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RESEARCH ON HIERARCHICAL COMPRESSION ALGORITHM FOR MASSIVE FAULT RECORDING DATA

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Abstract:

With the development and improvement of microcomputer technology and communication technology, China's current power system has introduced a large number of new power system fault recorders and substation integrated automation systems. A large amount of data is transmitted to the power grid dispatch center through the public telephone network (power carrier, microwave and other channels).Because the baud rate is unlikely to be too high, especially the transmission time will be very long, the fault wave device records the analog quantity and state quantity of the whole process of the system from before the fault to the normal working state is restored. Even if the IEEE COMTRADE binary recording format is used, the recording time will vary from a few seconds or tens of minutes.

Keywords: Com-trade data format; distortion measurement; lossy compression algorithm; decompression algorithm;

Introduction

Record data files can reach hundreds of thousands of K or hundreds of thousands of K, COMTRADE uses ASCII recording format. The data will be bigger. Currently, such large data files can be sent to the dispatch center. It usually takes 10 minutes or even tens of minutes. In addition, the fault record files of the relevant substations must be transmitted to the dispatch center, so that the dispatch center can obtain the fault information, and the judgment time is too long, which affects the correct dispatch of the operator and even delays the fault handling. The effective method to solve this problem is to compress the data sent by the sending end. The receiving end decompresses the received compressed data to obtain the original data, that is, data compression and decompression technology.

1. Recording format of oscilloscope data

At present, there are more than 20 manufacturers of fault recorders in China, but all types of fault recorders do not have a uniform fault recorder format and cannot fully meet the "Technical Specifications for Dynamic Recording of 220-550 kV Power System Faults" issued by the Ministry of Electric Power. The middle recorder dynamically records the requirements of process standards. The inconsistency and irregularity of the data recording format have brought great inconvenience to the failure analysis and simulation of the failure process after the accident.GLQ2 and WGL-12 are the two most widely used computer-based fault recorder models in China. The data file length of GLQ2 recorder is fixed, the recording time is 4.2s, the sampling frequency is 800hz, and 16 analog channels and 16 digital channels can be recorded simultaneously [1].The first 32 bytes of the data file are used to record the waveform time, start mode, start channel, device configuration

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information, record serial number, channel reactance value and other information. Starting from the 33rd byte of the data file, store the sample value of each channel. The sampling point of each channel is 3360.

The data file length of WGL-12 oscilloscope changes with the length of transient fault time. The maximum recording time is 10 minutes, and the maximum recording time is 48 analog channels and 72 digital channels. According to whether the system enters the steady state, the sampling frequency is divided into 1000hz and 200hz.In order to save memory, the data recording is divided into five periods of a, B, C, D, and E: period a: the state data of the system before the start of the large disturbance, directly record the sampling value of 20 points per week, and the recording time is less than 0.04s;Cycle B: the initial state data of the system after a large disturbance, the sampling value is directly recorded at 20 o'clock every week, and the recording time is not less than 0.1s;Cycle C: the mid-term state data of the system after a large disturbance, recording 4 values per week, the recording time is not less than 0.1s;Period d: system dynamic process status data, every 5 weeks record 4 values of the first week, recording time is not less than 1.9s;Period e: system steady-state process data, recorded 4 times every 50 weeks in the first week, and the recording time is not less than 10 minutes[2].

2. IEEE COMTRADE data format

2.1 COMTRADE file format

COMTRADE is a common format for IEEE standard power system transient data exchange. The standard defines the format of transient waveform and accident data files collected from power systems or power system models. The format is intended to provide a universal format that is easy to interpret for data exchange. It was proposed by IEEE in 1991 and revised and improved in 1999.Each COMTRADE record has a set of up to four related files, and each file has a different level of information[3].The four documents are as follows:

a) Title file

b) Configuration file

c) Data files

d) Information file

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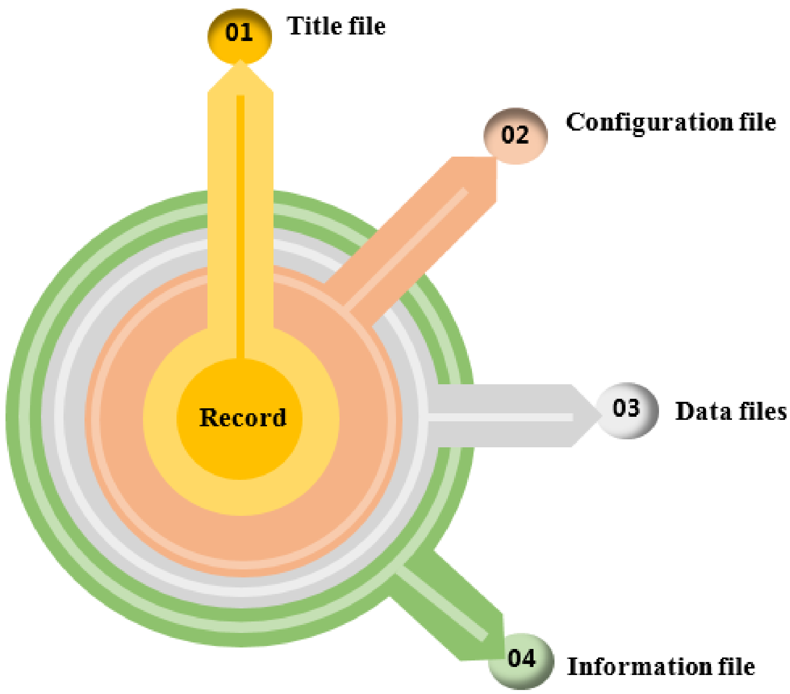
Figure 1.COMTRADE record



2.1.1Title file

The header file is an optional ASCII text file created by the creator of COMTRADE data. The creator of the title file can create any information in any order desired [4]. The format of the header file is ASCII.

2.1.2Configuration file

The configuration file is an ASCII text file (.DAT) file that correctly describes the data format, so it must be saved in a specific format. The file explains the information (.DAT) file contained in the data, including the sampling rate, number of channels, frequency, channel information, etc. A field in the first line of the configuration file identifies the year of the COMTRADE standard version on which the file is based (for example, 2015, 2018).If this field does not exist or is empty, it is assumed that the file follows the standard's original release date (2015). The configuration file also contains fields that identify whether the attached data file is stored in ASCII format or binary format [5].The configuration file contains the following information:

(A) Station name, characteristics of recording device, year of modification of COMTRADE standard

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(B) Number and type of channels

(C) Channel name, unit and conversion factor

(D) Line frequency

(E) Sampling rate and the number of samples at each rate

(F) Date and time of the first data point

(G) Trigger point and date and time

(H) Data file type

(I) Time stamp multiplier

2.1.3Data files

The data file contains the values of all input channels for each sample in the record. The data file contains the serial number and time stamp of each sample. These sampled values not only record the data of the analog input, but also record the state of the digital input [6].

2.1.4Information file

The information file is a special kind of information except that the creator wants to provide useful information to the user. The information file is optional. All documents defined by COMTRADE are explained in IEEE Std c37.111-1991 or IEEE Std c37.111-1999.

2.2Technical criteria for dynamic recording of power system faults

The power industry standard "220kV~500kV Power System Fault Dynamic Recording Technical Regulations" (DL/T 553-94) is a standard that must be followed in the development of fault recording devices. The standard stipulates in 3.6.5 that the output dynamic process record data should conform to the standard format compatible with ANSI/IEEE standard c37.111-1991 COMTRADE. At the same time, the standard stipulates that in the entire process of power system failure, data recording in analog quantity acquisition mode should be performed in chronological order [7].

Period A: The state data before the start of the system disturbance, directly output the original acquisition waveform, recording time ≥0.04s

Period B: the state data of the initial stage of the system's large disturbance, directly output the original acquisition waveform, and the recording time ≥0.1s

Cycle C: the state data of the system after a large disturbance in the middle period, which can output continuous effective value of the power frequency, and the recording time ≥1.0s

Cycle D: system dynamic process data, output a power frequency effective value every 0.1S, recording time ≥20S

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Period E: the dynamic data of the long process of the system, output an effective value of power frequency every 0.1s, and record time here ≥10min

There are two main features of data recording in the technical standard. One is segmented recording, and the other is that the recorded data can not only have sampled data at a certain sampling rate, but also record effective values at certain intervals instead of sampled values.

2.3 Microcomputer fault recorder and COMTRADE file

The basic structure of the microcomputer fault recorder is divided into an acquisition station and an analysis station. The collection station and the analysis station are connected by high-speed Ethernet. The collection station is responsible for the collection and recording of fault data. The original data collected or recorded by the collection station is not only stored in the hard disk of the collection station, but also uploaded to the analysis station through the network[8].The analysis station program is written in VC 6.0 and can complete functions such as data processing, waveform display, automatic analysis and remote communication. In data processing, files in COMTRADE format are automatically generated. After receiving the fault sampling data, the device directly processes the data into a COMTRADE data format file. The analog sampling frequency of the fault recorder is 5000 times/s, and the sampling period is adjusted according to the power system dynamic fault recorder technical specifications. Adjusting the C period to directly output the original acquisition waveform, recording time ≥ 1.0s, ABC period sampling frequency is 5000 times/s, store real-time simulation data; The de-cycle sampling frequency is 10 times/s, and the maximum value data is stored instead of the effective value, and the envelope waveform is easy to generate. We have omitted the header file and information file, defined the file name, and generated the configuration file (dir00).CFG and data files (dir00. DAT) are stored in the same batch folder dir00 according to different batches and failure times.

2.4 The main task of power system dynamic recording is to record the changes of power parameters and the behavior of relay protection and automatic safety devices after large disturbances such as short-circuit faults, system oscillations, and frequency and voltage collapses according to this technical specification. The main task of power system dynamic recording is to record data in different periods to meet the needs of the operation department for fault analysis and system analysis, and to record and output only data that meets actual needs as much as possible. To this end, the sampling method of ABCDE segment analog quantity on the technical standard side was determined. Figure 2:

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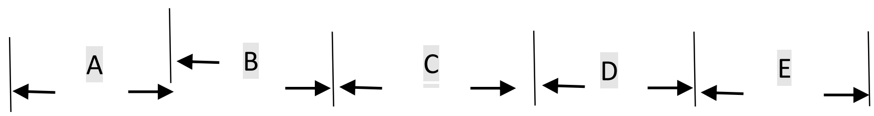
Figure 2 Failure dynamic technical criteria



Absolute moment t=0 of large system disturbance

Cycle A: State data before the start of the system disturbance. Output original recorded waveform and analysis value, recording time ≥0.04s

Period B: State data of the system in the early stage of large disturbance, output the original recorded waveform and analysis value, recording time ≥0:1s

Period C: Respect the state of the system in the middle of large interference, output the original recorded waveform or continuous effective power value, and the recording time ≥ 1s

Period D: System dynamic process teaching data, output a effective value of power frequency every 0.1s, recording time ≥20se

Period: The dynamic teaching data of the long process of the system. An effective value of power frequency is output every 1s, and the recording time is ≥10min until the fault or vibration ends. If there is a sudden variable exceeding the limit in the CDE section, then record it again from section B. The data recording of the technical standard has two main features. One is the most segmented recording. The second is that the recorded data has both sampling data with a certain sampling frequency and effective values stored at certain intervals.

3. Data file preprocessing

The record format of the fault data file shall comply with COMTRADE standards and ministerial technical standards [9].However, this particular recording format will result in the following redundancy in the teaching data file:

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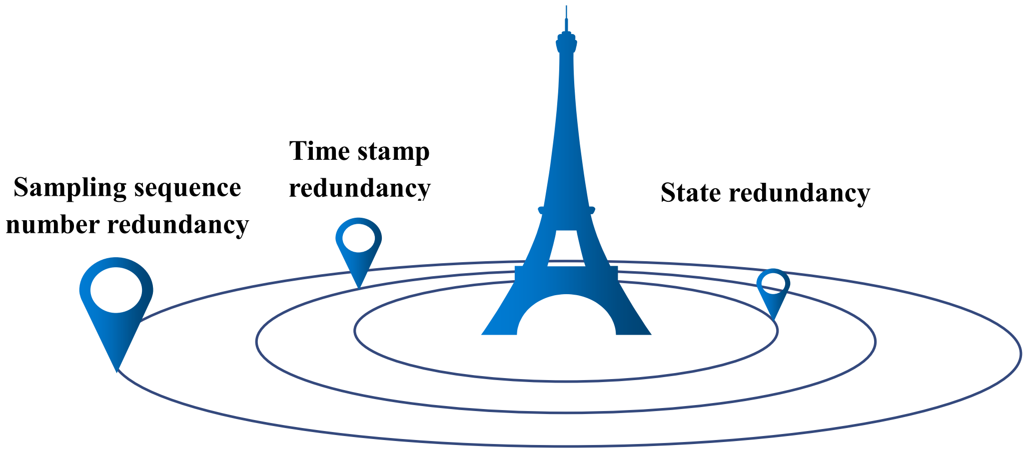
Figure 3: Redundancy



3.1.1Sampling sequence number redundancy

Each sampling point in the data file has a sampling sequence number, which increments from 1. The equidistantly increasing sampling sequence number provides little information. Because the data receiver only needs to know the maximum serial number, it can automatically generate each serial number[11].

3.1.2Time stamp redundancy

According to the national promulgated standards, the sampling frequency of the ABC section is the same, and the time stamps of the sampling points increase at equal intervals [10]. Sections D and e increase backward at intervals of the data retention period. Similar to the above, as long as the sampling rate and the number of the sampling point with the largest sampling rate are known, the sampling time of each sampling point can be calculated [12].

3.1.3State redundancy

A large number of switching signals are often received in the oscilloscope, and each sampling point of the standard will record these state quantities. Even if the state quantity does not change during the recording process, for the user, the only concern is that there are multiple different state quantities throughout the recording process, and the maximum sampling point serial number in this state. As long as the information is known, all state data of the file can be completely recovered [13].

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4. Lossy compression algorithm

4.1 Existing lossy compression methods can be divided into two categories: dead time compression and trend compression.

In the 1960s and 1970s, due to the needs of aerospace telemetry, researchers began to study data compression algorithms. In the early 1980s, Hale and Sellers proposed dead zone (boxcar) and reverse slope compression algorithms to compress data through prediction methods and applied them to the field of historical data monitoring. The trend compression is expressed by the revolving door algorithm, which greatly improves the compression rate of the real-time database and is widely used in the real-time database field. However, because the revolving door algorithm does not describe, record, and predict trend changes, there is still room for improvement in compression rate and accuracy. China's research on lossy compression algorithms mainly focuses on lossy compression algorithms for images and videos, such as vector quantization coding algorithms, a series of compression algorithms based on wavelet transform, etc. These algorithms are mainly used in the medical field. Kortman proposed the fan interpolation algorithm, which Peter A. James called the Slim algorithm. In 1995, the latter improved the slim algorithm and proposed the slim 2 and slim 3 algorithms. The compression ratio and compression accuracy of the algorithm are better than the revolving door algorithm, but it has not been applied in the real-time database system, the algorithm still has room for improvement.

4.2 Distortion measurement

Distortion measurement is a mathematical quantity that uses some distortion criteria to specify how close the approximation is to its original value. When viewing compressed data, distortion is usually considered based on the numerical difference between the original and reconstructed data. However, when the data to be compressed is an image, such measurements may not produce the expected results [14].For example, if the reconstructed image is the same as the original image, but is moved to the right by the vertical scanning line, it is difficult for ordinary human observers to distinguish it from the original image, so it can be concluded that the distortion is very small. When performing calculations digitally, we find large distortions due to large changes in each pixel of the reconstructed image. The problem is that we need a measurement method for perceptual distortion, not a simpler numerical method. Among the many digital distortion metrics that have been defined, we propose the three most commonly used image compression methods. If we are interested in the average pixel difference, we usually use the mean square error (MSE).It is defined as:

$$\sigma^2 = \frac{1}{N}\sum_{n=1}^{N}(x_n - y_n)^2$$

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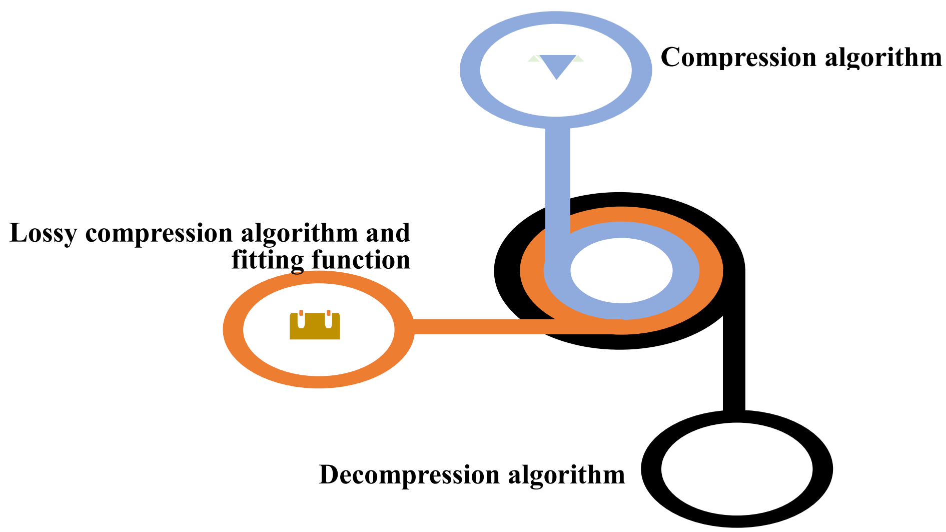
Among them, xn, yn and N are the input data sequence, the reconstruction data sequence and the length of the data sequence.

5. Lossy compression algorithm based on prediction and dynamic correction

Figure 4.Lossy compression algorithm



5.1 Lossy compression algorithm and fitting function

Through research and observation, it is found that different lossy compression algorithms can be classified according to the order of the fitting function corresponding to their decompression algorithm. For the dead zone compression algorithm, the corresponding fitting function is simple:

$$y' = y$$

For time t, this function is a zero-degree function, and the value with the difference less than the error tolerance range is ignored. When decompressing, it is calculated according to the value of the previous recording point, and the decompression algorithm is independent of time. The reverse slope compression algorithm, revolving door algorithm and SLIM algorithm, and the decompression algorithm all correspond to the fitting function:

$$y' = y_2 + k(t' - t_2)$$

$$k = (y_2 - y_1) / (t_2 - t_1)$$

For time t, the function is a main function, so the fit of these three algorithms is higher than the dead zone compression algorithm, thereby obtaining a higher compression ratio

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and higher recovery accuracy. In the test, the revolving door algorithm and the slim algorithm changed the numerical comparison to the slope comparison, which improved the compression ratio while ensuring efficiency. The slic2 algorithm uses this value to modify for simple trend prediction, but this sacrifices the accuracy of reduction. If the quadratic linear fitting function is used as the decompression algorithm, the decompression performance will be greatly reduced. Therefore, this paper proposes a compromise. Through prediction and dynamic correction, the compression effect is close to quadratic linear fitting, but the compression efficiency is not significantly reduced.

5.2 Compression algorithm

The data filtering process of the compression algorithm proposed in this paper is based on the SLIM sector interpolation method. On this basis, through prediction and dynamic correction, the compression ratio is greatly improved, and the reduction accuracy is also improved.

5.2.1 Initialize

The system initialization process includes recording the first two data p1(t1, v1), p2(t2, v2), and calculating the upper limit of the slope of the fan-shaped area at the beginning:

$r_{up} = (v_2 + T - v_1) / (t_2 - t_1)$

Lower slope limit:

$r_{down} = (v_2 - T - v_1) / (t_2 - t_1)$

Mid limit of slope:

$r = (v_2 - v_1) / (t_2 - t_1)$

The initial slope correction value dr is 0, and p1 is recorded as "last written data" as plast(tlast, vlast), and p2 is recorded as "last read data" as Pread (Tread, Vread)

5.2.2 Read and calculate data in real time

During the operation of the system, new real-time data is continuously read, and for the new data p(t,v) read in, the corresponding slope upper limit is calculated:

$r'_{up} = (v + T - v_{last}) / (t - t_{last}) + d_r *(t - t_{last})$

Lower slope limit:

$r_{down} = (v - T - v_{last}) / (t - t_{last}) + d_r *(t - t_{last})$ 2. 2. 3

Compared the data to determine whether to save it. If $r'_{up} > r_{up}$ and $r'_{down} > r_{up}$, then you need to save the new data; if $r'_{down} < r_{down}$ and $r'_{up} < r_{down}$, you also need to save the new data. Otherwise, the new data is not saved and only the parameters are readjusted.

5.2.3 Save data and adjust parameters

According to the results of 2.2.2, if new data needs to be saved, the slope correction value is calculated

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$d_r = ((v - v_{read}) / (t - t_{read}) - r) / (t_{read} - t_{last})$

Through the vertical line of "last read data", if $r'_{up} > r_{up}$, the intersection of the vertical line and r_{up} is written into the database and recorded as "last written data". If $r'_{down} < r_{down}$, write the intersection of the vertical line and r_{down} into the database and record it as "last written data", and recalculate:

$r_{up} = (v + T - v_{last}) / (t - t_{last}) + d_r *(t - t_{last})$

$r_{down} = (v - T - v_{last}) / (t - t_{last}) + d_r *(t - t_{last})$

If there is no need to save new data, if $r'_{up} < r_{up}$, adjust r_{up} to r' up, if $r'_{down} > r_{down}$, adjust r_{down} to r'_{down}. Regardless of whether or not to save new data, record the current data as "last read data".

The following is the pseudo code of the core part of the compression algorithm:

Read new data pair (t, v)

t1←t, v1←v, tlast←t, vlast←v

Read new data pair(t, v)

t2←t, v2←v, treat←t, vread←v rup←(v2+T-v1) / (t2-t1) rdown←(v2-T-v1) / (t2-t1) r←(v2-v1) / (t2-t1) dr←0

else

rup2←(v+T-vlast) / (t-tlast)+dr*(t-tlast)

rdown2←(v-T-vlast) / (t-tlast)+dr*(t-tlast)

if (rup2>rup and rdown2>rup) or (rup2<rdown and rdown2< rdown) then

dr←((v-vread) / (t-tread) -r) / (tread-tlast)

if rup2>rup then

vnew←vlast+rup(t-tlast)

else

vnew←vlast+rdown(t-tlast)

endif

vlast←vnew, tlast←tread

Save (vlast, tlast) to the database

rup←(v+T-vlast) / (t-tlast)+dr*(t-tlast)

rdown←(v-T-vlast) / (t-tlast)+dr*(t-tlast)

else

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if rup2<rup then rup←rup2

if rdown2>rdown then rdown←rdown2

endif

vread←v, tread←t

endif

repeat

5.3 Decompression algorithm

The decompression algorithm corresponding to the compression algorithm proposed in the paper is as follows. For the input query time period, the corresponding data set is read from the database. In order to reduce the amount of data transmitted on the network, the data fitting work is completed on the client [13].

When fitting on the client, for time t, reading the three most recent data pairs before t p1(t1, v1), p2(t2, v2), p3(t3, v3), calculate pt(t, vt) The method is as follows:

$k_1 = (v_2 - v_1) / (t_2 - t_1)$

$k_2 = (v_3 - v_2) / (t_3 - t_2)$

$v_t = v_3 + (t_3 - t_2)(k_2 + (k_2 - k_1)(t_3 - t_2) / (t_2 - t_1))$

Since the fitting of the output result is performed on the client, this process will not affect the efficiency of the server.

6. Algorithm efficiency

In this paper, the revolving door, SLIM, SLIM2 and the new algorithm are tested and compared in terms of theoretical efficiency and actual efficiency.

6.1 Theoretical efficiency

The theoretical efficiency can be tested and evaluated according to the mathematical model of each algorithm. The sine function y[i] = 100sin(t[i]) is selected as the test function. The estimated value of theoretical efficiency is shown in Table 1.Starting from t = 0, according to the rules of each lossy compression algorithm, sampling is performed at a sampling frequency of 1 per second, and the error tolerance range is ± 1.5.

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Table 1: Theoretical efficiency test of lossy compression

Algorithm	Compression ratio		Reduction error
Uncompressed	1		0
Revolving door	17.	8	1. 48
SLIM	35		1. 5
SLIM2	22.	1	1. 17
Algorithm	28.	5	1. 15

It can be seen from the table that the algorithm proposed in this paper is theoretically better than the revolving door and SLIM2.

6.2 Actual efficiency

The measured data is a sinusoidal function with noise y = 100sin (t) + G, where G is random noise. For this function, the average results of the actual tests are shown in Table 2:

Table 2: Actual efficiency test of lossy compression algorithm

Algorithm	Compression ratio		Reduction error
Uncompressed	1		0
Revolving door	10.	1	1. 5
SLIM	16.	7	1. 5
SLIM2	5. 3		1. 32
Algorithm	7. 8		1. 28

As can be seen from the above table, for the actual data with noise, the algorithm proposed in this paper improves the accuracy of reduction on the premise of ensuring the compression ratio. However, due to the addition of noise, the deviation between the predicted value and the actual value increases, so the compression ratio decreases a lot compared with the theoretical value.

Conclusion

This paper proposes a three-dimensional vision automatic tracking algorithm based on CUDA. Compared with the original CPU version of the horizon automatic tracking algorithm, the calculation speed has been significantly improved. However, since the automatic horizon tracking algorithm used in this paper is an iterative process, data needs to be copied between the display memory and the memory at each iteration. At the same time, when performing adjustment operations, different CUDA threads have different

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calculations, resulting in thread diversity , which also limits the speed of the algorithm in this paper. How to solve these two problems is the focus of the next step.

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