STUDY AND ANALYSIS OF DIGITAL WATERMARKING FOR PHOTOGRAMMETRIC IMAGES

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KEY WORDS: Digital Watermarking, Robustness, Geometric Transformation, Deformation

ABSTRACT: With the rapid development of information technology (IT) and communication technology (CT), people can obtain every kind of digital data more convenient than before. The consequence is that the "copyright protection" which prevent digital data from been duplicated should be paid much more attention. Digital watermarking is the process of embedding visible or invisible information into a digital signal which may be used to verify its authenticity or the identity of its owners. In the past, digital watermarking technology has been successfully applied to the "copyright protection" of various kinds of digital data, however the researches and applications of applying digital watermarking to geo-information data are still very inadequate. In this study, the digital watermarking technology is applied to the photogrammetric images, and the robustness of the embedded digital watermark and the impact on photogrammetric images are evaluated and analyzed. A digital watermark is called robust if it resists a designed class of modifications (or attacks) such as image transformation, shifting, rotation, cutting and zooming. In addition to the robustness, the quality evaluations such as the geometric deformation and radiometric distortion of the images which have been embedded with digital watermark should be considered. In this paper, the study and analysis of digital watermarking for photogrammetric images are firstly introduced, and some tests on real images set are illustrated. Finally, the summary and some suggestions of digital watermarking for photogrammetric images are presented for further applications.

1. PREFACE

The acquisition of photogrammetric images not only requires the high-accuracy apparatuses and equipments, but also a large amount of manpower, materials and financial resources for a long period. It is just because the very high cost, the importance of corresponding image copyright protection is shown when sharing the images. Currently, almost all of the photogrammetric images are stored and transmitted by adopting the digital method. However, the biggest disadvantage of digitalization is also because it is easily copied, modified and propagated. If some evil or illegal persons copy or distort the digital images or get their ownership under a fake name, it means the rights of the image owner are severely infringed. With the popularization of photogrammetric images and because they are increasingly valued, the image owners usually hope that they can get a balance between the protection of data ownership and supply of more convenient utilization method for the users.

Digital Watermark is a kind of image processing technologies which is developed to solve the intellectual property rights currently, since the Tirkel et al. (1993) put forward "Water Mark" in his research of "Electronic Water Mark", they are composed of one word "Watermark" later, such kind of technologies are classified as "Electronic Watermark" in relevant researches, and later, its application scope has been developed rapidly and continuously. The "Digital Watermark" is now usually used to act as the key words in the field. The main purpose of the digital watermark research is to embed the information of digital media owner into the media itself to establish a protection mechanism so that the owner can control the existed ownership. Generally, the most common and frequently-used data in digital media are the audio, pictures or films, thus the application of digital watermarking technology on those data is the most mature one. However, the protection of intellectual property rights of spatial data is in much short of relevant researches. The protection objects of digital watermark in spatial data include image data related to the photogrammetric images and Remote Sensing images, vector maps and Digital Elevation Model (DEM) whose safety is most valued. Different data types will use different watermark technologies according to their own characteristics. In this study, we will carry out the study and analysis on digital watermark based on the photogrammetric images.

According to the characteristics of the spatial data, its digital watermark research shall be discussed in two main directions: firstly, design the embedding and extracting algorithms of digital watermark with robustness, secondly, design the watermark technology that doesn't affect the quality of spatial data. The watermark algorithms for different spatial data are different, and the same principle for different algorithms is that they cannot damage the availability of spatial data and must reduce their influences on the quality of spatial data, that is to say, the data change caused by embedding the watermark into the spatial data shall be well controlled. As for the photogrammetric images, the data change means the change in pixel gray value for the image contents, and not only the human's vision quality is reduced, but also the automated processing results such as the follow-up image matching, image classification and image measurements are affected.

2. DIGITAL WATERMARK

The digital watermarking technology is to embed the trademark, script, image, any digital information or characteristic generated by the original image that can represent the author into the digital data and take them as the digital signature. When the digital content is embezzled illegally, the owner can extract the digital signature from the embezzled image to verify the ownership and apply for compensation from the embezzler according to the Copyright Law, the classification and relevant characteristics of digital watermark are briefly specified as bellows:

2.1 Classification of Digital Watermark

The digital watermark method can be classified into various types according to the visual perception, application, and extraction methods, and embedding methods, as shown in figure 1. It can be divided into visible digital watermark and invisible digital watermark in the aspect of visual perception, the visible digital watermark can be directly seen on the copyright image, but the invisible digital watermark cannot be seen in the image only by the naked eyes and it must be verified through the watermark extraction method. The visible digital watermark is convenient in use without requiring a complex calculated quantity, but it usually damages the quality of original image and the visual effect is not very artistic, therefore most of the watermark algorithms tend to adopt the invisible digital watermark to protect the spatial data.

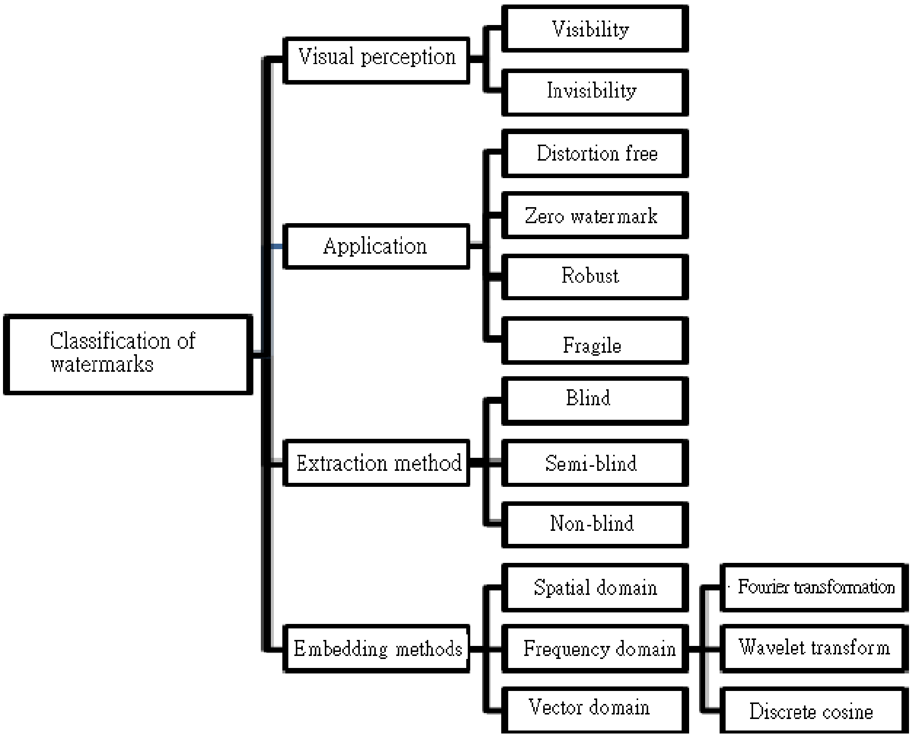


Figure 1. Classification of Digital Watermark Methods

As for the application, the digital watermark can be divided into robust watermark and fragile watermark according to its extraction effect. The robust watermark can still be extracted after the image is attacked (e.g. image translation, rotation or cutting) while the fragile watermark will be easily damaged after the image attack. At that time, the integrity of the extracted watermark can verify whether the data is falsified. The watermark can be divided into blind, non-blind and semi-blind watermarks based on the watermark extraction algorithm. The blind watermark doesn't need the original image data when it is extracted and thus is relatively practical in application, the non-blind watermark requires to be compared with the original data when it is extracted and thus it is of low practicability, and the semi-blind watermark requires partial original data when it is extracted. The watermark embedding can be performed on spatial domain (Schyndel *et al.*, 1994), frequency domain (Cox *et al.*, 1997) and the relatively hot vector domain in recent years according to the embedding location of watermark or technology adopted. The spatial domain watermark is directly hidden into the pixel of the picture, and the other two watermarks will require executing the data transform on the pictures first before they are embedded, and then they will be embedded into the transformed coefficients, and the method used for vector domain is the singular value decomposition (Liu and Tan, 2002). So far, most of the watermark algorithms are for the purpose of copyright protection, thus how to increase the robustness of watermark is the target of digital watermark researchers to struggle for. If the features of different watermark algorithms can be integrated based on the spatial data in the future, then it is able to provide a complete copyright protection for the spatial data.

2.2 Characteristics of Digital Watermark

The successful digital watermarks usually have the following characteristics:

1. Imperceptibility: as for the digital image embedded with the digital watermark, it is required to make sure that the quality of its original image is not affected at first so that the image embedded with the watermark cannot be identified by the naked eyes, which can also reduce the probability of being discovered and altered by some evil persons.

2. Un-Deletion: the watermark shall be closely combined with the original image, and it is very difficult for the illegal users with the attempt to remove the watermark.

3. Robustness: this refers to that the hidden information shall be equipped with the ability to resist against the general distorted compression and to treat the destructive signal. Although the image with hidden watermark has already suffered from the damage, the watermark can still be extracted to protect the rights of the original author.

4. Unambiguous: the extracted watermark shall be able to indicate the owner clearly and explicitly so as to confirm the ownership.

5. Security: the watermark shall be confidential, thus the secret key will be used to select the specified regions to hide the watermark. Only the person who enjoys the right owns the secret key and he/she can use the secret key to find out the regions where the watermark is hidden and then re-extract the watermark. Thus under such mode, the probability of hidden regions being guessed by the illegal persons is very low.

6. Blindness: in the actual application, as the space demand for image data storage is large, the transmission of excessive images will also cause the network bandwidth waste, thus when extracting the watermark, the extraction shall be designed as not requiring the original image as much as possible, thus there is no need to consider the increase of security to save original image.

7. Maximum capacity: under the premise that only micro distortion is occurred on the original drawing, if more and more watermark data quantity can be embedded, larger and larger robustness and accuracy can be improved, and even excessive data quantity can act as the watermark correction bits. However, this condition usually conflicts with the invisibility, therefore, it is necessary to gain a balance between the invisibility and the maximum capacity.

2.3 Photogrammetric Image Watermark

In recent years, with the rapid development and progress of the digital aerial camera, the applications of photogrammetric image become wider and wider. Thus the protection of ownership or image content accuracy of the photogrammetric image is an increasingly important issue, and the use of digital watermark to protect the copyright is one feasible method (Hsu and Cheng, 2010). The digital images obtained from aerial photogrammetry or remote sensing satellites consume a large amount of manpower and material resource during their manufacturing processes, thus the images are precious and expensive. Currently, most of the photogrammetric image data are stored in the form of digit, and even the old stimulated photos are stored in the form of digit after being scanned. The most common copyright protection method now is to embed the visible watermark into the photogrammetric image, but this method not only damages the integrity and beauty of the original image but also has a big effect on the follow-up analysis and application of the image. According to the purposes of taking the photogrammetric image, generally, it is the image data with the spatial attribute which designs the topographic map or transforms the images into the orthoimages through the object space and image space. The design of topographic map won’t change the image contents, thus the embedded watermark can be extracted correctly when it is required to confirm the copyright of the photogrammetric image embedded with watermark. To reduce the relief displacement or shield, the production of original orthoimages also requires the interpolation and cutting except for any correction. Besides, to make the orthoimages more artistic, various image processing such as mage toning and image contrast adjustment will also be conducted. In the field of digital image watermark, each manufacturing process of the orthoimages can be regarded as one attack to the watermark. If the watermark algorithm with a poor robustness is adopted for the copyright protection of photogrammetric image, it is obvious that it cannot meet the demands. If the applicable watermark algorithm for the photogrammetric image is to be developed, then it must be targeted at low distortion and high robustness.

3. WATERMARK BASED ON IMAGE CHARACTERISTICS

As for the watermark algorithm designed by this paper for photogrammetric image, its main purpose is to resist against the damage of orthoimages manufacturing process on the watermark. Based on this purpose, the first generation of watermark algorithm certainly will not meet the demands since it cannot resist against any attack. To meet that goal, this research makes uses of the concept of the second generation of watermark algorithm (Kutter*et al.*, 1999) whose main principle is to embed the watermark according to the image characteristics, and it is especially focus on the location of watermark embedding and the invariant feature of image. As for the selection of watermark embedding location adopted in this research, the Scale-Invariant Feature Transform (SIFT) method is used to get the keypoints that can resist against image attacks such as the rotation, proportional scaling and translation, and then the watermark is embedded and extracted according to the invariant feature of image.

3.1 SIFT Algorithm

Lowe (2004) put forwards the SIFT algorithm to transform the image feature into the local image descriptor based on the scale space. The descriptor keeps the invariance of the proportional scaling, rotation and brightness of image, and even keeps certain stability for the geometric distortion and affine transformation, thus it is always used in the searching and matching of the image characteristics. The SIFT firstly makes use of the Gaussian function and image pyramid to calculate the scale space and measures the scale-space extrema by combining with the difference of Gaussian (DoG), which is shown in figure 2. Assume the image after the Gaussian smoothing can be expressed as:

$$L(x, y, \sigma) = G(x, y, \sigma) \otimes I(x, y) \qquad (1)$$

Wherein, $I(x, y)$ is the original image, $G(x, y, \sigma)$ is the Gaussian functions at different scales, as shown in formula (2):

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} \exp^{-\left(x^2 + y^2\right)/\sigma^2} \qquad (2)$$

The difference of Gaussian is the difference of two Gaussian functions at different scales and has the feature of simple calculation. The process of image smoothing by the difference of Gaussian can be expressed as:

$$D(x, y, \sigma) = \left(G(x, y, k\sigma) - G(x, y, \sigma)\right) \otimes I(x, y) = L(x, y, k\sigma) - (x, y, \sigma) \qquad (3)$$

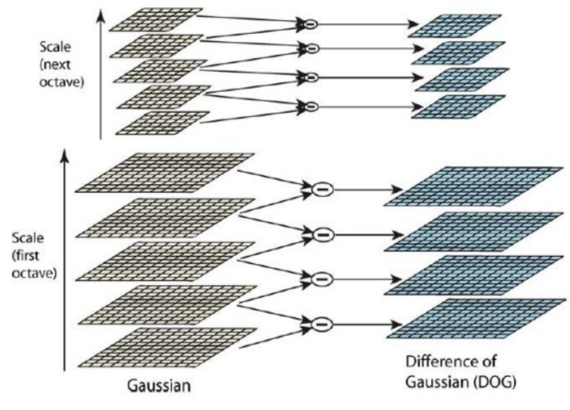


Figure 2. Schematic Diagram of Difference of Gaussian and Image Pyramid (Lowe, 2004)

The subtraction between two adjacent smoothing images can be expressed in figure 3. Each pixel shall be compared with 8 pixels in the surrounding area of existing scale and 9 pixels at relative positions of adjacent scale to determine the extrema detected in the scale space of difference of Gaussian and in space between images so as to obtain the image location, scale and orientation to each keypoint.

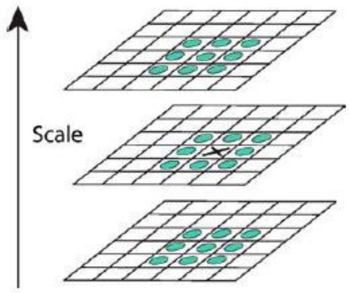


Figure 3. Schematic Diagram of Extrema Detection (Lowe, 2004)

As for the selected keypoint, its location and scale can be obtained by fitting the three-dimensional quadratic function. And 2×2 Hessian matrix H is taken as the criteria for the stability of keypoint to eliminate the keypoint with low stability and scale, the compute mode of stability is:

$$\text{Stability} = \frac{(D_{xx}+D_{yy})}{D_{xx}D_{yy}-D_{xy}} < \frac{(e+1)}{e} \tag{4}$$

$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{yx} & D_{yy} \end{bmatrix} \tag{5}$$

Wherein, e is the ratio of maximum characteristic value to the minimum characteristic value and is used to control the stability of the keypoint. D_{xx} , D_{yy} and D_{xy} are the derivatives of the scale space. And the gradient direction characteristics of the neighboring pixel of keypoint are then used as the directional information of each keypoint to provide the descriptor with the rotational invariance. The gradient magnitude and orientation of point (x, y) are respectively:

$$m(x,y)=\sqrt{(L(x+1,y)-L(x-1,y))^2+(L(x,y+1)-L(x,y-1))^2} \tag{6}$$

$$\theta(x,y)=\tan^{-1}\left(\frac{(L(x,y+1)-L(x,y-1))}{(L(x+1,y)-L(x-1,y))}\right) \tag{7}$$

where L is the scale of keypoint. Calculate the gradient direction of the neighboring pixel of the keypoint center and make use of the histogram to summarize the gradient direction of neighboring pixel. The scope of gradient orientation histogram is within 0~2π. In this research, a total of 128 directions are adopted for the statistics. The peaks in the orientation histogram represent the dominant directions of local gradients in the neighboring pixel of the keypoint. Figure 4 shows the dominant directions of the keypoint being determined by the orientation histogram of 8 directions.

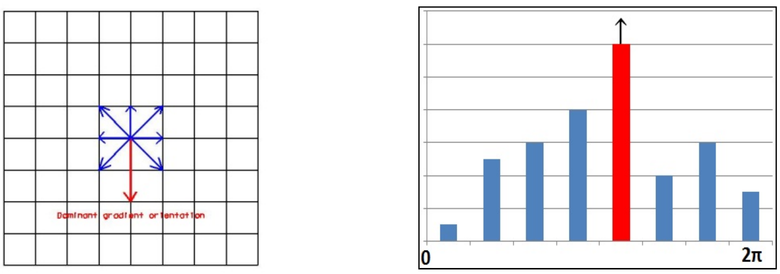


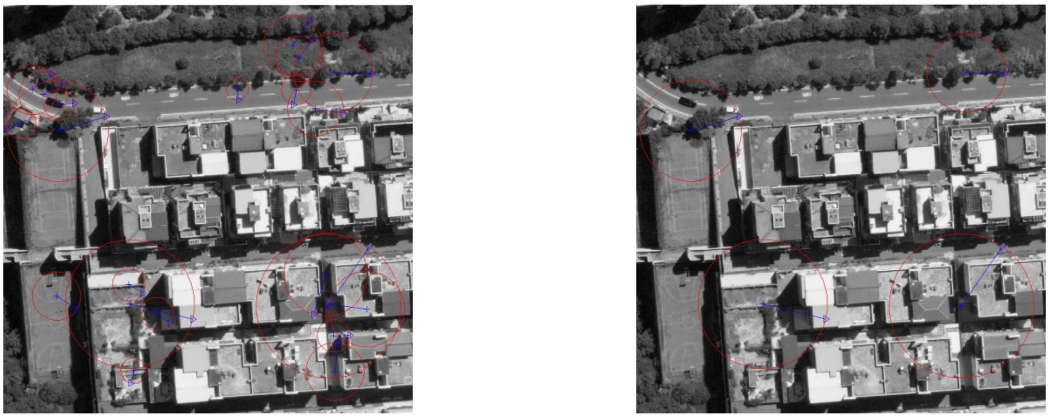
Figure 4. Using Histogram to Determine the Dominant Gradient Orientation

3.2 Selection of Watermark Embedding Area

Through the SIFT algorithm, the keypoint (x_0, y_0) and characteristic scale σ that aren't identified after the image scaling, rotation and brightness adjustment can be find out in the image. By combining with the circular area which solves the rotation problem, the circular area constituted by the characteristics of the keypoint is formed:

$$(x - x_0)^2 + (y - y_0)^2 = (S\sigma)^2 \tag{8}$$

where S is a parameter to adjust the radius of the circular area according to the characteristic scale of the keypoint. Figure 5(a) shows the circular areas selected by the characteristic scale and dominant gradient orientation of the keypoint (Tang and Hang, 2003). Since the circular areas of various keypoints are overlapped, 4 circular areas are selected to embed the watermark based on the demands on large characteristic scale and non-overlapping condition. Figure 5(b) shows the gradient orientation of the keypoint.



(a) (b)

Figure 5. Circular Areas Selected by Characteristic Scale and Dominant Gradient Orientation of Keypoints

3.3 Watermark embedding

By making use of the circular areas selected by SIFT, based on the dominant gradient orientation, it is required to carry out the image normalization so as to realize the image synchronization when embedding and extracting the follow-up watermark. The specific embedding steps are shown as bellows:

1. Figure 6(a) shows the circular areas selected by the feature points and figure 6(b) shows the image after the normalization in the dominant gradient orientation. To avoid the damage on the feature points by embedding the watermark,figure 6(c) shows the circular image in which the center feature point is removed from the circular image after normalization and it acts as an area of embedding watermark, and figure 6(d) shows the rectangular image after the circular image is reorganized.

2. Carry out a two-layer wavelet transform on the rectangular image and embed the watermark into the HL2 wavelet bandwidth decomposed from the two-layer wavelet. And the embedding method is shown in figure 7 and the embedding rule is shown in formula (9) and (10). When the embedding watermark $\mathrm{W(i,j)} = 0$

$$HL'2(i,j) = \begin{cases} HL2(i,j) - (HL2(i,j) mod\ T) + \frac{T}{4} & if\ 0 \le HL2(i,j)\ mod\ T < \frac{3T}{4} \\ HL2(i,j) - (HL2(i,j)\ mod\ T) + \frac{5T}{4} & if \frac{3T}{4} \le HL2(i,j)\ mod\ T < T \end{cases} \tag{9}$$

When the embedding watermark $W(i,j) = 1$

$$\begin{cases} HL2(i,j) - (HL2(i,j) mod\ T) - \frac{T}{4} if\ 0 \le HL2(i,j)\ mod\ T < \frac{3T}{4} \\ HL2(i,j) - (HL2(i,j)\ mod\ T) + \frac{3T}{4} if\ \frac{3T}{4} \le HL2(i,j)\ mod\ T < T \end{cases} \tag{10}$$

wherein, T is a constant to control the strength of watermark.

3. Conduct the wavelet inverse transform on the coefficients after embedding the watermark, the image containing watermark is obtained.

4. After conducting the inverse transform on the image containing watermark in the angle of image normalization, fill it in the original photogrammetric image, and a photogrammetric image centered on the feature point that contains local area watermark will be obtained.

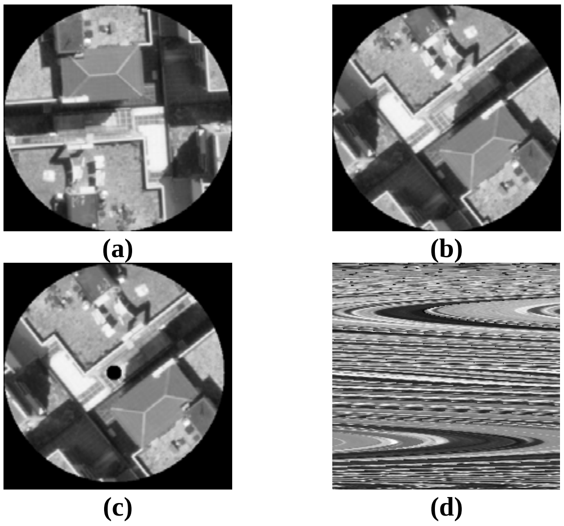


Figure 6. Selection, normalization, and rectangularity of the circular area by feature points

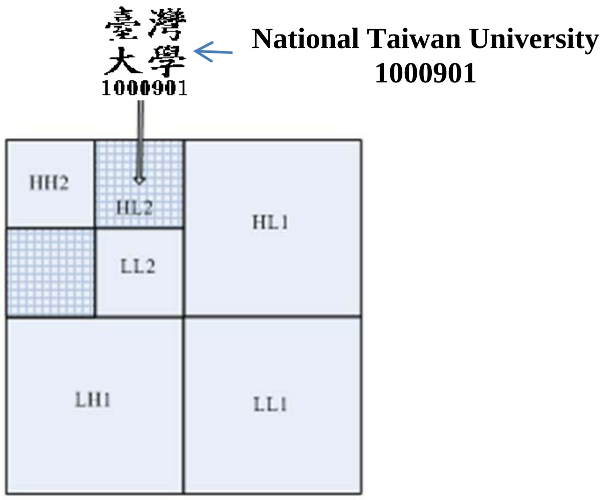


Figure 7. Schematic Diagram of Embedding Watermark

3.4 Watermark Extraction

By making use of SIFT to select the circular areas on the photogrammetric image containing local area watermark, based on the normalization of dominant gradient orientation of keypoint, it is required to synchronize the extracted watermark and the embedded watermark. And the specific extraction steps are shown as bellows:

1. Make use of SIFT to get the feature points of photogrammetric image containing watermark, gain the circular image based on the characteristic scale σ and dominant gradient orientation and carry out the image normalization, and remove annular image centered on the feature point, take it as the areas for watermark extraction and reorganize the annular image as the rectangular image.

2. Carry out the two-layer wavelet transform on the rectangular image.

3. From the HL2* wavelet bandwidth decomposed from the two-layer wavelet, get the information of embedded watermark. And the extraction rules are shown as bellows:

$$W^*(i,j) = \begin{cases} 1, & if \ \ \frac{1}{4}TT \leq mod(HL2^*(i,j),TT) \leq \frac{3}{4}TT \\ 0, & else \end{cases} \tag{11}$$

3.5 Assessment criteria of watermark algorithm

In this research, the confidentiality assessment of image embedded with the digital watermark is made by using the mean square error (MSE) between the image embedded with watermark and the original image, or the peak signal-to-noise ratio in formula (13). If the mean square error is small or the peak signal-to-noise ratio is big, then we can determine that the similarity of the two images is high.

$$MSE = \left(\frac{1}{m \times n}\right) \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left(I_{ij} - I'_{ij}\right)^2 \tag{12}$$

$$PSNR = 10\, log_{10} \frac{255^2}{MSE}\ dB \tag{13}$$

Wherein,

I represents the original image

I' represents the image embedded with watermark

$I(i,j)$ represents a pixel of the original image

$I'(i,j)$ represents a pixel of the image embedded with watermark

The robustness verification standards differ with different digital watermark types. If the digital watermark is a m×m black and white image, then formula (14) is adopted as the verification standard. Through the calculation in accordance with formula (14), if the NC value (within 0~1) is big, then the extracted watermark has a low degree of distortion or high livability, which can be clearly identified and determined by the human eyes.

$$NC = \frac{\sum_0^{m-1} \sum_0^{m-1} W(i,j) W^*(i,j)}{\sum_0^{m-1} \sum_0^{m-1} [W(i,j)]^2} \tag{14}$$

Wherein, W and W* are respectively the original watermark and the extracted watermark suffered from various attacks.

4. EXPERIMENTS

The object of this research is for the photogrammetric images. As for the treatment of spatial information, whether for the purpose of orthoimage manufacturing or drawing, the image matching operation affects the quality of future results. As for the damage degree of watermark on the photogrammetric image, we take the success rate of image matching as the effect index. Verified by the tests, the PSNR of image embedded with watermark after the two or three-layer wavelet transform shall be larger than 40, and then can the successful matching number maintain 80% of the successful number of image matching (Hsu and Cheng, 2010). Therefore, the quality assessment of image embedded with watermark requires that PSNR is larger than 40.

The size of selected photogrammetric image is 1200×1200, which is as shown in figure 5. The selected watermark content is the Chinese words of “National Taiwan University” coordinated with individual document No., which is specified as “1000901” , so as to act as the declaration of the person with ownership and distinguish different users. The contents of watermark are shown in figure 7. Figure 8(a) shows the content of original image and figure 8(b) shows the photogrammetric image embedded with watermark. The PSNR value of image embedded with watermark is 47.5 and the distortion of image embedded with watermark is expressed as relatively small. If the image embedded with watermark doesn't suffer from any geometric attack, the extracted watermark is shown in figure 9. The value of NC is 0.964 and the figure shows how to extract the embedded watermark correctly.

(a) (b)

Figure 8. (a) Contents of Original Image and (b) image Embedded with Watermark

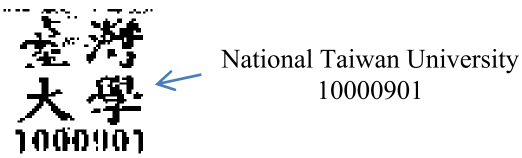


Figure 9. Content of Extracted Watermark

This study is mainly to test whether the watermark content can be correctly extracted after the original photogrammetric image is embedded with watermark and goes through the orthoimage manufacturing procedure. This research tests the robustness of watermark algorithm of the image after the JPEG compression, smoothing, brightness adjustment, regulation and contrast, amplification, translation, rotation and cutting, and the test results are shown in figure 10. It can be discovered from the extracted watermark in figure 10 that, the watermark algorithm adopted in this research can resist against general JPEG compression, brightness adjustment, regulation and contrast as well as various geometric attacks to image such as image amplification, translation, rotation and cutting.

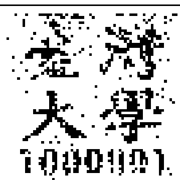
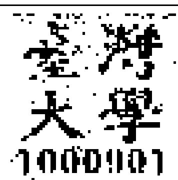
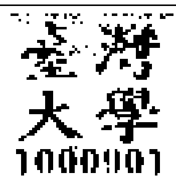
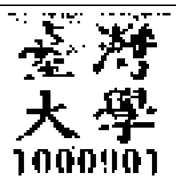
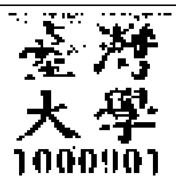
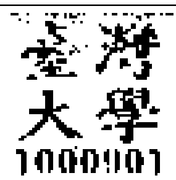
 JPEG(1/7) NC=0.818	 3*3 Smoothing NC=0.54	 Brightness adjustment10% NC=0.943	 Regulation and contrast 10% NC=0.966
 Two times amplified NC=0.965	 Translation (50,50) NC=0.965	 Rotation of 45 degrees NC=0.851	 Cutting of 1/4 NC=0.965

Figure 10. Resistance Ability of Watermark Algorithm after Various Image Processing

5. CONCLUSION AND FUTURE GOALS

This study mainly proposes the watermark algorithm for photogrammetric images in accordance with the requirements, thus the watermark algorithm is specially required to be able to resist against the geometric attacks. The selection of watermark embedding area adopts the SIFT algorithm to choose the keypoint, and the dominant gradient orientation is used to complete the image synchronization when embedding and extracting the watermark. The original image is still required to be rotated for three times to meet the synchronization demands even when it doesn't suffer from any attack. The accuracy rate of extracted watermark is 0.964, and this means that partial watermark information might be lost during the embedding process. In the future, the algorithm of embedding the watermark will be improved so that the photogrammetric image embedded with watermark will not only has a low distortion but also has an ability of resistance during the manufacturing process of orthoimages.

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