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Improved Pairwise Embedding for High-Fidelity Reversible Data Hiding

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Objectives

Eliminate the complex coding of 2D-RDH for embedding $\log_2 3$ bits/pair without any loss in performance.

PE-HS based RDH[1]

- Determine a predicted value $\hat{x}$ for each pixel x

142	146	143	140	140	142	140
142	144	142	141	139	142	145
143	141	143	138	139	139	144
144	145	x=141	139	141	139	140
144	142	142	140	139	142	140
144	139	140	136	142	137	140
143	144	143	140	144	134	139
147	142	141	143	140	136	138

$$\hat{x} = \left\lfloor \frac{143 + 145 + 130 + 142}{4} \right\rfloor = 140$$

- Compute the prediction error:

$$e = x - \hat{x}$$

- Select two host prediction errors:

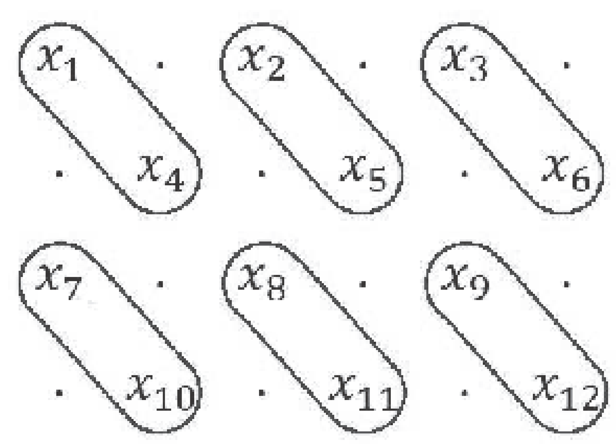
$$l = -1 \qquad r = 0$$

- Insert a data bit $b \in \{0;1\}$ into each pixel with the selected errors:

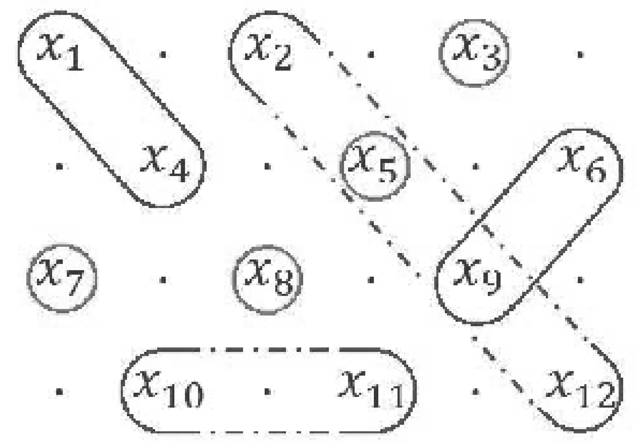
$$x' = \begin{cases} x - b, & \text{if } e = -1 \\ x + b, & \text{if } e = 0 \\ x - 1, & \text{if } e < -1 \\ x + 1, & \text{if } e > 0 \end{cases}$$

Pairwise RDH

- Determine the prediction values $\hat{x}$ and errors e;
- Group the pixels into pairs:



Classic fixed pairs[2]



Adaptive Pairs[3]

- Insert the hidden data into each pair:

$$(x', p') = \begin{cases} (x,p) + (s_x b_1, s_p b_2), & \text{if } e_x \in \{-1,0\} \text{ and } e_p \in \{-1,0\} \\ (x,p) + (s_x b_i, s_p b_i), & \text{if } e_x \in \{-2,1\} \text{ and } e_p \in \{-2,1\} \\ (x,p) + (s_x b_i, s_p), & \text{if } e_x \in \{-1,0\} \text{ and } e_p \in \{-2,1\} \\ (x,p) + (s_x, s_p b_2), & \text{if } e_x \in \{-2,1\} \text{ and } e_p \in \{-1,0\} \end{cases}$$

where: $s_x = \begin{cases} -1, & e_x < 0 \\ 1, & e_x \geq 0 \end{cases}$ $\quad s_p = \begin{cases} -1, & e_p < 0 \\ 1, & e_p \geq 0 \end{cases}$

$$(b_1, b_2) \in \{(0,0); (0,1); (1,0)\} \text{ and } b_i \in \{0;1\}$$

Proposed Scheme

Replace the three symbol based equation with one based on the (b_1, b_2) bits.

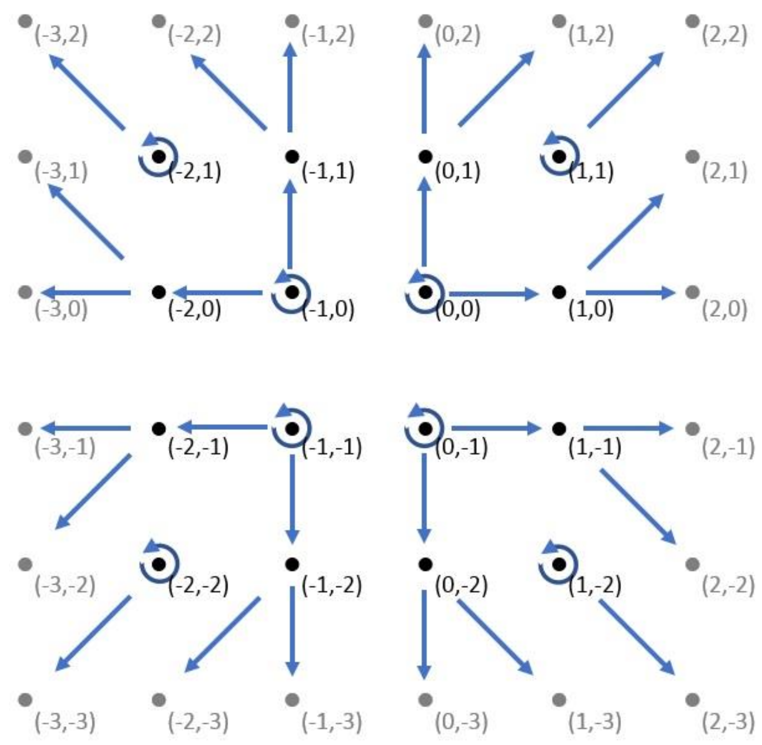
- If $(e_x, e_p) \in \{(0,0); (-1,0)\}$, then insert two bits of data:

$$(x', p') = \begin{cases} (x,p), & \text{if } (b_1,b_2) = (0,0) \\ (x,p) + (0, s_p), & \text{if } (b_1,b_2) = (0,1) \\ (x,p) + (s_x, 0), & \text{if } (b_1,b_2) = (1,0) \\ (x,p) + (0, -s_p), & \text{if } (b_1,b_2) = (1,1) \end{cases}$$

- If $(e_x, e_p) \in \{(-1,0); (-1,-1)\}$, then insert one bit of data:

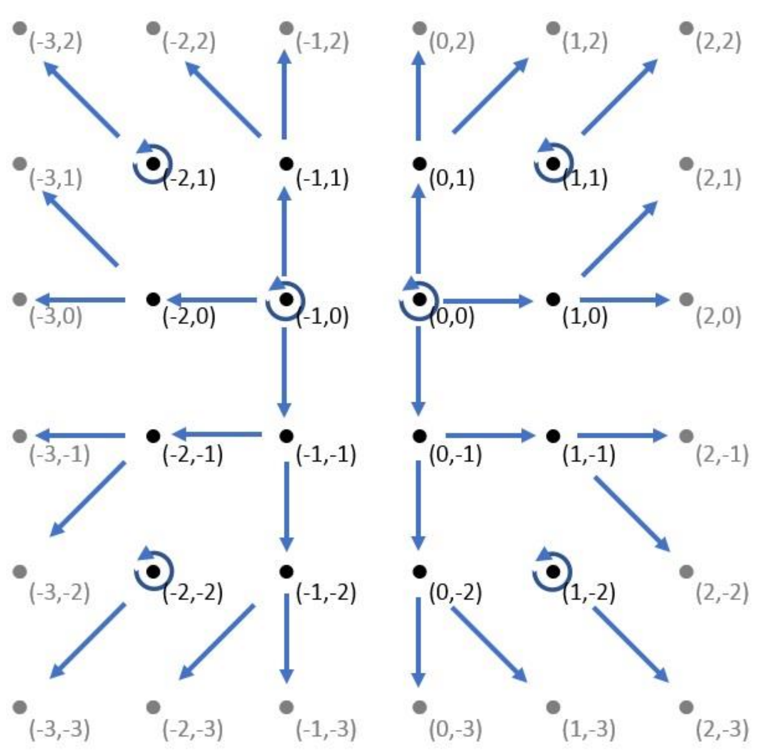
$$(x', p') = \begin{cases} (x,p) + (0, s_p), & \text{if } b = 0 \\ (x,p) + (s_x, 0), & \text{if } b = 1 \end{cases}$$

- Otherwise use the classic pairwise equations.



Pairwise embedding

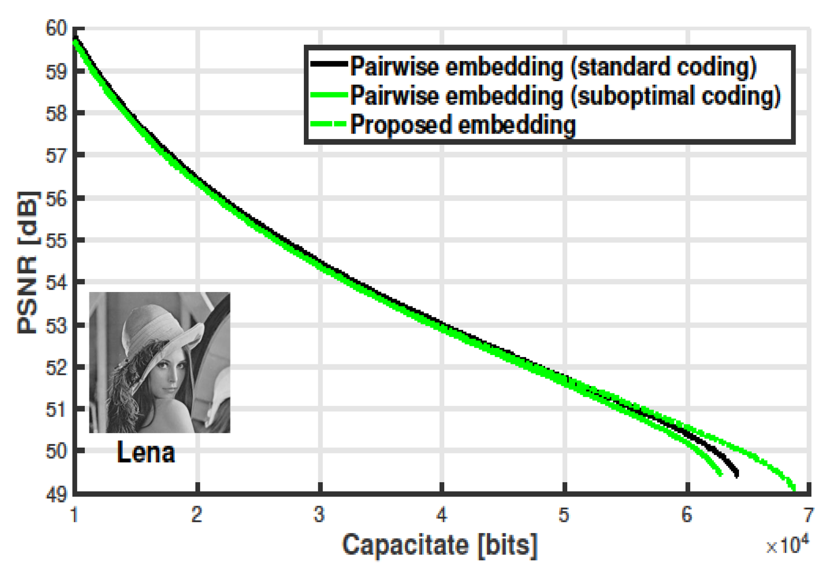
Embeds $\log_2 3$ bits/pair into 4 bins of the 2D histogram

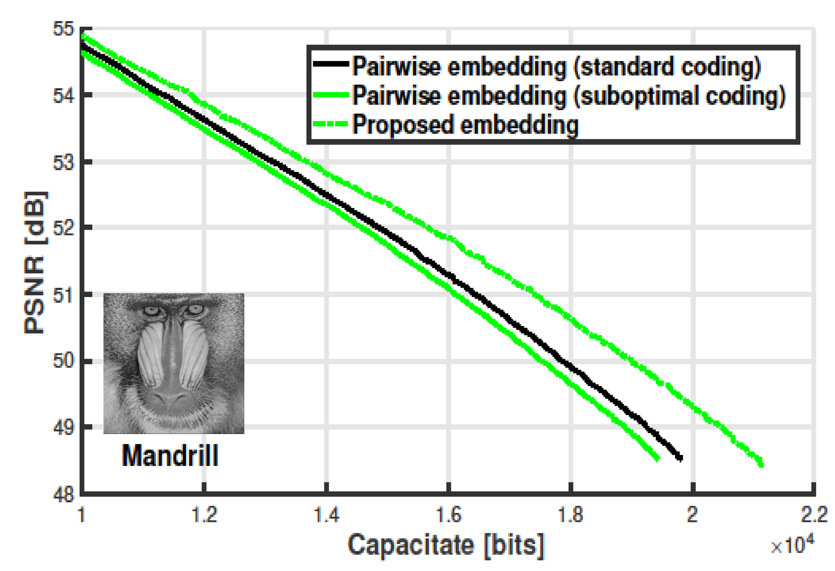


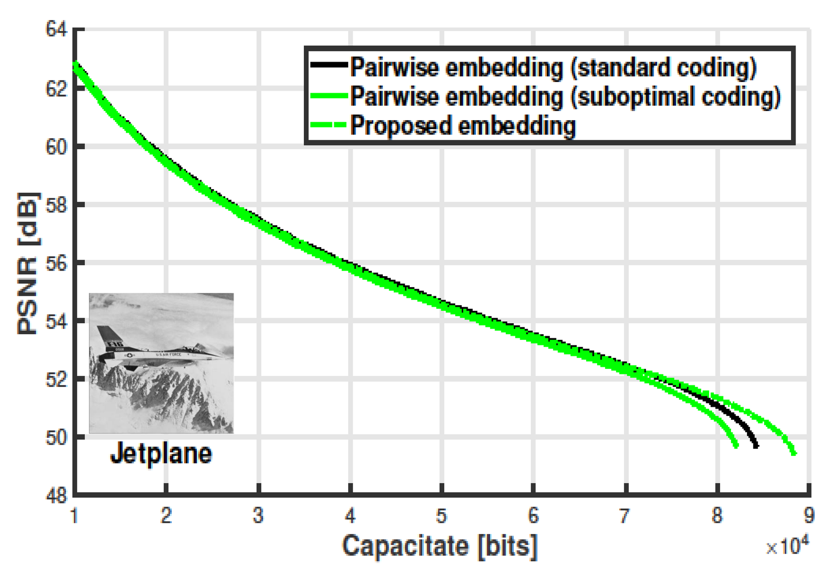
Proposed embedding

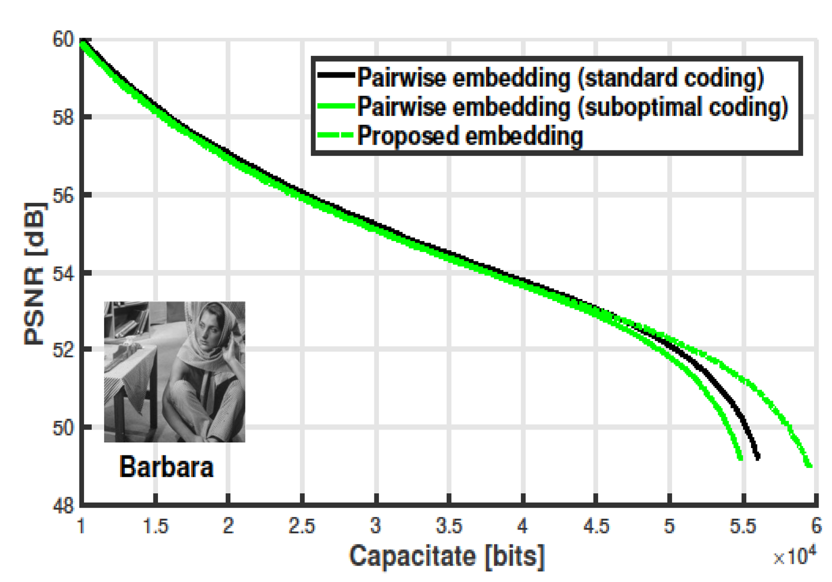
Embeds 2 bits/pair into the most populated 2 bins

Experimental Results









Conclusions

- ✓ Low complexity & high-fidelity 2D-RDH;
- ✓ Embeds either 1 or 2 bits per pair;
- ✓ Slight gain in embedding capacity;
- ✓ Appropriate for most 2D-RDH approaches.

1. W. Hong, T.-S. Chen and C.-W. Shiu. ”Reversible data hiding for high quality images using modification of prediction errors,” Journal of Systems and Software., vol. 82, no. 11, pp. 18331842, 2009.
2. B. Ou, X. Li, Y. Zhao, R. Ni and Y.-Q. Shi, ”Pairwise prediction-error expansion for efficient reversible data hiding,” IEEE Trans. on Image Processing, vol. 22, no. 12, pp. 5010–5021, 2013.
3. I.-C. Dragoi and D. Coltuc, ”Adaptive pairing reversible watermarking,” IEEE Trans. Image Process., vol. 25, no. 5, pp. 2420–2422, 2016.