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A Streaming Media Recompression Transmission Scheme for Agricultural Machinery Monitoring

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Abstract: Place a camera on the agricultural machinery, the video collected by the camera is transmitted by means of a wireless network to enable the operator to monitor the operation of the machinery and provide decisions accordingly when necessary. As video data contains large capacity, and the farmlands are distributed widely and remotely, it is difficult to ensure the stability of the transmission network. In this research, a binary recompression method was proposed to perform a secondary compression on the video sequence compressed by the encoder, which solved the problem of video transmission in dynamic network by reducing the number of bytes of data on the communication channel. The core idea is to change the distribution of the original sequence of "0" and "1" symbols in binary by designing mapping rules and compression rules through the idea of binary rearrangement, so that the same symbols can be gathered together as much as possible, thereby increasing the probability of compression. In the end, a test system was set up to verify that the recompressed transmission scheme proposed in this paper was able to effectively improve the quality of video transmission in farmlands.

1. Introduction

As farmlands are usually remote, making them difficult to provide high-quality and low-latency video transmission in a bandwidth-constrained network environment, which is a problem that cannot be ignored for remote monitoring of agricultural machinery. Currently, some scholars have conducted research on the inside of video frames and reduced the transmission delay through optimizing video encoding. However, because of the huge amount of data in the dynamic video, this method would consume a lot of network bandwidth. Therefore, through learning the history of wireless channels, some researchers [1] have predicted the changes in channel quality to provide a transmission scheme for the dynamic allocation of network resources for the transmission of video bitstream. But the quality of the transmitted video was lost as it used the dynamic adaptation method. Based on this, some researchers suggested that the video sequence compression could be improved or re-compressed [2], for example, a counter adaptation scheme was proposed in the literature [3], which further improved the efficiency of video encoding. The above hybrid video encoding technology has a feature in common, which they are only compressed by statistical redundancy that processes the transform coefficients and do not have noticeable effect for the highly compact video streams. In this case, we must explore a new video encoding technology that can be applied to the real-time transmission of high-quality video in real farmlands.

2. Binary recompression

According to H.264 coding theory [4], it can be seen that the statistical redundancy of the data compressed by the encoder is not obvious, and it is difficult to perform a secondary compression. And in accordance with Shannon's metric of Entropy of information [5], differences in entropy variables affect the distribution probability of the underlying binary symbols in the data, when the entropy variable reaches its peak, all binary symbols are evenly distributed. Based on the above problems, this paper has put forward a new binary recompression algorithm.

2.1. Compression algorithm design

Considering the diversification of scene distribution in different farmlands and the diversification of video data collected by the cameras, it is necessary to improve the original Shannon information entropy [5] and design the mapping rules that are able to meet the diversity of information sources. The first is based on Fibonacci mapping rules. The Fibonacci sequence is generated by a linear recursive relationship in (1).

$$1,2,3,5,8,13,21,34,55,\ldots \tag{1}$$

$$Fn_m = \begin{cases} 1,(m=1) \\ 2,(m=2) \\ Fn_{m-1}+Fn_{m-2}(m>2, m \in N) \end{cases} \tag{2}$$

Drawing on the Formula (2) of Fibonacci sequence, a low-complexity rule that applies to the conversion of binary sequences is proposed, namely, the mapping rule. For a given binary sequence: $T = \alpha_1, \alpha_2, \ldots, \alpha_n$, $T' = \beta_1, \beta_2, \ldots, \beta_n$ is used to represent the mapped sequence, so the mapping rule can be expressed as:

$$\beta_i = \begin{cases} \alpha_i\ (i \in Fn_m) \\ \bar{\alpha}\ (i \in Fn_m) \end{cases} \quad 1 \le i \le n. \tag{3}$$

For example, for binary symbol sequence A extracted from an encoded video bitstream, B is the sequence mapped by Formula (3), and B takes the opposite value of A with an underline symbol, which is located in the position of the Fibonacci sequence: 1, 2, 3, 5, 8, 13, 21, 34, 55, 89.

A: $\underline{000}1\underline{0}11\underline{0}1110\underline{1}0101100\underline{0}000000011101\underline{0}000110000011$
$001101100\underline{0}100100001100111011100110101111011\underline{1}0110$
B :11111111111100010110010000000011101100110000011
001101100110010000110011101110011010111101100110

From the above mapping, it can be seen that the probability of the appearance of binary symbols 0 and 1 in sequences A and B are different, hence, the information entropy of the two is different, therefore, there is a greater chance to compress the amount of information.

Considering the high correlation between adjacent symbols in the video stream, a re-compression algorithm is put forward extended on the basis of RLC (Run-Length Coding) algorithm[6], which is able to conduct multiple compression on some symbols. In addition, the rules of this compression algorithm are also an iterative loop, as shown in Figure 1, where iter_n represents the number of iterations, and its value range is $0\sim2^4-1$, which means that a sequence of symbols is able to be compressed up to 15 times.

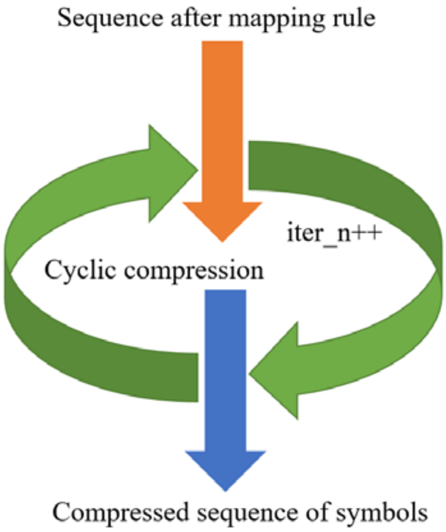

Figure 1: Schematic diagram of the rule of cyclic compression

For the binary symbol sequences containing only 0 and 1, let num0 be the number of 0 in the symbol sequence, num1 the number of 1 in the symbol sequence, in addition, the length of consecutive 0 and consecutive 1 is expressed as $len_{0i}(i \geq 1, len_{0i} \geq 1)$ and $len_{1j}(y \geq 1, len_{0j} \geq 1)$, respectively, moreover, the characteristic lengths of len_{0i} and len_{1j} are needed to define, denoted as $len_{0x}(x \geq 1, 0 \geq len_{0x} \geq 16)$ and $len_{0y}(y \geq 1, 0 \geq len_{0y} \geq 16)$, before the cycle starts, the iter_n needs to be set to 0, and the rules of the compression algorithm are described below.

Divide the binary symbols into 4 groups, namely $len_{0i} < len_{0x}$, $len_{0i} \geq len_{0x}$, $len_{1j} < len_{iy}$, and $len_{1j} \geq len_{iy}$. For the symbol sequences of $len_{0i} \geq len_{0x}$ and $len_{1j} \geq len_{iy}$, they need to be encoded. The entropy encodings of consecutive 0 and consecutive 1 are denoted as Qu_0 and Qu_1, and all Qu_0 and Qu_1 are put together to form a sequence of entropy encoding, which is denoted as Qu, where the calculation formula for entropy encoding is as follows:

$$Qu_0 = \frac{(len_{0i}+len_{0x})}{2} \quad (4)$$

$$Qu_1 = \frac{(len_{1j}+len_{1y})}{2} \quad (5)$$

In addition, it is also necessary to calculate the consecutive 0 and consecutive 1 redundant coding Re_0 and Re_1. Re_0 and Re_1 make up the redundant coding sequence Re, and the calculation methods of Re_0 and Re_1 are given in Formulas (6) and (7).

$$Re_0 = (len_{0i} + len_{0x})\%2 \quad (6)$$

$$Re_1 = \left(len_{1j} + len_{1y}\right)\%2 \quad (7)$$

For the symbol sequences of $len_{0i} < len_{0x}$ and $len_{1j} < len_{iy}$, no encoding is required, directly place them into the Qu according to the original sequence. Then combine len_{0x}, len_{1y} and the reversed Re together to compress iteratively to get a new set of symbol sequences. Then let the iter_n increase by 1 to the next round of the cycle, cycling until it cannot be compressed to return to the final sequence of compression symbol.

2.2. Video compression

H.264 uses the NAL unit to guarantee the adaptability of video streams to the network. The NAL unit consists of a NAL unit header and an RBSP (Raw Byte Sequence Payload)[7]. In order to enable the binary recompression method based on mapping rules proposed in this paper to adapt to the video data collected by the cameras, a new unit NAL network abstraction layer for video streams needs to be designed, as shown in Figure 2.

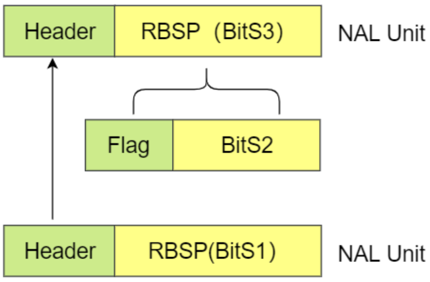

Figure 2: The new video packetization mode for media streaming transmission

For the video packetization mode of Figure 2, only some additional processing is required at the sending and receiving ends of the video transmission. On the sending side, the flag is a single bit flag, and by scanning the RBSP of the NAL unit, the original video stream can be obtained, denoted as BitS1. Use the binary recompression algorithm proposed in this paper to compress the video stream, if it can be effectively compressed, set the flag to 1, denoted the compressed binary sequence as BitS2, and put the flag and BitS2 together to form a new RBSP. Otherwise, set the $flag = 0$, put the flag and BitS1 together to form a new RBSP, denoted this new RBSP as BitS3, and package it with the original NAL unit header into a new NAL unit.

On the receiving side, the binary stream is obtained by scanning the RNSP of the NAL unit, denoted as BitS3, and store the first byte of bitS3 in the flag and the rest of the binary symbols in BitS2. If $flag = 1$, it means that the video stream is compressed by the binary recompression method, continue to use the cycling rules of Figure 1 to decode BitS2, use the BitS1 to represent the decoded video stream, and then further package the BitS1 into a new RBSP. Otherwise, package the bitS2 directly into a new RBSP. In the end, package this new RBSP with the original NAL unit header into a new NAL unit. After that, the new NAL unit can be decoded based on the traditional method.

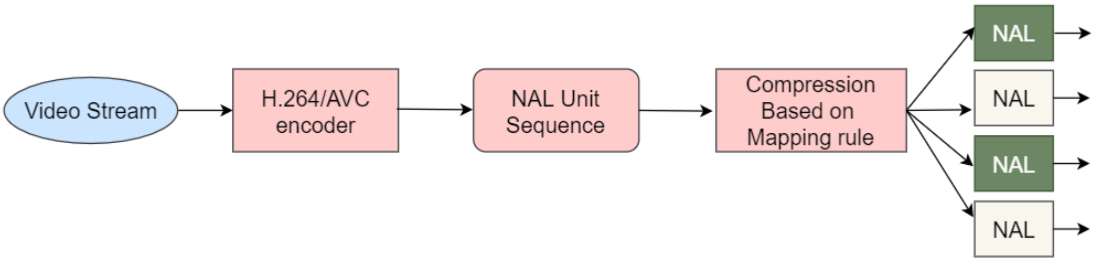

Figure 3: Video stream binary recompression method

The binary recompression flowchart of the video stream based on the mapping rule is shown in Figure 3. Recompress the NAL unit generated by the H.264/AVC decoder, the green NAL units in Figure 3 indicate that the binary recompression is carried out. Furthermore, the compression scheme is lossless, having almost no effect on the objective image of the video image, which its effectiveness of the algorithm can be evaluated by Formulas (8) and (9).

$$R = \frac{Com\_NAL}{Total\_NAL} \times 100\% \quad (8)$$

$$ADR = \frac{Orig\_Size - Com\_Size}{Total\_Frames} \times 100\% \quad (9)$$

In Equations (8) and (9), Com_NAL represents the number of NAL units actually compressed in the binary recompression scheme. $Total\_NAL$ is the total number of NAL units. Moreover, the hit ratio R represents the percentage of NAL units that are effectively compressed as a percentage of the total number of NAL units. $Orig\_Size$ represents the total size of the video bit stream obtained by the original encoder, and Com_Size represents the size of the video bitstream after re-compression through the re-compression scheme proposed in this paper. $Total\_Frames$ represents the total number of frames for the video. Therefore, ADR (Average Data Reduction) refers to the average data reduction rate per frame. The larger the R, the higher the proportion of the recompressed NAL. Similarly, the larger the ADR, the more the bitrate decreases per frame. Therefore, it can be considered that the larger the R and ADR, the better the compression effect.

3. Design and analysis of the experiment

In order to evaluate the transmission capacity of the recompression transmission scheme proposed in this paper under the circumstances of farmland, it is necessary to verify it in the real farmlands. For more convenience, this experiment uses the laptops instead of the system hardware and display required for field testing of the farmlands. A ThinkPad laptop with Intel Core i7 processor and 16GB of RAM was selected, meanwhile, the version 18.04 of Ubuntu on the virtual machine was run to set up a streaming server. During video codec and playback, the CPU of the laptop run at a rate of 600MHz. The binary recompression scheme was then integrated into the H.264 encoder, and the maximum length of each NAL unit was limited to 1000 bytes through setting the size of the H.264 slices on the encoder's parameters. Then, placed the IP camera on the agricultural vehicle, and let the vehicle move in the farmlands, with the speed controlled within 30km/h. The media streaming server controlled the video stream initiation and transmission of the camera and the client, and the distance between the agricultural vehicle and the receiving display was calculated through obtaining the position of the camera by GPS positioning.

Table 1: The average delay of the two compression transmissions

Average delay data (ms)													
		600m				900m				1200m			
Resolution		T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
480p25	Ycomp	201	235	294	243	288	295	304	296	304	311	332	316
	Ncomp	211	231	295	246	347	372	399	373	820	879	882	860
720p25	Ycomp	248	319	327	298	319	328	350	332	366	379	491	412
	Ncomp	215	227	313	252	352	359	382	364	830	838	859	842
1080p25	Ycomp	213	233	302	249	289	307	328	308	316	339	347	334
	Ncomp	291	327	337	318	367	402	472	414	852	893	887	877

Through the data acquisition system, the transmission delay of each video frame was recorded, and the data was collected every 60 minutes and the average was calculated, the collection time was marked T1, T2, and T3 respectively. For ease of comparison, Ncomp was used to represent the transmission method using the original encoder for compression, and Ycomp was used to represent the transmission method using the binary recompression scheme proposed herein for recompression. The specific mean delay data are shown in Table 1.

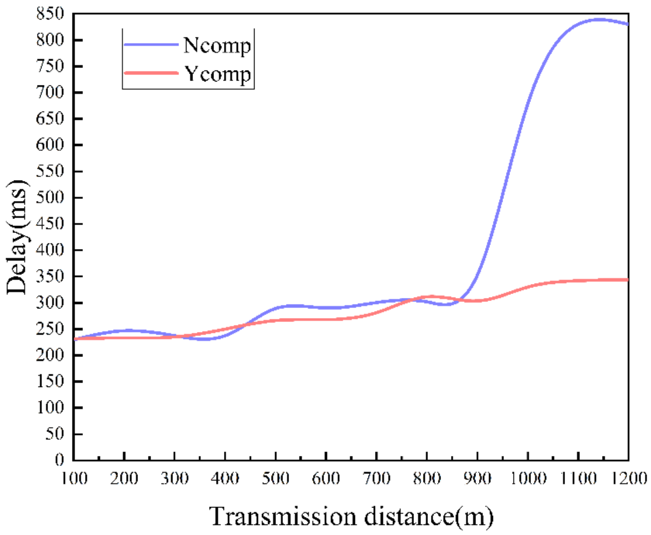

Figure 4: Diagram of transmission distance and average delay of two compression transmissions

As can be seen from Table 1 and Figure 4, when the transmission distance was less than 900m, the delay of the two compression transmission modes could be both maintained between 200ms and 350ms; When the transmission distance exceeded 900m, the Ncomp delay rose sharply to 830ms, which was intolerable for the real-time video surveillance scenarios, while the delay of the Ycomp compression transmission mode showed an upward trend; When the distance reached 1200m, the transmission delay could still be maintained within 400ms. It was worth noting that the average transmission delay of 720p resolution was higher than that of 1080p resolution. Through checking the log of the compression process, it can be found that the ADR value of the 1080p video sequence was significantly higher than that of the 720p video sequence, the ADR value corresponding to the 1080p video sequence was 97.33% and the ADR value corresponding to the 720p video sequence was 86.29%, which was 10.74% higher. Through further output of the logs, it can be found that, the statistical redundancy of the binary symbol sequences through mapping rules was larger, which was actually predictable, as the binary symbols of high-resolution video sequences were more compact, thereby presenting more statistical redundancy. According to Formula (9), the larger the ADR value means that the greater the probability of recompression, so the fewer bytes of the communication transmission channel, the less network congestion, therefore, the transmission delay is relatively low.

In addition, in Figure 5, a video quality comparison map with a resolution of 1080p for different transmission times was screenshotted. When using the Ncomp transmission, with the increase of transmission time, the image quality loss was serious, in addition to blur, there were also mixed color in part of the pixels, further aggravated the blur of the video, and when the transmission time lasted to 100 minutes, the blur of the video image using Ncomp compression transmission was intensified, which was impossible to distinguish the objects in the video. While the video transmitted through Ycomp had significantly improvement in its picture quality, and the high-definition picture was able to be maintained throughout the experimental test. Therefore, it can also be considered that the binary recompression scheme proposed in this paper is able to improve the clarity of long-term video transmission in dynamic networks.

Figure 5: Video quality effect of two transmission methods

4. Conclusion

Through the experiments of this research, it is found that the transmission delay of high-definition videos is closely related to the distance and duration of transmission, with longer transmission distance, the more transmission delay will be increased oftenly. When the transmission distance was 1200m, the transmission delay using the binary recompression transmission method could still be maintained below 400ms, which was 52.38% lower than the transmission delay before re-compression. Therefore, it can be considered that the streaming media recompression transmission scheme proposed in this paper is able to enhance the quality of video transmission in dynamic networks, providing an effective video transmission scheme for the remote monitoring of agricultural machinery. Furthermore, the impact of audio was not considered in all experiments in this research, as audio is not a core element in the observation and monitoring of agricultural machinery, and the introduction of audio may bring about audio and video synchronization and increase transmission delay. Meanwhile, for streaming data, the data rate required for audio during transmission is much lower than that of video data, thus the increase in throughput required for transmission is relatively low. However, audio plays a vital role in detecting machine operating failures and environmental perception, so it will be taken into account in subsequent researches for further optimization.

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References

[1] Chen, J., Wei, Z., Li, S., & Cao, B. (2020). Artificial intelligence aided joint bit rate selection and radio resource allocation for adaptive video streaming over F-RANs. IEEE Wireless Communications,27(2), 36-43.
[2] Subbarayappa, S., & Rao, K. R. (2021, February). Video quality evaluation and testing verification of H.264, HEVC, VVC and EVC video compression standards. In IOP Conference Series: Materials Science and Engineering (Vol. 1045, No. 1, p. 012028). IOP Publishing.
[3] Wu, C. Y., Singhal, N., & Krahenbuhl, P. (2018). Video compression through image interpolation. In Proceedings of the European conference on computer vision (ECCV) (pp. 416-431).
[4] Marpe, D., Wiegand, T., & Sullivan, G. J. (2006). The H.264/MPEG4 advanced video coding standard and its applications.IEEE communications magazine, 44(8), 134-143.
[5] Berdondini, A. (2020). A Simple Symmetry Present in Every Sequence Having Maximum Entropy Can Help Us to Overcome the Limit Defined by Shannon's First Theorem. Available at SSRN 3710546.

[6] Kim, S., Lee, S., Hong, M., & Jeong, J. (2020). Run-Length Coding for deep-learning activation data compression. In Proceedings of the Korean Society of Broadcast Engineers Conference (pp. 98-99). The Korean Institute of Broadcast and Media Engineers.

[7] Xu, C., Ren, W., Yu, L., Zhu, T., & Choo, K. K. R. (2020). A Hierarchical encryption and key management scheme for layered access control on H.264/SVC bitstream in the internet of things. IEEE Internet of Things Journal,7(9), 8932-8942.