Data Protection for Land Consolidation with Distortion Tolerable LSB Watermarking

LI LI, CHAO ZHANG, MINGXIN LIANG, DAOLIANG LI*
College of Information and Electrical Engineering
China Agricultural University
Beijing, P. R. CHINA, 100083
* Corresponding Author: Email Address: li_daoliang@yahoo.com, Tel: 86-10-62736764; Fax: 86-10-62737741. http://www.cicta.cn

Abstract: - With the rapid growth of Internet technology, data security protection has become an important issue. As a tool for improving the effectiveness of land cultivation, land consolidation plays an important role in enlarging farming plots and enhancing crop productivity. To fulfill land consolidation, more and more remote sensing images are widely used. This paper presents a LSB watermarking algorithm to protect the images data security. In the proposed scheme, the land reorganization planning map is embedded into a remote sensing image of the same area for information security and copyright protection. Before being embedded, the land reorganization planning map is compressively encoded. The contradiction between large information quantity and invisibility of digital water marking is perfectly eliminated. To avoid the shortcoming of being easily attacked in the original LSB method, the host image is preprocessed by exclusive-OR (XOR) operation. That is, the value of the least significant bit is decided by the XOR result of the first several bits. The watermark signal is embedded into the LSB of the processed host image by XOR operation. Moreover, by applying an optimal adjustment process, the watermarked image has the ability of distortion tolerance. The experimental results fully illustrate that the embedded watermark is not only imperceptible to the human eyes, but also has better security in the statistical sense. Moreover, the proposed scheme is superior in terms of its distortion tolerance.

Key-Words: - land consolidation, watermarking, least significant bit (LSB), exclusive-OR (XOR) operation, remote sensing image, data protection, land reorganization planning map

1 Introduction

The availability of suitable farm land is one of the most critical challenges facing the agriculture. Land consolidation is a long-term practice to enlarge farming plots and to enhance crop productivity [1,2]. With the growing concern about land resource management and the associated decline in land quality, land consolidation has led to the attention in many countries.

Land consolidation refers to a serial of activities, which deal with improving of productivity and working conditions in rural areas, production of reconstruction plans for rural settlement, and proving of rural life. It has been associated with broader social and economic reforms from the time of its earliest applications in Western Europe. With the growing concern about land resource management and the associated decline in land quality in many countries, land consolidation has become one of the most attractive worldwide research topics. And the requirement for land consolidation also becomes higher [3-6]. The land consolidation pays attention not only to the quantity, but also to the quality and zoology protection.

The fulfillment of each land consolidation phase more or less depends on supplement of spatial data. There are a variety of manners to collect spatial data. The basic spatial information in the early years is the existing condition maps. Significant developments in the field of remote sensing, especially in terms of spatial and spectral resolution, provide a fast and easy spatial data collection manner for a land consolidation project. The use of remote sensing high resolution images will be extremely feasible in the land projects [7]. By using remote sensing images, land consolidation can be completed in half of the time that traditional techniques require and the project can cost 35 times cheaper than that the traditional techniques cost [8].

For the land consolidation application, high fidelity is required. If the remote sensing images are tampered, the remote sensing image cannot provide strong evidence of land consolidation effect, and land consolidation operators will get error information about the present state of project area, land used classification, the condition about water management, drainage, road systems, and etc. The error information could have a negative impact on land consolidation decision-making and lead to error investment. So it is necessary to ensure the security of the remote sensing image data. However, the data security studies in the land consolidation projects mainly focused on database security design. And there is little attention to the security of remote sensing imagery used in land consolidation.

An efficient way to data security protection is watermarking technique. Typically digital watermarking is a process of embedding information bits into kinds of meaningful media signal without producing perceptible artifacts [9]. There are a variety of embedding techniques, ranging from spatial-domain modification to transform-domain spread spectrum methods [10]. Watermarking has been widely used to protect the copyright of digital images[11-13]. In 2008, Kumari and Rallabandi[14] applied digital watermarking to remote sensing image. Their study mainly discussed the application of common watermark techniques in remote sensing images. They did not take the characteristic of the land consolidation into account. So if the size of the watermark map is a little large, it is not easy to hide into the host image.

As a common watermarking method, LSB methods embed the message by toggling the least significant bit (LSB) of the image pixel, or of the palette image index, or of the transform coefficient. The prominent advantage of LSB methods is the high capacity. So this paper presents a LSB watermarking algorithm to embed the land reorganization planning map in a remote sensing image of the same area for information security and copyright protection.

In the LSB conventional method, the payload message is inserted into the LSB of each pixel value without obvious perceptible distortion. If additional information capacity needs to be embedded, two or more LSBs of each sample byte can be over written. The extraction of the information is accomplished in the reverse way, i.e., by reading the bits in the same scanning order to reconstruct the payload data. In this well-known LSB method, the distortion can be considered unnoticeable in the sense of the human vision, because the pixel values are shifted by only one level of 255 color levels. But the LSB algorithm could be easily attacked by the counterfeiting attack, especially from the point of statistical property. When a uniformly random sequence is scattered in the LSB plane, its random nature can lead to its detection. Furthermore, when the same information is inserted to a series of host images, the payload information can be detected and thus the watermark can be removed from the images or be forged.

To overcome the shortcoming of the traditional LSB embedding algorithm, this paper makes use of the XOR operation to remedy the statistical problem. In this developed method, the LSB signal is preprocessed by the XOR operation, and then the watermark data are inserted by bit's XOR of watermark sequence and LSB sequence. So the embedded data depend substantially on the original data and the watermark is invisible. In the similar way, we extract the watermark using XOR operation.

Further more, remote sensing images in land consolidation projects may be compressed, or cause faults during Internet transmitting. This situation is allowed, but the incorrect extracted data is not allowed. Therefore, we regulate the scheme to balance the contradiction between the quality of embedding images and the ability of distortion tolerance. Then the developed watermarking scheme can not only prevent the quality of the processed image from being seriously degraded, but also simultaneously achieve distortion tolerance.

The remainder of this paper is organized as follows. Section 2 describes the algorithm of developed LSB watermarking algorithm. In Section 3, we perform some comparisons with traditional method to verify the performance of the proposed scheme and report the experimental results. Finally, Section 4 concludes this paper.

2 Developed LSB Embedding and Extraction

The traditional LSB scheme outlined in the previous section can be directly used for data embedding with lower perceptibility. However, the robustness against attacks is weak, and the embedded information can be detected using its statistical property, especially if the watermark has unique statistical character. This shortcoming can be remedied by encrypting the LSB signal when inserting the payload information. Our method accomplishes the encrypting by XOR operation. Fig. 1 shows a block diagram of the proposed algorithm. The detail methodology and principles are listed in Fig. 1.

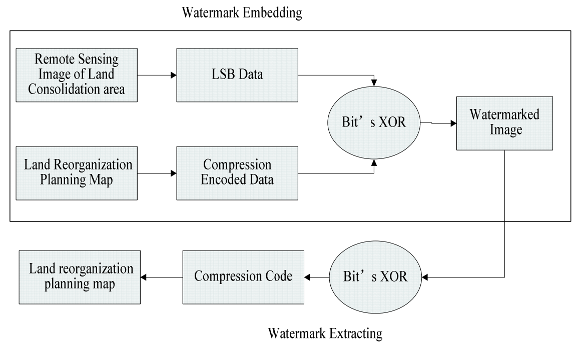


Fig. 1 Watermark Embedding and Extracting algorithm

According to Chan and Cheng [15], the watermarking processing can be expressed mathematically as follows:

$$M_i = C_i - (l_i - W_i) \tag{1}$$

where C_i represents the ith pixel in the host image C, M_i is the ith pixel in the watermarked image, W_i is the embedding data, $W_i \in \{0,\cdots,2^k-1\}$, and k is number of embedding bits per pixel. l_i can be compute by:

$$l_i = C_i \mod 2^k \tag{2}$$

Here the message Y to be embedded into the k-rightmost LSBs of the cover-image C is n-bits. And it must be rearranged to form a conceptually k-bit virtual image W represented as :

$$W = \{W_i,\ W_i \in (0,1,\cdots,2^k-1)\} \tag{3}$$

If Y is the n-bit secret message represented as:

$$Y = \{y_i,\ y_i \in (0,1)\} \tag{4}$$

And the mapping between W_i and the watermark sequence y_i can be defined as:

$$W_i = \sum_{j=0}^{k-1} y_{i\times k+j} \times 2^{k-1-j} \tag{5}$$

To assure that the watermarked image achieves the ability of distortion tolerance and at the same time maintains a good quality [16], the embed algorithm is rewritten as:

$$M_i = \begin{cases} wfactor\times\left[\dfrac{C_i}{wfactor}\right] - wfactor\times\left(2^k + (l_i - W_i)\right) + \left[\dfrac{wfactor}{2}\right] & for\ \ -2^k \prec (l_i - W_i) \prec -2^{k-1} \\ wfactor\times\left[\dfrac{C_i}{wfactor}\right] - wfactor\times(l_i - W_i) + \left[\dfrac{wfactor}{2}\right] & for\ \ -2^{k-1} \le (l_i - W_i) \le 2^{k-1} \\ wfactor\times\left[\dfrac{C_i}{wfactor}\right] + wfactor\times\left(2^k - (l_i - W_i)\right) + \left[\dfrac{wfactor}{2}\right] & for\ \ 2^{k-1} \prec (l_i - W_i) \prec 2^k \end{cases} \tag{6}$$

And

$$l_i = \left[\frac{C_i}{wfactor}\right] \mod 2^k \tag{7}$$

where $wfactor \in \{1,2\cdots,8\}$. Based on the data capacity of the land consolidation project, k is usually set as 1. $wfactor$ is restricted to be an integral power of 2. And W is equal to Y.

Mathematically, the embedded message bits can be recovered from the ith pixel in the watermarked image M_i by:

$$W_i = \left[\frac{M_i}{wfactor}\right] \mod 2^k \tag{8}$$

2.1 Watermark Image Compression Encoding

Land reorganization planning map contains the land use plan information and has high correlation with remote sensing image of the same area in land consolidation. So it is suitable to be embedded as watermark. Usually, land reorganization planning map is of the similar dimension of the remote sensing image. It is necessary to encode the planning map compressively.

To preserve all the information in the planning map, we adopt a lossless compression algorithm. In the image of planning map, there are only several kinds of color as shown in Fig. 2. In fact, it is not necessary to use three bytes to describe a pixel as the BMP image format. According to our observation, there are no more than ten kinds of colors in the usual planning map images. Using the concept of indexed color, we define sixteen numerals (0-15) to describe the colors. Thus, one pixel can be described by only four bits and one byte can contains two pixels, that is, the higher four bits and lower four bits describe two different pixels. In addition, we use 48 (16*3) bytes to describe the indexed color. Finally, the compressed data obtains an indexed image and sixteen color levels.

Fig. 2 A sample of land reorganization planning map

Using this scheme, the volume of planning map can be reduced largely while keeping information lossless. For example, the volume of one 128*128 RGB image is 49152 (128*128*3) bytes in the BMP format and the volume is 8240 (128*128*0.5+16*3) bytes after our preprocessing. The smaller size makes it easy to embed the planning map into remote sensing images.

2.2 Pre-processing for LSB

The purpose of the pre-processing for LSB is to scramble the statistical character of the information.

When a grayscale image such as panchromatic image is considered as the host image, the least significant bits (LSBs) of the remote sensing image pixels are firstly calculated. Assuming the host data can be expressed as a sequence of bits $\mathbf{X} = \{x_i, i = 0,1,2,3,\cdots 7\}$, the pre-processing for every byte data is to produce the LSB value based on the first seven bits:

$$x_{wbit} = x_{wbit+1} \oplus x_{wbit+2} \oplus \cdots \oplus x_7 \qquad (9)$$

where $\oplus$ denotes exclusive-OR (XOR) operator. $wbit$ is gotten from $wfactor$:

$$wbit = \log_2 wfactor + 1 \qquad (10)$$

The XOR based LSB method also can apply to color images directly. If the host is a multi-spectral image with three bands: red, green, and blue bands, LSBs would be obtained for R, G, and B, three channels respectively.

2.3 Watermark Embedding

Now we'll embed the watermark bit stream into the least significant bits of the corresponding embedded pixel.

After the index compression encoding of the watermark image is finished, the watermark information can be considered as binary data stream. And the LSB sequence of host image can been obtained based on Equ. 9. To assure the accuracy detection of watermark, the watermark data include three parts: the size of the planning map, indexed image and color level information. Assuming the LSB sequence can be represented using matrix-vector notation $X_{wbit} = \{x_{wbit\ n}, n = 0,1,2,3,\cdots\}$ and the land reorganization planning map is expressed as data sequence $S = \{s_n,\ n = 0,1,2,3,\cdots\}$, the watermarked sequence will be obtained by combining the LSB sequence and the watermark sequence with exclusive-OR (XOR) operator:

$$y_n = x_{wbit\ n} \oplus s_n \qquad (11)$$

where $\mathbf{Y} = \{y_n, n = 0,1,2,3,\cdots\}$ is the watermark sequence.

Then $\mathbf{Y}$ can be embedded into the LSBs of the host data according to Equ.6.

For a multi-channel remote sensing image pixel, e.g. a multi-spectral image pixel with RGB three bands, three watermark bits can be embedded. And for each gray remote sensing image pixel, only one secret bit can be embedded. Usually, a remote image with lower spectral resolution will have higher spatial resolution. So it is not difficult to embed the planning map into the multi-spectral image or the panchromatic image.

The watermark inserted in this way is not nakedly exposed to the detector as in the traditional LSB embedding methods. Because the XOR operation makes the statistical property of the LSB data in the watermarked data not the same as the watermark information and stochastic, the watermark is now not so easy to detect.

2.4 Watermark Extracting

In the proposed watermark detection scheme, planning map is determined without the original image.

As shown in Fig. 1, the extraction of the watermark can be accomplished in the inverse way of the embedding operation. First, the watermarked sequence Y can be gotten according to Equ.8 by scanning the LSB data of the watermarked image in the same order as the embedding process. Then the watermark data will be obtained by the following step:

$$s_n = x_{wbit\ n} \oplus y_n \qquad (12)$$

where $x_{wbit\ n}$ can be gotten in the same way as shown in section 2.2, i.e., it can be computed as follows:

$$x_{wbit\ n} = x_{wbit+1\ n} \oplus x_{wbit+2\ n} \oplus \cdots \oplus x_{7\ n} \qquad (13)$$

Evidently, if one doesn't know the embedding algorithm, the watermark does not been modified or forged by simple method of testing or statistical analyzing.

3. Experimental Results

The simulation results are presented to show the performance of the developed LSB embedding algorithm in this section.

Generally, there are some desirable characteristics that a watermark should possess. First, the watermark should be imperceptible, that is, the difference between the original image and the watermarked image should not be obvious and the watermark should be invisibly. Therefore, the forgers cannot perceive the existence of the embedded watermark and tamper the image without awareness. Second, it should be statistically secure, that is, a statistical analysis should not produce any advantage from the attacking point of view. Therefore, the watermark can be accessed only by the legal uses. Finally, the watermark should be robust, that is, watermark can resist common image processing attacks such as compression and mild transmission errors.

To demonstrate the above character of the proposed watermarking scheme, the experiments are carried out from three main points of view: (i) watermark imperceptibility in the sense of human sense, (ii) watermark security in the sense of statistical property, (iii) watermark robustness.

In our experiments, we employed 2 remote sensing images, shown in Fig. 3, to be the host images. The host images are a multi-spectral image with the size of 465×750 and a panchromatic image with the size of 1744×3270. And the watermark image shown in Fig. 2, is a 726×355 planning map of almost the same area as the host images. The experiments were implemented on a personal computer with 512M RAM and a 1.60 GHz processor.

a) Multi-spectral image with the size of 465×750

b) Panchromatic image with the size of 1744×3270

Fig. 3 Original remote sensing images

3.1 Watermark Imperceptibility

The corresponding watermarked images are given in Fig. 4. It can be seen that the watermarks are intuitively invisible to human eyes for both RGB image and gray image.

The perceptibility performance can be quantified in terms of the peak signal to noise ratio (PSNR) given by:

$$PSNR = 20\log_{10}\frac{255}{RMSE} \quad (14)$$

where RMSE means root mean-squared error of the pixel magnitudes. Let the original un-watermarked host image of M by N pixels be *x(i, j)* and the watermarked counterpart be *X(i, j)*, then RMSE will be:

$$RMSE = \sqrt{\sum\sum\left(x(i,j) - X(i,j)\right)^2 / MN} \quad (15)$$

The PSNR quantify the distortion between the pre-watermarking image and the post-watermarking image. The PSNR values for Fig. 4a and Fig. 4b are shown in Table 1. The PSNR values are all higher than 30 dB, which means that the watermarked image is identical to the original image under normal observation. Comparing the PSNR values for different parameter *wbit* shown in Table 1, we can see that smaller *wbit* value means better image quality. And from the results, we can find that a large *wbit* value means better ability of distortion tolerance. So if one wants to get watermarking images with better distortion tolerance, the proposed method with larger *wbit* will be a better selection. Simultaneity, the image quality is acceptable.

Table 1 PSNR values of the multi-spectral image and the panchromatic image with *wbit*=1, 2 and 3

	wbit=1	*wbit*=2	*wbit*=3
Multi-spectral image	47.688	40.672	34.767
Panchromatic image	58.482	51.574	45.854

a) Watermarked multi-spectral image

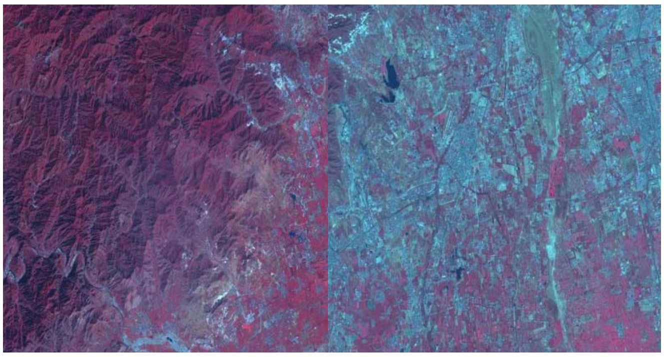
b) Watermarked panchromatic image

Fig. 4 Watermarked images

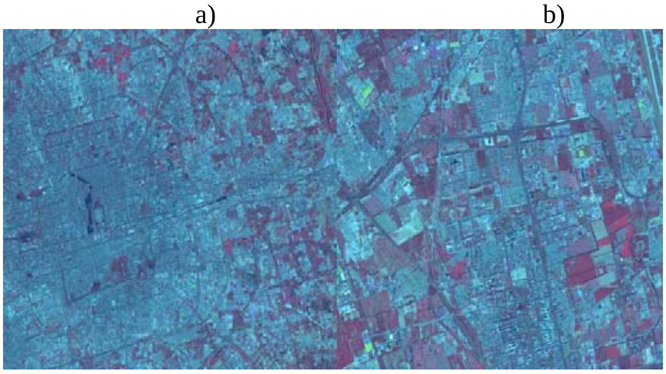
3.2 Statistical Security

The prominent advantage of the developed LSB algorithm is its statistical imperceptibility. Especially, when the same information is embedded to different images, this character makes a statistical analysis produce no advantage for the watermark detection and removal from the attacking point of view. To test the statistical property, we implement a comparison between traditional LSB method and our developed XOR-based LSB method with four different images shown in Fig. 6. The embedded watermark image used is the same one shown in Fig. 5. The LSB values of the watermarked images are extracted and are used to produce the histogram. Fig. 7 gives the histogram results of the images processed by the traditional LSB method and Fig. 8 is the results of the images processed by the XOR-based LSB method.

Fig. 5 Watermark image with the size of 100 x86



a) b)



c) d)

Fig. 6 Four original images with the size of 400x400

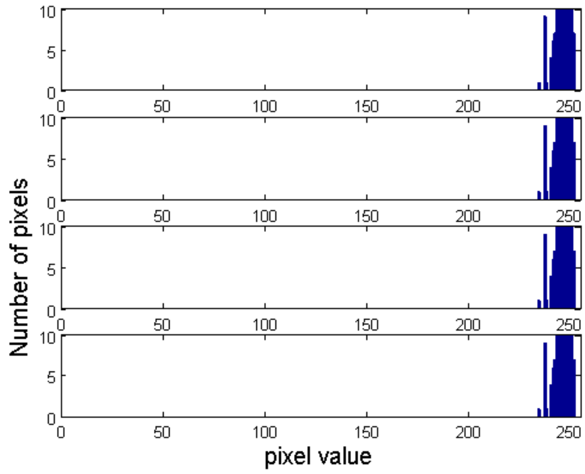


Fig. 7 The histogram of the LSB information after traditional LSB embedding

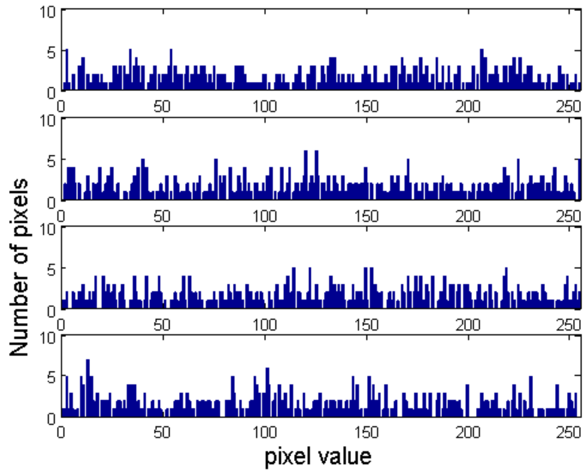


Fig. 8 The histogram of the LSB information after developed LSB embedding based on XOR

From Fig. 7, it can be seen that the LSBs of different images watermarked with same watermark image have the identical histogram. But if the watermark is inserted via XOR operation according to our method, the histograms of different watermarked images differ from each other as shown in Fig. 8. It demonstrates that the developed LSB algorithm tousles the statistical character of the watermarked images and makes the watermark resistant to attacks.

3.3 Watermark Robustness

In land consolidation projects, remote sensing images may be compressed to reduce the file size or be altered accidentally. So the watermarking method should still be able to detect and extract the watermark. Usually, the distortions are limited to those that do not produce excessive severe degradations. Otherwise, the transformed object would be unusable. [17]

To evaluate the ability of distortion tolerance, here introduce two familiar attacks in land consolidation project.

First, compression. The digital watermarking algorithms should be robust under different levels of JPEG compression. Second, additive noise. This may stem from transmission errors. The watermark is required to resist mild noise.

Fig. 9 and Fig. 10 show the extracted watermarks for jpeg compression image and additive noise stained image respectively. The results show the proposed algorithm deals with compression and additive noise well and the extracted watermark can maintain a good similarity with the original one.

Fig. 9 Extracted map from watermarked image after jpeg compression with ratio 3.2

Fig. 10 Extracted map from watermarked image with white noise

To quantify the correctness of the extracted data from the attacked images, the Bit Error Ratio (BER) is introduced:

$$BER = \frac{\sum_i B_i \oplus B_i^{'}}{n}$$

where B_i represents the *i*th bit of the original secret data, $B_i^{'}$ represents the *i*th bit of the extracted secret data, and n denotes the number of the bits of the secret data.

Fig. 11 shows the BER values changing versus the compression when *wbit*=1, *wbit*=2, and *wbit*=3. While Fig. 12 shows the BER values changing versus the variance of the white noise when *wbit*=1, *wbit*=2, and *wbit*=3.

Fig. 11 shows that the compression ratio affects the BER value greatly if the watermarked image is jpeg compressed. The bigger the compression ratio is, the bigger the BER value becomes. When the compression ratio exceeds certain level, the land reorganization planning map can't be extracted any more. Another factor to affect the BER values is the parameter *wbit*. For a certain compression ration, the smaller value of BER corresponds to larger *wbit*, which means when higher ability of distortion tolerance is required, a larger *wbit* is required.

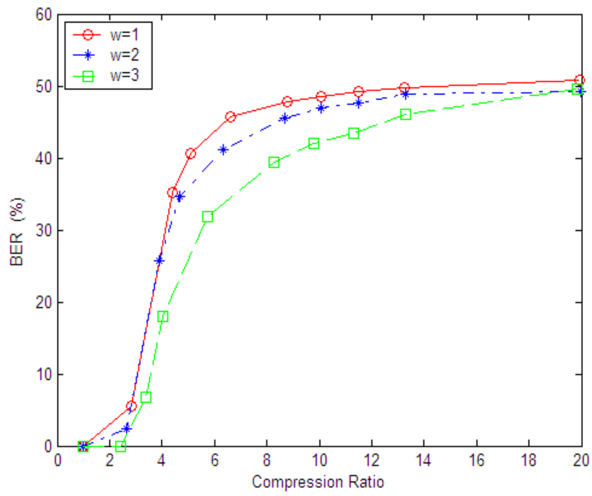


Fig. 11 BERs of secret data change versus the compression ration

When some noise exists in the transmission process, the quality of the watermarked image will be degraded. And it will be more difficult to extract the secret watermark. Fig. 12 demonstrates the truth directly: when the variance of the white noise is bigger, the BER value comes bigger correspondingly. If the noise exceeds certain level, the BER will be large enough to make the extraction impossible. But larger parameter *wbit* can make up the effect of the noise in some degree. For a certain variance of noise, larger *wbit* comes out the smaller value of BER. So it can be seen that when the parameter *wbit* is larger, the better ability of distortion tolerance is obtained.

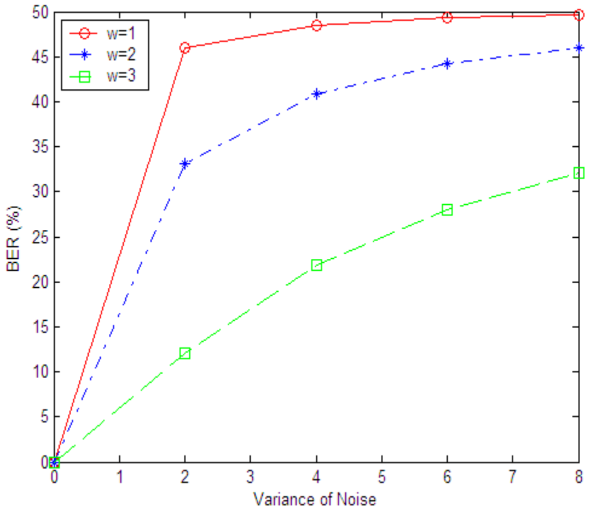


Fig. 12 BERs of secret data change versus the variance of noise

Seeing from the above simulation results synthetically, we can obviously find that the parameter *wbit* acts as a regulator between the ability of distortion tolerance and the watermark imperceptibility. Therefore, the proposed scheme is an optimal method in the sense of its distortion tolerance and at the same time it can obtain a good image quality.

4. Conclusion

Land consolidation plays an important role in enlarging farming plots and enhancing crop productivity. And remote sensing imagery can provide the spatial data/maps and offer great advantages for the fulfillment of a land consolidation project. The data security of the images used in land consolidation becomes important.

To protect the data security, especially in the land consolidation projects, this paper presents an improved LSB watermarking algorithm to embed the land reorganization planning map into a remote sensing image. In our scheme, the land reorganization planning map is compressively encoded before embedded into the protected remote sensing image. Then, the host image is preprocessed by exclusive-OR (XOR) operation to avoid the shortcoming of being easily attacked in the original LSB method. And LSB embedding is regulated by a parameter, so the proposed scheme provides good ability of distortion tolerance. If the watermarked images are JPEG compressed or suffer such distortion as adding noises, the proposed scheme can extract the secret data with a lower BER when the parameter is appropriately selected. It is suitable for the land consolidation application environment where the remote sensing images usually suffer from corruption such as adding noises and JPEG lossy compression.

The experimental results fully demonstrate that the embedded watermark is imperceptible to the human eyes and is more secure in the statistical sense.

Acknowledgement

This research is funded by the National High Technology Research and Development Program of China titled "Land Consolidation Remote Sensing Monitoring Technique and Application" (contract number: 2006AA12Z129). All authors would like to appreciate many experts from Land Consolidation Centre, The Ministry of Land and Resources P. R. C., EU-China Center for Information & Communication Technologies of China Agricultural University, for their co-operation and support.

References:

[1] S.T. Sevkiye, An analysis on the efficient applicability of the land readjustment (LR) method in Turkey, *Habitat International*, Vol. 31, No. 1, 2007, pp. 53-64.

[2] D.Y. Hwang, W.H. Wu, Financial system reform in Taiwanb, *Journal of Asian Economics*, Vol. 18, No. 1, 2007, pp. 21-41.

[3] E. Monke, F. Avillez, M. Ferro, Consolidation policies and small-farm agriculture in Northwest Portugal. *European Review of Agricultural Economics*, Vol. 19, 1992, pp. 67–83.

[4] J.F. Huang, R.Hi Wang, H.Z. Zhang, Land consolidation and GIS application in Xinjiang, China, *Proceedings of the SPIE*, Vol. 6411, 2006, pp. 64111S .

[5] D. Terry, Complications for traditional land consolidation in Central Europe, *Geoforum*, Vol. 38, No. 3, 2007, pp. 505-511.

[6] B.T. Gopal, S.N. Gajendra, Alternative options of land consolidation in the mountains of Nepal: An analysis based on stakeholders' opinions, *Land Use Policy*, Vol. 25, No. 3, 2008, pp. 338-350.

[7] T. Pietro, T. Luigi, S. Tazio, etc., Mapping regional land displacements in the Venice

coastland by an integra ted monitoring system, *Remote Sensing of Environment*, Vol. 98, No. 4, 2005, pp. 403-413.
[8] T. Cay, O. Corumluoglu, F. Iscan, A study on productivity of satellite images in the phanning phase of land consolidataion projects, *Proceedings of ISPRS2004*, 2004, pp. 379-385.
[9] C.I. Podilchuk, E.J. Delp, Digital watermarking: algorithms and applications, *IEEE Signal Processsing Magazine,* Vol. 18, No. 4, 2001, pp. 33－46.
[10] C.C. Lin, W.H. Tsai, Secret image sharing with steganography and authentication, Journal of Systems and Software, Vol. 73, 2004, pp. 405 －414.
[11] S.S. Maniccam, N. Bourbakis, Lossless compression and information hiding in images, *Pattern Recognition,* Vol. 37, No. 3, 2004, pp. 475－486.
[12] G.C. Langelaar, I. Setywan, R.L. Lagendijk, Watermarking digital image and video data, *IEEE Signal Processing Magazine,* Vol. 17, No. 5, 2000, pp. 20-46.
[13] C.T. Hsu, J.L. Wu, Multiresolution water-marking for digital images, *IEEE Trans. Circuits System II*, Vol.45, 1998, pp.1097-1101.
[14] B.P. Kumari, V.P.S. Rallabandi, Modified patchwork-based watermarking scheme for satellite imagery, *Signal Processing*, Vol. 88, No. 4, 2008, pp. 891-904.
[15] C.K. Chan, L.M. Cheng, Hiding data in images by simple LSB substitution, *Pattern Recognition*, Vol. 37, No. 3, 2004, pp. 469－474.
[16] X.Y. Wu, Z.H. Guan, Hiding data in spatial domain images with distortion tolerance, *Computer Standards & Interfaces,* Vol. 31, 2009, pp. 458-464.
[17] F. Perez-Gonzalez, J. R. Hernandez, A tutorial on digital watermarking, *Security Technology, Proceedings of IEEE 33rd Annual 1999 International Carnahan Conference,* 1999, pp. 286 – 292.