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Data Hiding Using ar^{2}w^{2}curve

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Abstract

Internet applications always need the data transfer in safe way. Data safety may be provided by cryptography and steganography. Existence of data is hidden with the use of steganography. This paper study the lsb embedding in images with second order ar^{2}w^2 curve (space filling curve). The PSNR high value represents better image quality (less distortion).

Keywords: Data Hiding, Space Filling Curve

1. Introduction

From the early ages of human history data hiding concept are in use worldwide for the delivery and transportation of high value information. Information security is now a familiar term. Subliminal channels are the means of secret communications. The cost of storage, bandwidth and processing are rapidly decreasing due to the increasingly popular digital media. Stego signal is a composite signal having message and host signal respectively. Different ways in which data hiding classified as relative to importance of cover and message signals, nature of cover, unmodified cover with types of subliminal communication. Digital watermarking uses variety of signal processing tools and algorithms that are based on the aspects of HVS, noise characteristics, signal transforms properties.

2. Introduction to Data Hiding

Cryptography makes data transformation into cipher text form which makes it unreadable for the receiver. Digital Watermark in which embedded data is used for the indicator of ownership for the host signal. Temper proofing is the protection of the modification of host signal from the authored state. Still images are the most likely candidate for data hiding. HVS shows sensitivity to contrast and it is function of spatial frequency with masking effects of edges regarding luminance and chrominance. HVS is sensitive to the change of the luminance and insensitive to very low spatial frequencies such as continuous changing of the brightness within an image.

The goal of data hiding is to have data hidden, inaudible, imperceivable and invisible which means the presence of data is not noticed. The data are encoded into the media and It should be immune to modification by intentional, intelligent attempts or to anticipated manipulation. The embedded data is asymmetrically coded for keeping it in the host signal but the data is not difficult to access. Data integrity is intact by error correction coding. Practical methods are developed for minimizing embedding Impact in steganography. All steganographic algorithms aims in the minimize distortion for preserving some image model. Images are the most likely candidate for data hiding. Images are subjected for operations like cropping, blurring, compression or filtering. Any pixel or block of pixels are accessed for data hiding in images.

Commonly used distance or metric measure : mean square error (MSE),

$$\mathrm{MSE} = d(\mathbf{S}, \mathbf{C}) = \sum_{i=1}^{N} \frac{(\mathbf{S} - \mathbf{C})^2}{N}.$$

Where cover signal C and Stego signal S.[2]

3. Space Filling Curve

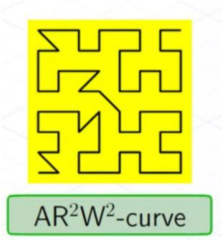
Curve that passes through every point in every dimension. The correlation of adjacent pixels are inherent in the structure of images. The difference histogram lossless data hiding method increases data hiding capacity by utilizing the structure in images while keeping the low distortion. The neighbouring pixels are highly correlated and with strong correlations bins with smaller differences in magnitude are obtained.
Smaller magnitudes bins are modified for data hiding with more space while keeping low visual artifacts. With stronger correlation more space for data hiding will be available before embedding. On the Euclidean distance(spatial) of the pixels, the correlation is dependent on the scanning distance. Row by row is the conventional method which is not optimal in terms of distance.
A continuous map of a 1-D interval into a 2-D area (plane filling) or a three-dimensional volume is termed to be space filling curve. David Hilbert, a German mathematician, discovered a simple space-filling curve known as the Hilbert curve, which fills a square. Space filling curve can map an image to a sequence.
Space filling curves are extensively used for mapping multidimensional space into one dimensional space. Space filling curve order mapping scheme in data can be used to transform from a higher dimensional data to lower dimensional data. Mapping multidimensional space into one dimensional space have many applications like geographical information systems, multimedia databases, image processing, parallel computing etc. SFC passes every cell element (pixel) from the multidimensional space so that every cell can be visited once.
The concept of space filling curve developed by Cantor set Peano(1883) and Hilbert(1891) gave explicit descriptions of space filling curves. A self intersecting curve, discovered by Peano is the one that passes through every point in unit square, a mapping from unit interval onto unit square. Peano solved that such mapping could be continuous.

4. LSB Embedding with second order ar^{2}w^{2}curve

The attributes of steganography are capacity(payload), security, imperceptibility(invisibility), undetectability with robustness. Using digital images one of the most popular embedding methods is the Least Significant Bit (LSB) replacement, where lsb of cover elements/pixels are replaced with message bits.
Message embedding using a lsb [8] of pixel is

$$\mathrm{Is}\ ((i, j) = \begin{cases} \mathrm{I}\ (i, j)-1 & \mathrm{LSB}\ (\mathrm{I}(i, j))=1 \text{ and } m = 0 \\ \mathrm{I}(i, j) & \mathrm{LSB}\ (\mathrm{I}(i, j))= m \\ \mathrm{I}\ (i, j)+1 & \mathrm{LSB}\ (\mathrm{I}(i, j))\neq 0 \text{ and } m = 1 \end{cases}$$

A potential weakness is the asymmetry in the embedding operation. Imperceptibility can be measure with PSNR, SSIM etc. [4]



AR^2W^2 curve is used such that pixels are selected (8 pixels for 8bit, 16 pixels for 16 bit etc.) and 8x8 block of pixels are accessed in the order using AR^2W^2 curve.

5. LSB Matching

LSB replacement method is trivially modified as +- embedding LSB matching. Compared to LSB. The embedding operation is balanced so it is harder to detect. LSB mapping is near optimal as the information of a single pixel are utilized. Assumption regarding spatial steganography is that embedding algorithms are insecure. Bits are embedded in the representation values of pixels.[5]

6. Patchwork

A specific statistic one that has a gaussian distribution based on pseudorandom statistical process. Patches are chosen at pseudo randomly such that image data are lightened or darkened. Patchwork is independent of the host image with high resistance to mostly nongeometric modification if images. With extremely low embedded data rate its usefulness is limited to digital watermark. This lightening and darkening of pixels in some random blocks represent a signature for data hiding. This is independent from the contents of host image. This makes the patchwork resistant to most of the non-geometrical image modifications. Instead of single points considering the several points for patchwork makes it resistant for lossy compression or typically from finite impulse filters. Patchwork may be sensitive to affine transformations which makes it fairly resistant to cropping. Patchwork makes majority of the energy concentrated in high frequency. This makes it imperceptible but removal of the code is possible with lossy compression. So, patchwork has low embedding data rate which makes it eligible for the watermark embedding.

7. Texture Block Coding

The continuous random texture patterns of a picture are used to hide data. This coding is low bit rate data hiding. A random texture pattern from the picture copied to a region or area with the similar texture. Identically textured regions of the image is the result of the technique. Under most nongeometric transformations inner parts of the block changes by making the regions reasonably large. It has a disadvantage that human operator is required for choosing source and destination regions.

8. LSB Embedding with ar^2w^2 curve Results (SSIM, PSNR etc.)

SSIM is a image quality index, where and image is compared with the reference image which is perfect quality. Similarity measurements in ssim separates out three components, luminance, contrast and structure. The perceived change is in the structural information. SSIM outperforms the MSE. SSIM can be calculated on various image windows.
The two windows having same size NxN SSIM is calculated as

$$\text{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

with:

- μ_x the pixel sample mean of x;
- μ_y the pixel sample mean of y;
- σ_x^2 the variance of x;
- σ_y^2 the variance of y;
- σ_{xy} the covariance of x and y;
- $c_1 = (k_1 L)^2$, $c_2 = (k_2 L)^2$ two variables to stabilize the division with weak denominator;
- L the dynamic range of the pixel-values (typically this is $2^{\#bits\ per\ pixel} - 1$);
- $k_1 = 0.01$ and $k_2 = 0.03$ by default.

Structural Dissimilarity index measure may be derived from ssim

$$\text{DSSIM}(x,y) = \frac{1 - \text{SSIM}(x,y)}{2}$$

Mean Square Error

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2$$

Peak Signal to Noise Ratio

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2.$$

The PSNR (in dB) is defined as

$$\begin{aligned} PSNR &= 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \\ &= 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \\ &= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE). \end{aligned}$$

Various Message lengths inserted into lsb of the pixels in image Bear.jpg

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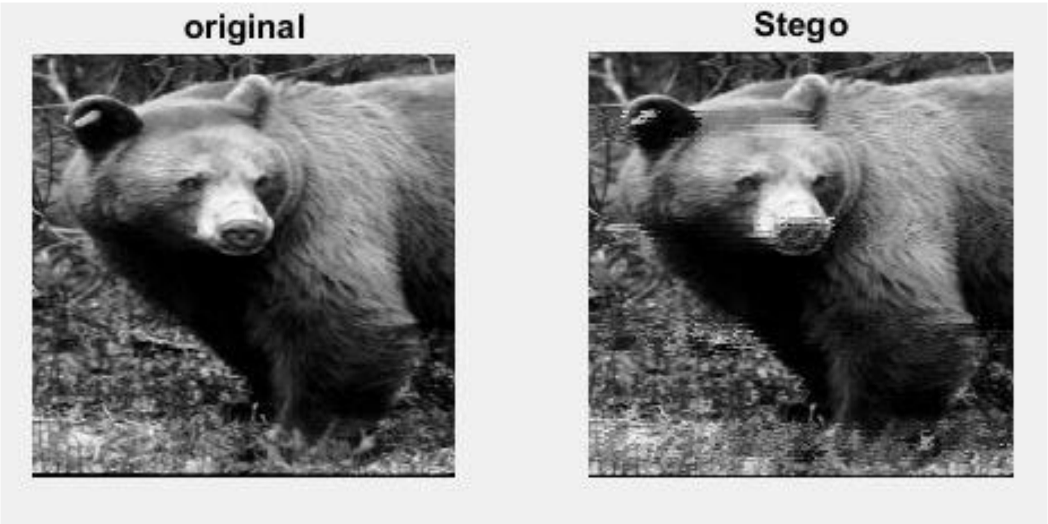
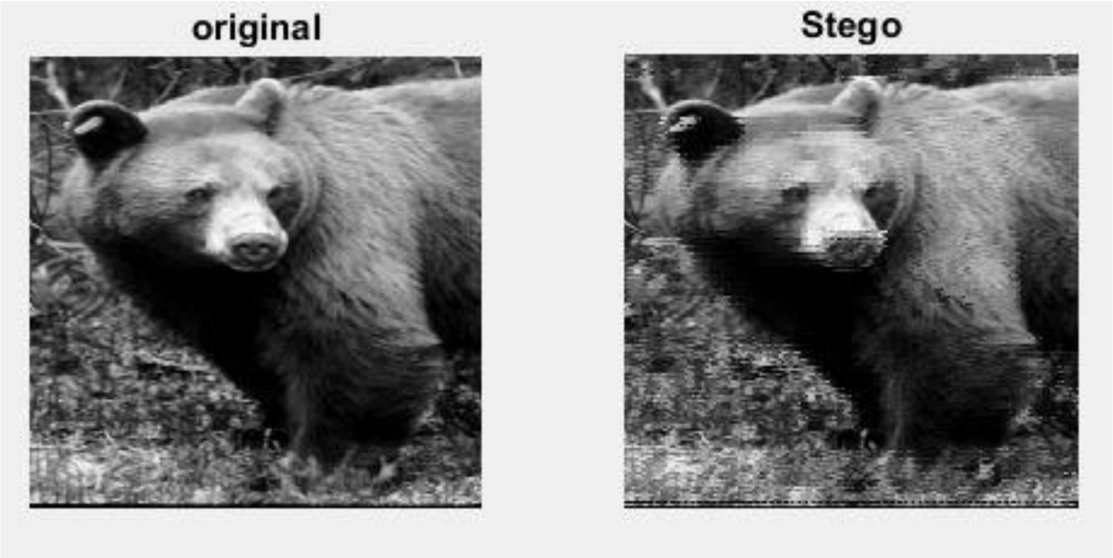
Table 1: LSB embedding in Bear image

Picture	Message Length	SSIM	SNR	PSNR
Bear.jpg	8 bit	0.8089	18.1131	25.6638
	16 bit	0.7193	15.5902	23.1426
	24 bit	0.6308	13.9188	21.4716
	32 bit	0.5712	13.2761	20.8307
	40 bit	0.5010	12.7509	20.2962
	48 bit	0.4123	11.8695	19.4019
	56 bit	0.3404	11.1053	18.6291
	64 bit	0.2714	10.3098	17.8255

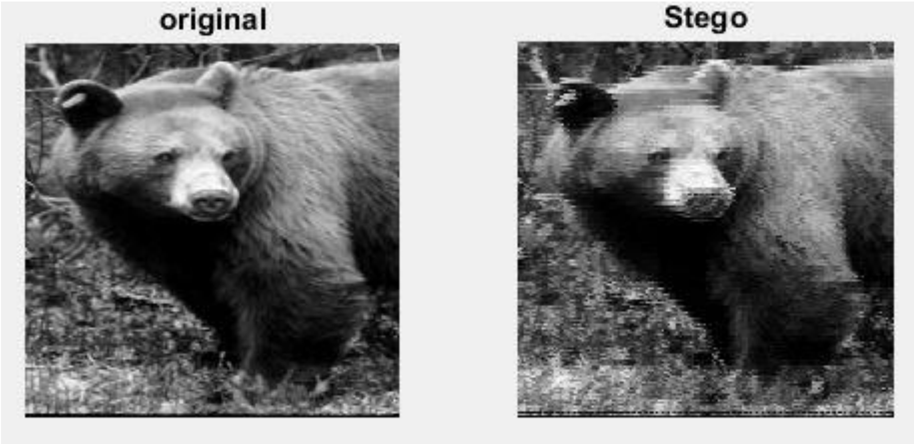
8 bit Bear



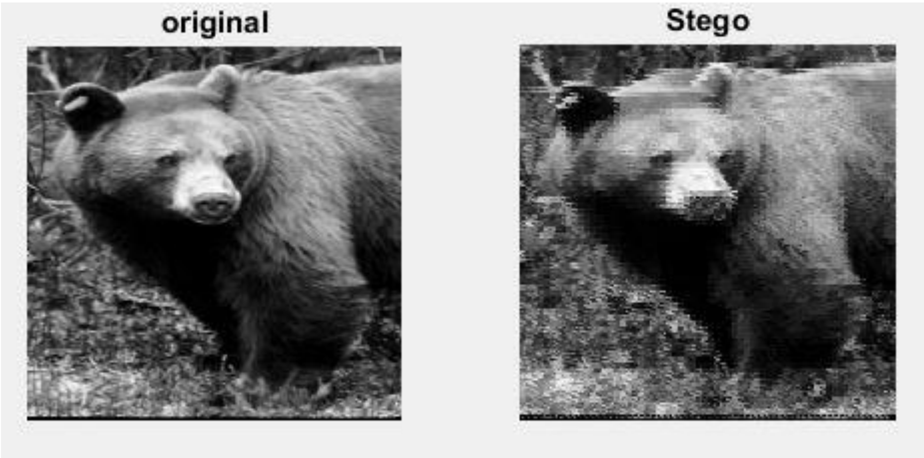
16 bit bear



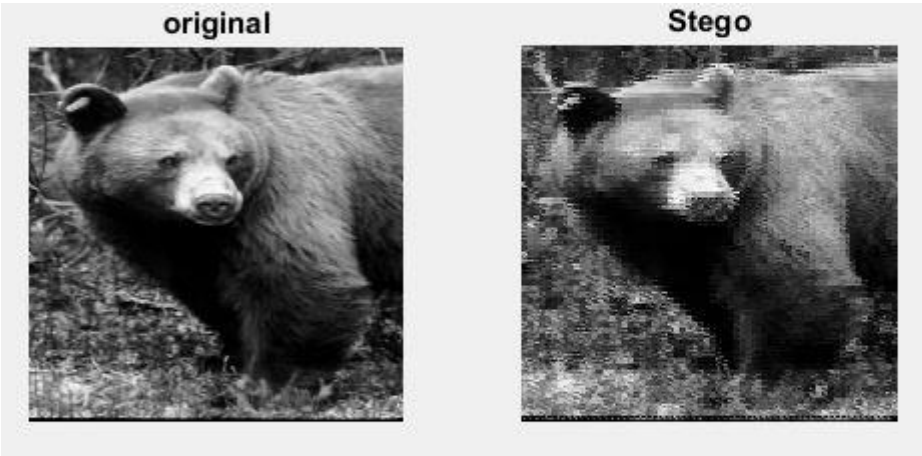
24 bit bear



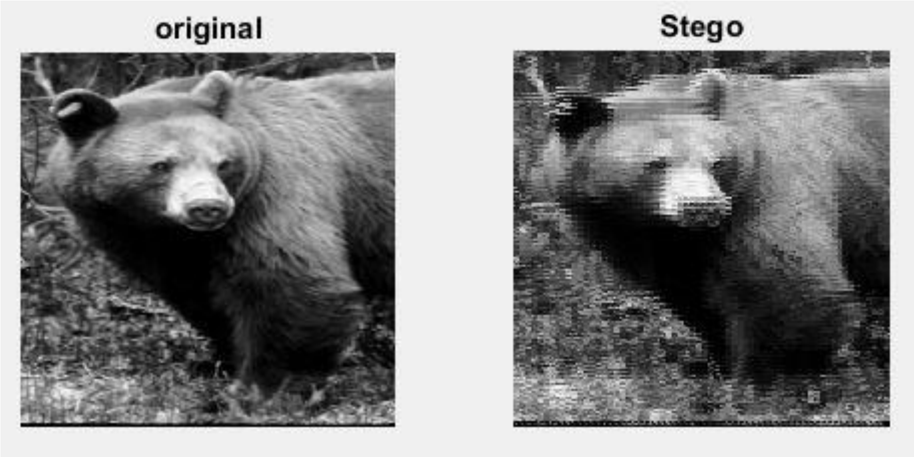
32 bit Bear



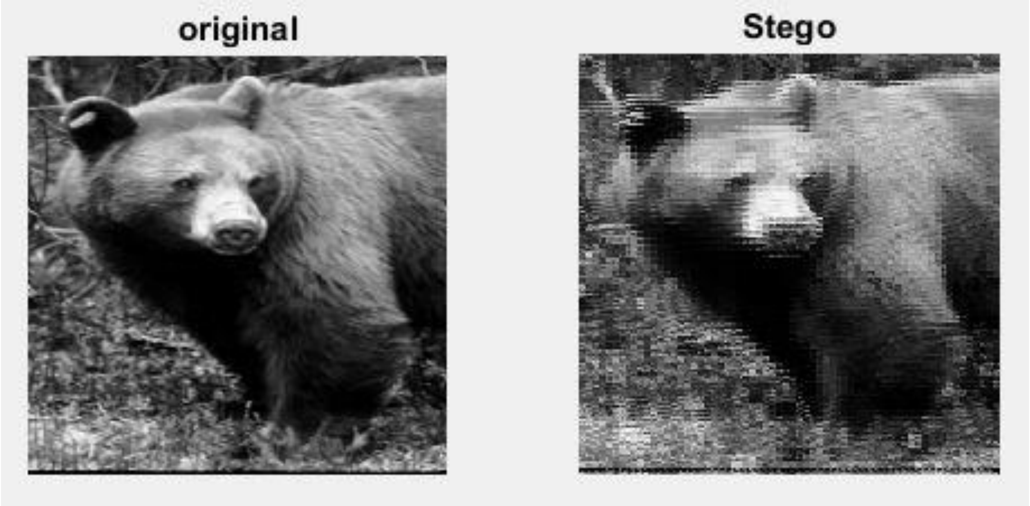
40 bit Bear



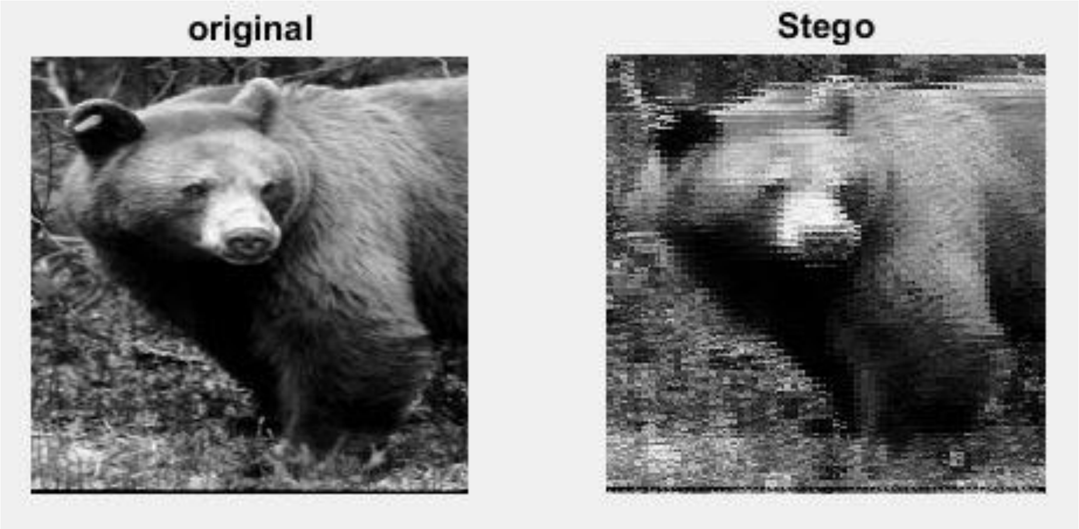
48 bit Bear



56 bit Bear



64 bit Bear

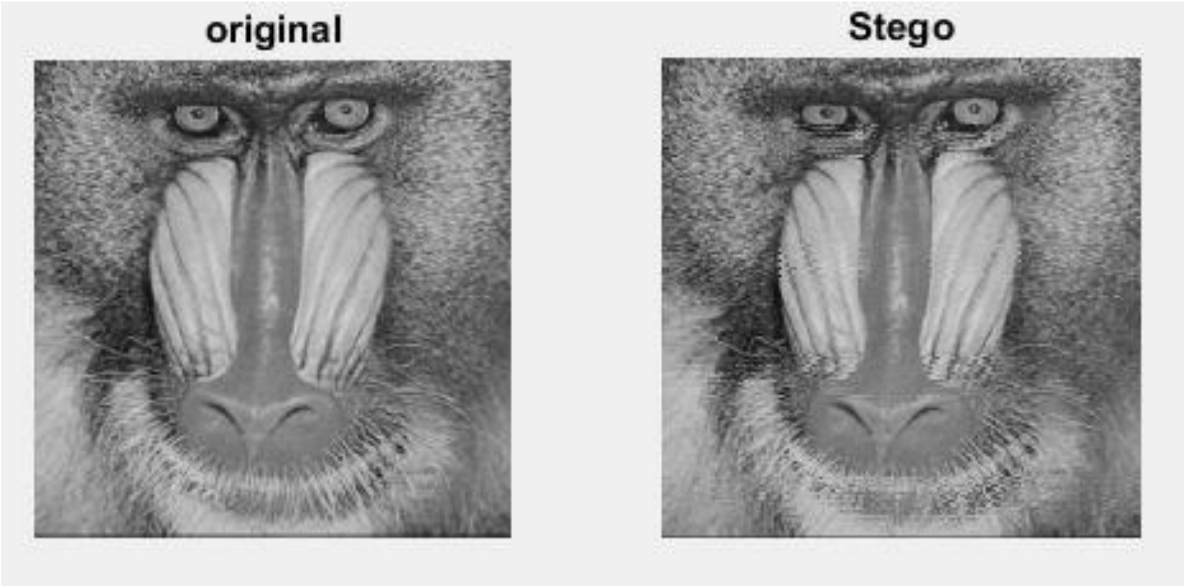


Various Message lengths inserted into lsb of the pixels in image Baboon.jpg

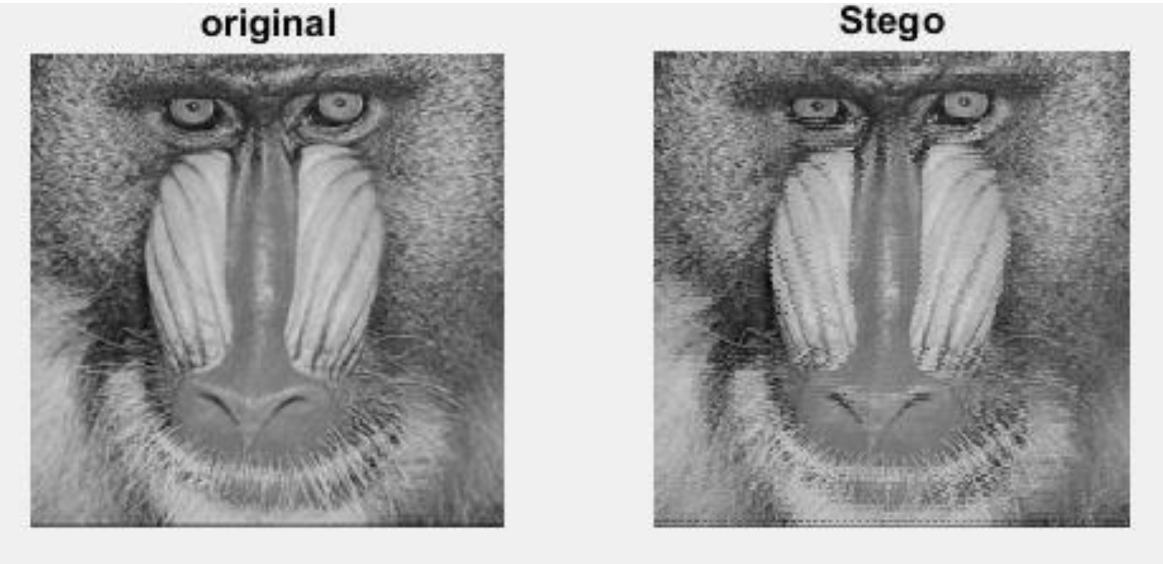
Table 2: LSB embedding in Baboon image

Picture	Message Length	SSIM	SNR	PSNR
Baboon.jpg	8 bit	0.8400	23.3299	28.9144
	16 bit	0.7547	20.8328	26.4174
	24 bit	0.6585	19.0731	24.6608
	32 bit	0.5862	18.1657	23.7546
	40 bit	0.5088	17.4689	23.0505
	48 bit	0.4218	16.6418	22.2134
	56 bit	0.3464	16.6418	22.2134
	64 bit	0.2742	15.2017	20.7550

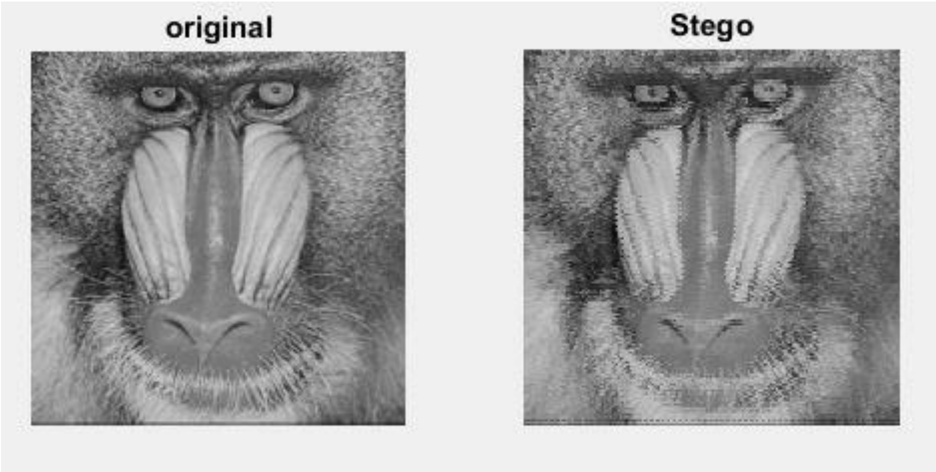
8 bit Baboon



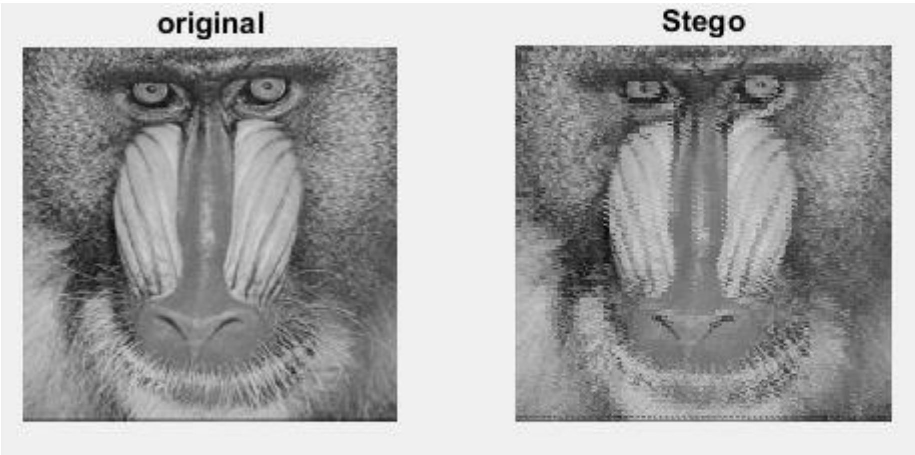
16 bit Baboon



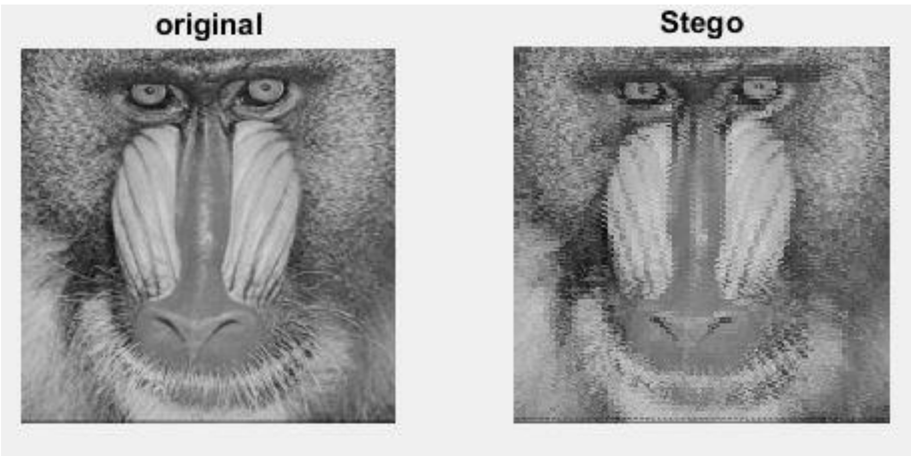
24 bit Baboon



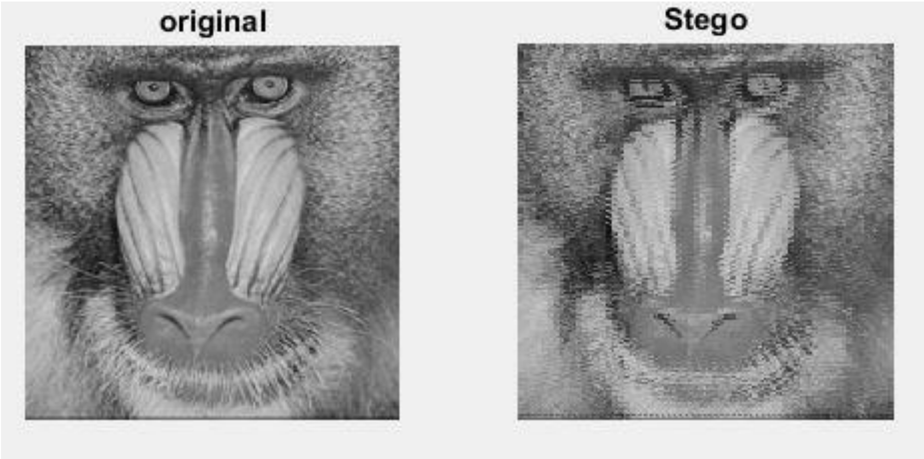
32 bit Baboon



40 bit Baboon

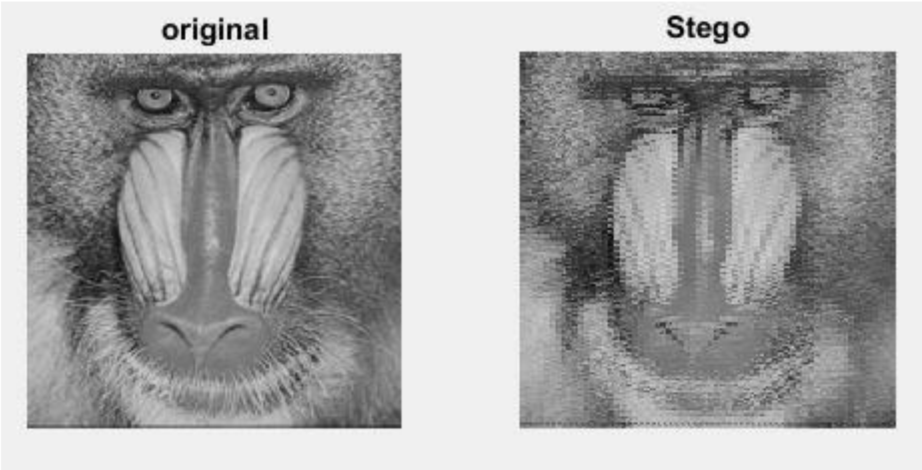


48 bit Baboon



56 bit Baboon

64 bit Baboon

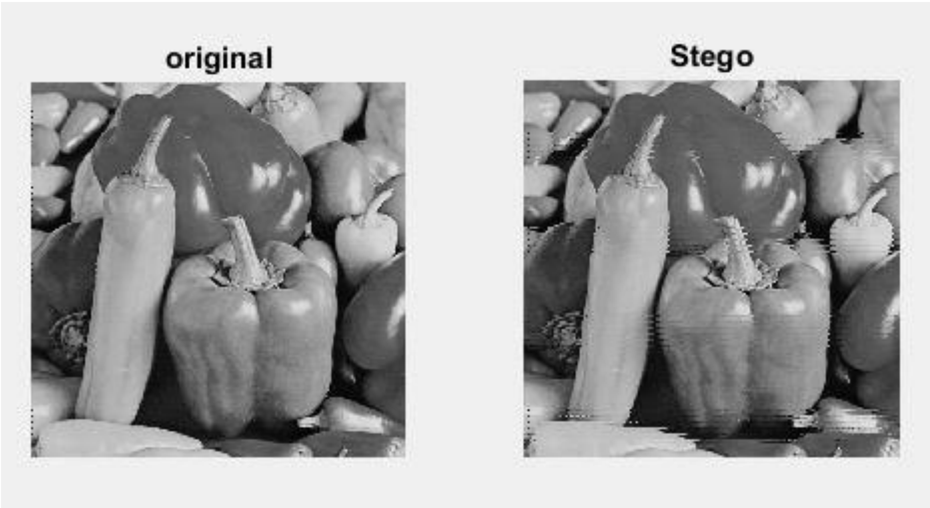


Various Message lengths inserted into lsb of the pixels in image Peppers.jpg

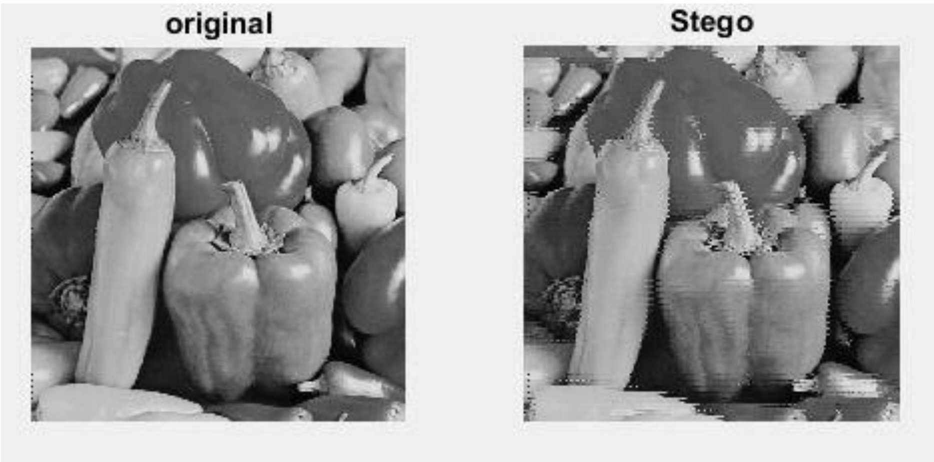
Table 3: LSB embedding in pepper image

Picture	Message Length	SSIM	SNR	PSNR
Peppers.jpg	8 bit	0.8501	20.7916	26.5174
	16 bit	0.7977	18.9510	24.6700
	24 bit	0.7325	17.4081	23.1229
	32 bit	0.6800	16.5193	22.2301
	40 bit	0.6185	15.7077	21.4144
	48 bit	0.5578	14.8550	20.5626
	56 bit	0.5098	14.2341	19.9409
	64 bit	0.4543	13.5212	19.2280

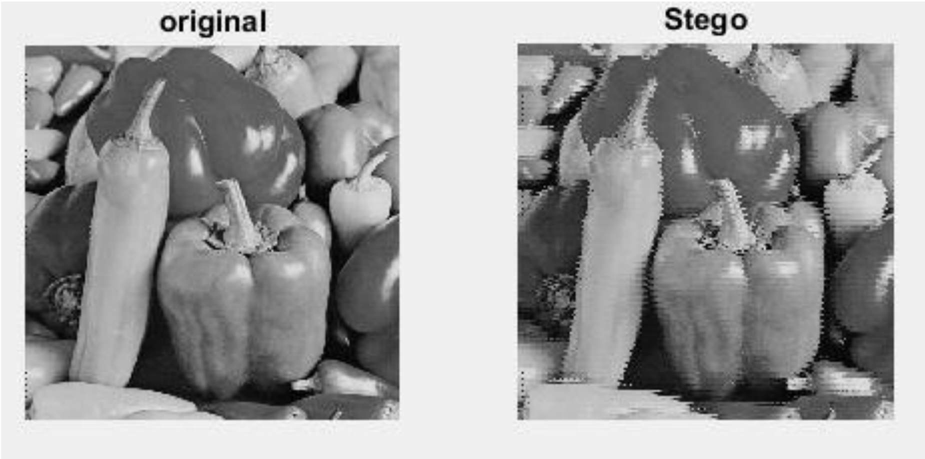
8 bit Peppers



16 bit Peppers



24 bit Peppers

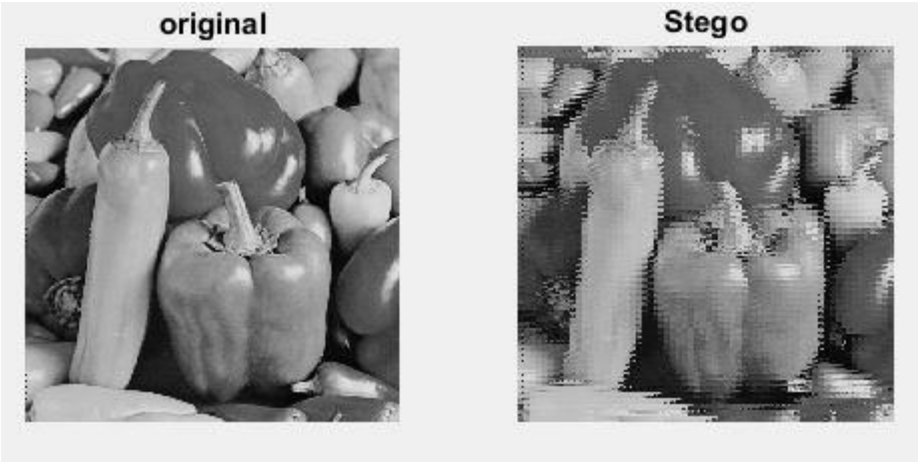


32 bit Peppers

40 bit Peppers

48 bit Peppers

56 bit Peppers



64 bit Peppers

Various Message lengths inserted into lsb of the pixels in image Lena Image

Table 4: LSB embedding in image

Picture	**Message Length**	**SSIM**	**SNR**	**PSNR**
Lena.jpg	8 bit	0.8881	23.8817	29.5924
	16 bit	0.8450	21.7670	27.4770
	24 bit	0.7839	20.0460	25.7525
	32 bit	0.7310	18.8623	24.5647
	40 bit	0.6745	17.9364	23.6354
	48 bit	0.6282	17.1567	22.8522
	56 bit	0.5905	16.6005	22.2896
	64 bit	0.5476	15.8933	21.5748

16 bit Lena

24 Bit Lena

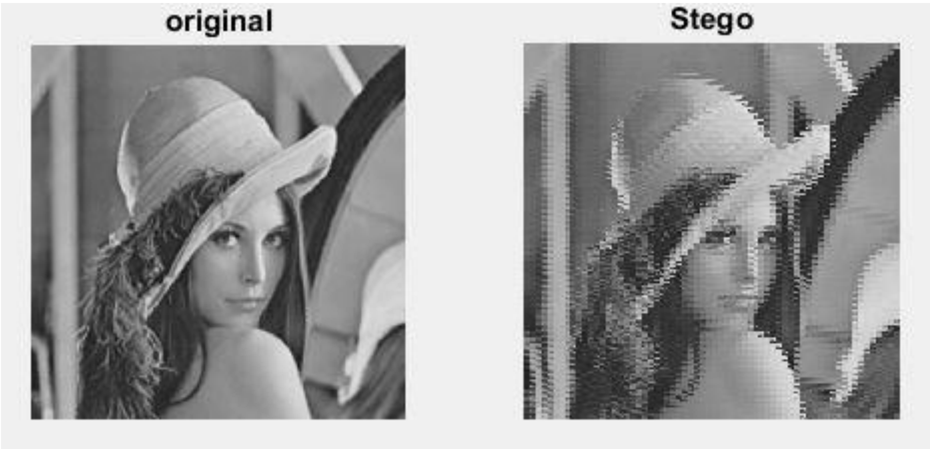
32 bit Lena

40 bit Lena

48 bit Lena

56 bit Lena

64 bit Lena



9. Conclusion

This article study the lsb embedding in images with the order of pixels using the ar^2w^2 curve space filling curve. PSNR and SSIM are the quality measures for the cover and stego images. At a time 8x8(64 pixels) pixel are selected for embedding, out of which different 64 bits are available for embedding, based on the requirement 8, 16, 24, 32, 40, 48, 56, 64 bits lsb of these pixels are changed for embedding the secret information. The change in the SSIM, SNR and PSNR give the relation of the data embedded with perceptibility, distortion. Less embedding rate and good PSNR means images are more similar. In simple terms if the embedding data is increased then the distortion in the image also increases.

10. Acknowledgement

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