A Robust video watermarking approach based on QR code

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***Abstract*—Video watermarking embeds copyright mark called watermark in video frame to prove the ownership of video copyright. Compared with more mature image watermarking algorithms, video watermarking algorithms require higher robustness. This paper encodes the watermark into QR code and makes full use of the high fault tolerance of QR code, proposes a watermark generating and decoding strategy based on the characteristics of QR code, which improves the robustness of the watermarking algorithm. The experimental results show that the algorithm is more robust than the algorithm using random binary string or scrambling QR code as watermark.**

Keywords- Video watermark; QR code; High robustness

I. Introduction

With the rapid development of multimedia and network technologies, the dissemination of digital works has become very convenient. People can easily copy digital works through computers, which has caused serious digital copyright problems. In order to realize the copyright protection of video works, researchers have proposed digital video watermarking technology (hereinafter referred to as video watermarking technology). Video watermarking technology hides the watermark information representing the copyright of the work imperceptibly in the video work. In the event of infringement, it is correctly extracted and used to protect the copyright of the video work.

A practical video watermarking algorithm must have both invisibility and robustness, that is, after the watermark is embedded, people cannot see the change in video quality; at the same time, even if the video is attacked by various forms, the embedded watermark can be Extract it correctly. On the premise of ensuring imperceptibility, improving robustness as much as possible is the goal of watermarking research. In order to improve the robustness of the algorithm, most researchers start by increasing the complexity of the algorithm. However, the increase in computational overhead makes it difficult to apply the algorithm to practical work related to copyright protection.

In recent years, QR code (Quick Response Code) technology has been widely used in various fields. With its high security, fast reading speed, high data density, and small footprint, it has brought countless conveniences to people's lives. QR code technology uses a specific encoding method to encode a string into a regular binary image, representing characters 0 or 1, respectively; in the recognition stage, scan the QR code image with a camera or other scanning code recognition device, and analyze it to quickly get it The string information. This process is very similar to the watermark generation and decoding process. Therefore, QR code can be embedded into video works as watermarks. And using the QR code as a watermark for video watermarking algorithms can have the following advantages: the length of the string that can be encoded by the QR code is much longer than the length of the string directly used for the watermark, which can increase the embedding capacity of the watermark; QR code It has a strong fault-tolerant mechanism, which makes the extracted watermark decoding rate high, which can improve the robustness of the watermark algorithm.

Based on this, this article introduces the QR code technology into the design and implementation of the video watermark algorithm. According to the principles of QR code encoding and decoding, a watermark generation and decoding strategy is designed to enhance the security of the watermark and improve the robustness of the watermark algorithm. It is robust, and the algorithm is computationally efficient, which is suitable for practical applications of copyright protection.

The content of this article is arranged as follows: Section II discusses the related work. Section III summarizes the preliminary work of this article. Section IV introduces the method proposed in this paper in detail. Section V discusses the experimental results. Section VI concludes.

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II. Related work

Most video watermarking algorithms embed random binary sequences as watermark in video [1]-[3], which is simple in generating method, but the watermark information is not unique and authoritative, and it can not establish reliable and verifiable authentication system, so that the right of digital copyright can not be realized, Because each watermark scheme has a fixed embedding capacity, the length of watermark in these algorithms is restricted by the embedding capacity, which makes the random sequence length shorter. At the extraction end, these algorithms need to extract watermark frame by frame, and get the final string by statistical decision, which has high time complexity and low extraction efficiency; Or after extracting the watermark information, we need to introduce the original watermark to verify the accuracy of the extraction, and can not realize the blind watermark algorithm. In the practical application, most of the cases can not know the original watermark, so it can not be applied to copyright protection.

In order to solve the above problems, in some studies, the copyright information is encoded as QR code, which is embedded into the video as a watermark. In the extraction stage, the QR code watermark is directly scanned and decoded to quickly obtain the copyright information it carries. This kind of method can achieve blind watermark extraction, and the extraction efficiency is high. But at present, this kind of algorithm does not make full use of the advantages of QR code to optimize the algorithm. Yang et al. [4] embedded the location identifier of QR code into the video as the tag information. In the watermark extraction stage, only when the extracted tag information is the location identifier, other watermark information can be extracted. This method only uses part of the functional characteristics of QR code, and does not involve the information of QR code data area, It does not really take advantage of its strong robustness and high efficiency. In addition, there are some watermarking algorithms [5]-[9] in order to improve security, QR code is preprocessed such as encryption and scrambling, and the preprocessed QR code is used as watermark information. This kind of algorithm is simple to implement and has high security, but after the video is attacked, it may cause the wrong watermark bits to disperse to the QR code function area, resulting in the QR code can not be decoded, which affects the robustness of the watermarking algorithm; In addition, the QR code uses 8-bit binary number (codewords) as the unit for error correction, once the number of error codewords exceeds the error correction capacity, the encoded string cannot be decoded. However, this kind of algorithm ignores this characteristic, resulting in the error bit in the extracted watermark bits scattered in multiple codewords of QR code, resulting in the number of error codewords exceeding the error correction capacity, So the decoding rate of QR code is low.

In the extraction phase, the existing algorithms [4]-[9] scan QR code directly using the third-party decoders such as ZBar or camera, and parse the copyright information. This method is simple and easy to implement, but the decoding rate of QR code is strictly limited by the error correction capacity. Only when the number of error code words does not exceed the error correction capacity can the QR code be decoded correctly, otherwise no copyright information can be obtained.

This paper will start from the QR code encoding and decoding principle, according to the QR code encoding principle, generate robust watermark sequence, and according to the QR code decoding principle, realize the watermark decoding method of high translation rate.

III. Preliminaries

A. RS Code

RS(Reed-Solomon) code is a kind of non binary cyclic block code with strong error correction ability, and it is also the most widely used error control code in data communication and information storage. The basic idea of RS code is to select a suitable n-k polynomial g (x) (called generating polynomial) in RS code represented by (n, k), so that the generated polynomials can divide the information polynomials, that is, the information polynomials are the multiple of the generated polynomials. Where n represents the total length of the information sequence and k represents the length of the encoded information. Therefore, RS code is encoded by dividing the original data information polynomial by generating polynomial. The remainder is redundant information with error correction ability, which is added to the original information to form the final coding information. Calculate the received information polynomial by the remainder of generating polynomial at the receiver, and take whether the remainder is 0 as the criterion to determine whether there is any error in the received information. If the remainder is 0, it means that the received information is correct, otherwise, the maximum $t = (n-k)/2$ errors are corrected by further calculation. Therefore, for a (n, k) RS code, it can correct up to t error information, and it is suitable for correcting the burst error of error location aggregation. Because of this feature, it is widely used in digital communication and storage.

B. QR Code

Denso wave developed a matrix two-dimensional barcode in 1994, which can be read quickly, so it is named QR code [10]-[11]. Compared with ordinary bar code, QR code can store more abundant data information, and can encrypt text, URL address and other types of data by using a variety of modes such as number, letter, byte and Chinese character. QR code uses horizontal and vertical directions for data processing, so it takes up less space with the same amount of information. QR code is widely used in information management system of e-ticketing, commodity sales, mobile marketing and other industries due to its advantages of fast reading speed, large storage capacity and small space occupation.

QR code is a square grid formed by the arrangement of black and white modules. According to the size of specifications, it can be divided into 40 versions. The size of version 1 is 21 * 21, and that of version 40 is 177 * 177. Each version symbol adds 4 modules to each side of the previous version. QR code symbol includes function area for positioning and correcting graphics and coding area for recording specific data information and version information. The function area is the coding invariant area, that is, each version of QR code has its own fixed function area graphics. When the size and error correction level of QR code remain unchanged, the function area does not change with different coding strings; The coding area has no fixed symbol, and the information capacity increases with the increase of version.

The data in the coding area of QR code adopts RS coding, including data codeword and error correction codeword. Therefore, when some QR codes are lost or damaged, RS code can be used to correct the error in the unit of codeword (every 8-bit binary number is a codeword) until the image data is recovered. The successful decoding rate of QR code with certain damage (called error correction level) can be divided into four levels: L, M, Q and H. The recovery rate of each level is 7%, 15%, 25% and 30% respectively.

In this paper, we choose H-level QR code to study, in order to achieve the maximum error correction ability. According to the coding characteristics of QR code symbol, when QR code is embedded as watermark, only the variable coding area can be selected. The QR code size, error correction level, mask mode, coding mode and copyright mark length are used as the key to deduce the invariant coding area at the extraction end. Figure 1a shows a QR code with error correction level of H, size of 25 * 25 and fixed mask mode is generated from a string with encoding length of 14 in byte mode, and Figure 1b shows the coding invariant region can reach 289 bits. In this case, if only the variable region except the coding invariant region is embedded into the video works as watermark information, the amount of embedded data can be reduced by up to 46%, which can achieve better invisibility under the premise of consistent robustness.

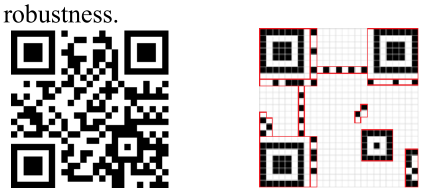

Fig. 1a.QR code of 25 * 25 Fig. 1b. Invariant region

Fig. 1.QR code of 25 * 25 and Invariant region

IV. METHODS

A. Generating watermark

1) *Problems and Motivations:* Because the error correction principle of QR code is to correct and decode the code word (i.e. 8-bit binary number), and the error correction capacity is related to the error correction level, version and coding mode selected during coding, which is fixed value. For example, the QR code error correction capacity of version 2-H byte mode code is 14 code words. If the number of wrong code words in this QR code exceeds 14, the QR code cannot be recognized, but the number of bits in a code word has no influence on its recognition rate, that is, the recognition effect of one bit and 8 bits in one code is the same. Therefore, the number of wrong codes can be reduced by clustering the wrong positions in QR code, Higher decoding rate can be obtained. Also, each pixel in digital image does not exist independently. It is often that each pixel point has a high correlation with its adjacent pixel points. If a pixel point in the image is modified, the pixel points in its neighborhood will change accordingly. If the scrambled QR code is embedded in the video frame, when the video frame is changed due to the pixel point being attacked, the bits prone to error in the watermark are scattered among the QR code words, which results in the number of error words exceeding the error correction capacity of the QR code, so that the extracted QR code can not decode the string information.

2) *Proposed:* Based on the above discussion, a strategy for generating a robust watermark sequence based on the traversal sequence of the QR code is proposed, and Figure 2 shows the flow chart. The specific process is described as follows:

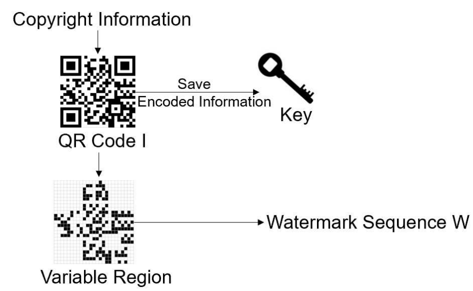

Fig. 2. Watermark generating process

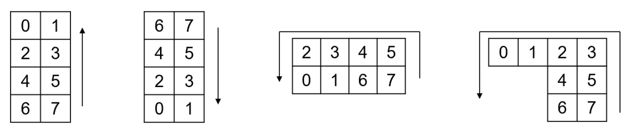

Fig. 3. Codeword traversal sequence

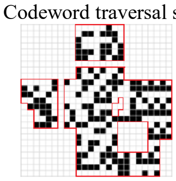

Fig. 4. Variable region

Step 1: according to the QR code coding principle, the copyright information X is encoded to generate the corresponding QR code symbol I, and the size, error correction level, mask mode, coding mode and copyright information length of the 2-H version QR code are saved with the key K;

Step 2: according to the QR code word traversal sequence from 7 to 0 as shown in Figure 3, starting from the lower right corner pixel (19, 24), traverse the bits of the coding variable region as shown in Figure 4 in order, and generate the watermark sequence W with length of L, $\{w_1, w_2, \ldots, w_l$, L = 336} so as to ensure that the bits in the same code word can be embedded into the same region in the video frame in aggregation.

B. Embedding and extracting watermark

After generating the watermark sequence, in order to further enhance the anti-attack ability of the algorithm and reduce the impact of the energy change on the watermark caused by the attack, the video scene switching frame is selected to embed and extract the watermark. Because of the continuity of video content in time and space, there is no significant change in video content in a certain period of time. The most representative scene switching frame is selected for embedding and extracting the watermark. At the same time, the efficiency of watermark algorithm is improved, and the visual masking of watermark can be further enhanced by using the scene conversion effect in video, The robustness of the watermark is improved because of the uncertainty of the selected scene switching frame in the video stream. In addition, the resynchronization strategy is used to embed repeatedly on multiple video scene switching frames, which effectively resists frame processing attack.

After calculating the video scene frame, it is divided into N*N image blocks. Each image block is used to hide the watermark bits of one bit. The watermark information is embedded in sequence, and the adjacent image blocks hide the bit bits of the same code word in QR code. In each image block, the same embedding and extracting scheme as DQAQT [12] proposed in the first elder sister of thesis is used to embed and extract the watermark.

C. Decoding watermark

1) *Problems and Motivations:* Finally, we need to reconstruct the extracted watermark sequence into QR code and decode it to determine the final copyright information. The decoding rate of QR code is related to the error correction capacity. Only when the number of error code words does not exceed the error correction capacity can the QR code be decoded, otherwise no string information can be obtained. The experimental results show that the distribution of dislocations in the extracted QR code watermark is different due to the different types and degrees of attacks in the process of video transmission. Most of the dislocations in the extracted QR code are concentrated in the error correcting codeword, while the data codeword which truly represents the copyright information has only a few bit errors. However, the QR code can not be decoded because the number of error correcting codewords exceeds its error correcting capacity. And each scene switching frame in the video is embedded with the same watermark. The watermark extracted from the embedded region will have a strong correlation with the original watermark even if a single bit is extracted incorrectly. However, the false watermark extracted from the region where the watermark has never been embedded does not meet the rules of embedding and extracting, which is equivalent to a randomly generated pseudo sequence and has weak correlation with the original watermark. Therefore, according to the correlation principle, even if there is no original watermark, the false watermark can be eliminated.

2) *Proposed:* Based on the above discussion, a watermark decoding strategy that uses QR code encoding rules for decoding to improve robustness is proposed, and Figure 5 shows the flow chart. The specific process is described as follows:

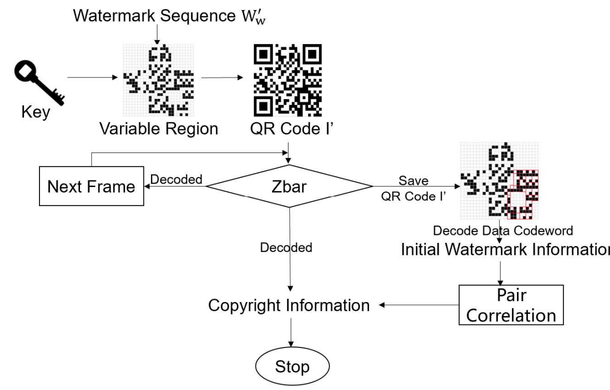

Fig. 5. Watermark decoding process

Step 1: using key K to reconstruct the extracted binary watermark sequence W ', the extracted QR code symbol I' is obtained;

Step 2: using the QR code decoder ZBar to decode the QR code symbol I '. If the information in the current frame can be successfully decoded, the string information X' decoded in the current frame will be taken as the final copyright information, and the watermark extraction process will be terminated [13]; Otherwise, record the QR code symbols that cannot be decoded, and continue to process the next frame until all scene switching frames are processed. If all the QR code cannot be decoded, proceed to Step 3;

Step 3: according to the encoding mode saved as K and selecting the corresponding QR code encoding rules, as shown in Table 1, the data code words of the QR code I' that Zbar cannot decode are sequentially decoded to obtain the character string information X', where the data codeword is the part of the red frame in the coding variable region shown in Figure 5;

TABLE I. QR CODE ENCODING MODE

Encoding mode	Bits/char	Possible character
Numeric only	$3\frac{1}{3}$	0,1,2,3,4,5,6,7,8,9
Alphanumeric	$5\frac{1}{2}$	0-9 A-Z space $ % * + - . / :
Binary/byte	8	ISO 8859-1
Kanji	13	Shift JIS X 0208

Step 4: according to the principle of correlation, any two extracted strings are related in pairs. If the correlation between a string and more than half of the strings is greater than 0.5, the string is used as the initial watermark information. Finally, all the initial watermark information is aligned bit by bit, and the final copyright information is formed by bit by bit statistical decision.

V. Experimental Results and Analysis

A. Experimental setup

In order to illustrate the feasibility and effectiveness of this method, this section verifies the robustness of the watermark through experiments. The experimental data set contains 10 videos with 1920 * 1080 resolution. In the experiment, Visual Studio 2019 is used to program, and OpenCV 3.4.10 and ffmpeg 4.2.2 are used to encode and decode video files and embed and extract watermark.

In this paper, the QR code sequence generated by our watermark generation method, the QR code scrambled by Arnold and the 0/1 binary string are embedded into the video as watermarks. The three cases are represented as proposed measured, QR code Arnold and string based respectively. In the extraction stage, the QR code watermark is decoded by ZBar and our watermark decoding method, and the 0/1 binary string is analyzed statistically. In order to compare the experimental results fairly, QR code and string code have the same copyright information in the above three cases, and the length is equal, so that the embedding amount is consistent in the three cases.

B. Performance evaluation

In this paper, bit error ratio (BER) is used as the evaluation standard of watermark robustness. BER can measure the robustness objectively by calculating the ratio of error bits in the extracted watermark. The lower BER value is, the higher the robustness of the watermark is; vice versa. The calculation formula is as follows：

$$\mathrm{BER} = \frac{N_{err}}{N_{len}} \times 100\% \qquad (1)$$

where BER is the bit error rate of the extracted watermark, N_{err} is the number of error bits in the extracted watermark, and N_{len} is the total number of bits in the watermark.

This paper compares the ability of proposed meted, QR code Arnold and string based to recover hidden watermark from watermarked video after image processing attack and geometric attack. Table 2 shows the attack type, parameter setting and simulation results. The results show that the proposed method achieves lower BER than other methods, so it can effectively improve the robustness of the algorithm.

TABLE II. ATTACK TYPE, PARAMETER SETTING AND SIMULATION RESULTS

Attack type	Parameter setting	String-Based	QR Code-Arnold	Proposed-Method
Gaussian Noise	0.02	0.42	0.21	0
Salt & Pepper Noise	0.02	0.41	0.23	0
Median Filtering	3*3	0.48	0	0
Average Filtering	3*3	0.43	0	0
Scale	1280*720	0.36	0.12	0
Crop	0.2*0.2	0.50	0.39	0.13
Rotate	2	0.53	0.32	0.21

VI. Conclusion

According to the principle of QR code encoding and decoding, this paper proposes a strategy to generate watermark sequence according to QR code word traversal order, and a QR code decoding strategy with high translation rate. Experimental results show that the proposed strategy can effectively improve the robustness of the watermarking algorithm. In the future, we will design a more robust watermarking algorithm based on the proposed strategy.

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References

[1] M. Asikuzzaman and M. R. Pickering, "An Overview of Digital Video Watermarking," IEEE Transactions on Circuits and Systems for Video Technology, vol. 28, no. 9, pp. 2131-2153, 2018.

[2] X. Yu, C. Wang, and X. Zhou, "A Survey on Robust Video Watermarking Algorithms for Copyright Protection," Applied Sciences, vol. 8, no. 10, 2018.

[3] Q. T. Su and B. J. Chen, "Robust color image watermarking technique in the spatial domain," (in English), Soft Computing, vol. 22, no. 1, pp. 91-106, Jan 2018.

[4] Y. Chen, "Research on Video Watermarking Algorithm Based on Singular Value Decomposition, " Anhui University,2013.

[5] L. Hsu, H. Hu, H. Chou, "A blind robust QR Code Watermarking Approach Based on DCT, " 2019 4th International Conference on Control, Robotics and Cybernetics. CRC, 2019, pp:174-178.

[6] Q. Dang, L. Kessi, and M. Coustaty, "A Blind Document image watermarking approach based on Discrete Wavelet, " 2019 International Conference on Document Analysis and Recognition Workshops (ICDARW). IEEE, 2019, pp. 56-60.

[7] C. Patvardhan, P. Kumar, and C. Vasantha Lakshmi, "Effective Color image watermarking scheme using YCbCr color space and QR code," Multimedia Tools and Applications, vol. 77, no. 10, pp. 12655-12677, 2017.

[8] Z. WANG, L. SUN, and M. LI, "QR Code Watermark Technology with Strong Robustness, " Packaging Engineering, vol. 33, no. 15, pp. 84-87, 2012.

[9] N. JI, X. LYU, and Y. GU, "Blind Watermarking Algorithm for Color Image in Contourlet Domain Based on QR Code and Chaotic Encryption, " packaging engineering , vol. 38, no. 15, pp. 173-178, 2017.

[10] T. J. Soon, "QR code, " Synthesis Journal, 2008, pp. 59-78.

[11] P. Kieseberg, M. Leithner, M. Mulazzani, L. Munroe, S. Schrittwieser, M. Sinha, and E. Weippl, "QR code security, " in Proceedings of the 8th International Conference on Advances in Mobile Computing and Multimedia. ACM, 2010, pp. 430–435.

[12] Y. Huang, B. Niu, H. Guan, and S. Zhang, "Enhancing Image Watermarking With Adaptive Embedding Parameter and PSNR Guarantee," IEEE Transactions on Multimedia, vol. 21, no. 10, pp. 2447-2460, 2019.

[13] Z. Lv, H. Guan, Y. Huang, and S. Zhang ,"Using QRCode to Enhance Extraction Efficiency of Video Watermark Algorithm," Proceedings of the 1st International Conference on Culture-oriented Science & Technology, 2020, pp. 336-339.