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Robust Watermarking for Protection of Geospatial Data

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Abstract. Geospatial data can be stored efficiently and with a very high quality using computers. It becomes easy to duplicate and distribute it with rapid development of communication network. This paper presents the watermarking algorithm for copyright protection of geographical maps composed in vector format. In the proposed algorithm, watermark is embedded in low frequency coefficients of wavelet transform. Impact of embedding strength on visual degradation of vector map is observed. Experimental results show that the proposed algorithm is robust against noise, data compression, format exchanging, and vertex addition/deletion.

Keywords: Vector Geospatial Data, Digital Watermarking, Wavelet Transform, Robust.

1. Introduction

Geographical Information System (GIS) has been used in military and government agencies for many years. Recently, Geo-spatial data is increasingly used in many applications like navigation systems, location based services offered by cell phones with Global Positioning System (GPS), Web based map services, and developing GIS for city planning and disaster management.

GIS data acquisition is expensive and time consuming process as it requires lots of labor and information resources to acquire geospatial data. With rapid development in Internet and communication technology, it is easy to publish, manage and distribute maps in digital form. One can buy some GIS layers, make copies from them and distribute them without taking permission from the original owner of that data. As GIS data may contain some sensitive information, it should be protected from unauthorized users. To avoid illegal duplication and distribution, one of the remarkable methods used for copyright protection is digital watermarking. Using it, one can easily trace and prove the unauthorized distribution and reproduction of watermarked data.

Vector digital map is made up of features such as points, lines, polylines, and polygons to represent objects like river, lake, road, and contour. Based on embedding method, vector data watermarking algorithms are classified as spatial domain and transform domain algorithms. Spatial domain algorithms are using the features of vector data and topological relations to embed the watermark in vector data. Transform domain algorithms alter frequency transform of the features to embed watermark data. Methods proposed in [1, 2, 3, 4, 5, 6, and 7] are spatial domain methods for watermarking vector map, where watermark is embedded by changing vertex coordinates within some error tolerance. These algorithms are not robust to compression and deletion attacks.

In transform domain algorithms, transformation is performed on features and then watermark is embedded into it. Most common transforms used are Fourier transform, Cosine transform, and Wavelet transform. Algorithms proposed in [8, 9, 10, 11, and 12] are transform domain algorithms. Some algorithms

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in this category are fragile to noise attack. In general, transform domain algorithms are more robust than spatial domain algorithms but gives less accuracy than spatial domain algorithms.

This paper presents wavelet decomposition based watermarking algorithm for copyright protection of vector data. Wavelet transform is the obvious choice as it is not sensitive to local modification, reflects local features better, and deals with noise in better way than any other transform.

2. Watermark Embedding Process

Three-level wavelet decomposition is performed on vector data, and then digital watermark is inserted in low frequency coefficients of decomposed data. The watermarked data is transformed by inverse wavelet transform. Figure 1 shows the basic flow of embedding watermark for geospatial data. Embedding is performed as:

$$A'(x) = A(x) + p * w(x) \quad x \in [0, n-1] \tag{1}$$

Where, *A(x)* represents low frequency coefficients of wavelet transform, p is strength of embedding, n is number of bits for the embedded watermark. *w(x)* is the watermark to be embedded and it is represented as:

$$W = \{w(x)\}, \quad x = 0, ..., n-1, \; w(x) = \pm 1 \tag{2}$$

3. Watermark Detection Process

Watermark is detected by applying wavelet decomposition to both original data and watermarked data. Low frequency coefficients of the both are compared to detect watermark W. Basic schematic flow for watermark detection is shown in figure 2. Watermark *W* can be extracted according to equation as follows:

$$C(x) = A_D(x) - A(x)$$

$$W_D(x) = \begin{cases} 1 & C(x) \geq 0 \\ -1 & C(x) < 0 \end{cases} \tag{3}$$

Where $A_D(x)$ is watermarked data, *A(x)* represents original data, and $W_D(x)$ is detected watermark.

To evaluate similarity between original watermark and extracted watermark, Normalized Correlation (NC) is calculated. It is represented as:

$$NC = \frac{\sum_{x=0}^{n-1} w(x) w'(x)}{n} \tag{4}$$

Where, *w(x)* is original watermark, *w'(x)* is extracted watermark, and *n* is length of watermark.

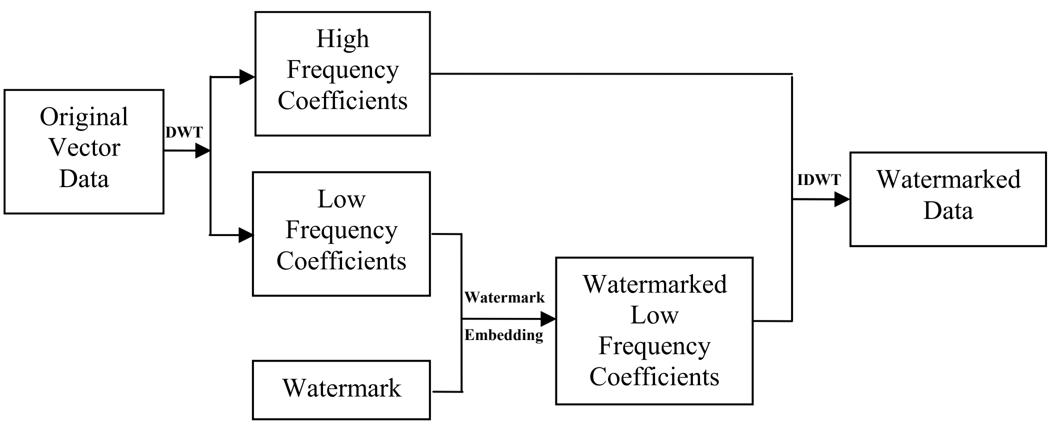


Fig.1: Schematic flow for watermark embedding.

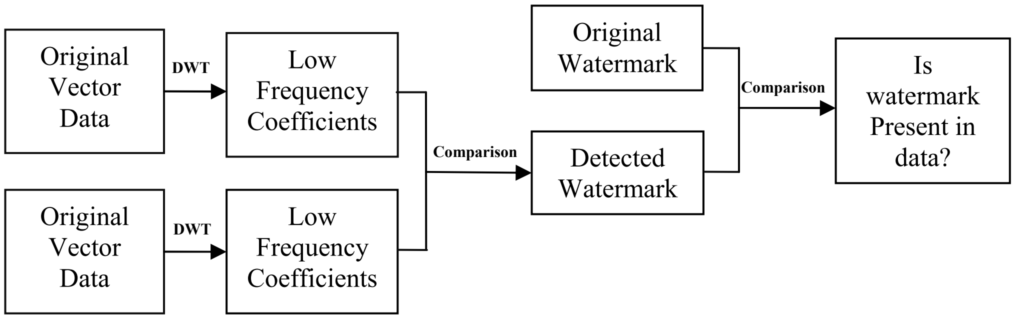
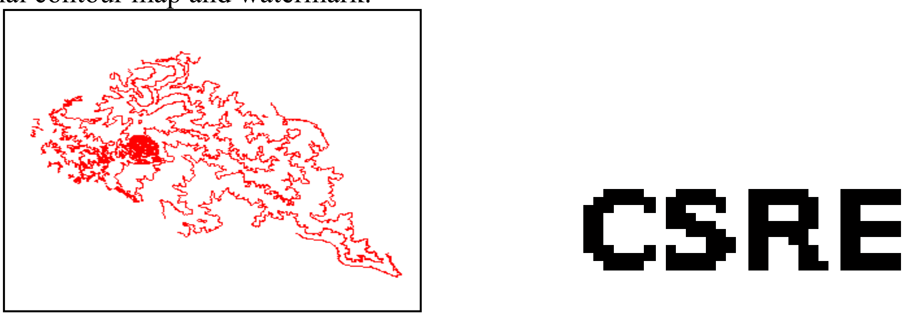


Fig. 2: Schematic flow for watermark detection.

4. Experimental Results

To evaluate the scheme, 2-D vector map “Shahpaur_contour_polyline.shp” including 17,399 coordinate points with the scale 1:500000 is used. The watermark of size 29x70 pixels is used for watermarking. Figure 3 shows original contour map and watermark.



(a) (b)

Fig. 3: (a) Original Map (b) Original Watermark.

4.1. Imperceptibility

Figure 4 shows original and watermarked data. Watermarked contour map is superimposed over the original contour map. Red lines are the original contour data and blue lines are the watermarked contour data. It is noted that the proposed watermarking algorithm have good imperceptibility by comparing original and watermarked data.

Even though, robustness of watermark depends on embedding strength, it also causes visual degradation. Therefore embedding strength is one of the important factors for fair benchmarking and performance evaluation of watermarking [13]. Strength of embedding parameter p is set to 0.1, 0.3, and 0.5 and the degradation has been observed. Visual degradation increases as p increases. Figure 5 shows visual degradation for p=0.3 and 0.5.

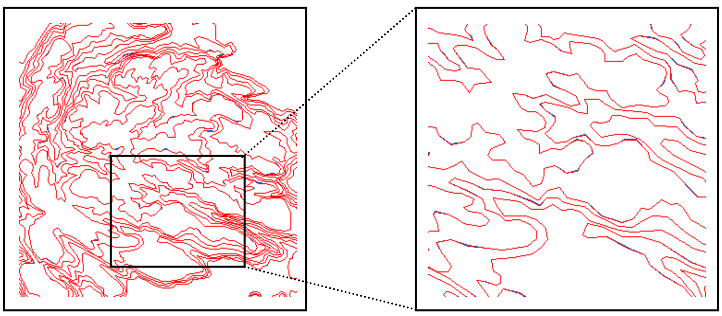
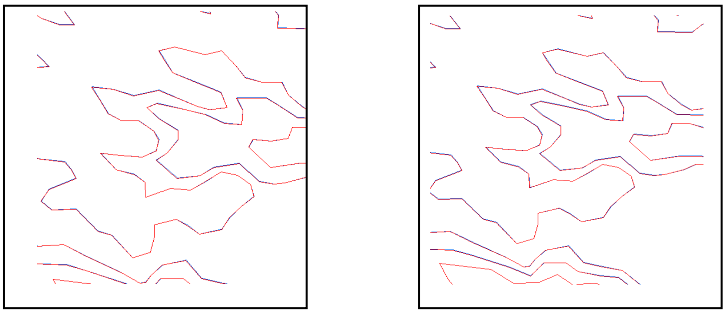


Fig. 4: Imperceptibility of Embedded watermark data

4.2. Robustness for Attacks

Robustness of watermark is evaluated for different attacks; imposition of random noise, compression, format change, and addition/deletion of vertices of watermarked data. Table I shows detected watermarks and correlative coefficients for the listed attacks. Random noise is added into vertex coordinates of watermarked contour map. For addition of vertex coordinates, redundant vertex coordinates are generated and added in watermarked contour map. Similarly, for deletion of vertex coordinates, non feature points are extracted with the help of Douglas Peucker algorithm [14] and deleted from watermarked contour map. The proposed method has good robustness against noise, compression and vertex deletion attack. Finally, on format change of watermarked data as well as on addition of vertex coordinates, the watermark is extracted perfectly with correlative coefficient nearly equal to one.



(a) (b)

Fig. 5: Visual Degradation. (a) Embedding strength=0.3. (b) Embedding strength=0.5.

Table I: Robustness against attacks

Results	Extracted Watermark	Normalized Correlation (NC)
Noise		0.903269
Compression		0.876492
Format Exchange		1
Coordinate Addition		1
Coordinate Deletion		0.954062

5. Conclusion

In this paper, we have presented wavelet based digital watermarking algorithm. The experiment shows that visual degradation is more if the strength of embedding is more. Robustness is evaluated using attacks like noise, format changing, compression, and addition/deletion of coordinates. The proposed algorithm has good imperceptibility and robustness. Future work will include improving robustness for other types of attacks like cropping and map simplification vector data. Also, use of cryptographic standards along with watermarking can be exploited which will help to provide more security for geospatial data.

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