Jerzy KOROSTIL, **Łukasz NOZDRZYKOWSKI**
FACULTY OF COMPUTER SCIENCE, WEST POMERANIAN UNIVERSITY OF TECHNOLOGY,
Żołnierska St. 49, 71-210 Szczecin

Impact analysis of the wavelet order on the visibility of the image

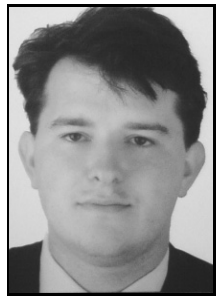
Prof. Jerzy KOROSTIL

He works at the Faculty of Computer Science in West Pomeranian University of Technology – Szczecin since 2000 year. Research interests relate to steganography, security of computer networks and software.

e-mail: jkorostil@wi.zut.edu.pl

M.Sc., eng. Łukasz NOZDRZYKOWSKI

PhD student at the Faculty of Computer Science in West Pomeranian University of Technology – Szczecin since 2006 year. Research interests relate to steganography and cryptography, security of computer networks. In private, administrator of the web portal.



e-mail: lnozdrzykowski@wi.zut.edu.pl

Abstract

An analysis of the impact changes of wavelets family order to the determination possibility of a visibility contrast changes in digital image there is presented in the article. To determine the visibility there is proposed to use a contrast sensitive function CSF which corresponds to the human visual system. Determination of the visibility is done by the referencing frequency of contrast changes on the normalized curve CSF. This analysis is important from the point of view of moving the image parameters from spatial domain to wavelets domain, when we can use several wavelets orders. Taking the important parameters to the analysis can reduced the visibility of distortion in destination image formed after steganography hiding messages. Moves of all calculations from spatial domain to wavelets allows to reduce the demand of the resource. Wavelets transform can be used to determine which image is suitable to hiding in them a specific portion of data and can be used to hiding messages in wavelets coefficients.

Keywords: wavelet analysis, digital images, wavelets order, visible of contrast changes, steganography.

Ocena wpływu wzrostu rzędu falek na postrzegalność obrazu

Streszczenie

W artykule przedstawiono analizę wpływu zmiany rządu rodzin falek na możliwość wyznaczania widocznych zmian kontrastu. Do wyznaczania widoczności proponuje się stosowanie funkcji czułości kontrastu CSF, której zastosowanie jest bliskie postrzegalności ludzkiego wzroku. Wyznaczanie widoczności odbywa się poprzez odniesienie częstotliwości zmian kontrastu na znormalizowaną krzywą CSF. Analiza taka jest ważna z punktu widzenia przenośności istotnych parametrów obrazu z dziedziny przestrzennej do dziedziny falkowej, gdy możliwe jest wykorzystanie wielu rzędów falek. Branie istotnych parametrów do analizy pozwala na zmniejszenie ilości widocznych zmian w obrazie wynikowym powstałym poprzez steganograficzne ukrywanie wiadomości. Przeniesienie wszystkich obliczeń do dziedziny przestrzennej pozwala zmniejszyć zapotrzebowanie na zasoby. Transformata falkowa może być użyta do wyznaczania obrazów przydatnych pod kątem ukrywania w nich określonej porcji danych oraz może być użyta do ukrywania wiadomości we współczynnikach falkowych.

Słowa kluczowe: analiza falkowa, obrazy cyfrowe, rząd falek, widoczność zmian kontrastu, steganografia.

1. Introduction

Analysis of the digital images with the use the wavelet transform allow to determine the positions in digital images, where steganography image hides not adding the visible distortions to destination image [1], which shouldn't arise as a result of using the steganography algorithm [2, 3]. Determination of this sites can be done with use the characteristic parameters of digital image calculated from image wavelet representation. Wavelets transform also can be used to determine which image is suitable to hiding in them a specific portion of data. To visibility change analysis the contrast sensitive function CSF can be used, which is corresponding to the human vision.

The article presents an analysis of the use a specific wavelets order to determine a visibility changes a pixels value in digital images. Determining the useful wavelets orders is important for the moving essential image parameters from spatial domain to transform domain [4, 5]. Because image important parameters can be used to determine places of hiding messages, so it is important that parameters stay unchanged from source image to destination image who arises after message hiding. CSF function also can be used to determine invisibility of the image changes. Invisible is this, what have a contrast changes in high frequency range, which is expressed in cycles per degree.

The rest of paper is organized as follows. Section 2 shows the digital image wavelets representation. In Section 3, we formulate a model of a visibility of the changes in digital images. Section 4 shows the analysis of the visibility for the different orders of wavelets in digital images, and finally, we conclude the paper in Section 5.

2. Digital image wavelets representation

For the analysis of the images we can use a parameters determined from the wavelet transform. Wavelet transform uses the window variable size to obtain different information about the testing signal. By less sampling the information about low frequencies is obtained. Obtaining information about the higher frequencies is guaranteed by denser sampling.

Wavelet transform is performed by dividing signal into several components. This is done by mapping the basic wavelet on the signal. Here is used the moving and scaling the basic wavelet. Wavelet transform can be applied to the decomposition of one-dimensional and two-dimensional signal. Because image is the two-dimensional signal, so it is analyzed by the two-dimensional wavelet transform. The result is a complex image of four parts [4]:

- Section LL: approximation – is obtained by using scaling function
- Section LH: vertical details – is obtained by using vertically wavelet function
- Section HL: horizontal details – is obtained by using horizontally wavelet function
- Section HH: diagonal details – is obtained by using diagonally wavelet function.

Wavelet decomposition is used in steganography to hiding information in digital images. Wavelet analysis is also used to determine the parameters from the images. In the analysis, these parameters can reduce the visibility distortions in destination images.

3. Visibility of changes in digital images

To determine the visibility of changes in digital images the normalized contrast sensitive function CSF can be used, which characterized the human visual system. In article [5] there is presented the possibility of using the contrast sensitive function to determine invisibility, which is the inverse to the visibility change in image. The changes arise as a result of hiding information in digital images. In article [5] there is presented possibility of moving function CSF to wavelet domain.

Normalized contrast sensitive function *H*(*f*) presents dependency of Manos and Sakrison [6][7], which is determined by the equation (1):

$$H(f) = 2.6 \times (0.192 + 0.114 \times f) \times e^{[-(0.114 f)]^{1.1}}, \qquad (1)$$

where *f* is frequency of changes defined in cycles per degree. Function CSF is presented in Fig. (1).

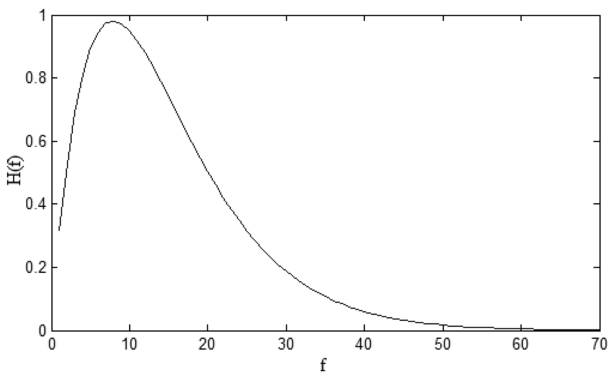


Fig. 1. Normalized contrast sensitive function
Rys. 1. Znormalizowana funkcja czułości kontrastu

According to Figure (1), human eye is most sensitive to frequency changes in the range about 10 cycles per degree. Sensitivity decreases with increasing changes of the contrast frequency. Changes above 60 cycles per degree are invisible to the human eye.

Contrast sensitivity and invisibility of contrast changes can be also presented on optotype tables which are used in medicines to study the human vision. In such tables contrast sensitivity is determined by the using the optotypes, which decrease the contrast level and decrease the optotype size. The optotypes are determinated by the one degree view but whth a different distance of observation. Each optotype corresponds to the specific frequency of contrast changes and can be used as a parameter of invisibility of contrast changes, [5].

4. Analysis of visibility for the different orders of wavelets

Determination of the visibility of the contrast changes in digital images is done by the referencing the contrast change frequency to the normalized curve CSF. For the analysis has been used a monitor with diagonal *D*=19 inches. In the analysis of invisibility or visibility changes in image on computer screen, distance of observation *v* is equal 0.8 meter from the monitor. Then we must calculate how much pixels are displayed in one degree of human vision pole. Number of pixels in one degree is expressed as the ratio of monitor resolution and frequency sampling f_s. Frequency sampling f_s is determined by the equation (2):

$$f_s = \frac{2v \tan(0.5^\circ) \times r}{0.0254}, \qquad (2)$$

The resolution *r* of monitor can be calculated from the equ. (3):

$$r = \frac{\sqrt{x^2 + y^2}}{D}. \qquad (3)$$

For the 19 inches monitor with the size of 1280x1024 pixels the resolution *r* is equal 86.27 pixels per degree. Then number of pixels in one degree per cycle f_s is equal 47.42.

In analyzed impact wavelet order influence on the visibility of contrast changes in digital image the standardized wavelet functions proposed in articles [4-5] has been used These function were proposed to calculation important parameters from the image. Taking the parameters to the image analysis can reduce the distortion visibility in destination image formed after hiding messages.

A possibility of moving important attributes from spatial domain to wavelet domain is presented in the work [4]. As an important and transferable attributes were recognized: the number of levels in the red colour; in histogram of colours: mean, variance, dispersion, kurtosis; in Co-Occurence Matrix: contrast, entropy and homogeneity for the vertical data.

According to the analysis, important attributes have a possibility to be transfer from the spatial domain to wavelets domain. In the analysis were used the following wavelet families: Daubechies, Symlets and Coiflets. The proposed wavelets and level of the decomposition to transfer the important attributes to wavelet domain are presented in Table 1, where portability is about 100 percent (for example, entropy of the wavelet Symlets order 7).

Tab. 1. Wavelet functions and approximation levels proposed to parameter transfer from spatial domain to wavelet domain
Tab. 1. Funkcje falkowe i poziomy aproksymacji proponowane do przenoszenia parametrów z dziedziny przestrzennej do falkowej

Attribute	Wavelet	Order	Level
Number of Red Colour	Daubechies	1-5	2
Mean	Symlets	7, 8	3
Variance	Coiflets	5	2
Dispersion	Coiflets	1-5	3
Kurtosis	Daubechies	4-9	3
Contrast	Symlets	7	3
Entropy	Symlets	7	3
Homogenity	Symlets	7	3

Because digital colour image can be analyzed by several orders and families of wavelets, when parameters are transferable from spatial do wavelets domain, so in the next part has been analyzed the visibility of changes in image for different wavelet orders.

To determine the invisibility level there is used the normalized contrast sensitive function CSF defined by Manos and Sakrison. The analysis was done on the group of images with various texture. Images analyzed were at angle equal one degree and distance of observation equal 0.8 meter from monitor. All images had height equal 300 pixels.

Examplary analysis dependencies of the wavelet order to the visibility of contrast changes on the image with height equal 300 pixels are presented in the Figure (2). The analysis was done on the first level of approximation.

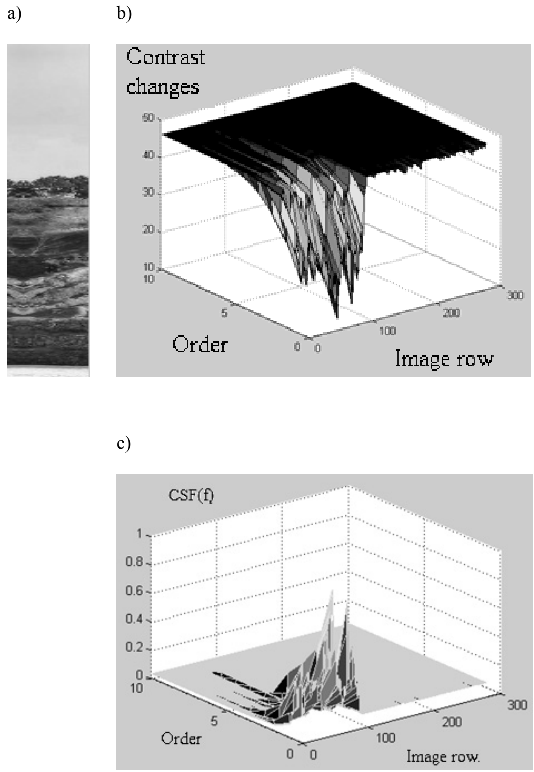


Fig. 2. Changes of visibility depending of the order of wavelets Daubechies: a) original image, b) number of contrast changes, c) visibility of changes by function CSF

Rys. 2. Zmiany widoczności w zależności od rzędu falki Daubechies: a) obraz oryginalny, b) liczba zmian kontrastu, c) widoczność zmian w zależności od funkcji CSF

Figure 2b presents the number of changes of contrast expressed in cycles per degree, which increases with wavelet order to the level 50 cycles per degree. This means that each pixel of the row has a different value of the contrast. The number of contrast changes calculated for the rows and wavelet order which mapped on the CSF is presented in the Figure 2c.

When wavelet order of Daubechies family is increased then visibility of contrast changes in digital image is decreased. This is shown of graph 2c in low values of function CSF, which represents the visibility of the contrast changes. The most visible contrast changes were obtained for the second order of wavelets. Histogram of the distribution limits of the visibility of contrast changes in the depending on the wavelets order is presented in Figure 3 for ten random images.

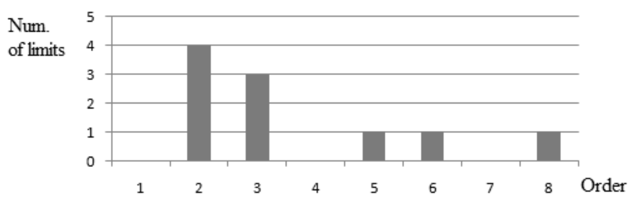


Fig. 3. Histogram of the distribution limits of the visibility of contrast changes in the depending on the wavelets order of Daubechies family

Rys. 3. Histogram rozkładu granic widoczności zmian kontrastu w zależności od rzędu falek Daubechies

For that wavelet family above second and third order, visibility of contrast changes disappears. This is caused by increasing the sampling frequency. This gives many minor changes in the approximation of the image. Their frequency is high, so according to the CSF, they are invisible to the human eye. So, to image analysis we take the lower orders of the Daubechies wavelet.

Results received for Coiflet family are presented in Figure 4.

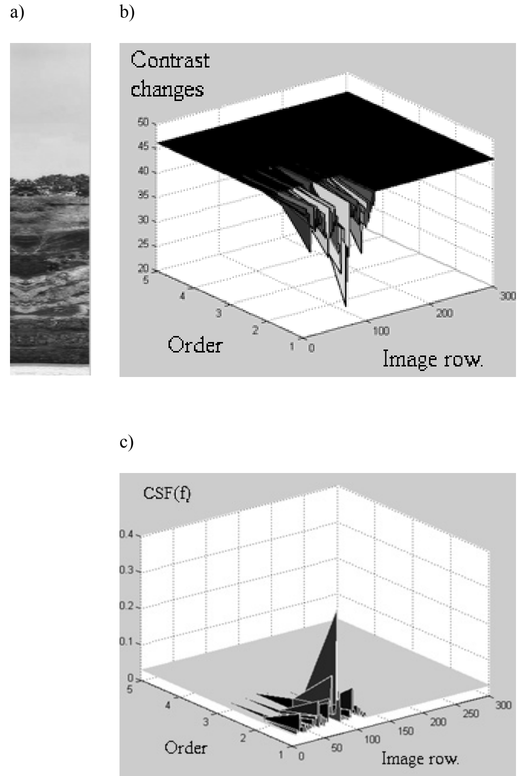


Fig. 4. Changes of visibility depending of the order of wavelets Coiflets: a) original image, b) number of contrast changes, c) visibility of changes by function CSF

Rys. 4. Zmiany widoczności w zależności od rzędu falki Coifleta: a) obraz oryginalny, b) liczba zmian kontrastu, c) widoczność zmian w zależności od funkcji CSF

Figure 4 shows once again that the best results for the visibility of changes are obtained for lower orders of Coiflet family. Higher orders generate many small contrast changes, which frequency is so small, that they are invisible. A histogram of the distribution limits of the visibility of contrast changes in the depending on the wavelets order for the Coiflet family is presented in the Figure 5.

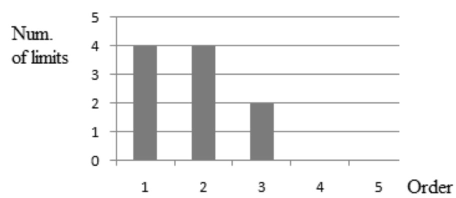


Fig. 5. Histogram of the distribution limits of the visibility of contrast changes in the depending on the wavelets order of Coiflet family

Rys. 5. Histogram rozkładu granic widoczności zmian kontrastu w zależności od rzędu falek Coifleta

For the Coiflet family the first order of wavelets is the best for analyzing the image parameters. Above third order numbers of contrast changes are too great to observe the visible changes in the image.

These results were compared with the one obtained by the use the wavelet Symlets family to image analysis. Their use in the analysis were considered as important for determining invisible changes in digital images which were caused by hidden steganography message [4, 5]. They are presented in Figure 6.

The order which causes the visibility changes in approximation image for the Symlets wavelets is larger than the orders in previous families. Here we have a sensible limit of the eight order.

A histogram of the distribution limits of the contrast change visibility in the dependency of the wavelet order for the Symlets family is presented in the Figure 6.

a) b) c)

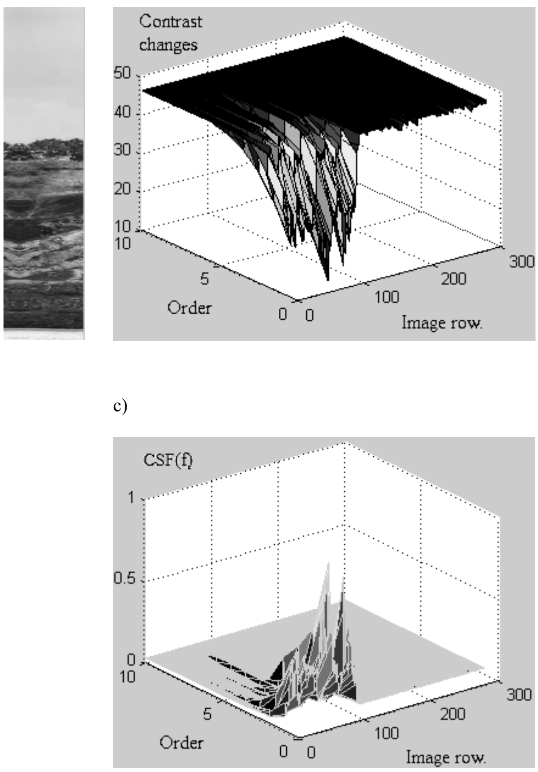


Fig. 6. Changes of visibility depending of the order of wavelets Symlets: a) original image, b) number of contrast changes, c) visibility of changes by function CSF

Rys. 6. Zmiany widoczności w zależności od rzędu falki Symleta: a) obraz oryginalny, b) liczba zmian kontrastu, c) widoczność zmian w zależności od funkcji CSF

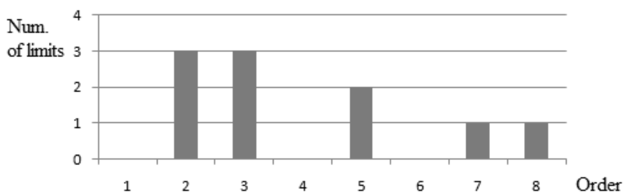


Fig. 6. Histogram of the distribution limits of the visibility of contrast changes in the depending on the wavelet order of Symlets family

Rys. 6. Histogram rozkładu granic widoczności zmian kontrastu od rzędu falek Symlets

According to the histogram, for the Symlets family can be used larger orders than in the case of the Coiflets wavelets. Again, a better results gave lower orders wavelets.

5. Conclusions

Wavelet analysis is good tool for the determining the important attributes of the digital images [4-6]. There is elaborated the method to the determination the useful images to steganography hiding messages, and places to the hiding messages are pointed out. The visibility analysis and determination of the important attributes from the image in wavelet domain is accomplished. By the analysis of the wavelet order impact on the visibility contrast changes in image, there is shown the usefulness of wavelet orders to study properties of images.

The most useful wavelet orders for the analysis of the visibility contrast changes are lower orders. They move a visible contrast changes to the image approximation. When move an important parameters of image from spatial domain to wavelet domain and when there is a possibility to use a several wavelet orders, then it is the best to choose the lower wavelet orders.

6. References

[1] Nozdrzykowski Ł.: Analiza istotności miar obrazu wpływających na zmniejszenie zniekształceń spowodowanych steganograficznym ukrywaniem wiadomości w obrazach w oparciu o funkcję CSF. Metody Informatyki Stosowanej, vol. 3, pp. 57-64, 2009.

[2] Bailey K., Curran K.: An evaluation of image based steganography methods. Multimedia Tools and Applications, vol. 30, Issue: 1, pp. 55 – 88, 2006.

[3] Conway Maura: Code wars: Steganography, signals intelligence, and terrorism Knowledge. Technology & Policy, vol. 16, Issue: 2, pp. 45-62, 2003.

[4] Korostil J., Nozdrzykowski Ł.:. Wyznaczenie zależności pomiędzy istotnymi parametrami obrazu dla zmniejszenia widoczności ukrycia wiadomości w obrazach pomiędzy dziedziną przestrzenną a transformaty falkowej. Metody Informatyki Stosowanej, vol. 4, 2009.

[5] Korostil J., Nozdrzykowski Ł.:. The security level of a particular blind steganographic systems. Elektronika, vol. 11, pp. 41-44, 2009.

[6] Mannos J. L., Sakrison D.S.:. The Effects of a Visual Fidelity Criterion on the Encoding of Images. IEEE Trans. on Information Theory, vol. 20, pp. 525-535, 1974.

[7] Wen Lu, Xinbo Gao, Xuelong Li, Dacheng Tao: An Image Quality Assessment Metric Based Contourlet. IEEE Int. Conf. on Image Processing 2008. IEEE Signal Processing Society 2008. http://www.video.eecs.berkeley.edu/Proceedings/ICIP2008/pdfs/0001172.pdf, [access: 2009].

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