A Multi-level Watermarking Algorithm for Raster Geographic Data Based on Watermark Information Segmentation Mechanism

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Abstract: This paper presents a multi-level digital watermarking algorithm suitable for raster geographic data. First, the new problems caused by the multi-level distribution of raster geographic data and its impact on watermark embedding/detection are analyzed; and then, a watermark information segmentation mechanism is designed, the multi-level watermark embedding strategy is established on this basis, thereby building the multi-level digital watermarking algorithm of raster geographic data based on the watermark segmentation mechanism with the traditional robust digital watermarking algorithm as the prototype; finally, the experimental comparison and analysis of the multi-level watermarking algorithm and the prototype algorithm are made. Results show that the proposed multi-level digital watermarking algorithm not only maintains the performance of the prototype algorithm, but also effectively solves new problems caused by the multi-level circulation of raster geographic data, such as multi-copyright protection and multi-user tracking, and has a high practical value.

1. Introduction
Raster geographic data is the foundation of digital city and intelligent earth, and plays an important role in national economy and national defense construction. With the rapid development of computer technology and cartographic technology, the scope and depth of the application of raster geographic data have been continuously expanded, so that its characteristics of multi-level distribution and multi-level circulation are more obvious. For the robust watermarking technology in the traditional sense, the main consideration is the embedding/detection of a single watermark information. By the embedding position of watermark, it can be divided into: 1) the spatial domain watermarking algorithm, i.e. directly modifying the spatial data values to embed the watermark information\cite{1-6}; 2) the transform domain watermarking algorithm, i.e. using mathematical tools including DFT, DCT, DWT and Contourlet to transform the frequency domain of data, and embed watermark information in the transform domain coefficient\cite{7-13}. When the traditional robust watermarking technology is applied to data copyright protection and data distribution, the single user tracking and other fields cannot solve new problems caused by the multi-level distribution and circulation of data, such as multi-user tracking and multi-copyright protection. The multi-level digital watermarking technology provides practical solutions to above problems.

The multi-level digital watermarking technology is developed based on the traditional watermark technology. That is, a number of different watermark informations are embedded in the same data carrier to identify multiple copyrights of data, track the infringement at all levels, etc. Compared with the traditional watermark technology, the multi-level digital watermark technology has led to new problems,
such as error accumulation of watermarks at all levels, interference of embedding/detection of watermarks at all levels, and compromised robustness of watermarking algorithm at all levels. On this basis, in order to solve above key problems, this paper combines the data characteristics of raster geographic data and properties of multi-level watermarks, considers from the perspective of multi-copyright protection and multi-user tracking of raster geographic data, and studies the multi-level digital watermarking algorithm which meets the requirements for the application of raster geographic data.

2. Multi-level watermarking strategy based on the watermark segmentation

2.1 The watermark information segmentation mechanism

In the traditional watermarking algorithm, only the embedding of a single piece of watermark information is usually considered in the design process. A series of meaningless watermark information are usually regarded as a whole, and then the watermark information is corresponded to the carrier data, and the whole watermark information is embedded into the carrier data according to a certain rule. In Figure 1, the meaningless watermark information is regarded as a whole for embedding and detection of the watermark information.

![Fig.1 Sketch map of holistic watermark information](image)

Since the watermark information can be considered as a whole, it can also be divided and considered as a combination, which is the overall watermark information composed of multiple segments of watermark information. When the watermark information is embedded, the combined overall watermark information is still considered as the object. In this way, multiple segments of watermark information are fused well without interfering each other. At the same time, multiple segments of watermark information are embedded into the carrier data. In the process of the detection of watermark information, the overall watermark information can be extracted first, and then the corresponding segmented watermark information is extracted according to the needs, so as to achieve the purpose of detecting the segmented watermark information. A schematic diagram of the segmentation of watermark information is as shown in Figure 2 below.

![Fig.2 Strategy of watermark information segmentation](image)

2.2 Segmented embedding/detection strategy of watermark

The watermark information segmentation strategy is compared with difference levels of watermark information when the raster geographic data circulates on the multi-level distribution chain. It can be inferred that there is a great similarity between the two. Therefore, based on the prototype algorithm, the multi-level watermarking algorithm of raster geographic data is constructed by adopting the strategy of watermark information segmentation.

First, the two-level watermarking algorithm is used as an example for analysis. For the two-level watermarking algorithm, the data distribution chain has two levels. That is to say that, there are two pieces of watermark information, so the overall watermark information can be divided into two parts. The first level of watermark information in the two-level distribution chain forms the first half of the
overall watermark information, and the second level of watermark information forms the second half of the overall watermark information, this two parts form a complete watermark information sequence. The specific two-level watermark information segmentation principles are shown in Figure 3 below.

![Fig.3 Sketch map of segmentation watermark information](image)

The watermarks are embedded and detected according to the rules formulated by the prototype algorithm after the two-level segmentation of the watermark information as shown above. It should be emphasized that whether the watermark information meets the embedding/detection conditions should be judged here. The specific process is as follows:

The first level of watermarking algorithm is used to embed/detect the first level of watermark information. First, under the guidance of the data-watermark synchronization function constructed by the prototype algorithm, the position of the watermark information bit corresponding to the data point to be embedded/detected in the overall watermark sequence is found; and then, if the position of the watermark bit in the overall watermark sequence belongs to the first level of watermark information, the first level of watermarking algorithm is adopted for subsequent watermark embedding/detection; if the watermark bit belongs to the second level of watermark information, because the first level of watermarking algorithm is used only for the embedding/detection of the first level of watermarks, the watermark information does not meet the requirements for the embedding/detection of the first level of watermarking algorithm (actually the second level of watermarking algorithm is required here). Then the watermarks are not embedded/detected, and they will be processed with the second level of watermarking algorithm. All the data points to be embedded/detected are judged circularly with the above principles, so as to judge whether they meet the embedding/detection conditions of the first level of watermarking algorithm, until all the data points to be embedded/detected are processed.

For the second level of watermarking algorithm, the watermark embedding/detection judgment flow of the second level of watermark information to be embedded/detected is similar to that of the first level of watermarking algorithm, and it will not be described here.

The watermark information segmentation strategy is extended to any multi-level watermarking algorithm. Assume that the circulation depth of raster geographic data on the multi-level distribution chain is $N$. Then the corresponding digital watermarking algorithm also needs $N$ levels. Correspondingly, there are $N$ levels of watermark information on the multi-level distribution chain. Therefore, the overall watermark information is equally divided into $N$ parts. After that, each segment of watermark information corresponds to all levels of watermark information on the multi-level distribution chain. The watermark information at all levels is organized according to a certain rule to form a complete watermark information sequence. The segmentation principles of $N$ levels of watermark information are shown in Figure 4 below.

![Fig.4 Sketch map of n-segmentation watermark information](image)
3. Experiment and analysis
In order to verify the performance of the proposed multi-level watermarking algorithm, relevant experimental analysis was carried out. The experimental data used were 7,340×5,746 gray-level remote sensing images. In the experiment, the three-level watermarking algorithm will be used as the test object, and the watermark information at all levels will be embedded into the test data at the same time based on the first-level, second-level and third-level watermarking algorithm. Because the multi-level watermarking algorithm is designed and improved based on the prototype algorithm, the three-level watermarking algorithm is basically similar to the prototype algorithm in the aspects of the invisibility of the watermarking algorithm and the error caused by the embedding of the watermark information. It will not be verified again here. Next, after the watermarks of the remote sensing image data containing watermarks are attacked with different intensities in different ways, the watermark information of the first, second and third level is extracted to test the robustness of the watermarking algorithm at all levels.

The robustness test and analysis is made of the remote sensing image data containing the first, second and third level of watermark information, and it is compared with the prototype algorithm. The watermark attack methods selected mainly include data compression, Gauss noise, USM sharpening, conventional cutting, geometric translation and geometric shearing.

(1) Table 1 corresponds to the detection results of watermark information after the conventional watermark information (single watermark information) is embedded with the prototype algorithm.

| attack methods | attack intensities / detecting result | detecting result |
|----------------|--------------------------------------|------------------|
| data compression | compression percent (%) | 70.3 | 51.8 | 38.9 | 23.5 | 20.4 |
| | detecting result | 1.0(√) | 1.0(√) | 1.0(√) | 1.0(√) | 0.98(√) |
| gauss noise | add intensity (R) | 0.1 | 0.5 | 1.0 | 1.5 | 2 |
| | detecting result | 1.0(√) | 1.0(√) | 0.96(√) | 0.96(√) | 0.96(√) |
| USM sharpening | sharpening percent (%) | 10 | 30 | 50 | 80 | 100 |
| | detecting result | 1.0(√) | 1.0(√) | 0.96(√) | 0.92(√) | 0.92(√) |
| conventional cutting | cutting percent (%) | 10 | 30 | 50 | 70 | 90 |
| | translation amount (P) | 10 | 50 | 100 | 500 | 1000 |
| geometric translation | detecting result | 1.0(√) | 1.0(√) | 1.0(√) | 1.0(√) | 1.0(√) |
| geometric shearing | shearing percent (%) | 90 | 70 | 50 | 30 | 10 |
| | detecting result | 1.0(√) | 0.99(√) | 0.96(√) | 0.96(√) | 0.92(√) |

(2) Table 2 corresponds to the robustness analysis results of the first level of watermarking algorithm, i.e. the detection results of the first level of watermarking information for the data containing watermarks after the watermark attack on the remote sensing image data containing the first, second and third level of watermark information.

| attack methods | attack intensities / the first level of watermark detecting result | detecting result |
|----------------|---------------------------------------------------------------|------------------|
| data compression | compression percent (%) | 70.3 | 51.8 | 38.9 | 23.5 | 20.4 |
| | detecting result | 1.0(√) | 1.0(√) | 0.97(√) | 0.97 (√) | 0.97 (√) |
| gauss noise | add intensity (R) | 0.1 | 0.5 | 1.0 | 1.5 | 2 |
| | detecting result | 1.0(√) | 0.97(√) | 0.94(√) | 0.87(√) | 0.75(√) |
| USM sharpening | sharpening percent (%) | 10 | 30 | 50 | 80 | 100 |
| | detecting result | 1.0(√) | 1.0(√) | 1.0(√) | 1.0(√) | 0.99(√) |
| conventional cutting | cutting percent (%) | 10 | 30 | 50 | 70 | 90 |
In terms of the robustness of algorithm, comparing the watermark information detection results in Table.2, Table.3, and Table.1, it can be found that the first, second and third level of watermarking algorithm have good resistance to the conventional watermarking attacks such as data compression, noise adding, clipping, sharpening and cutting. The overall robustness is slightly lower than that of the prototype algorithm (only one watermark information is embedded), but the difference is small. Especially for the watermark attacks such as data compression, geometric cutting and geometric translation, the detection results of the watermark information at all levels are basically not different from those of the prototype algorithm at the same intensity with the same attack method. The experimental results show that the designed multi-level watermarking algorithm can inherit the performance of the prototype algorithm, and effectively complete the embedding/detection of the watermark information at all levels. The watermarking algorithms at all levels are robust, and achieve the goal of the algorithm design. The reason is that in the multi-level watermarking algorithm proposed in this paper first a complete watermark sequence is equally divided, and then the watermark information at all levels in the circulation on the multi-level distribution chain is corresponded to the segmented watermark information, and an effective watermark-data correspondence method is established. Finally, when the watermarks are embedded, the watermark information at all levels is combined into a whole to consider. When the watermarks are detected, the overall watermark information is split into hierarchical watermarks. With the segmentation-combination-segmentation of the watermark information, the watermark information at all levels can be fused well without interfering each other, and the other aspects of the algorithm are basically consistent with those of the prototype algorithm. Therefore, the multi-level watermarking algorithm proposed in this paper can not only solve the problems such as accumulative errors and mutual interference of embedding/detection of watermarks at all levels, but also inherit the robust performance of the prototype algorithm.

At the same time, comparing the watermark information detection results in Table.2, Table.3, it is found that for the watermark attacks with the same intensity and method, the robustness of the first, second and third level of watermarking algorithm has no significant difference, and there is no obvious
difference of strength. It fully shows that the algorithm proposed in this paper is balanced for the watermarks at all levels, and the design of the multi-level watermarking algorithm is not biased, which effectively guarantees the practicability of the watermarking algorithms at all levels.

4. Conclusion
The digital watermarking technology is an advanced technology in the field of data security protection. In this paper, a multi-level watermarking algorithm for raster geographic data is constructed based on the prototype algorithm through the design of the watermark information segmentation strategy in view of the current situation of the multi-level distribution of raster geographic data and requirements for the application of the multi-level watermarking algorithm. The experimental results show that the multi-level watermarking algorithm can effectively solve a series of new problems caused by the multi-level watermark embedding, such as the accumulative errors, interference and compromised robustness of watermarks at all levels, and achieve the targets such as multi-copyright protection and multi-user tracking for raster geographic data. However, this algorithm is not applicable in case of many data distribution levels, which is the problem to be considered and solved for future research.

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