# A Recent Survey Of Reversible Watermarking Approaches

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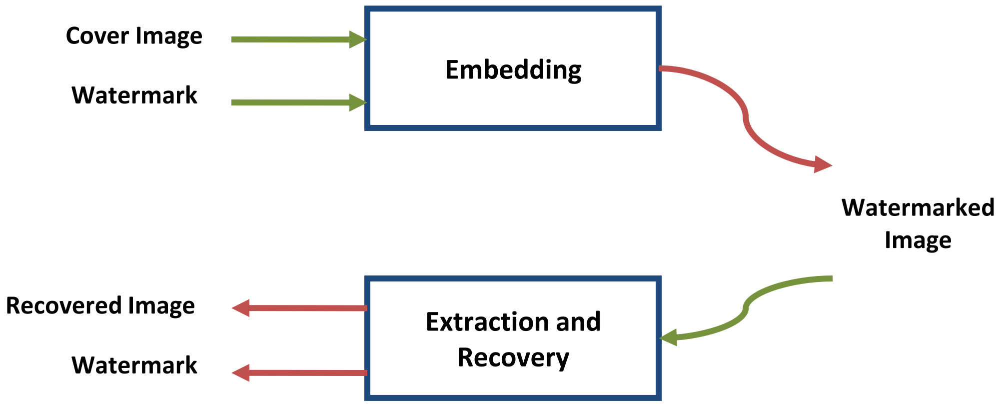
# Presentation Layout

- Introduction
- Categories
- Comparison
- Conclusions

# Introduction

- Digital watermarking
- Properties
  - Imperceptibility
  - Robustness
  - Capacity

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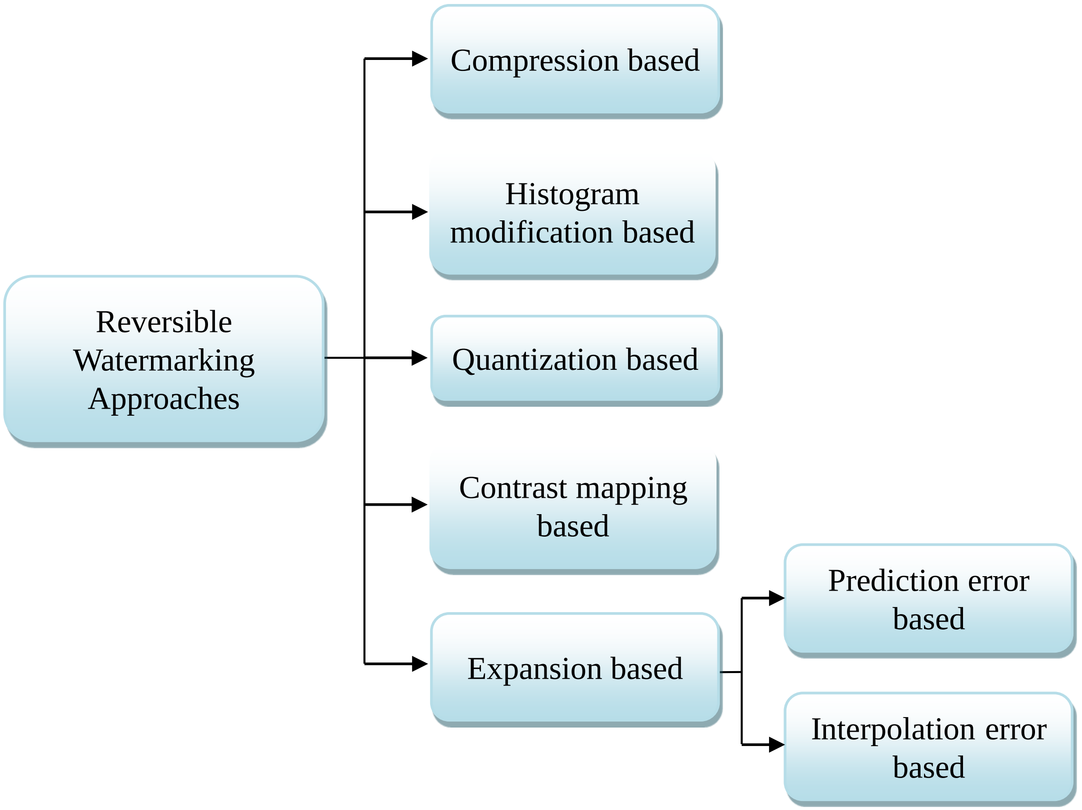
# Classification of Watermarking

- Hard to draw a precise boundary among different categories

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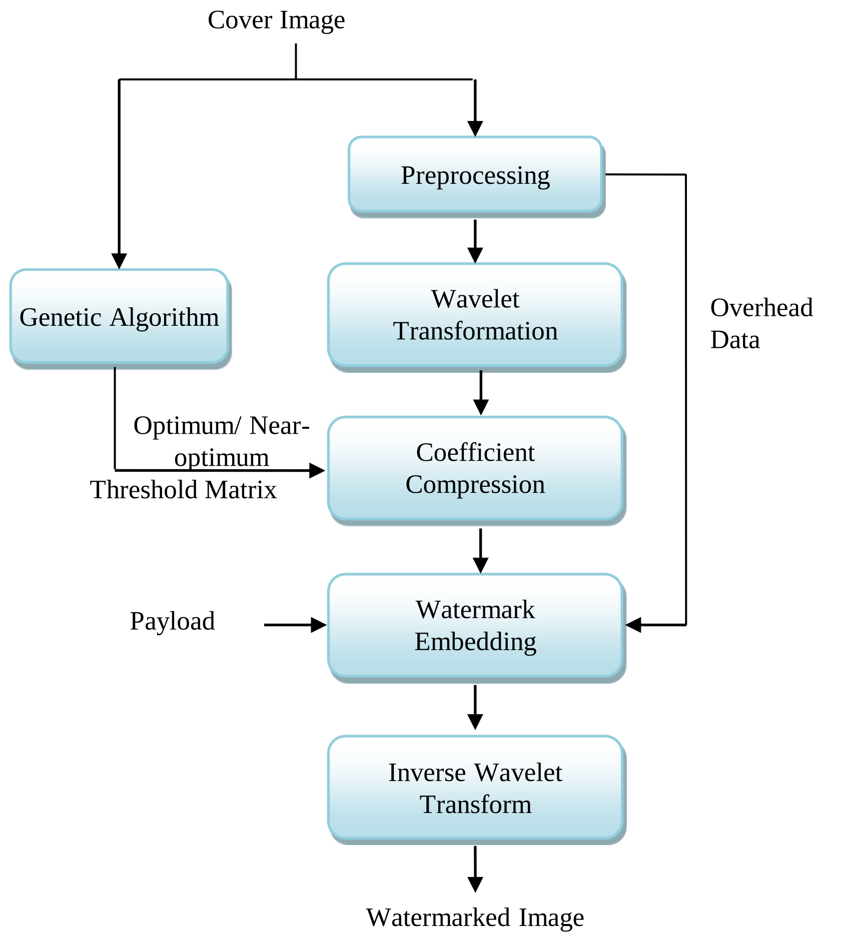
# Compression based RW

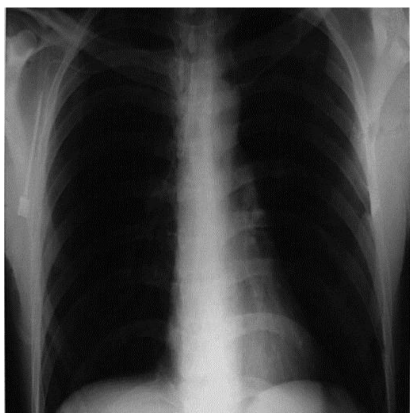
- Compresses a part of cover image for embedding data
  - Data space is required to store additional data
- Block diagram: Arsalan et al. 's



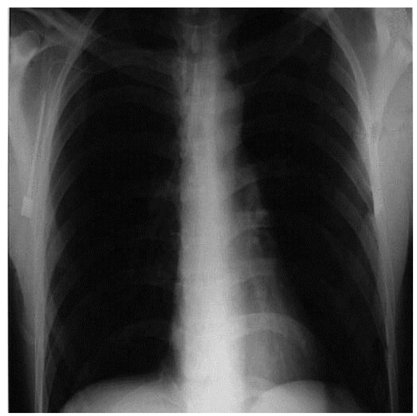

M. Arsalan, S. A. Malik, and A. Khan, "Intelligent reversible watermarking in integer wavelet domain for medical images," *Journal of Systems & Software*, vol. 85, no. 4, pp. 883–894, Apr. 2012.

# Compression based RW

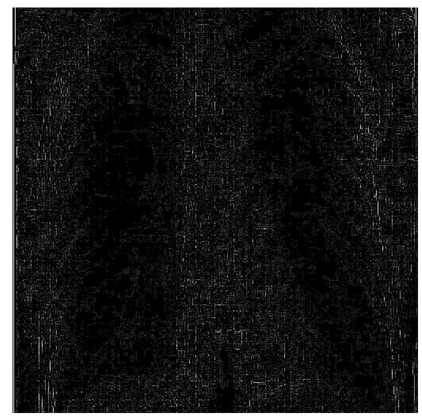
- PSNR: *42.72dB*
- Embedding capacity: *0.7bpp*



Chest X-Ray Image



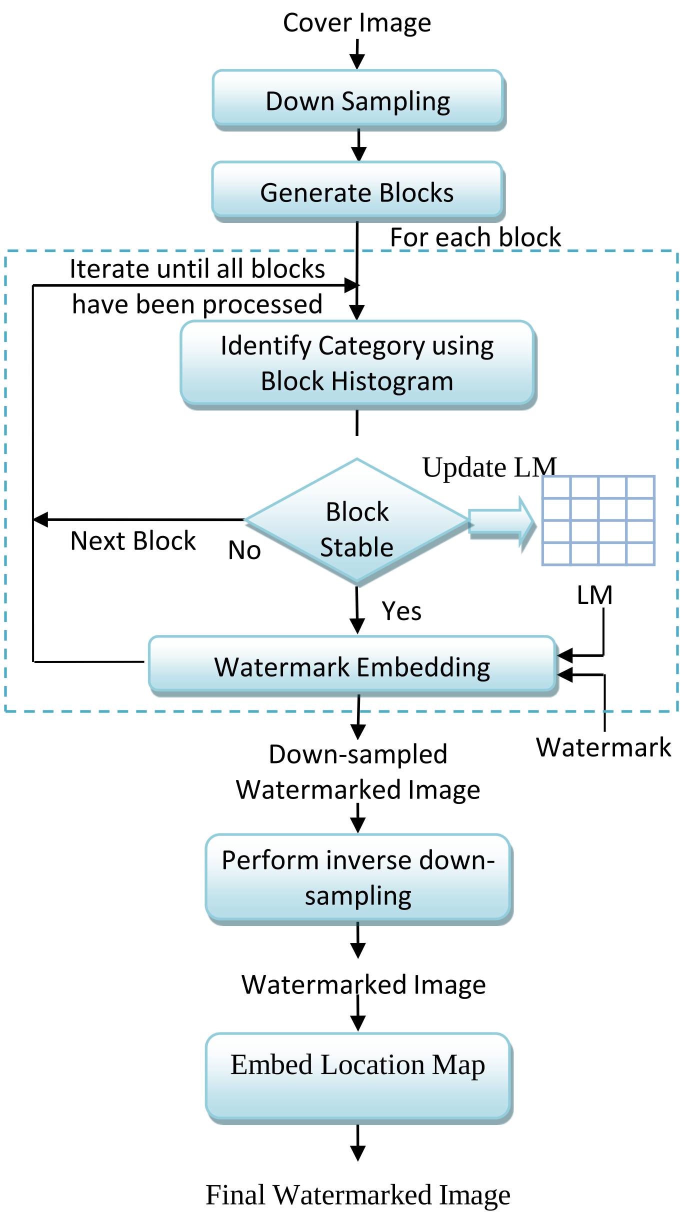
Watermarked Image



Enhanced difference

M. Arsalan, S. A. Malik, and A. Khan, "Intelligent reversible watermarking in integer wavelet domain for medical images," *Journal of Systems & Software*, vol. 85, no. 4, pp. 883–894, Apr. 2012.

# Histogram Shifting based RW




M. Kamran, "Computational intelligence based reversible image watermarking," M.S. thesis, Dept. Electrical Engineering, PIEAS, Islamabad, Pakistan, 2010.

# Histogram Shifting based RW

- PSNR: *41.65dB*
- Embedding capacity: *0.8bpp*

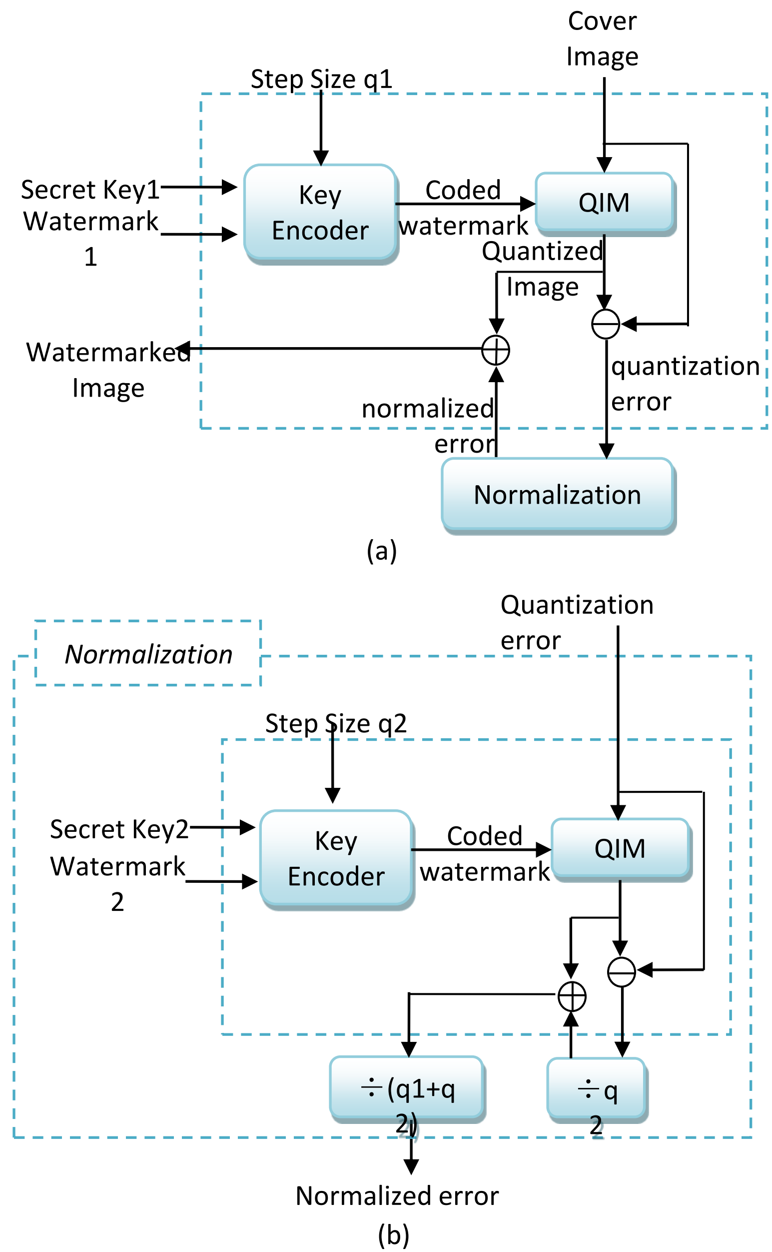
Cameraman Image

Watermarked Image

Enhanced Difference

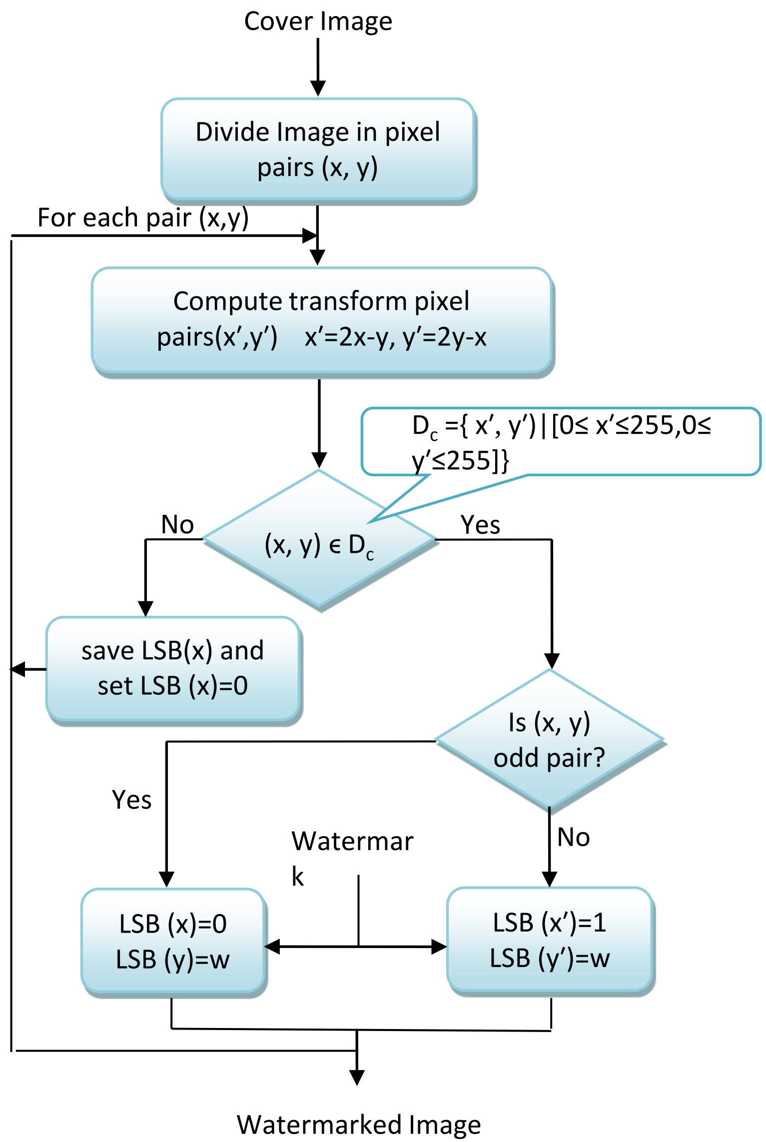
M. Kamran, "Computational intelligence based reversible image watermarking," M.S. thesis, Dept. Electrical Engineering, PIEAS, Islamabad, Pakistan, 2010.

# Quantization based RW



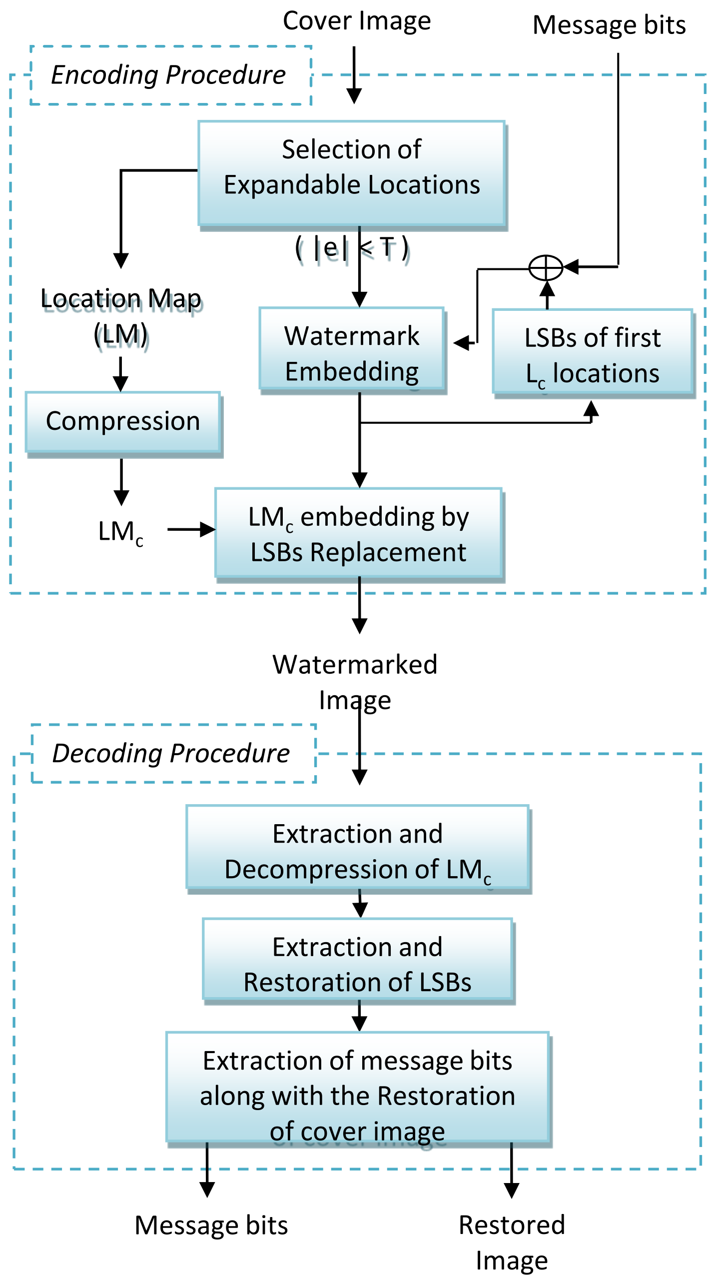

L. T. Ko, J. E. Chen, Y. S. Shieh, H. C. Hsin, and T. Y. Sung, "Nested Quantization Index Modulation for Reversible Watermarking and Its Application to Healthcare Information Management Systems," *Computational and Mathematical Methods in Medicine,*, vol. 2012, Article ID 839161, p. 1-8, 2012.

# Contrast Mapping based RW




D. Coltuc and J. Chassery, "Very fast watermarking by reversible contrast mapping," *IEEE Signal Processing Letters*, vol. 14, no. 4, pp. 255–258, Apr. 2007.

# Prediction Error based RW




D. M. Thodi and J. J. Rodriguez, "Prediction-error based reversible watermarking," in Proc. IEEE *Int. Conf. on Image Processing,* 2004, pp. 1549–1552.

# Prediction Error based RW

- PSNR: *37.01 dB*
- Embedding capacity: *0.4 bpp*

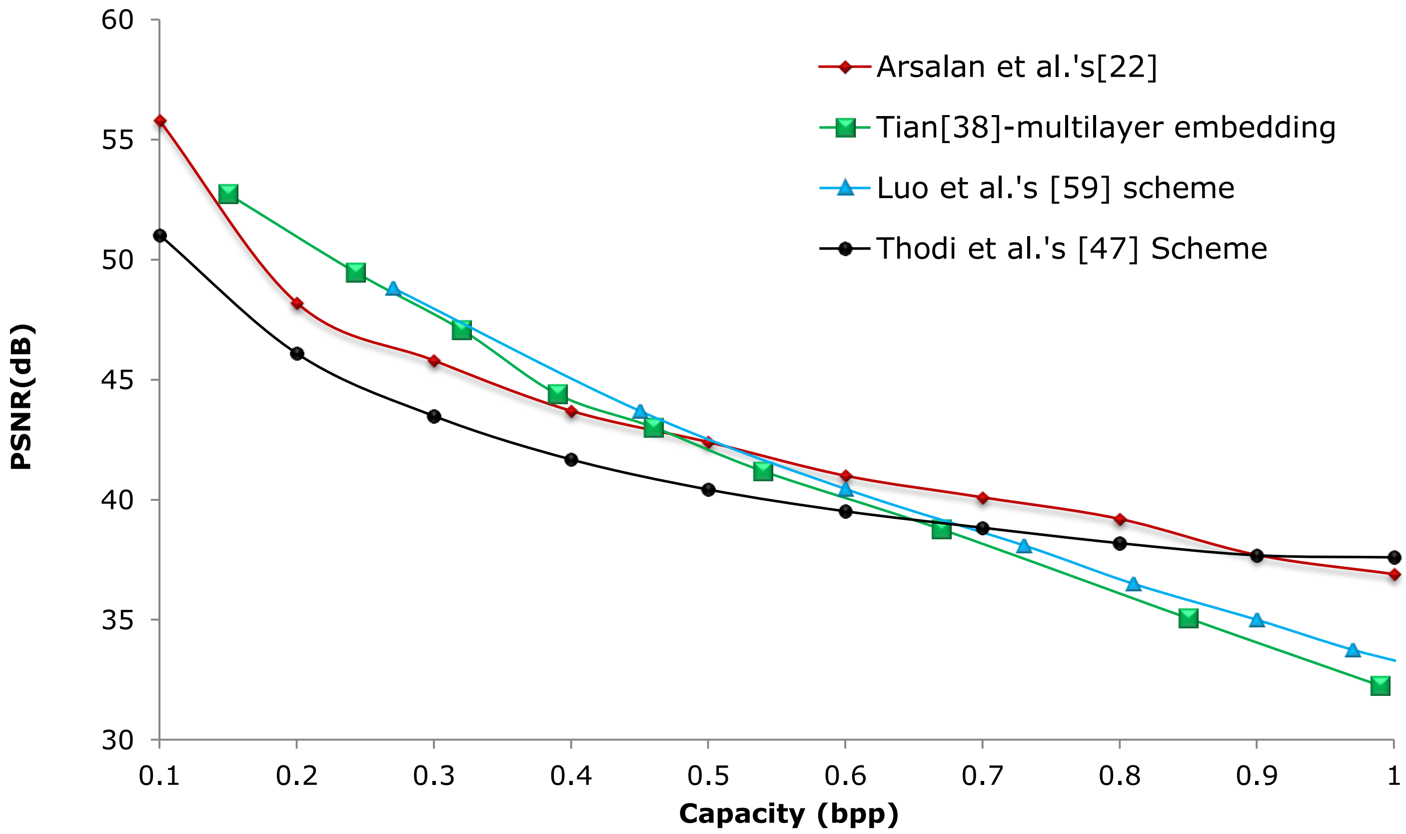
Lena Image

Watermarked Image

Enhanced Difference

D. M. Thodi and J. J. Rodriguez, "Prediction-error based reversible watermarking," in Proc. IEEE *Int. Conf. on Image Processing,* 2004, pp. 1549–1552.

# Comparison




**PSNR vs. Capacity curve for different reversible watermarking techniques using Lena image**

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# Comparison

| Technique | TYPE | Blind/ Semi-Blind | Remarks |
|---|---|---|---|
| **Compression based Reversible Watermarking** | | | |
| Celik et al. (2005) | FRAGILE | Blind | Outperforms Fridrich et al.'s [17] scheme Embedding capacity depends on quantization levels. |
| Xuan et al. (2005) | FRAGILE | Blind | Improved capacity vs. PSNR tradeoff. High Auxiliary data. |
| Arsalan et al. (2012) | FRAGILE | Blind | Improved capacity vs. PSNR tradeoff. High training time. |
| **Histogram based Reversible Watermarking Techniques** | | | |
| Vleeschouwer et al. (2001) | Semi-Fragile | Blind | Introduces salt pepper noise. |
| Vleeschouwer et al. (2003) | Semi-fragile | Blind | Introduces salt pepper noise. |
| Ni et al. (2008) | Robust to JPEG compression | Semi-Blind | Not completely reversible. |
| Gao et al.(2009) | Robust to JPEG compression | Semi-Blind | Requires high auxiliary data . Offers relatively low capacity. |
| **Quantization based Reversible Watermarking** | | | |
| Ko et al. (2012) | Fragile | Blind | Uses nested QIM to achieve reversibility. |
| **Contrast Mapping based Reversible Watermarking** | | | |
| Coltuc et al. (2007) | Robust to cropping | Blind | Simple in implementation. Does not need additional data compression. |
| Lu et al. (2008) | Robust to cropping | Blind | Shows better PSNR compared to [38]. |
| **Expansion based Reversible Watermarking** | | | |
| Tian (2003) | Fragile | Blind | Uses inter-pixel redundancy. Higher embedding capacity and PSNR than [17] and [22]. |
| Luo et al. (2010) | Fragile | Blind | Offers better imperceptibility and higher capacity compared to [29]. Boundary pixels are not utilized in embedding. |
| Abadi et al.(2010) | Fragile | Blind | Improves Luo et al.'s [63] method by utilizing boundary pixels in embedding |



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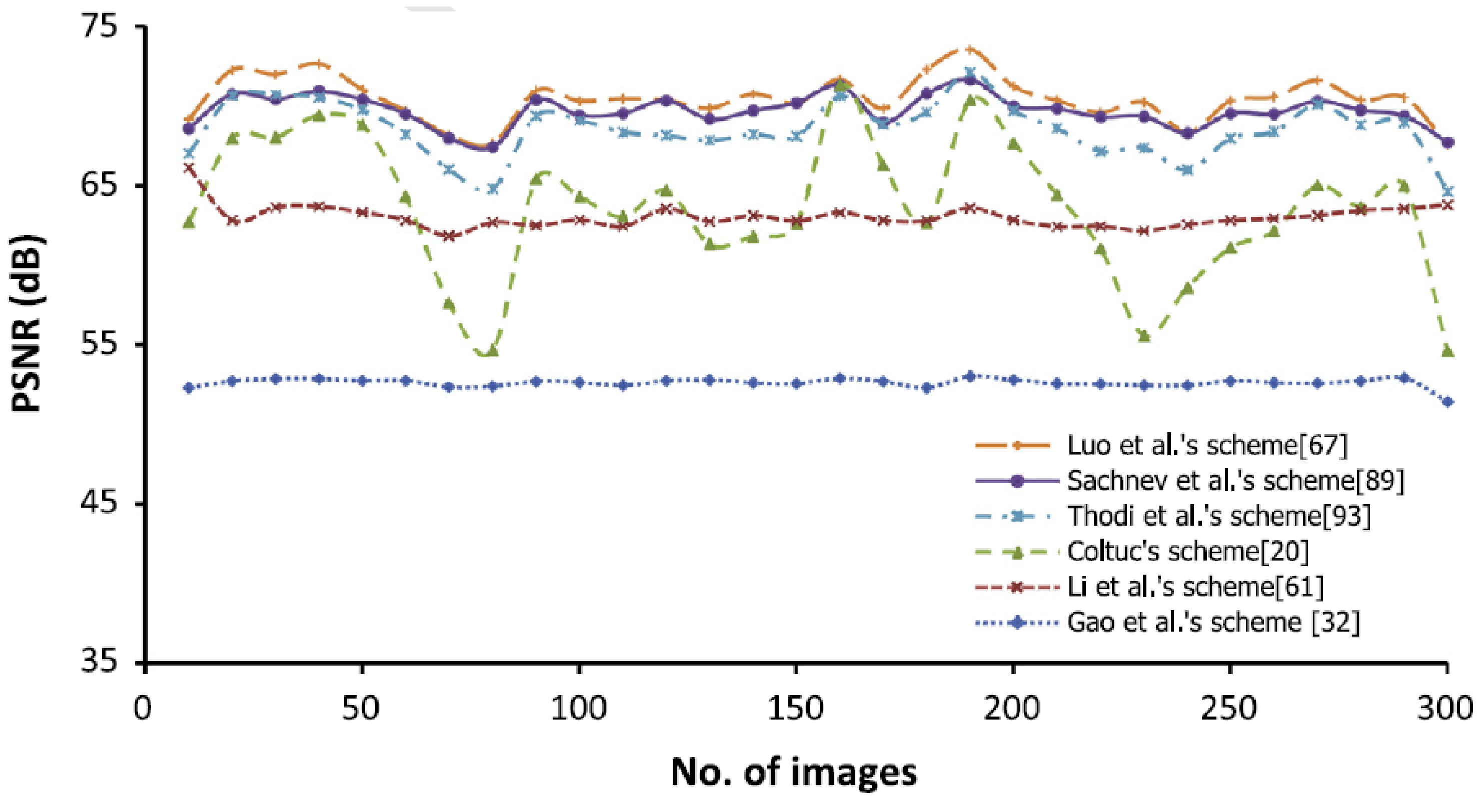
# Comparison

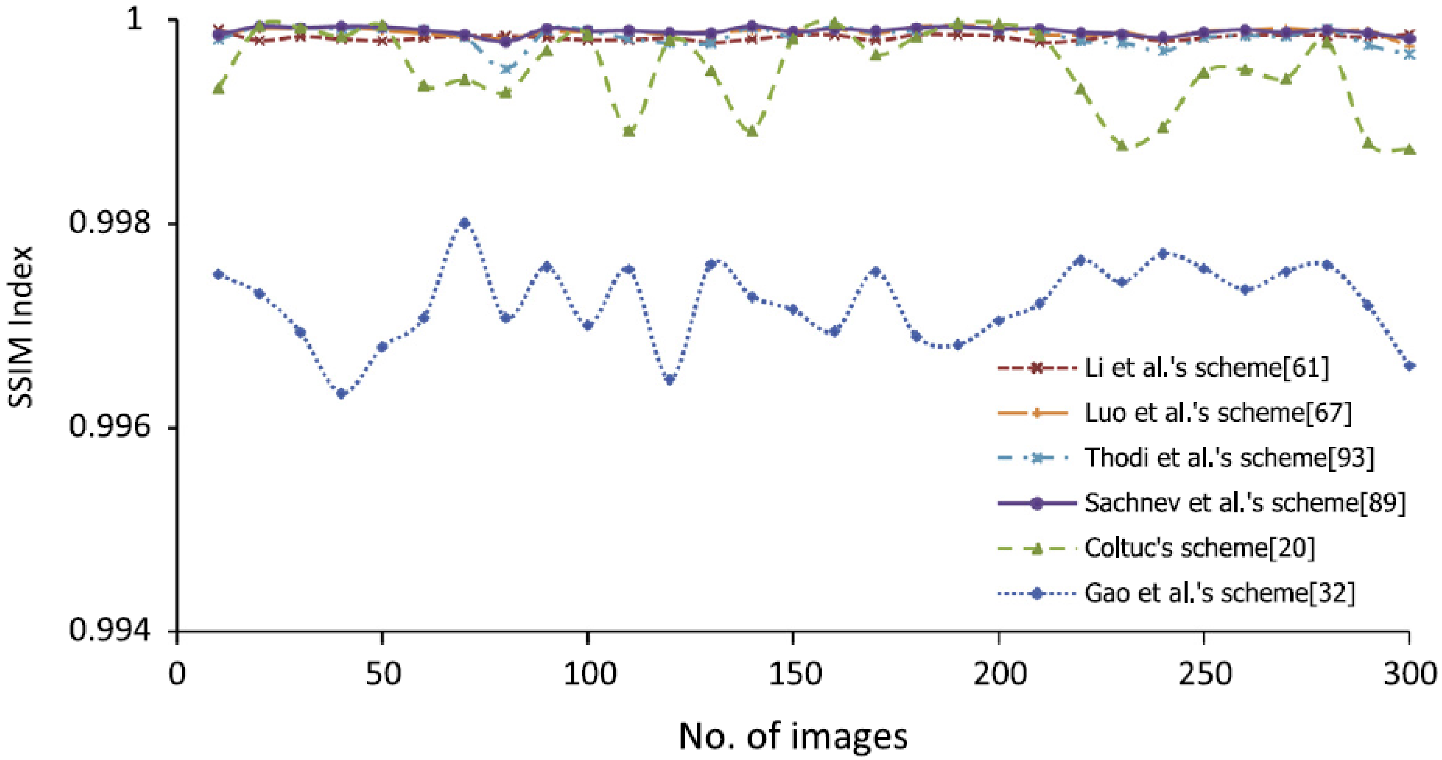
| Technique | Expansion Type | Predictor Type(No. of Pixels used in prediction) | Remarks |
|---|---|---|---|
| Thodi et al. | Prediction Error | MED(3) | Outperforms Tian's DE method at high embedding rates.<br>Achieves approximately 1 bpp embedding rate with single embedding. |
| Thodi et al. | Prediction Error | MED(3) | Introduces HS method to replace large LM with much smaller auxiliary information.<br>Maximum embedding capacity is around 1bpp in a single pass. |
| Sachnev et al. | Prediction Error | Rhombus Pattern Prediction(4) | Two stage embedding method makes each pixel available for embedding in an ideal case, thus allowing the embedding capacity to reach 1 bpp.<br>It offers better performance than that of [47]. |
| Chen et al. | Additive Prediction Error | Full Context Prediction(8) | Utilizes full context for more accurate estimation and small prediction-error.<br>It causes less embedding distortion.<br>It shows high embedding capacity compared to [47] at constant PSNR. |
| Ou et al. | Additive Prediction Error | Weighted Average(4) | In case of Lena image, this method performs better than [48] on average about 1dB higher, when the embedding rate is above 0.2bpp.<br>In case of Airplane image, it provides about 3dB high PSNR on average. |
| Tudoroiu et al. | Prediction Error | MED(3) | Uses block map to reduce the size of LM [46].<br>For block size 8x8, it outperforms the basic LM approach and provides comparable results with the HS approach [47]. |
| Luo et al. | Prediction Error | Compensated Average(4) | Uses compensation concept during data embedding.<br>It can improve the PSNR obtained in [48] to 0.5 dB or above.<br>Wrong judgment of modification direction with large translation quantity can cost too much. |
| Coltuc | Prediction Error | MED(3),<br>GAP(7),<br>SGAP(4) | It analyzes the trade-off between optimization of embedding and improvement in performance of the proposed scheme.<br>Considerable performance improvement is shown for the case of MED and SGAP predictors. |
| Coltuc | Prediction Error | JPEG4(4) | Very simple low distortion transform.<br>Suitable for application that requires low embedding capacity like captioning, labeling etc.<br>Outperforms Tian's DE transform. |
| Li et al. | Prediction Error | PVO(4) | Provides high fidelity at rather low embedding rate<br>Like [54], it is useful in applications requiring low embedding capacity |

# Comparison




**Average PSNR of 10 images versus number of images at a constant embedding capacity of 1 K bits**

# Comparison




**SSIM index averaged over 10 images versus number of images at a constant embedding capacity of 1 K bits**

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# Conclusions

- Categorized reversible watermarking into four major categories
  i. Compression based
  ii. Histogram modification based
  iii. Quantization based, and
  iv. Expansion based watermarking

- Performance was analyzed through capacity, imperceptibility,and computational cost.
- Our analysis is that expansion based reversible watermarking approaches are effective, and easy to implement compared to some other reversible watermarking techniques.

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# Conclusions

- Almost all of the reversible watermarking approaches create space for bit embedding by effectively performing less HVS observable manipulations in the contrast of an image.
  - This happens directly in case of contrast based, while indirectly in case of histogram processing, Compression, etc. based reversible watermarking approaches.
- However, the effective approach is the one that can create more space at low cost of HVS-observable distortions.

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# THANK YOU