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Second Order Predicting-Error Sorting for Reversible Data Hiding

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2016.9.19

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Framework of RDH

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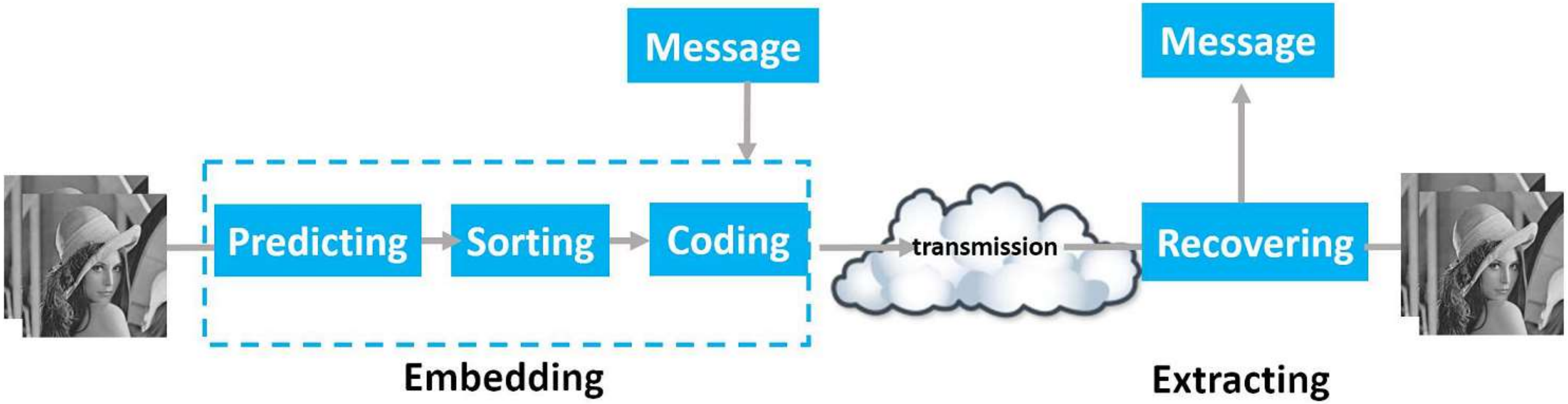

Related Work

- Prediction
  - median edge detection (MED)
  - gradient adjusted prediction (GAP)
  - differential adaptive run coding (DARC)
  - extended gradient-based selection and weighting (EGBSW)
- Sorting
  - reduce the location map by arranging the pairs of pixels in order
  - use local variance values to sort the predicted errors
  - use the sum of absolute differences between diagonal blank pixels in local region
- RDH for color images
  - based on prediction-error expansion that can enhance the prediction accuracy in one color channel through exploiting the edge information from another channel

Proposed Method

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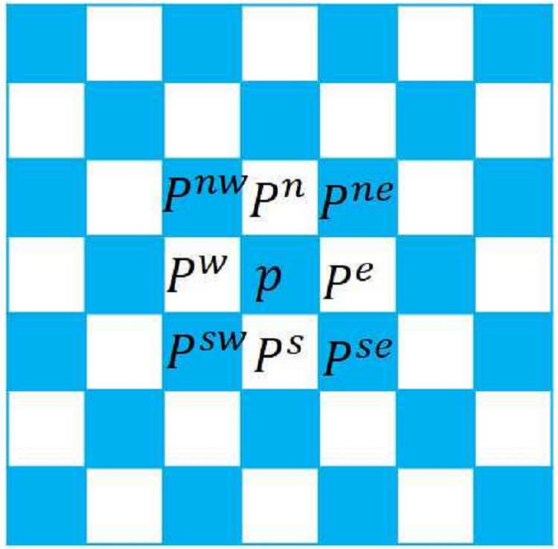
- Second order predicting-error
  - A double layered embedding method
  - $D_{avg} = |\sum_{k=1}^{8} \alpha_{avg}^{k} p_r^k - p_r|$
  - $D_{dir} = \min\left\{\left|\frac{p_r^w+p_r^e}{2} - p_r\right|, \left|\frac{p_r^n+p_r^s}{2} - p_r\right|, \left|\frac{p_r^{nw}+p_r^{se}}{2} - p_r\right|, \left|\frac{p_r^{ne}+p_r^{sw}}{2} - p_r\right|\right\}$
  - $|D_{avg} - D_{dir}|$ indicates whether the reference sample is located on an edge.
  - $\hat{p}_c = \begin{cases} \lfloor (p_c^w + p_c^e + p_c^n + p_c^s)/4 + 0.5 \rfloor & |D_{avg} - D_{avg}| \le \rho \\ \lfloor P(p_c^k | D_{dir}) + 0.5 \rfloor & |D_{avg} - D_{avg}| > \rho \end{cases}$
  - For instance, when $D_{dir} = |\frac{p_r^n+p_r^s}{2} - p_r|$, then $P(p_c^k | D_{dir}) = \frac{p_r^n+p_r^s}{2}$.



Second Order Prediction-Error

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- First order predicting-error:

$$\Delta e_c = p_c - \hat{p}_c$$
$$\Delta e_r = p_r - \hat{p}_r$$

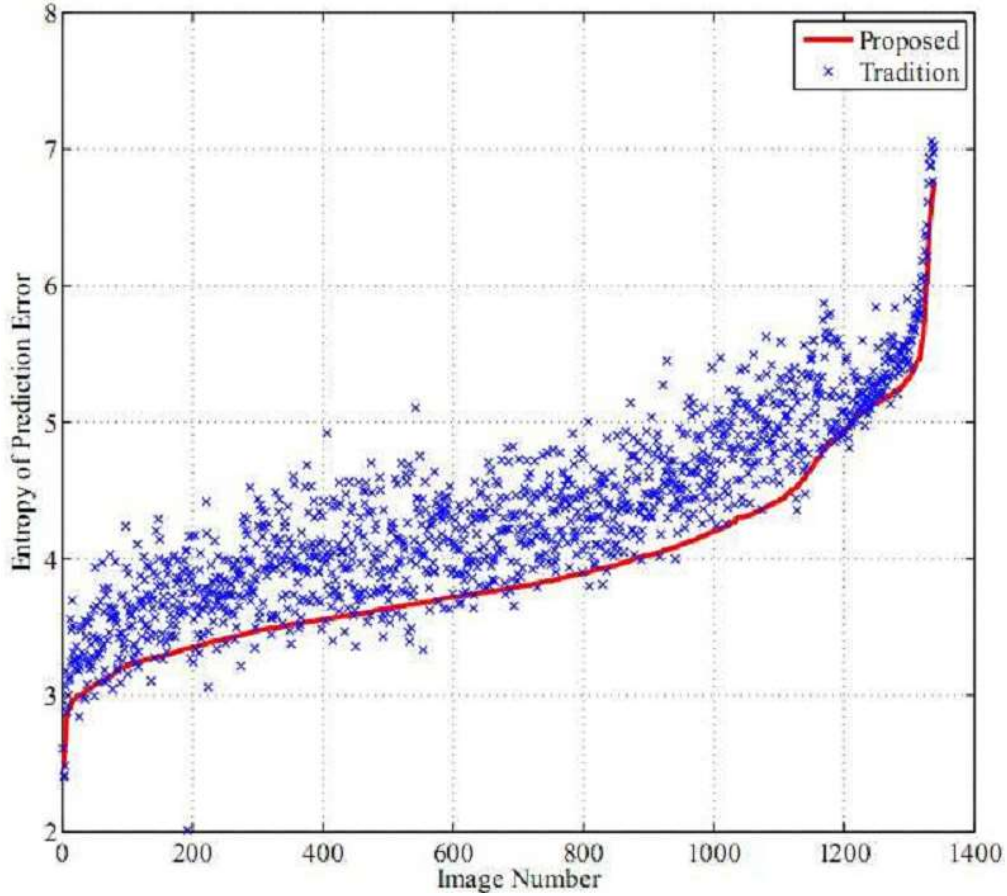
- Second order predicting-error:

$$\Delta^2 e = \Delta e_c - \Delta e_r$$

- Prediction-error sequence:

$$\Delta^2 e = (\Delta^2 e_1, \ldots, \Delta^2 e_N)$$

- Entropy is used to evaluate the performance of prediction.



Sorting Based on Generalized Normal Distribution

- Generalized normal distribution density function:

$$f(\Delta e|u,\alpha,\beta)=\frac{\beta}{2\alpha\Gamma\left(\frac{1}{\beta}\right)}\exp\left\{-\left|\frac{(\Delta e-u)}{\alpha}\right|^{\beta}\right\}$$

- Since $\Delta e_c \sim GND(u_c,\alpha_c,\beta_c)$ and $\Delta e_r \sim GND(u_r,\alpha_r,\beta_r)$,

$$f(\Delta^2 e)=-\int_{-\infty}^{+\infty} f_{\Delta e_c-\Delta e_r}(\Delta e_c,\Delta^2 e-\Delta e_c)d\Delta e_c$$

$$=-\int_{-\infty}^{+\infty}\frac{\beta_c\beta_r}{4\alpha_c\alpha_r\Gamma\left(\frac{1}{\beta_c}\right)\Gamma\left(\frac{1}{\beta_r}\right)}\times exp\left(-\left|\frac{(\Delta e_c-u_c)}{\alpha_c}\right|^{\beta_c}\right.$$

$$\left.-\left|\frac{(\Delta^2 e-\Delta e_r-u_r)}{\alpha_r}\right|^{\beta_r}\right)d\Delta e_c$$

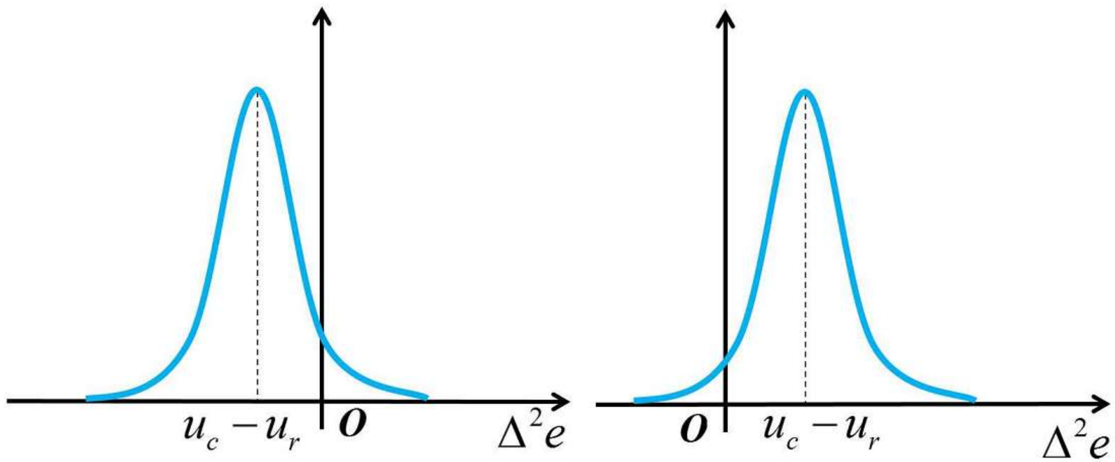
Sorting Based on Generalized Normal Distribution

- $\beta = 1$:

$$f(\Delta^2 e) = -\int_{-\infty}^{+\infty} f_{\Delta e_c - \Delta e_r}(\Delta e_c, \Delta^2 e - \Delta e_c) d\Delta e_c$$

$$= \frac{\alpha_c}{2(\alpha_c^2 - \alpha_r^2)} exp\left(-\frac{|\Delta^2 e - (\boxed{u_c - u_r})|}{\alpha_c}\right)$$

$$- \frac{\alpha_r}{2(\alpha_c^2 - \alpha_r^2)} exp\left(-\frac{|\Delta^2 e - (\boxed{u_c - u_r})|}{\alpha_r}\right)$$

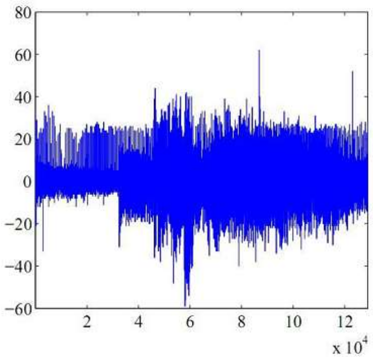


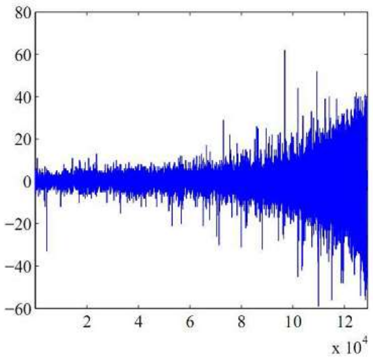
Sorting Based on Generalized Normal Distribution

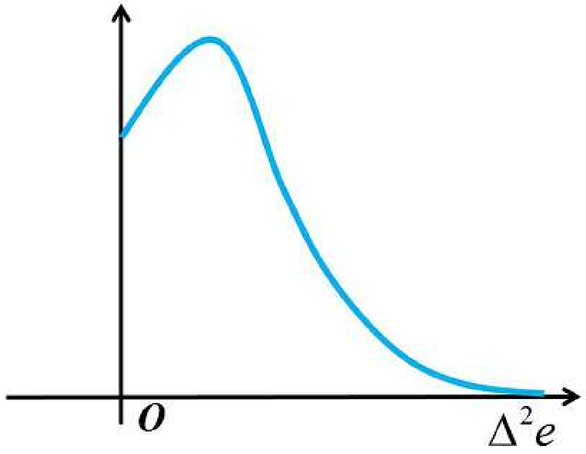
- $\Phi(\Delta^2 e) = |f(\Delta^2 e)|$, and the expectation of function $E[\Phi(\Delta^2 e)]$ has positive correlation to $u_c - u_r$.
- $\Phi(\Delta^2 e) = \frac{a}{2\alpha_c}\left(\exp\left(-\frac{|u-\alpha_c|}{\alpha_c}\right) + \exp\left(-\frac{|u+\Delta^2 e|}{\alpha_c}\right)\right) - \frac{b}{2\alpha_r}\left(\exp\left(-\frac{|u-\Delta^2 e|}{\alpha_r}\right) + \exp\left(-\frac{|u+\Delta^2 e|}{\alpha_r}\right)\right)$
- $E[\Phi(\Delta^2 e)] = -\int_0^{+\infty} \Delta^2 e \Phi(\Delta^2 e) d\Delta^2 e$

$$= a \times exp\left(-\frac{u}{\alpha_c}\right) - b \times exp\left(-\frac{u}{\alpha_r}\right) + u$$

- $E[\Phi(\Delta^2 e)] \le \lambda$ are used in data embedding







Framework of Data Hiding for the 3 Channels

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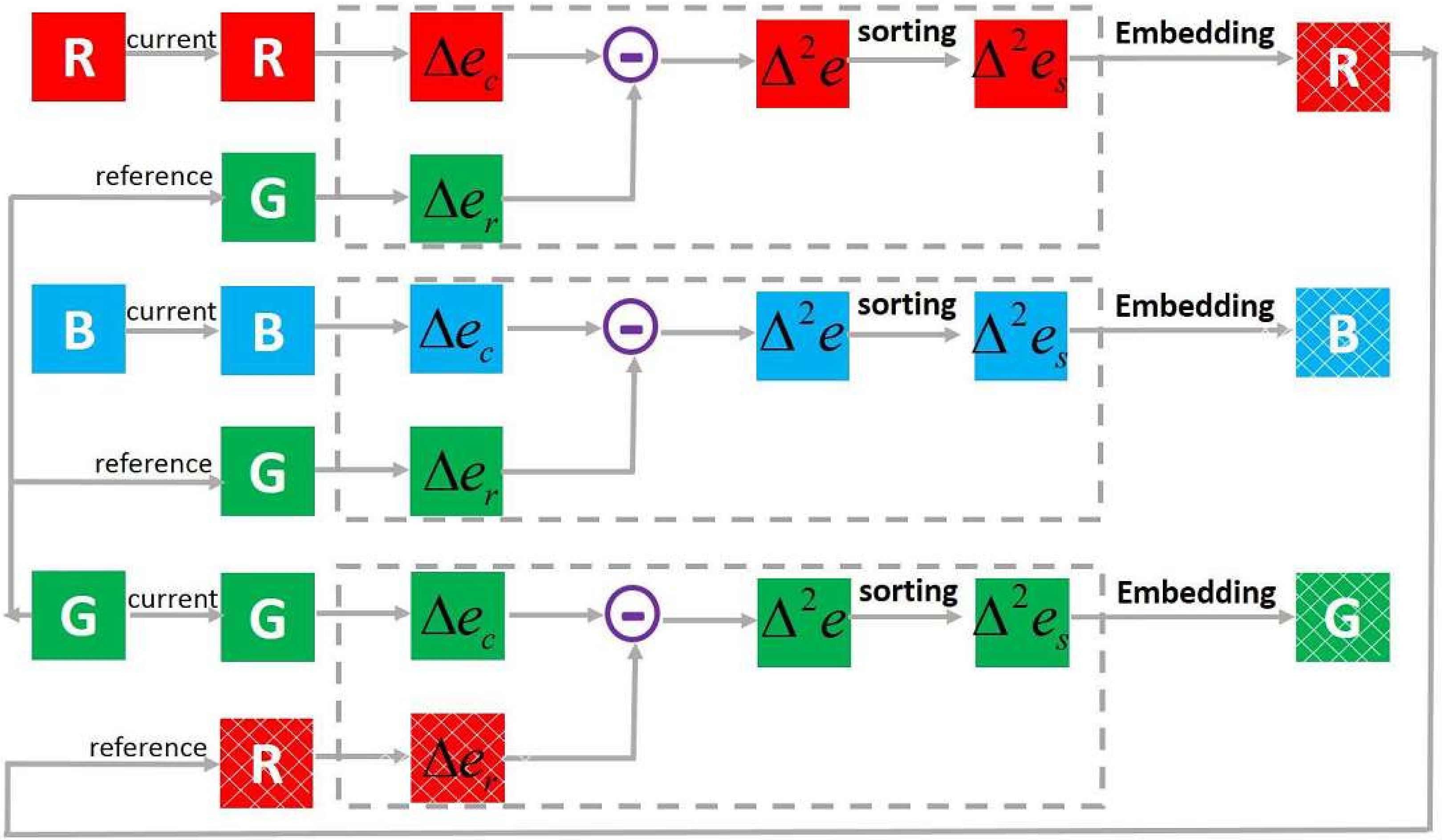
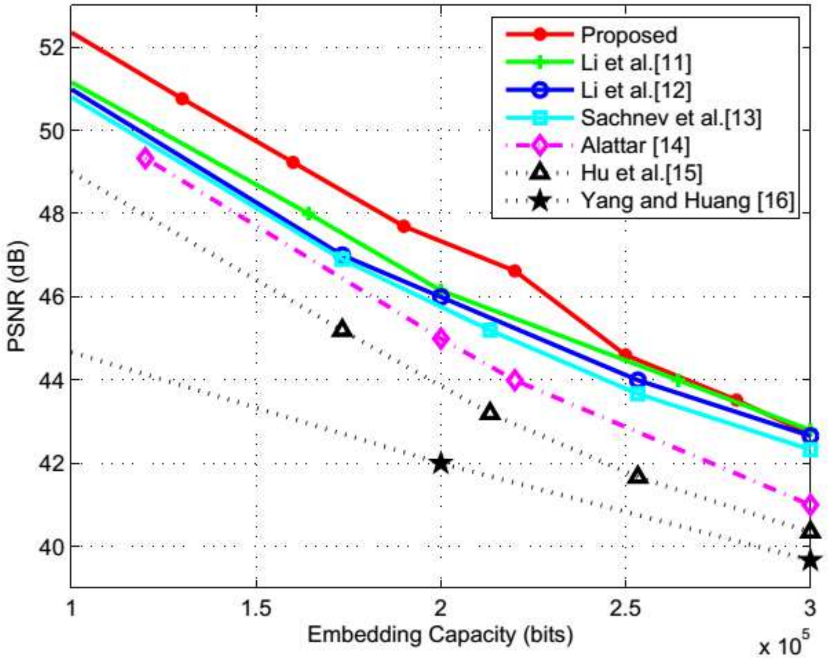
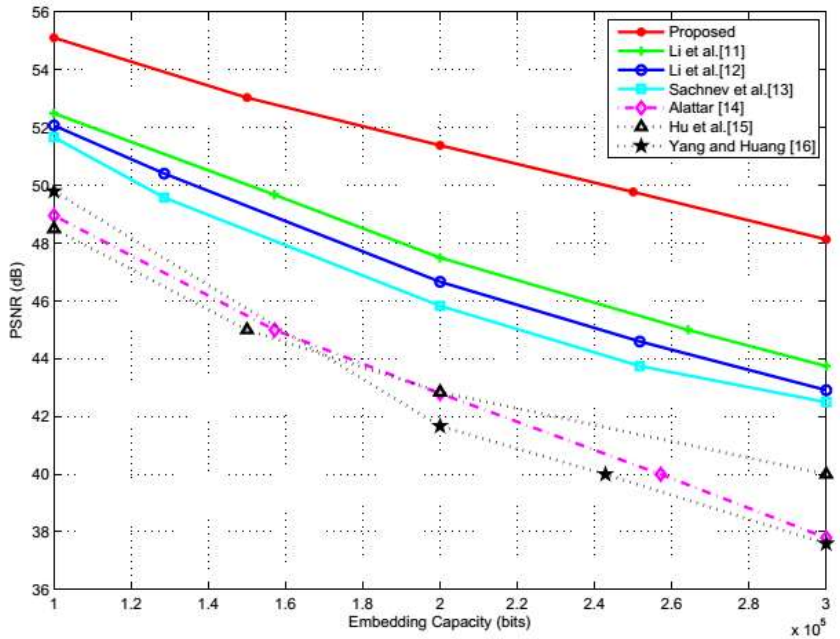


Experiment & Analysis



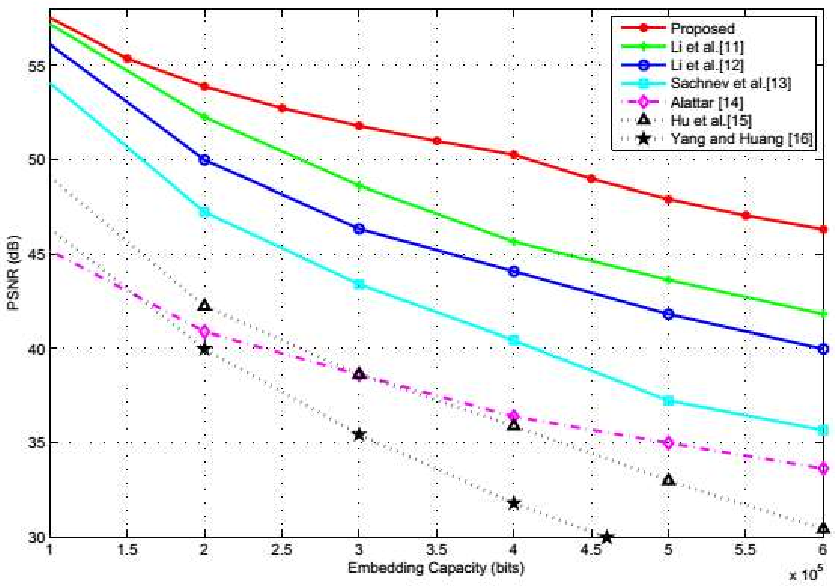
(a) Lena



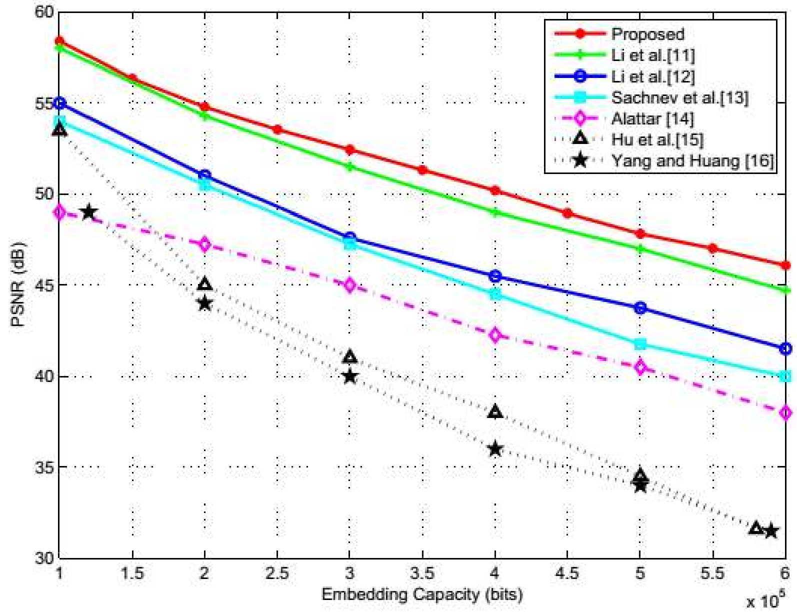
(b) Barbara

[11] J Li, X Li, B Yang. *Reversible data hiding scheme for color image based on prediction-error expansion and cross-channel correlation*. Signal Processing, 2013.
[12] J. Li, X. Li, B. Yang. *PEE-based reversible watermarking for color image.* ICIP, 2012.
[13] V. Sachnev, H. J. Kim, J. Nam, S. Suresh, and Y. Shi. *Reversible watermarking algorithm using sorting and prediction.* IEEE TCSVT., 2009.
[14] A.M. Alattar. Reversible watermark using the difference expansion of a generalized integer transform. IEEE TIP, 2004.
[15] Y. Hu, H. Lee, J. Li. DE-based reversible data hiding with improved overflow location map. IEEE TCSVT, 2009.
[16] H. Yang, K. Hwang. Reversible data hiding for color BMP image based on block difference histogram. Proceedings of the Fourth International Conference on Ubimedia Computing (U-Media), 2011.

Experiment & Analysis



(a) Kodak-01



(b) Kodak-24

[11] J Li, X Li, B Yang. *Reversible data hiding scheme for color image based on prediction-error expansion and cross-channel correlation*. Signal Processing, 2013.
[12] J. Li, X. Li, B. Yang. *PEE-based reversible watermarking for color image.* ICIP, 2012.
[13] V. Sachnev, H. J. Kim, J. Nam, S. Suresh, and Y. Shi. *Reversible watermarking algorithm using sorting and prediction.* IEEE TCSVT., 2009.
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[16] H. Yang, K. Hwang. Reversible data hiding for color BMP image based on block difference histogram. Proceedings of the Fourth International Conference on Ubimedia Computing (U-Media), 2011.

Conclusion

- Propose a novel second order **predicting** and **sorting** technique for reversible data hiding.
- The method make full use of the feature of the edge information obtained from another color channel and high correlation between adjacent pixels. So it will reflect the local context complexity for pixel and prediction accuracy of prediction-error.
- Experimental results show that the proposed method has better results compared to the other six recent works of Li et al. [11], Li et al.[12], Sachnev et al. [13], Alattar [14], Hu et al. [15], Yang and Huang [16].

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THANKS FOR LISTENING!

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