t_2,b_1,b_2} D_{p\ t_1,t_2,b_1,b_2}$$

subject to $C_{p\ t_1,t_2,b_1,b_2} \ge C,\ t_1 < t_2,\ b_1 = b_2$.

Experimental Results



Test image	PSNR results for a given capacity [dB]					
	10,000 bits		20,000 bits		30,000 bits	
	Pairwise PVO	Proposed scheme	Pairwise PVO	Proposed scheme	Pairwise PVO	Proposed scheme
Kodim01	63.52	64.07	58	59.42	53.81	55.39
Kodim02	64.26	64.3	60.79	60.76	58.59	58.84
Kodim03	65.55	65.38	61.59	62.43	59.44	60.31
Kodim04	64.09	63.91	59.94	60.42	57.72	58.19
Kodim05	62.27	63.03	58.32	58.77	54.67	55.85
Kodim06	66.09	66.22	61.41	62.64	58.38	60.02
Kodim07	65.11	64.64	61.42	62.13	59.22	60.08
Kodim08	59.87	60.54	55.7	55.89	-	-
Kodim09	63.84	63.44	60.05	60.45	57.82	58.66
Kodim10	63.44	63.34	59.81	60.30	57.51	58.17
Kodim11	65.26	65.73	61.29	61.82	58.23	59.50
Kodim12	64.74	64.64	60.75	61.55	58.38	59.32
Kodim13	58.29	58.19	52.1	52.23	-	-
Kodim14	62.06	62.49	57.83	58.26	54.73	55.57
Kodim15	65.61	65.02	61.45	61.86	59.24	59.8
Kodim16	65.07	65.08	61.01	61.92	59.20	59.76
Kodim17	64.07	64.26	59.83	60.8	57.86	58.31
Kodim18	61.32	61.8	57.32	57.8	54.40	55.06
Kodim19	63.4	63.38	59.89	60.13	57.60	57.86
Kodim20	65.53	62.55	62.47	62.63	60.42	60.73
Kodim21	63.87	63.75	60.04	60.81	57.61	58.5
Kodim22	63.07	63.4	59.22	59.6	56.50	57.05
Kodim23	64.89	64.44	60.87	61.45	58.87	59.64
Kodim24	63.18	62.57	59.99	58.8	56.96	56.02
Average	63.68	63.71	59.63	60.11	57.6	58.3

Conclusions

- ✓ a more efficient data hiding scheme that better exploits the 2D prediction error histogram;
- ✓ linear programming → optimal embedding;
- ✓ outperform other recent PVO schemes.

* B. Ou, X. Li and J. Wang, High-fidelity reversible data hiding based on pixel-value-ordering and pairwise prediction-error expansion. Journal of Visual Communication and Image Representation, 2016.