Reversible Blind Watermarking for Medical Images Based on Wavelet Histogram Shifting

Hêmin Golpîra[1], Habibollah Danyali[1, 2]

1- Department of Electrical Engineering, University of Kurdistan, Sanandaj, Iran

2- Department of Telecommunication Engineering Shiraz University of Technology, Shiraz, Iran

hemin.golpira@uok.ac.ir , hdanyali@ieee.org

***Abstract*— *This paper proposes a blind reversible watermarking approach for medical images based on histogram shifting in wavelet domain. An integer wavelet transform is applied to map the integer host image components to integer wavelet coefficients. The watermark information is inserted into the high frequency subband regions of the transformed image. According to the capacity required for the watermark, two thresholds, T_1 and T_2, are selected, one in the begging part and the other in the end part of the histogram of the high frequency subbands of the transformed image. Two zero-points, Z_1 and Z_2 are also created by properly shifting the beginning and the end parts of the histogram. The part of the histogram located between the two thresholds remains unchanged. The binary watermark data are inserted in the thresholds and zero-points locations. The high PSNR (above 53dB) obtained for several watermarked medical images, indicates imperceptibility of the approach. Experimental results also show superiority of the proposed approach in compare to some other methods that are based on histogram shifting in spatial as well as integer wavelet domains. Enabling lossless reconstruction of both watermark and host image, beside providing the high quality for the watermarked image, make the proposed approach attractive for medical image watermarking applications.*

***Keywords*— *watermarking, histogram shifting, medical images, reversible, zero-points, integer wavelets.*

I. INTRODUCTION

Modern digital healthcare systems facilitate easy access to medical data and provide easy way to distribute and manipulate them. Exchange of medical data could efficiently provide easy and fast access to medical experts and decrease healthcare costs. Medical images play an important role in diagnosis of many diseases. In exchange procedure, large amounts of vital information of patient such as bio-signals are usually transmitted with medical images from one healthcare to others [1]. Inserting patient's information to digital content such as images can combine the advantages of data authentication with memory utilization [2]. The exchange process is usually done through non-secure environment such as the Internet and therefore increases the risk of unauthorized access to the patient's information. To overcome this challenge, watermarking is a solution [1, 3, 4].

Digital image watermarking refers to the process of embedding a watermark (e.g. text, sound or a logo image) into the host image which enables authentication of the original image. There are several methods based on applications and requirements of digital product's owners. In case of medical images, reversibility of the watermarking algorithm is an important requirement to ensure lossless detection of both host image and the watermark at destination for correct diagnosis and authentication [1]. To achieve lossless watermarking in wavelet domain, an integer wavelet transform as well as a reversible watermarking algorithm are required. Integer wavelet transform maps integer image components (pixels) to integer coefficients in wavelet domain and therefore prevents overflow when the coefficients are coded into specified number of bits [5, 6].

Due to the increased exchange of medical images between healthcares, reversible image watermarking algorithms has recently become an emerged research area [2, 5-13]. In [8, 9] histogram shifting in spatial domain is used for lossless data hiding. They introduced zero-points and peak-points in image histogram for watermark insertion. In [10] histogram compression in spatial domain is used to create gaps for data embedding. It needs extra data to be sent with the watermarked image to be able to reconstruct the host image and the watermark. In [13] the method introduced in [9] was developed to embed more data in host image by using a lossless data hiding. Since images histogram vary for different images, it is difficult to insert high payload of watermark in host image without any perceptible disturbance. To solve this problem and to increase the capability of watermarking algorithm to be applied to any image, the process of watermarking is better to be done in wavelet domain. In other words, histogram of images in spatial domain doesn't fall into a routine pattern; but in wavelet domain, histogram of the coefficient in high frequency

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sub-bands has a Laplacian-like distribution. Moreover due to low impact of disturbance in high frequency sub-bands of image on human visual system (HVS), wavelet coefficients located in these subbands are better candidates for watermark embedding.

In [12] the host image is first divided to non-overlapping blocks and then data to-be-embedded is embedded in high frequency wavelet coefficients of each block. The insertion process is done via LSB-substitution or bit shifting. To achieve reversible algorithm the side information must be embedded in the host image which has negative impact on imperceptibility of the watermarked image. In [5], the idea introduced in [8, 9] for histogram shifting method in spatial domain is applied to integer wavelet decomposed image. A zero-point close to the peak point of the histogram is first created in the histogram and the watermark bits are inserted in this point based on the idea of histogram shifting. If data to-be-inserted is remained, a new zero-point is created and this process is continued until all watermark bits are inserted. All zero-points are in the middle region of histogram where more coefficients are located in this area and therefore more capacity for watermark insertion is provided. However this requires a wide region of the histogram to be shifted and consequently has a negative impact on the imperceptibility of the watermarked image.

To overcome the imperceptibility challenge and provide better visual quality for watermarked image, it is required that the shifted regions of the histogram of the high frequency subbands to be as small as it can be. More over the shifted parts need to be located in the beginning and end parts of the histogram where contain higher frequency values that are less sensitive to HVS. This paper proposes an algorithm which fulfils the above mentioned requirements for histogram shifting of the high frequency wavelet subbands. Based on the capacity required for the watermark data, two thresholds,

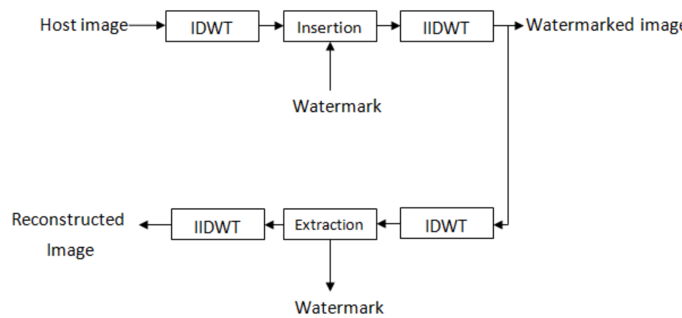


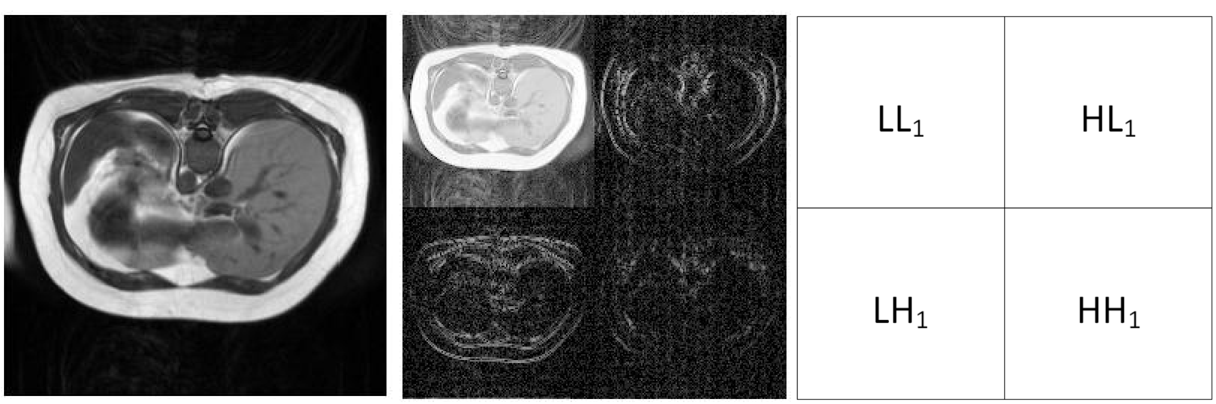
Fig. 1. Block diagram of the proposed watermarking system

one in the beginning part (left part) and the other in the end part (right part) of the histogram are selected and the left and right hand side of the histogram is shifted to left and right by one unit respectively to create two zero-points. The watermark data is then properly inserted in the position of these thresholds and zero-points in the histogram. The middle part of the histogram is kept unchanged. The proposed approach is completely reversible and could blindly extract both host image and the watermark without any loss.

The rest of this paper is organized as follows. In Section 2 the block diagram for the proposed watermarking system is introduced. Section 3 discusses the insertion and extraction algorithms. In Section 4, simulation details and simulation results are explained and finally Section 5 concludes the paper.

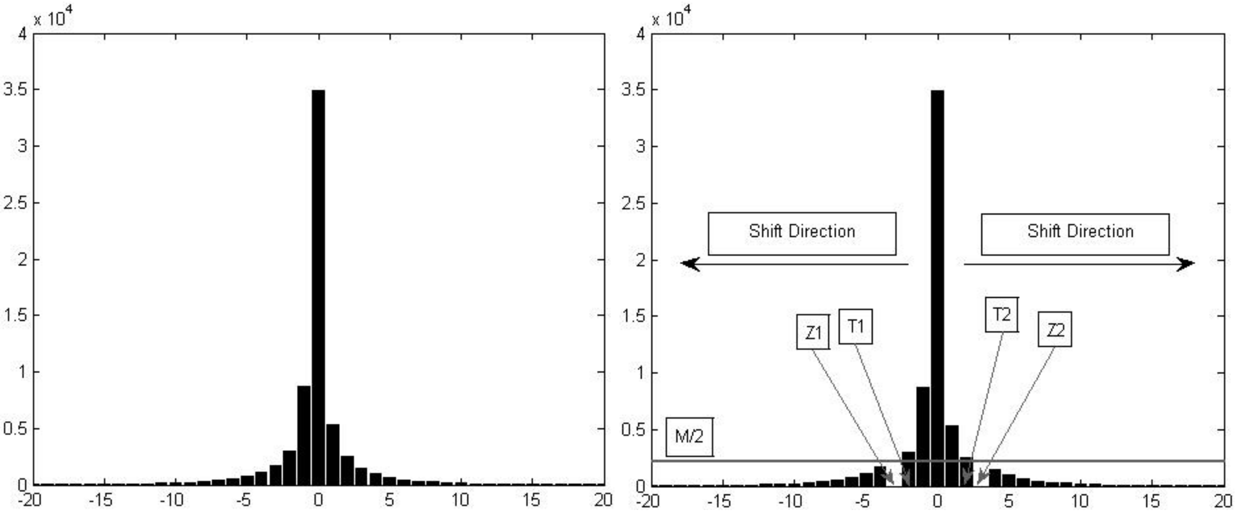
II. THE PROPOSED WATERMARKING SYSTEM

The block diagram of the proposed watermarking system is depicted in Fig. 1. In the insertion side, the host image is first transformed to wavelet domain by applying a 2D integer discrete wavelet transform (IDWT). The watermark insertion is then done (details will be given in the next section) and the inverse IDWT (IIDWT) is applied to the watermarked



(a) (b) (c)

Fig. 2. (a) A medical host image, (b) decomposed image by applying one level of IDWT, (c) frequency subbands of (b)



(a) (b)

Fig. 3. (a) Typical histogram of high frequency subbands of a medical gray scale image, (b) histogram shifting (T_1 and T_2 are thresholds and Z_1, Z_2 are zero-points)

coefficient to obtain the watermarked image in the spatial domain. In the extraction side, all of these stages are done in reverse direction to extract the host image as well as the watermark. Note that the extraction process is blind and does not need the host image for watermark extraction.

III. Insertion and extraction algorithm

Applying one level of a 2D wavelet to an image decomposed the image to four subbands, one low frequency subband called LL1 and three high frequency subbands referred to as LH1, HL1 and HH1 as shown in Fig. 2. Fig. 3(a) shows a typical histogram of the high frequency subbands of a medical image after applying a one-level IDWT. The figure shows a Laplacian-like distribution around a peak-point. Two points, called thresholds, are first selected according to the capacity required for the watermark data. For example for an M-bit watermark pattern, we draw a horizontal line at M/2 to find the proper thresholds, one in the left side (beginning part) of the histogram, called T_1, and the other in the right side (end part), called T_2, as shown in Fig. 3(b). Then the left side of T_1 is shifted to left by one unit and the right side of T_2 is shifted to right by one unit. This shifting causes to appear two gaps, one at the left of T_1 and the other at the right of T_2 which called zero-points and referred to as Z_1 and Z_2 respectively. The thresholds and zero-points are used during watermarking insertion and extraction algorithms. Note that several pairs of coefficients in the range of $[T_1, T_2]$ can be selected as thresholds. We select T_1 and T_2 that allow minimum required shift to the histogram while provide required capacity for inserting the watermark data. Details of these algorithms are as follows:

A- *The Watermark Insertion Algorithm*

1- Apply L levels of a 2D IDWT to the host image to obtain the decomposed image, which consists one low frequency subband called LL_L and 3×L high frequency subbands referred to as LH_i, HL_i, HH_i where i=1, 2… L (see Fig. 2).

2- Find T_1 and T_2 (as mentioned above) on the histogram of the high frequency subbands (i.e. LH_i, HL_i, HH_i, i=1, 2… L).

3- Create the zero-points (Z_1 and Z_2):

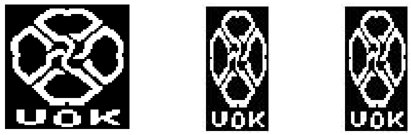
   a. Shift the left side of T_1 to left by one unit to create zero-point Z_1 (Fig. 3(b)).

   b. Shift the right side of T_2 to right by one unit to create zero-point Z_2 (Fig. 3(b)).

Note that these thresholds and zero-points guarantee the smallest area shift on the histogram according to the capacity required for the watermark and therefore expect to provide better imperceptibility for the watermarked image.

4- Insert the watermark (W):

   a. Create two low resolution versions of the binary watermark image (W), one by



(a) (b) (c)

Fig. 4. (a) The binary image used as watermark, W, 64×64 bits, (b) W_1, even columns of W, 64×32 bits, (c) W_2, odd columns of W, 64×32 bits

taking the even columns of W, called W1 and the other by taking the odd columns of the W, called W2 (see Fig. 4).

b. Place zero and one bits of W_1 at T_1 and Z_1 respectively: find the coefficients in the high frequency subbands of the decomposed image that their value is equal to T_1. For each found coefficient (C_i) embed one bit of $W_1(W_{1i})$:

$$C_i = C_i - W_{1i} \quad i = 1,2,\ldots M/2$$

c. Place zero and one bits of W_2 at T_2 and Z_2 respectively: find the coefficients in the high frequency subbands of the decomposed image that their value is equal to T_2. For each found coefficient (C_i) embed one bit of $W_2(W_{2i})$:

$$C_i = C_i + W_{2i} \quad i = 1,2,\ldots M/2$$

5- Apply L levels of a 2D inverse IDWT to obtain the watermarked image in spatial domain.

B- The Watermark Extraction Algorithm

1- Apply L levels of a 2D IDWT to the watermarked image to obtain the decomposed watermarked image, which consist one low frequency subband called LL_L and 3×L high frequency subbands referred to as LH_i, HL_i, HH_i where i=1, 2… L.

2- Extract the watermark (W):

a. Scan the high frequency subbands of the decomposed image to find the coefficients that their value is equal to T_1 or Z_1. For each found coefficient extract one bit of W_1 by considering T_1 as zero and Z_1 as one.

b. Scan the high frequency subbands of the decomposed image to find the coefficients that their value is equal to T_2 or Z_2. For each found coefficient extract one bit of W_2 by considering T_2 as zero and Z_2 as one.

c. Reconstruct of W by using W_1 and W_2 as even and odd columns of W respectively.

3- Shift the high frequency subbands histogram in reverses direction:

a. Shift the left side of T_1 to right by one unit.

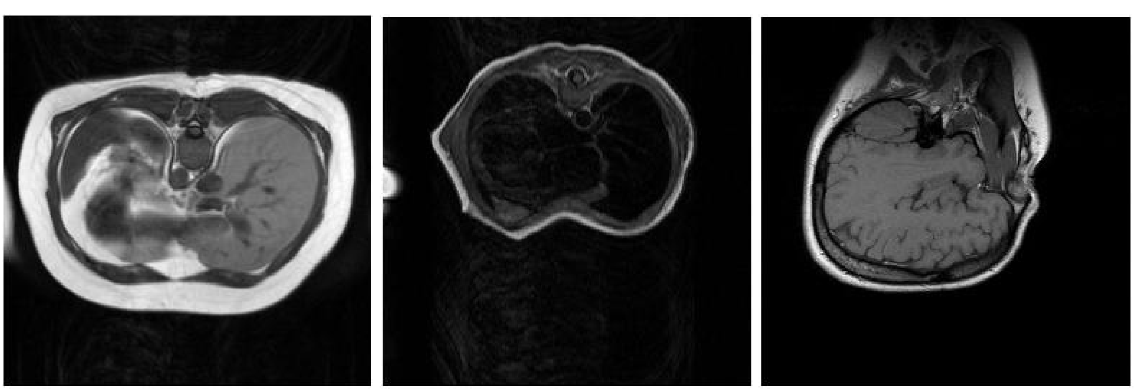
b. Shift the right side of T_2 to left by one unit.

4- Apply L levels of a 2D inverse IDWT to reconstruct the original host image.

There is no need to have the host image during watermark extraction process; therefore the process is completely blind.

IV. Experimental Results

The proposed reversible watermarking algorithm has been



(a) (b) (c)

Fig. 5. A slice of the medical images used for test: (a) MR_liver_t1, (b) MR_ped_chest, (c) MR_sag_head

Table 1. PSNR results for the watermarked images obtained from the proposed algorithm and some other related algorithms

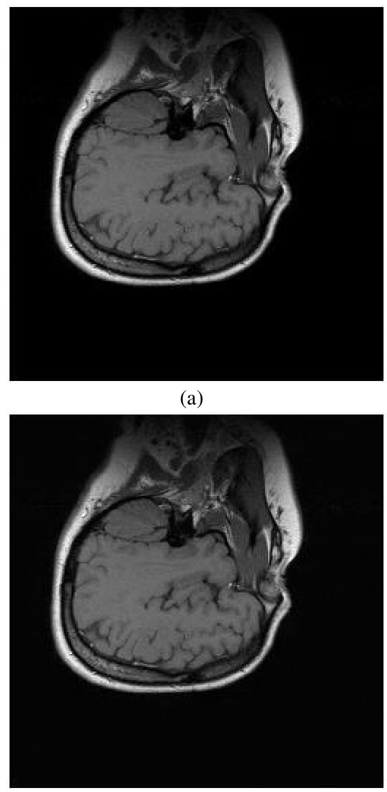
Host image name	Host image size	Logo Size	PSNR(dB) L=1, (proposed method)	PSNR(dB) L=2, (proposed method)	PSNR(dB) (Spatial domain), Ref.[9]	PSNR(dB) L=1, Ref.[5]
MR_liver_t1(58 slices)	256×256 (Pixels)	32×32 (Bits)	57.02	53.06	48.70	51.17
MR_ped_chest(77 slices)			58.05	54.40	49.10	51.57
MR_sag_head(56 slices)			57.20	52.32	51.24	52.03
MR_liver_t1(58 slices)		64×64 (Bits)	53.49	50.25	48.64	50.94
MR_ped_chest(77 slices)			53.99	51.17	49.02	51.31
MR_sag_head(56 slices)			53.03	49.18	51.15	51.94

implemented in Matlab. Three MRI data sets, MR_liver_t1 (58 slices), MR_ped_chest (77 slices) and MR_sag_head (56 slices), have been used as host medical images for test. Fig. 5 shows one slice of each set. Host images are gray scale with spatial resolution of 256×256 pixels. A binary image with resolution of 64×64 pixels has been used as watermark (see Fig. 4(a)). For each MRI data set, watermarking has been done for all slices. For all cases the PSNR reported in this section for each MRI data set is the mean value obtained for all watermarked slices.

Table 1 shows the results obtained for the proposed algorithm. The experiments for the proposed algorithm are done for the cases with one and two levels (i.e. L=1, 2) of IDWT applied to the host images. For L=1 and L=2, the watermark data is inserted in the three and six high frequency subbands respectively (LHi, HLi, HHi, i=1...L). For both cases the PSNR obtained for watermarked images are quite high, which confirms imperceptibility of the proposed watermarking algorithm. As a visual result, Fig. 6 shows the host and watermarked images for slice 14 of MR_sag_head data set. It is obvious that the human visual system (HVS) can't identify any disturbance in the watermarked image.

According to the results presented in Table 1, PSNR value for the proposed algorithm with L=1 is greater than with L=2. It is due to the part of the watermark bits that is inserted into the three middle high frequency subbands (LH2, HL2, HH2) for L=2. These subbands contain some lower frequency components in compare to LH1, HL1, and HH1 which have negative impact on imperceptibility of the watermarked image.

Overall comparison between some other reversible algorithms (e.g. [9] and [5]) and the proposed algorithm in terms of PSNR is also presented in Table 1. The results, confirms that the proposed algorithm overcomes the algorithms introduced in [9] and [5]. In these algorithms the threshold are selected to be very close to the peak point of the histogram. In case of medical images, peak point in the image histogram in spatial domain (as used in [9]) are around zero as shown in Fig. 7. Hence, histogram shifting needs a wide-band of the image histogram to be shifted which has a negative impact on the PSNR of the watermarked image. Histogram distribution in wavelet domain (as used in [5]) for medical images as shown in Fig. 3(a), has a very narrow-band. Therefore, the method used in [5] which selects zero-points to be closed to the peak-point of the decomposed image histogram, is not suitable for medical images. In Fig. 8, PSNR values for several payloads (e.g. 0.15, 0.62, 0.125,



(a)

(b)

Fig. 6. (a) Host image, (b) watermarked image (PSNR=59.05dB)

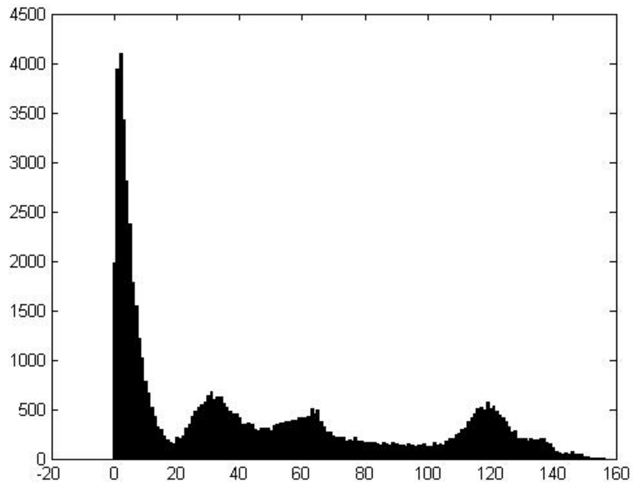


Fig. 7. Typical histogram of a medical gray scale image in spatial domain

0.25, 0.5 bits/pixel) are depicted for the proposed algorithm and compared with the results obtained for the algorithms introduced in [5] and [9]. The results clearly show better performance for the proposed algorithm.

V. Conclusion

A reversible blind watermarking approach in wavelet domain, suitable for medical image watermarking was proposed. Two thresholds, one in the beginning and the other in the end part of the histogram of the high frequency subbands of the integer wavelet decomposed image were selected. For each threshold a zero-point was created by properly shifting a side part of the histogram. The locations of the thresholds and zero-points in the histogram were used for inserting the binary watermark data. The watermark extraction process is blind and both watermark and host image is completely reconstructable without any loss. Experimental results obtained for several medical images show very high quality (PSNR above 53 dB) for the watermarked images. Taking to account the advantage of low impact of distortion in high frequency sub-bands as well as caring about the wide central part of the histogram to remain unchanged, enable the proposed approach to achieve higher imperceptibility and overcomes the similar histogram shifting approaches

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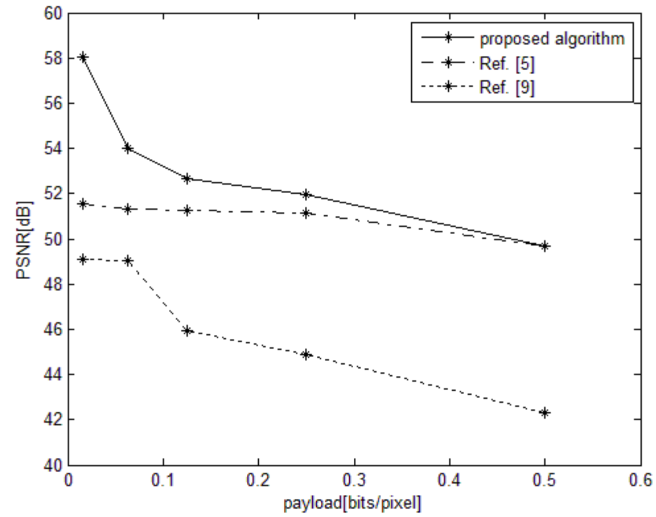

Fig. 8. PSNR value for different payloads for MR-ped-chest set

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