AN ADAPTIVE WATERMARKING ALGORITHM FOR DEM BASED ON DFT

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Abstract: In this paper, a digital watermarking algorithm is proposed for DEM data to protect the DEM copyright. The algorithm is based on the human visual system (HVS) and the discrete Fourier transform (DFT). Firstly, the location of watermarking is ascertained adaptively according on the features of DEM data. Then, the watermark information is embedded to the lowness frequency of the texture region DFT. Finally, the DEM data is transformed by DFT and the data with watermarking information is obtained. The experiments demonstrate that the proposed algorithm can not only satisfy the watermark transparency, but also have little effect on the DEM elevation, the slope and the contour. In addition, the algorithm is robust to the some noise attacks.

Keywords: digital elevation model, digital watermark, discrete Fourier transform, slope, accuracy, adaptive

1 Introduction

As an important part of the spatial data infrastructure and “Digital Earth”, digital elevation model (DEM) data is valuable in science research and application. So how to protect the copyright and the economic interests of DEM owners has become an imminent practical problem [1~5], and it is in this context where watermarking techniques come to help us to protect the ownership rights

The digital watermarking is a new technique of copyright protection in recent years, The secret information in the digital product is not only imperceptible for the human visual system, but also is difficult to remove by the pirates [6].

Due to its outstanding advantages in the protection of various types of data, digital watermarking has become an active and important area of research, and mainly focuses on the copyright protection of the image, video, audio and some multimedia information [7~12]. As a new kind of digital product, the copyright of geospatial data protection has been drawing more and more attention.And there had been some studies for watermarking on DEM data. For example, Liu[1] pointed out that the digital watermarking of usual digital images was not suitable for DEM as “not altering the elevation precision and the results of application to an extent of DEM besides transparency”. In addition to some digital watermarking algorithms were presented to protect DEM based on the discrete cosine transform (DCT) and the discrete wavelet transform (DWT). Luo et al. [2] proposed an improved watermarking algorithm based on DWT, which could adaptively get the watermarking embedding strength based on the expansion of wavelet-domain quantization noise of the human vision system (HVS). He et al. [3,4,5]proposed a DEM copyright protection and camouflage technique based on DEM histogram, which can get back the DEM non-destructively and can realized the watermark information blind detection. These studies promote the DEM copyright protection. Nevertheless, it is worth noting that very few of these studies aimed at the characteristics of the DEM data. Compared with the usual digital images, DEM has its own character and application value. Besides the general functions of the usual digital images watermarking, the DEM watermarking has some special demands.

In this paper, an adaptive watermarking algorithm for the embedding location is brought forward, based on the HVS, the DEM characteristics and the discrete Fourier transform (DFT).

2 Algorithm Principle

For DEM, the terrain lines are the important feature as collecting more terrain information and composing the terrain framework [1].Meanwhile, the terrain lines are very sensitive for the human vision. If altering the watermark information on the terrain lines, not only the vision quality of DEM will go down, but also the DEM accuracy will be reduced, and even its application value will be lost. Furthermore, the terrain lines will be different for different DEM. So the embedding location of watermark information will shift adaptively with the different DEM. Hence, the watermarking algorithm should be more robust embedding the watermark information into the terrain lines.

2.1 Selecting the suitable data region

Some studies indicate that the human vision is more sensitive on the flat areas and the edge of the regions compared to other regions.Meanwhile, the topographic parameters, such as slope and aspect, are more sensitive for the change of flat areas and edge of the regions than the change of other regions. In order to satisfy the imperceptibility of digital watermarking and the application accuracy of DEM, the watermark information should not be embedded into these regions.

2.2 Embedding the watermark information

According to the above analysis, Figure 1 illustrates the flow chart of DEM digital watermarking algorithm based on DFT.

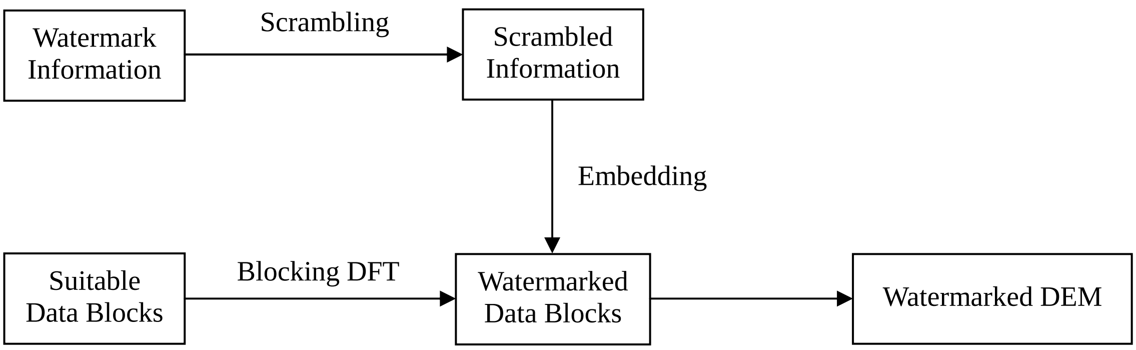


Fig.1 Flow chart of embedding watermarking

(1) Creating the watermark information: here is a significative watermark information, as Figure 2, which is a binary image. The image can be recorded as two-valued sequence $W=\{w_i\}(i=1,2,\cdots,k)$, where $w_i=\pm 1$. The watermark information $W'=\{w'_i\}(i=1,2,\cdots,k)$ can be got after scrambling the two-valued sequence.

Fig.2 The watermarking image

(2) Selecting the embedding location: The DEM data is divided into $N\times N$ non-overlapping data blocks. Therefore, the suitable data blocks can be got by the above method.

(3) Embedding watermark: The scrambled watermark information W' is embeded to the lowness frequency of the texture region DFT. The embedding formula is described as

follows: $M' = \{m_i + \alpha \cdot w'_i\}(i = 1,2,\cdots,k)$;

(4) Generating watermarked DEM: The watermarked DEM I' can be got through IDFT.

2.3 Detecting the watermark information

The detection of watermark information is the inverse process of the embedding watermark information. If possessing the key and the original DEM, the watermark information could be detected.

For estimating the similarity degree between the detected watermark and the original watermark, the following formula is adopted:

$$NC = \frac{1}{L}\sum_{i=1}^{L} b_i, \quad (i = 1,2,\cdots,L) \qquad (1)$$

Where, $b_i = XNOR(w_i, w^*_i)$, w_i is the original watermark information, w^*_i is the detected watermark information, and L is the length of watermark.

3 The results and analysis of the experiments

In order to verify the proposed algorithm, a DEM is selected as experimental data, where the size is 512 × 512 and the grid interval is 20 m.

3.1 The accuracy analysis of watermarked DEM

Table 1 illustratess the basic information of the original DEM and the watermarked DEM, and Table 2 illustratess the statistical results of elevation error and slope error of watermarked DEM. Figure 3 shows the comparison of elevation of original and watermarked DEM, and Figure 4 shows the comparison of slope of original and watermarked DEM. Figure 5 shows the comparison of contour lines of original and watermarked DEM.

Table 1 The basic information of the original DEM and the watermarked DEM

	Min. Ele.	Max. Ele.	Mean Ele.	Min. Slope	Max. Slope	Mean Slope
Original DEM	210 m	1022 m	547 m	0.0°	71.14°	32.04°
Watermarked	210 m	1022 m	547 m	0.0°	71.62°	32.04°

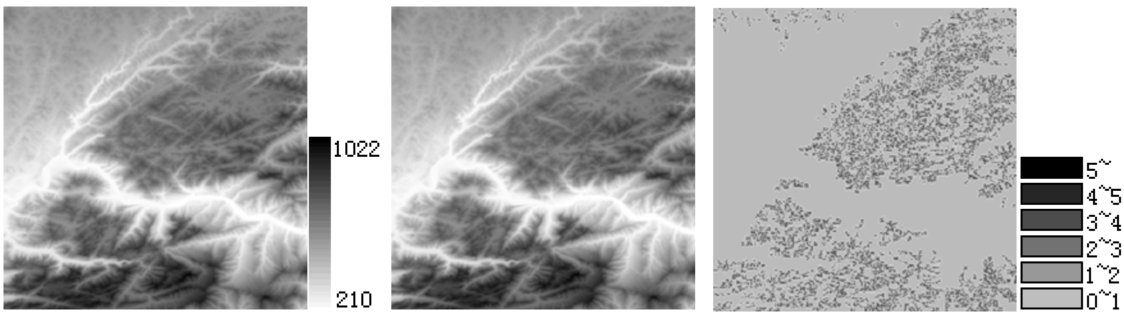
DEM

Table 2 The statistical results of elevation error and slope error of watermarked DEM

Error	0~1	1~2	2~3	3~4	4~5	$\geq$5	Max	RMSE
Ele. Error	84.45%	3.83%	5.91%	5.81%	0.0%	0.0%	3.0 m	0.892
Slope Error	78.40%	8.52%	7.41%	3.90%	1.77%	0.0%	4.99°	1.221

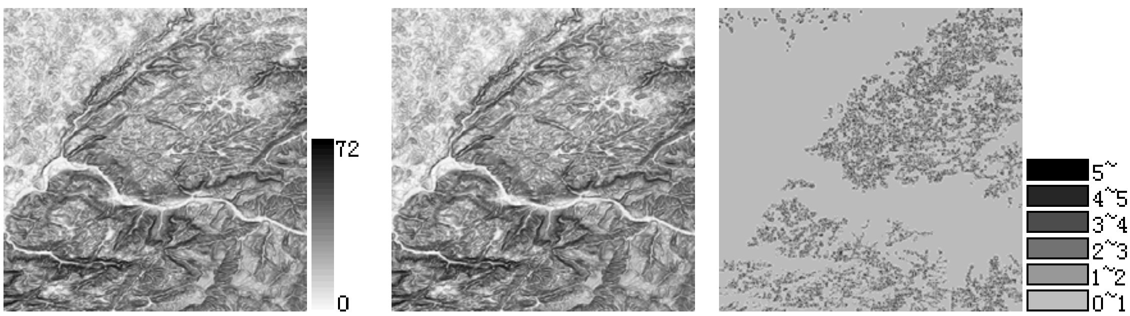
Table 1 indicates that the change of basic information between the original and watermarked DEM is not obvious. Table 2 shows the statistical results of elevation error and slope error of watermarked DEM, and the errors are mostly less than 3 units. This indicates that this algorithm has obvious advantage at controlling the data accuracy.

Figure 5 shows the change of contour lines after watermarking. In the figure, the contour lines of watermarked DEM are very close to the original contours. So the watermarked contours can satisfy the application in practice.



(a) Original DEM (b) Watermarked DEM (c) The Elevation Error

Fig. 3 The comparison of elevation of original and watermarked DEM



(a) Original Slope (b) Watermarked Slope (c) The Slope Error

Fig. 4 The comparison of slope of original and watermarked DEM

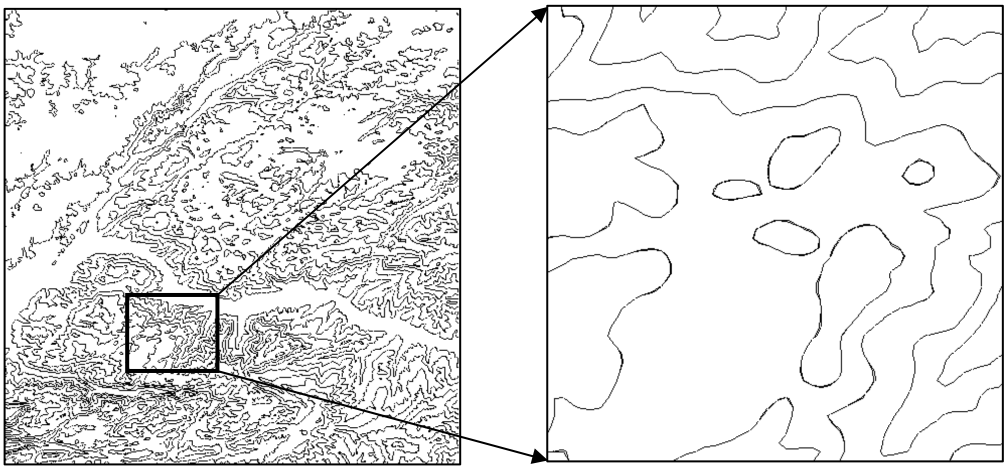
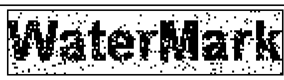


Fig. 5 The comparison of contours of original and watermarked DEM

3.2 Robustness assessment

In this paper, some noise data is added to the DEM data to study the watermarking robust. The correlation coefficient of detection result is computed by formula (1). Table 3 illustratess the detection results. These experimental results indicate that the proposed algorithm is very robust to the noise.

Table 3 The results of detecting watermarking

The noise range	[-1，1]	[-3，3]	[-5，5]
The detection result			
The correlation coefficient	0.998	0.927	0.861

4 Conclusion

Digital watermarking is a rapid and important issue in digital security,

As digital watermarking provides a potential program for the copyright protection of DEM, it is valuable in practice. From what has been addressed in the previous sections, we can see that most of existing digital watermarking algorithms are mostly proposed for the requirements of multimedia data. Nevertheless there are little scheme that takes into account the characteristics of DEM, therefore, it is not suitable for DEM data. The experimental results demenstrate that the proposed algorithm is not only able to keep the terrain characteristics of original DEM, but also can reduce the slope error. Moreover, the proposed novel algorithm has better imperceptibility and is robust to noise attack.

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