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Investigation on Fast Response Performance of Dam Deformation Monitoring System with Wireless Sensor and Virtualizing Technique

Shengjun Xie

Campus network management center, Southwest University for Nationalities
xieshj@swun.edu.cn

Abstract

Dam deformation monitoring is quite important. Monitoring of dam deformation is important for ensuring people's normal lives and reducing losses. Dam deformation often experiences a relatively long time. The deformation rate is relatively small at the beginning time, and it is large at the later stage. Monitoring at the early stage of dam deformation is of great significance. The wireless sensor network has the characteristics of not being affected by the terrain, convenient arrangement and so on, which can be used to monitor the deformation of the dam. In order to improve the transmission efficiency of the wireless sensor network, data compression is helpful for the energy savings and transmission rate improving. In this paper, a dam monitoring system based on wireless sensor networks is developed. In this paper, a dam monitoring system based on wireless sensor network and GPS multi antenna is developed. In the network monitoring system and data acquisition using wireless sensor module, data transmission using data compression technology and data cache technology. At the end of the monitoring terminal, desktop cloud technology is used to process the data collected and show the real time dam deformation condition. This method can also be used in other object motion or deformation with large range and other monitoring field to improve the monitoring efficiency.

***Keywords**: wireless sensor, fast response, dam deformation, data compression, virtualization*

1. Introduction

The deformation of dam [1-4] is a kind of destructive behavior. Dam safety not only affects the benefit of the project of the play, but also related to the life and property safety of the downstream. Therefore, dam safety attracts more and more attention. Dam deformation monitoring [5-8] is quite important, and the dam deformation monitoring is an important means to understand the working condition of the dam. Dam deformation often experiences a relatively long time. The deformation rate [9-10] is relatively small at the beginning time, and it is large at the later stage. Monitoring at the early stage of dam deformation is of great significance.

In the existing dam monitoring systems, the distributed control mode is generally used, and the connection between each monitoring point, monitoring region and the central control station of the monitoring system is according to the wire. Due to the wide geographic range of the general monitoring of dams, the cable laying is a complex project, and adjustment, expansion, and maintenance of the monitoring point is also inconvenient. With widely application of the wireless sensor network [11-13] and all kinds of intelligent sensor [14-16], it is possible to establish the digital wireless monitoring system for the dam.

Wireless sensor network technology used in the dam safety monitoring has the advantages of high accurate detection and monitoring flexibility, which can be better than

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that of traditional monitoring technology. It can not only provide greater flexibility and mobility and reduce the cost and energy, but also achieve the advanced control measures of statistical sampling, data fusion, query monitoring and dynamic feature upgrades according to the self-adaptation network and wireless communication technology between the wireless sensor nodes through distributed cooperation.

In order to improve the real-time dam deformation monitoring performance, GPS (global position system) positioning technology [17-19] together with wireless sensor technology is used to achieve this function. GPS, which has the advantages of high accuracy, fast speed, all-weather performance, becomes one of the most advanced means of deformation monitoring. However, in most of the monitoring conditions, the normal monitoring mode is that each monitoring point is allocated with a GPS receiver. When the dam is large and wide, the cost of deformation monitoring system will be higher. If use the GPS multi antenna method [20-22], the cost will be low. Therefore, dynamic deformation monitoring technology with multi antenna method can greatly reduce the deformation monitoring system cost.

Due to the slow process of deformation of the dam, data amount is small. The interval between two data collection time is longer, while it will be shorter at the latter stage, which means the rapidly increasing data amount. From this point, a terminal processing device with low speed can’t meet the demand of the data processing [23-25] at the latter stage of the deformation. It is also a waste when the high speed processing terminal device is adopted due to the small data amount in the early stage. In order to solve this problem, desktop cloud technology can be used to connect the monitoring system to the server of the dam, and the server can be used to process the monitoring data.

Desktop cloud technology [26-27] virtualizes the server resources into several types of virtual desktop, and each kind of desktop is divided into a plurality of mirror distributed to each image on a client machine. Each client only operates some necessary software, and most of the computing power and storage capacity are unified in the server. The client can run the image configuration of desktop applications to complete all the work, and greatly reduce the client configuration requirements. More important, the server and desktop virtualization technology can virtualize a variety of desktops and divide the resources. Meanwhile, unified application software and unified security protection can be used to improve the information and security management. In dam deformation monitoring, deformation monitoring will only occupy less server resources. Even if in the latter stage, the monitoring work processed in the server will have little impact on the main task.

In order to improve the efficiency of data transmission in wireless sensor network system, the data with compression process will have a great help for both wireless sensor energy saving and the transmission rate. In order to shorten the data transmission time of wireless sensors, the transmitted data will be stored in the cache [28-29] modules of wireless sensor unit, which can realize the function of sending at any time with a timely manner. In this paper, a dam monitoring system based on wireless sensor network and GPS multi antenna is developed. In the network monitoring system and data acquisition using wireless sensor module, data transmission using data compression technology and data cache technology. At the end of the monitoring terminal, desktop cloud technology are used to process the data collected and show the real time dam deformation condition. The remainder of the paper is shown as the following: The dam monitoring system design is described in Section 2; the simulation experiment is introduced in Section 3; and the conclusion is shown in Section 4.

2. Composite Monitoring Method

The composite monitoring method includes the data collection unit, data compression unit, data storage unit, data transmission unit, and desktop cloud. The wireless network system includes the data collection unit, data compression unit, data storage unit and data transmission unit.

(1) Data collection system. The data collection unit is mainly include the data collected by the multi antenna GPS system. It can be shown in Figure1.

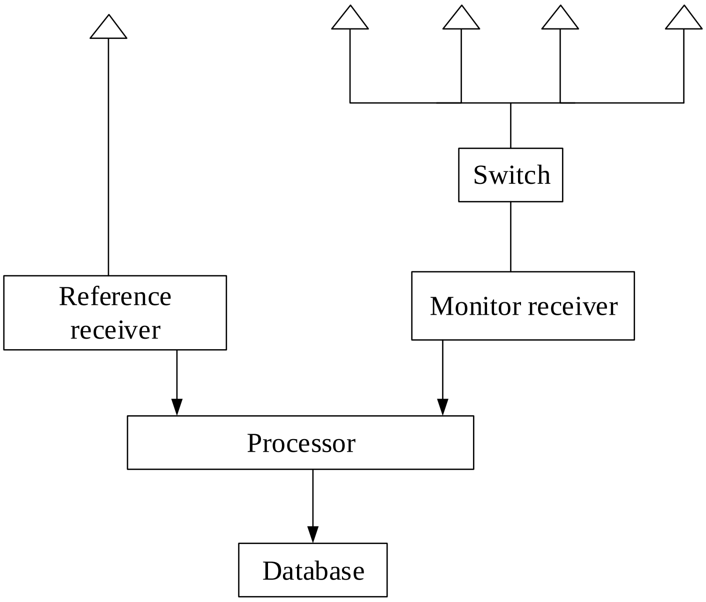

Figure 1. Data Collection Unit in the Monitoring System

Due to the variation of the deformation rate, the data collection time should be adaptive to fit for the deformation monitoring. If set the initial data collection time interval is t_0, and the interval will be shortened with the deformation rate. The N_{th} collection time interval t_N can be calculated as following:

$$t_N = k \frac{1}{S_n - S_{n-1}} t_{N-1} \tag{1}$$

Where, t_N / t_{N-1} are the N_{th} / $(N\text{-}1)_{th}$ collection time interval;

k : the shortening coefficient;

$S_n - S_{n-1}$: the deformation amount during a collection time interval.

(2) Data compression unit

Compared to the traditional floating-point notation, compressed BCD code can meet the demand of numerical accuracy and time consumption at the same time. Normally, the position information is often composed of 18 byte, which is the necessary information to be transmitted. In the 18 byte information, the order is: (1) the acquisition time; (2) latitude, (3) longitude; (4) speed; (5) direction and orientation. Multi-byte variable adopts the mechanism of high byte in the front and low byte in the post.

Due to the small deformation rate, the data collected by the wireless sensor will not contain the year information. In the data package, only month and day information will be included. Year information of the data will be added in the processing terminal device. This can reduce the data transmission amount. The data compression method is divided into two steps:

(1) The initial process step. The time and other redundant information would be cleared, and the left data will be packaged with various labels. This can help with the data

recovery in the computer and processing software. The initial process step is shown in Figure2.

(2) Data compression for the left information. The data left after the preprocess step will be packed in the cache. Then, the data will be compressed. In this step, compression works will be realized according to the recoding method.

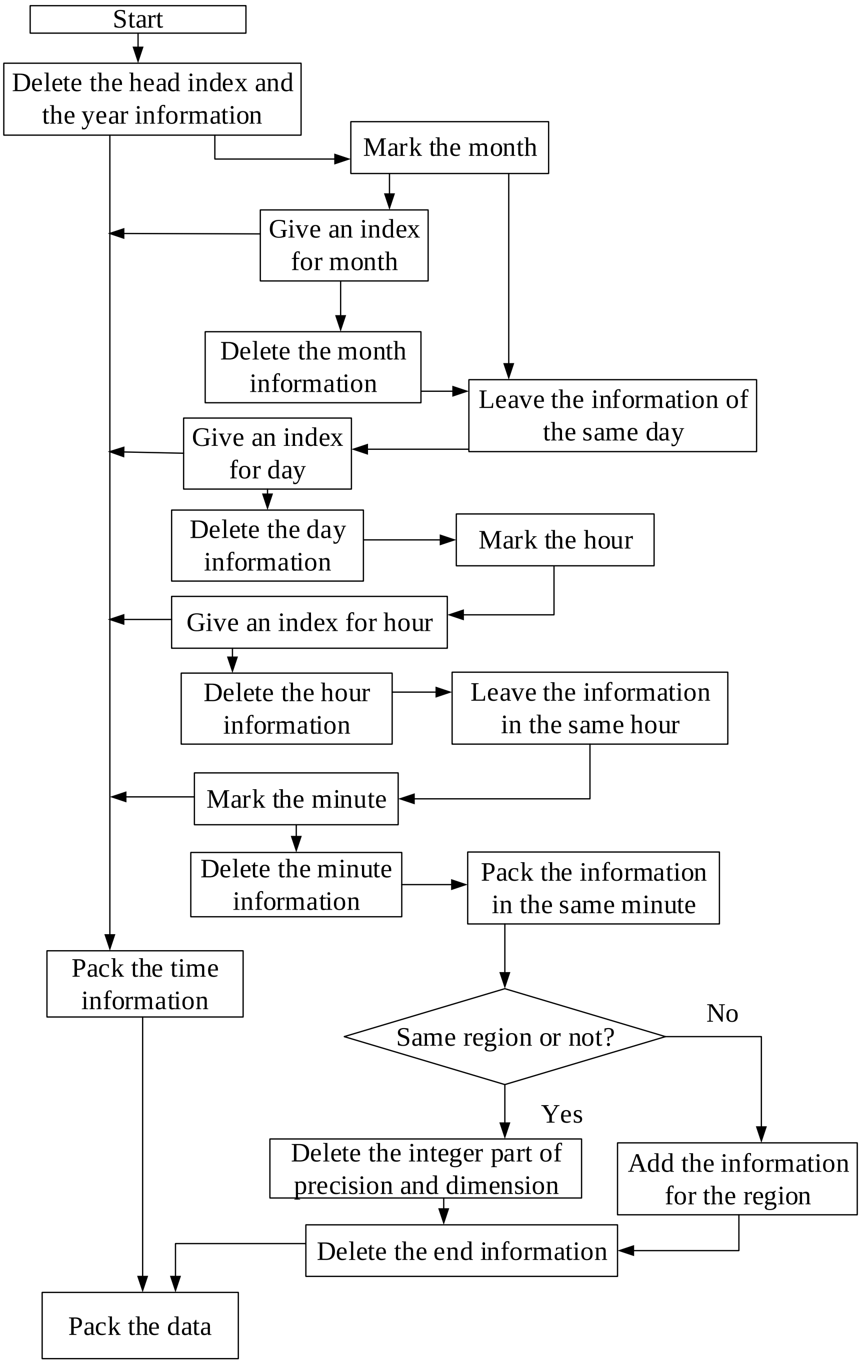

Figure 2. Flow Chart of Pre-Processing for Time and Region Data

The Hoffman Code is the basis, and the preprocessed data will contain much useful information with least compression. Meanwhile, information entropy, which is widely used in the assessment of information, is adopted as the index to test the amount of information. The compressed digital rate will be equal or bigger than the entropy of original data.

(3) Other units

Other units include a data storage unit, data transmission unit, and desktop cloud. For the data storage unit, the cache technology is used to help improving the read and write speed due to its fast speed. Data transmission unit adopts the queuing theory. Each data to be transmitted only can be transferred when the receiver of the terminal device is free. When a wireless sensor is transmitting data, the latter one should wait until the receiver is free. For the terminal device, desktop cloud technology is used. It occupies a part of resource of the server. These units work in a flow chart shown in Figure3.

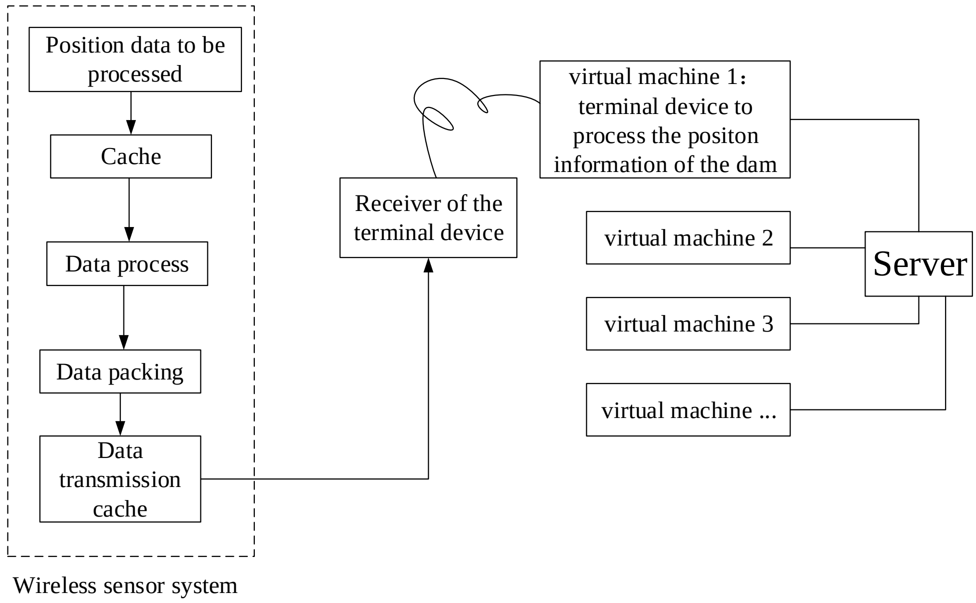

Figure 3. Flow Chart of Units from the Data Packing to Terminal Device

3. Simulation and Results

In the simulation, a set of GPS data is used in the first step. With this set of data, the simulation experiment is studied. The preprocessed data are firstly compressed by Huffman method, and the appearing possibility of each character is shown in Figure4.

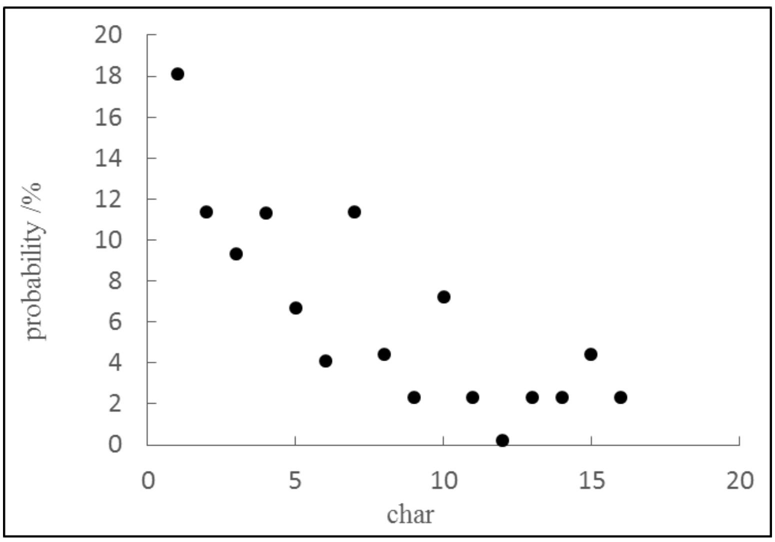

Figure 4. Appearing Possibility of Each Character

The entropy of the data is calculated by:

$$H(x) = -\sum_{i}^{n} p(x_i)\log_2 p(x_i) \tag{2}$$

Then Hoffman method is adopted to encode the data after the pre-processing. The information entropy is:

$$H(x) = -\sum_{i=0}^{15} P(x_i)\log_2 P(x_i) = 3.62 \tag{3}$$

The mean code length is:

$$\overline{L} = \sum_{i=0}^{15} P_i n_i = 3.59 \tag{4}$$

Where, S_i : point position i in the dam;
n: the time interval;
v_i : the real time speed;
T_m: the starting time in one period;
T_n: the ending time in one period;
R_1 : set the value of t,
R_2 : set for t_m and t_n.
$t \in R_1$; $t_m, t_n \in R_2$, and $t_m < t_n$

In fact, in the monitoring system, there are two types of encoding method: Huffman method and differential Huffman method. In the detailed calculation, the Huffman method will be firstly used. When the appearing probability of 0 is lower, the different Huffman method will be used to increase the probability of 0. This can improve the compression rate.

In order to process the data with a higher compression ratio, it should set a period. In order to study the compression ratio in a different day, the period is set as 24h, and the first time interval is set as 6h, which means that there are 4 times data collection.

The Table.1 gives some information of 7 group data sets used in the experiment. Due to the large amount of the data collected by the multiple wireless sensor in the latter stage of the dam deformation, lots of data are used in the experiment.

Table 1. Data Amount of Each Data Group

period	1	2	3	4	5	6	7
Data amount	215253	214654	213153	213906	214788	214202	215371

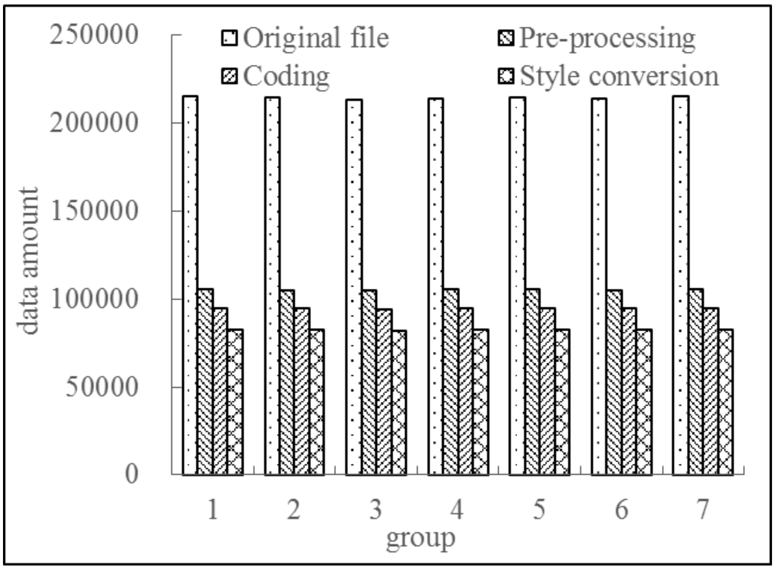

Figure 5. Data Amount after Each Process Step

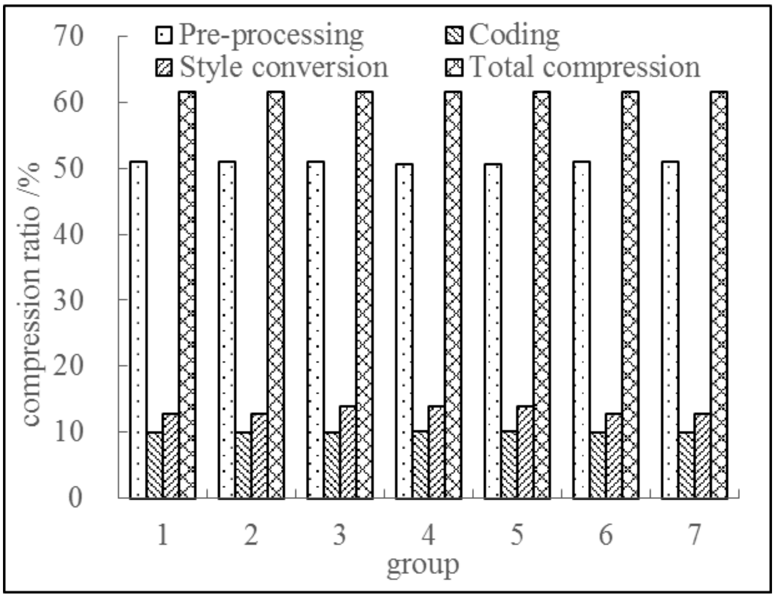

Figure 5. Data Compression Rate of Each Process Step

From the Figure 4 and Figure 5, it can be seen that the data amount has been greatly removed. The ratio is about 51%. For each step, Hoffman coding compression rate is about 10%, which is a relatively high compression rate. The style conversion compression ratio is around 13%. The total compression ratio is maintained at about 61%, which means the relatively high compression rate. The high compression rate will help to reduce the energy consumption of the wireless sensor unit and improve the transmission rate. This means that the fast response for the deformation.

The compression method used in this paper is compared with the existing compression algorithms, including the differential Huffman method adopted in the monitoring system, and the results are shown in Figure 6 and Figure 7. It can be shown that the new developed method has a higher compression rate. The compression method proposed in this paper compresses more data. This means the new compression method has a higher working efficiency, which can help to improve the efficiency of the monitoring system.

The Figure 8 give the comparison of the compression ratio of the new compression method and existing method under the condition of data set with small data amount. It can be seen that the new compression method still have a higher compression rate. Meanwhile, the compression rate of the new method on small data amount set will have a relatively higher compression rate.

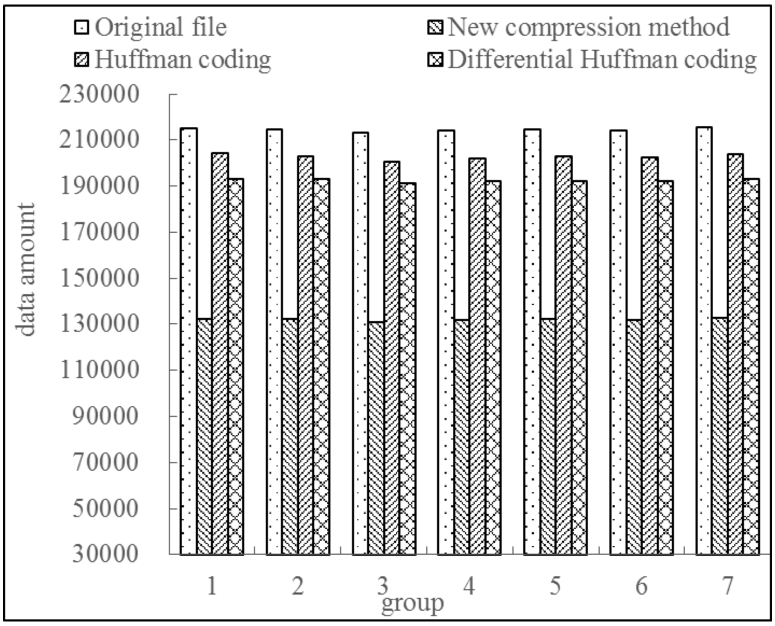

Figure 6. Compression Amount with Different Methods

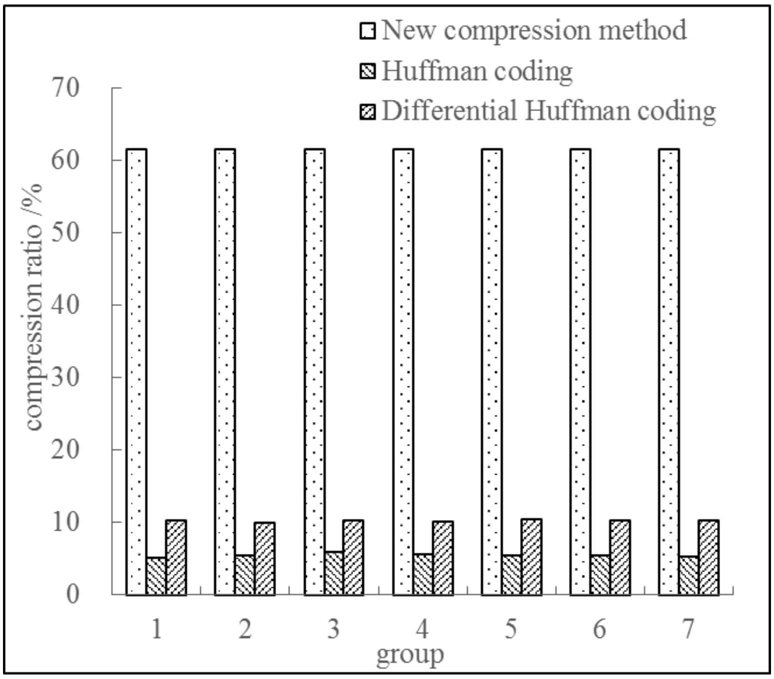

Figure 7. Compression Ratio with Different Methods

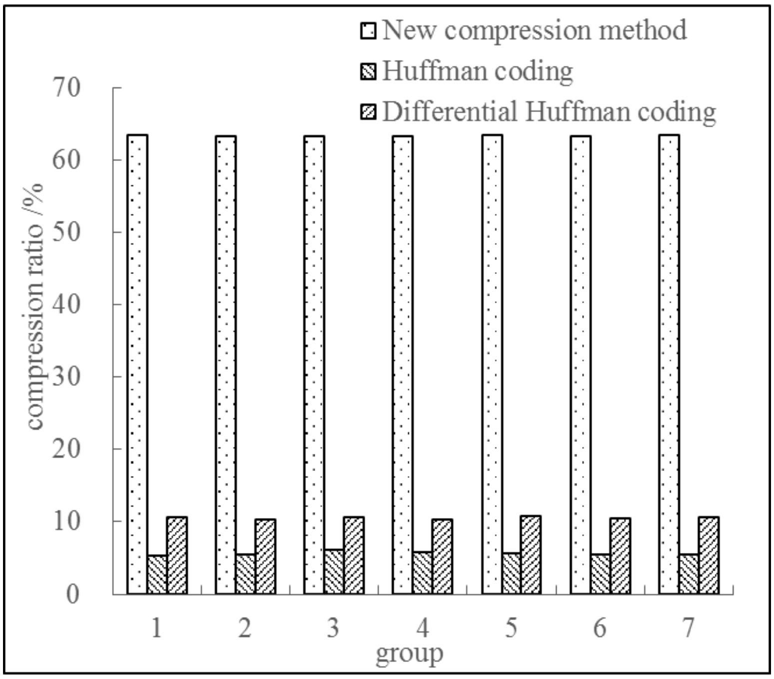

Figure 8. Compression Ratio with Different Methods on Small Data Amount

4. Conclusion

The deformation of the dam is a kind of destructive behavior. Dam safety not only affects the benefit of the project of the play, but also related to the life and property safety of the downstream. Therefore, dam deformation monitoring is quite important. In the existing dam monitoring systems, the distributed control mode is generally used, and the connection between each monitoring point, monitoring region and the central control station of the monitoring system is according to wire, which will increase the complexity of the system.

In order to simplify the monitoring work, combined with the dam deformation characteristics, a dam monitoring system based on wireless sensor network and GPS multi antenna is developed in this paper. In the network monitoring system and data acquisition using wireless sensor module, data transmission using data compression technology and data cache technology. At the end of the monitoring terminal, desktop cloud technology is used to process the data collected and show the real time dam deformation condition.

In the simulation experiment, the compression rate of the data has been studied. The results show that the compression method referred in this paper has a higher compression rate and higher response speed. The high compression rate will help to reduce energy consumption during the data transmission process, and the high response speed will help the monitoring work with high efficiency. This method can also be used in other object motion or deformation with large range and other monitoring field to improve the monitoring efficiency.

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