Z-checker (ZC)

User Guide (Version 0.1.1)

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Table of Contents

Table of Contents 1
1. Brief description 2
2. Design Framework 3
2. Installation of Z-checker 4
    2.1 Stand-alone installation 5
    2.2 One-command installation (using Z-checker-installer) 5
3. Testing 5
    3.1 Testing based on stand-alone installation 5
    3.2 Automatic testing with Z-checker-installer 8
    3.3 Manual testing without Z-checker-installer 10
4. Application Programming Interface (API) 12
    4.1 Initialization and finalization of the Z-checker environment 12
        4.1.1 ZC_Init 12
        4.1.2 ZC_Finalize 12
    4.2 Generic I/O 13
        4.2.1 ZC_readDoubleData in bytes 13
        4.2.2 ZC_readFloatData in bytes 13
        4.2.3 ZC_writeFloatData_inBytes 13
        4.2.4 ZC_writeDoubleData_inBytes 13
        4.2.5 ZC_writeData in text 14
    4.3 Data property analysis 14
        4.3.1 ZC_genProperties 14
        4.3.2 ZC_printDataProperty 15
        4.3.3 ZC_writeDataProperty 15
        4.3.4 ZC_loadDataProperty 16
    4.4 Data Comparison 16
        4.4.1 ZC_compareData 16
        4.4.2 ZC_printCompressionResult 17

4.4.3 ZC_writeCompressionResult 18
4.4.4 ZC_loadCompressionResult 18
4.5 Setting monitoring calls in compressor codes 18
4.5.1 ZC_startCmpr 18
4.5.2 ZC_startCmpr_withDataAnalysis 18
4.5.2 ZC_endCmpr 19
4.5.3 ZC_startDec 19
4.5.4 ZC_endDec 19
4.6 Plotting the analysis data suitable for Gnuplot 19
4.6.1 ZC_ plotHistogramResults 19
4.6.2 ZC_plotComparisonCases 20
4.6.3 ZC_plotAutoCorr_CompressError 20
4.6.4 ZC_plotAutoCorr_DataProperty 21
4.6.5 ZC_plotFFTAmplitude_OriginalData 21
4.6.6 ZC_plotFFTAmplitude_DecompressData 21
4.6.7 ZC_ plotErrDistribtion 22
4.7 Generating Gnuplot scripts 22
4.7.1 genGnuplotScript_linespoints 22
4.7.2 genGnuplotScript_histogram 23
4.7.3 genGnuplotScript_lines 23
4.7.4 genGnuplotScript_fillsteps 23
4.9 Calling R script from Z-checker 23
4.9.1 ZC_callR_1_1d 24
4.9.2 ZC_callR_2_1d 24
4.9.3 ZC_callR_1_2d 25
4.9.4 ZC_callR_2_2d 25
4.9.5 ZC_callR_1_3d 26
4.9.5 ZC_callR_2_3d 27
5 Configuration file 28
6. Version history 28
7. Q&A and Trouble shooting 28

1. Brief description

Due to vast volume of data being produced by today's scientific simulations and experiments, lossy data compressor allowing user-controlled loss of accuracy during the compression is a relevant solution for significantly reducing the data size. However, lossy compressor developers and users are missing a tool to explore the features of scientific data sets and understand the data alteration after compression in a systematic and reliable way. To address this gap, we design and implement a generic framework, called Z-checker.

On the one hand, Z-checker combines a battery of data analysis components relevant for data compression. On the other, Z-checker is implemented as an open-source community tool for which users and developers can contribute and add new analysis components based on their additional analysis demand.

In this user guide, we present the design framework of Z-checker, in which we integrated evaluation metrics proposed in prior work as well as other analysis required by lossy compressor developers and users. For lossy compressor developers, Z-checker can be used to characterize critical properties (such as entropy, distribution, power spectrum, principle component analysis, auto-correlation) of any data set to improve compression strategies. For lossy compression users, Z-checker can obtain the compression quality (compression ratio, bit-rate), provide various global distortion analysis comparing the original data with the decompressed data (PSNR, SNR, normalized MSE, rate-distortion, rate-compression error, spectral, distribution, derivatives) and statistical analysis of the compression error (maximum/minimum/average error, autocorrelation, distribution of errors). Z-Checker can perform the analysis with either course (throughout the whole data set) or fine granularity (by user defined blocks), such that the users/developers can select the best-fit, adaptive compressors for different parts of the data set. Z-checker features a visualization interface displaying all analysis results in addition to some basic views of the data sets such as time series.

2. Design Framework

Z-checker has three important features. (1) Z-checker can be used to explore the properties of original data sets for the purpose of data analytics or improvement of lossy compression algorithms. (2) Z-checker is integrated with a rich set of evaluation algorithms and assessment functions for selecting best-fit lossy compressors for specific data sets. (3) Zchecker features both static data visualization scripts and an interactive visualization system, which can generate visual results on demand.

The design architecture of Z-checker is presented in Figure 1, which involves three critical parts, including user interface, processing module, and data module.

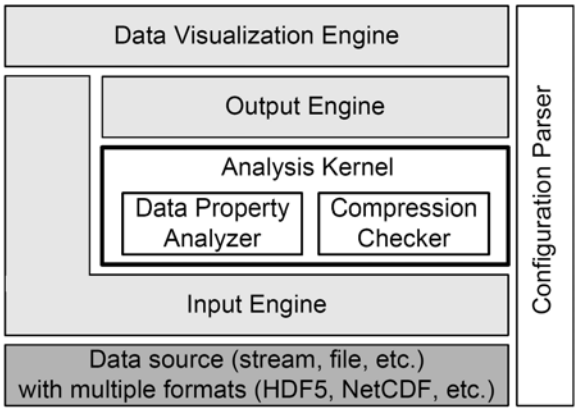


Fig. 1 Design Framework of Z-checker

- **User interface** includes three key engines, namely input engine, output engine, and data visualization engine, as shown in the light-gray rectangles in Figure 1. They are in charge of reading the floating-point data stream (either original data or compressed bytes), dumping the analyzed data to disks/PFS, and plotting data figures for the visualization of analysis results. The Data Visualization Engine also provides the interactive mode through a web-browser interface.
- **Processing module**, in the whole framework, is the core module, which includes Analysis Kernel and Configuration Parser. The former is responsible for performing the critical analysis, and the latter is in charge of parsing user's analysis requirement (such as specifying input file path, specifying compression command/executable, and customizing the analysis metrics on demand). Specifically, the analysis kernel is composed of two critical sub-modules, data property analyzer and compression checker, which are responsible for exploring data properties based on original data sets and analyzing the compression results with specified lossy compressors, to be discussed later in more details.
- **Data source module** (shown as dark-gray box in the figure) is the bottom layer in the whole framework, and it represents the data source (such as data stream produced by scientific applications at runtime or the data files stored in the disks).

2. Installation of Z-checker

We provide two alternative ways to install Z-checker, stand-alone installation or z-checker-installer.

The former is installing Z-checker individually, without installing third-party dependencies or compression libraries. The z-checker-installer is recommended for generic users, because it will check if the required third-party libraries are already installed. If not, it will download and install the dependencies automatically before installing Z-checker. It also includes some state-of-the-art lossy compressors such as SZ and ZFP, and also provides a set of scripts allowing users to generate the compression report by running only one command.

2.1 Stand-alone installation

The Z-checker library/tool can be cloned by the following command:
git clone https://github.com/CODARcode/z-checker
or downloaded from http://www.mcs.anl.gov/~shdi/download/z-checker-0.1.1.tar.gz
Perform the following three simple steps to finish the installation:
./configure --prefix=[INSTALL_DIR]
make
make install

You'll find all the executables in [INSTALL_DIR]/bin or [DOWNLOAD_PACKAGE]/examples. The static library (.a files) and shared library (.so files) can be found in [INSTALL_DIR]/lib. The key executables are described in Section 3.

2.2 One-command installation (using Z-checker-installer)

1. git clone https://github.com/CODARcode/z-checker-installer
2. Run z-checker-install.sh will download latexmk, gnuplot, Z-checker, ZFP, and SZ and install them one by one automatically, and then add the patches to let ZFP and SZ fit for Z-checker.
(*Note: in the future, If you want to update your package based on your already installed z-checker-installer, you can execute z-checker-update.sh for simplicity, instead of rerunning z-checker-install.sh*)

3. Testing

3.1 Testing based on stand-alone installation

The executables are in [INSTALL_DIR]/bin and [DOWNLOAD_PACKAGE]/examples.

After the installation described above, you can test the sample data sets in [DOWNLOAD_PACKAGE]/examples/testdata/x86. You can also download more data sets, CESM-ATM and MD-simulation (exaalt), which are available only for the purpose of compression research.

- CESM-ATM: http://www.mcs.anl.gov/~shdi/download/CESM-ATM-tylor.tar.gz
- MD-simulation (exaalt): http://www.mcs.anl.gov/~shdi/download/exaalt-dataset.tar.gz

We describe them as follows.
(Tips: You can run the executables or scripts without any inputs to see the help information)

- analyzeDataProperty (or analyzeDataProperty.sh):

Usage: ./analyzeDataProperty.sh [datatype (-f or -d)] [data directory] [dimension sizes....]

Example: ./analyzeDataProperty.sh -f /home/shdi/CESM-testdata/1800x3600 3600 1800

Description: The analysis results will be put in the directory called dataProperties.

In particular,

- [variable_name].fft keeps the spectrum information (generated by FFT), including real part and imaginary part.
- [variable_name].fft.amp contains the amplitude of the spectrum data.

Notice: You need to set *checkingStatus* to ANALYZE_DATA and set *executionMode* to OFFLINE in the configuration file before running the analyzeDataProperty command.

- compareDataSets (or compareDataSet.sh)

Usage: compareDataSets [dataType -f or -d] [config_file] [compressionCase] [varName] [oriDataFilePath] [decDataFilePath] [dimension sizes...]

Example: compareDataSets -f zc.config SZ 8_8_128 testfloat_8_8_128.dat testfloat_8_8_128.dat.out 8 8 128

Description:

If you just want to compare the reconstructed data with the original data, you can use executable compareDataSets, as shown below.

compareDataSets [config_file] [oriDataFilePath] [decDataFilePath] [dimension sizes...]

Three output files (.cmp, .autocorr, and .dis) will be stored in the directory compareResults/:

- .cmp file keeps the general information about the compression results.
- .autocorr file keeps the auto correlation of the compression errors with different lags.
- .dis is about the PDF of compression errors.

Notice: You need to set *checkingStatus* to ANALYZE_DATA and set *executionMode* to OFFLINE in the configuration file before running the compareDataSets command.

- generateGNUPlot:

Usage: ./generateGNUPlot [config_file]

Example: ./generateGNUPlot zc.config

Description: generateGNUPlot will find compression results in the three directories: dataProperties, compressionResults and compareCompressors, and plot figures accordingly.

Notice: Before running the command generateGNUPlot, you need to make sure you already run analyzeDataProperty and comapreDataSets to generate the following two directories in the working space: ./dataProperties and compressionResults. You also need to set the *checkingStatus* and *executionMode* to COMPARE_COMPRESSOR and OFFLINE respectively. The parameter *compressors* are composed of a set of two-tuples – compressor_name:working_space_path. The working_space_path is the directory that contains the dataProperties directory and the compressionResults directory. The parameter comparisonCases includes the compression cases, which should also be consistent with the parameters used when running the compareDataSets command. We give some examples to further illustrate how to use generateGnuPlot correctly. In the following examples, suppose

orig.raw stores the double-precision floating-point data, and approx.raw and approx.raw2 store reconstructed data generated by SZ compressor using error bound of 1E-2 and 1E-4, respectively.

Suppse you already generate the

Step 1: Generate dataProperties

Go to the working directory of Z-checker (suppose it is /home/sdi/Z-checker/examples), and then execute analyzeDataProperty as follows.

#./analyzeDataProperty **var1** -d zc.config /home/sdi/Data/orig.raw 8000000

Step 2: Generate compression results based on the decompressed data files.

Go to the working directories of all compressors and run the following command respectively. (As follows, we use SZ and ZFP as examples)

#cd **/home/sdi/sz_workspace**

#./compareDataSets -d zc.config **SZ(1E-2)** **var1** /home/sdi/Data/orig.raw /home/sdi/Data/approx_sz_1E-2.raw 8000000

#./compareDataSets -d zc.config **SZ(1E-4)** **var1** /home/sdi/Data/orig.raw /home/sdi/Data/approx_sz_1E-4.raw 8000000

#cd **/home/sdi/zfp_workspace**

#./compareDataSets -d zc.config **ZFP(1E-2)** **var1** /home/sdi/Data/orig.raw /home/sdi/Data/approx_sz_1E-2.raw 8000000

#./compareDataSets -d zc.config **ZFP(1E-4)** **var1** /home/sdi/Data/orig.raw /home/sdi/Data/approx_sz_1E-4.raw 8000000

Notice: the variable name (here, var1) should be consistent in Step 1 and Step 2.

Step 3: Generate data figures

Go back to the working directory of Z-checker and execute generateGNUPlot:

cd /home/sdi/Z-checker/examples

./generateGNUPlot zc.config

Notice: before running the step 3 to generate the data figures, you need to make sure zc.config is configured correctly based on the compressor name and the working directory.

compressors = **SZ**:**/home/sdi/sz_workspace** **ZFP**:**/home/sdi/zfp_workspace**

compressionCases = **SZ(1E-2)**,**ZFP(1E-2)** **SZ(1E-4)**,**ZFP(1E-4)**

Then, you will find a set of data files generated in the current directory.

- generateReport (or generateReport.sh):

Usage: ./generateReport [config_file] [title of dataset]

Example: ./generateReport zc.config CESM-ATM-tylor-data

Description: generateReport assumes that the data properties and compression results are already generated in the three key directories, dataProperties, compressionResults and compareCompressors, and it will generate the figures and the pdf report based on them.

Notice:

The testing cases can be found in **[ZC_Download_Package]/examples**

You can use "make clean;make" to recompile all the example codes, or compile them by the customized Makefile.bk as follows:

make -f Makefile.bk
(Makefile.bk allows you to compile your customized source codes.)

For simplicity, you can use [ZC_Package]/example/*test.sh* to test some examples (such as data property analysis code).
More tests related to compression analysis need to be performed with some data compressor such as SZ (https://collab.cels.anl.gov/display/ESR/SZ). More details will be described later.

3.2 Automatic testing with Z-checker-installer

After the simple one-command installation described in Section 2.2, you can download the testing data sets, CESM-ATM and MD-simulation (exaalt).

- CESM-ATM: http://www.mcs.anl.gov/~shdi/download/CESM-ATM-tylor.tar.gz
- MD-simulation (exaalt): http://www.mcs.anl.gov/~shdi/download/exaalt-dataset.tar.gz

Then, you are ready to perform the compression quality checking by Z-checker.
You can generate compression results with SZ and ZFP using the following simple steps:
(Note: you have to run z-checker-install.sh to install the software before doing the following tests)

(1) Configure the error bound setting and comparison cases in errBounds.cfg.
(Example settings are already in the errBounds.cfg. You can change it based on your demand, such as the list of compression errors)

errBounds.cfg:

```
#SZ_ERR_BOUNDS specifies the list of error bounds in the evaluation for SZ compression.
SZ_ERR_BOUNDS="1E-1 1E-2 1E-3 1E-4 1E-5"

#ZFP_ERR_BOUNDS specifies the list of error bounds for ZFP compression.
ZFP_ERR_BOUNDS="1E-1 1E-2 1E-3 1E-4 1E-5 1E-6 1E-7"

#comparisonCases specifies the cases in which the different compressors will be compared with each other.
#For instance, "sz_f(1E-2),sz_d(1E-2),zfp(1E-2) sz_f(1E-4),sz_d(1E-4),zfp(1E-4)" means that the three compressors will be compared (w.r.t. compression ratio and PSNR) based on error bound = 1E-2 and 1E-4 respectively.
comparisonCases="sz_f(1E-2),sz_d(1E-2),zfp(1E-2) sz_f(1E-4),sz_d(1E-4),zfp(1E-4)"

#numOfErrorBoundCases specifies the number of error bound cases you want to present for each compression metric in the report.
```

```
#For instance, numOfErrorBoundCases=3 means that the compression metrics (such as distribution of compression errors), will only select three cases evenly in the list of error bounds.
#More specifically, if SZ_ERR_BOUNDS="1E-1 1E-2 1E-3 1E-4 1E-5", then only 1E-1, 1E-3, and 1E-5 will be used to plot the compression results for SZ.
#Without the setting numOfErrorBoundCases, the compression results with each error bound will be presented, leading to a very long report.
numOfErrorBoundCases="3"
```

(2) Create a new test-case, by executing "createNewZCCase.sh [test-case-name]". You need to replace [test-case-name] by a meaningful name.

For example:

[user@localhost z-checker-installer] ./createNewZCCase.sh CESM-ATM-tylor-data

Note: after creating a test-case, you should be able to find:

- two new directories [test-case-name]_fast, [test-case-name]_deft are generated in z-checker-installer/SZ ;
- one new directory called [test-case-name] is generated in z-checker-installer/zfp;
- one new directory called [test-case-name] is made in z-checker-installer/Z-checker

The new directories above contain the corresponding running scripts, which will be called later (by running runZCCase.sh) to perform the checking operations.

(3) Perform the checking by running the command "runZCCase.sh": runZCCase.sh [data_type] [error-bound-mode] [test-case-name] [data dir] [dimensions....].

There are two ways to specify the data files to be analyzed.

Option 1: Putting the data files with the same dimension sizes in the same directory. In the following example, we put five single-precision floating-point data files whose dimensions are all 1800x3600 in the directory /home/shdi/CESM-testdata/1800x3600.

[user@localhost z-checker-installer] ./runZCCase.sh -f REL CESM-ATM-tylor-data /home/shdi/CESM-testdata/1800x3600 3600 1800

Description:

- -f means that the data set is single-precision floating-point data.
- REL means that the error bounds used in the compression are based on value_range.
- CESM-ATM-tylor-data is the name of the testing case.
- [dimensions….] follows the column-major style. In the above example, the matrix in C programming code style is 1800x3600, so the dimensions sizes should be 3600 1800.

Option 2: Listing all the data files and corresponding information in a configuration file (e.g., varInfo.txt"), as follows:

#varInfo.txt:

CLDHGH:LITTLE_ENDIAN:FLOAT:1800x3600:/home/sdi/Data/CESM-ATM-tylor/1800x3600/CLDHGH_1_1800_3600.dat

CLDLOW:LITTLE_ENDIAN:FLOAT:1800x3600:/home/sdi/Data/CESM-ATM-tylor/1800x3600/CLDLOW_1_1800_3600.dat

FLDSC:LITTLE_ENDIAN:FLOAT:1800x3600:/home/sdi/Data/CESM-ATM-tylor/1800x3600/FLDSC_1_1800_3600.dat

FREQSH:LITTLE_ENDIAN:FLOAT:1800x3600:/home/sdi/Data/CESM-ATM-tylor/1800x3600/FREQSH_1_1800_3600.dat

PHIS:LITTLE_ENDIAN:FLOAT:1800x3600:/home/sdi/Data/CESM-ATM-tylor/1800x3600/PHIS_1_1800_3600.dat

Then, run the following command:

[user@localhost z-checker-installer] ./runZCCase.sh -f REL varInfo.txt

(4) Then, the report are generated in z-checker-installer/Z-checker/[test-case-name]/report. All the figures can be found in z-checker-installer/Z-checker/[test-case-name]/report/figs. For more information, you can locate the specific results as follows:

- In z-checker-installer/Z-checker/[test-case-name]/dataProperties: The *.prop files contain the property analysis results about the data set, such that min value, max value and entropy value. The *.fft* files are the FFT analysis result about the data set. The *.autocorr* files contain the auto-correlation coefficient results with different lags.
- In z-checker-installer/Z-checker/[test-case-name]/compressionResults: The *.cmp files contain the results about compression quality, such as compression ratio, maximum compression error, PSNR, SNR, MSE, compression time, and decompression time. The *.dis files are about the distribution of compression errors. The *.autocorr files contain the auto-correlation coefficients of the compression error with different lags.
- In z-checker-installer/Z-checker/[test-case-name]/compareCompressors: This directory contains the results about the comparison among different compressors. For example, rate-distortion_psnr_FREQSH_1_1800_3600.dat.txt presents rate-distortion figure (PSNR vs. bit-rate) for the variable FREQSH with the dimension size 1800x3600; the file crate_sz_f(1E-2)_sz_d(1E-2)_zfp(1E-2).txt compares the compression rate (i.e., compression speed) across three compression solutions with the same error bound 10^{-2}. cratio_sz_f(1E-2)_sz_d(1E-2)_zfp(1E-2).txt refers to compression ratio and drate_sz_f(1E-2)_sz_d(1E-2)_zfp(1E-2).txt indicates the decompression rate.

3.3 Manual testing without Z-checker-installer

Testing procedure:

Download a compression library, such as SZ (https://collab.cels.anl.gov/display/ESR/SZ), and then put the data compression monitoring interfaces before and after the compression/decompression function. Recompile the compression library. And then, perform the compression using some data set. The analysis results (such as compression rate, compression ratio, compression errors) will be stored in the directory called compareData/.

Example (with SZ):

1. Download SZ-1.4.9 from https://collab.cels.anl.gov/display/ESR/SZ

2. Install SZ package by the following steps:

(tar –xzvf sz-1.4.9-beta.tar.gz;cd sz-1.4.9.1-beta;./configure --prefix=[INSTALL_DIR]; make;make install)

3. Copy the testing code testfloat_CompDecomp.c from Z-checker's examples/ directory to SZ's example/ directory, and compile it by the following command (you need to replace the bolded parts by the installation paths on your own machine)

```
#compile_CompDecomp.sh
#!/bin/bash
SZPATH=[SZ_INSTALL_DIR]
ZCPATH=[Z-Checker_INSTALL_DIR]
SZFLAG="-I$SZPATH/include -I$ZCPATH/include $SZPATH/lib/libsz.a $SZPATH/lib/libzlib.a $ZCPATH/lib/libzc.a"
gcc -lm -g -o testfloat_CompDecomp testfloat_CompDecomp.c $SZFLAG
```

4. Run testfloat_CompDecomp:

./Testfloat_CompDecomp [sz_config_file] [zc_config_file] [compressor_name] [testcase] [absErrBound] [input_data_file_path] [dimension_sizes…..]

Example:

Set the compression mode in configuration file sz.config to *SZ_BEST_SPEED*, then:

```
absErrBound=1E-3
compressor_case=sz1.4_f($absErrBound) #sz1.4_f refers to sz1.4(best_speed_mode)
testcase=varName
datapath=testdata/x86/testfloat_8_8_128.dat

testfloat_CompDecomp sz.config zc.config "${compressor_case}" ${testcase} ${absErrBound} ${datapath} 8 8 128
```

(***Note***: You need to copy zc.config from Z-checker's examples/ directory to SZ's example/ before running the above command.)

5. After running testfloat_compDecomp, the compression results will be kept in compareData/ directory.

"sz(1E-3):varName.cmp" keeps the compression results, including compression time, decompression time, compression rate, decompression rate, PSNR, SNR, compression factor, maximum compression error, etc.

"sz(1E-3):varName.autocorr" keeps the auto-correlation values of the compression errors with different lags.

"sz(1E-3):varName.dis" keeps the distribution (PDF) of the compression errors.

6. Change the compression mode in sz.config to be *SZ_BEST_COMPRESSION* , and then rewind the above steps 4 with the compressor_case tagged as **sz1.4_c**, as shown below.

```
absErrBound=1E-3
compressor_case=sz1.4_c($absErrBound) #sz1.4_c is sz1.4(best_compression_mode)
testcase=varName
```

datapath=testdata/x86/testfloat_8_8_128.dat

testfloat_CompDecomp sz.config zc.config "${compressor_case}" ${testcase} ${absErrBound} ${datapath} 8 8 128

7. Now, we are ready to compare the compression results between the two "compressors": sz1.4_f vs. sz1.4_c, as follows:

Go back to Z-checker's examples/ directory, and then set the compressors as follows:

compressors = sz1.4_f:sz-1.4.9-beta/example sz1.4_c:sz-1.4.9-beta/example

comparisonCases = sz1.4_f(1E-3),sz1.4_c(1E-3)

Note: the format of the compressors string is [compressor_name]:[directory of running command]. The comparisonCases follows such as format: [compressor_case1],[compressor_case2] [compressor_case3],[compressor_case4] ……

8. Run the following command to generate the comparison figure files (in .eps format):

./generateGNUPlot zc.config

(Note: the eps files will be generated and put in the current directory).

4. Application Programming Interface (API)

Programming interfaces are provided in C, and we provide a wrapper to call R script in the C code.

4.1 Initialization and finalization of the Z-checker environment

4.1.1 ZC_Init

int ZC_Init(char *configFilePath);

Description: ZC_Init is used to load the parameters set in the configuration file and allocate memory.

4.1.2 ZC_Finalize

void ZC_Finalize();

Description: ZC_Finalize is used to free the memory (data structure such as hash_table and compression result elements) allocated during the assessment.

4.2 Generic I/O

4.2.1 ZC_readDoubleData in bytes

double *ZC_readDoubleData(char *srcFilePath, size_t *nbEle);

Description: ZC_readDoubleData is used to read the double-precision binary data file.

Arguments: char *srcFilePath – the file path of the binary data file

Int *nbEle – the number of data points in the data set.

Return: the pointer that points to the data set read from the file

4.2.2 ZC_readFloatData in bytes

float *ZC_readFloatData(char *srcFilePath, size_t *nbEle);

Description: ZC_readFloatData is used to read the single-precision binary data file.

Arguments: char *srcFilePath – the file path of the binary data file

size_t *nbEle – the number of data points in the data set.

Return: the pointer that points to the data set read from the file

4.2.3 ZC_writeFloatData_inBytes

void ZC_writeFloatData_inBytes(float *data, size_t nbEle, char* tgtFilePath);

Description: write single-precision floating-point data into a file in binary format.

Arguments: float *data – the data set

size_t nbEle – the number of data points

char* tgtFilePath – the file path of the data file

4.2.4 ZC_writeDoubleData_inBytes

void ZC_writeDoubleData_inBytes(double *data, size_t nbEle, char* tgtFilePath);

Description: write double-precision floating-point data into a file in binary format.

Arguments: double *data – the data set

size_t nbEle – the number of data points

char* tgtFilePath – the file path of the target data file

4.2.5 ZC_writeData in text

void ZC_writeData(void *data, int dataType, size_t nbEle, char *tgtFilePath);

Description: write data in the textual format

Arguments: void *data – the data set

Int dataType – the data type (either ZC_FLOAT or ZC_DOUBLE)

size_t nbEle – the number of data points

char* tgtFilePath – the file path of the target data file

4.3 Data property analysis

4.3.1 ZC_genProperties

ZC_DataProperty* ZC_genProperties(char* varName, int dataType, void *oriData, size_t r5, size_t r4, size_t r3, size_t r2, size_t r1);

Description: perform property analysis and generate the analysis results..

Arguments: char* varName – the name of the variable

int dataType – the data type (either ZC_FLOAT or ZC_DOUBLE)

void* oriData – the data set analyze

size_t r5,r4,r3,r2,r1 – the sizes along each dimension (r1 changes fastest)

Return: the pointer pointing to the data structure ZC_DataProperty.

ZC_DataProperty:

```
typedef struct ZC_DataProperty
{
	char* varName;
	int dataType; /*ZC_DOUBLE or ZC_FLOAT*/
	size_t r5;
	size_t r4;
	size_t r3;
	size_t r2;
	size_t r1;

	void *data;

	long numOfElem;
	double minValue;
	double maxValue;
	double valueRange;
	double avgValue;
	double entropy;
	double zeromean_variance;
	double* autocorr; /*array of autocorrelation coefficients*/
	complex* fftCoeff; /*array of fft coefficients*/
	double* lap;
} ZC_DataProperty;
```

4.3.2 ZC_printDataProperty

void ZC_printDataProperty(ZC_DataProperty* property);

Description: Print the key property analysis results to the screen.

Arguments: ZC_DataProperty* property – the property results to print.

4.3.3 ZC_writeDataProperty

void ZC_writeDataProperty(ZC_DataProperty* property, char* tgtWorkspaceDir);

Description: Write the property analysis results to the files.

Arguments: ZC_DataProperty* property – the property results to dump

char* tgtWorkspaceDir – the target workspace directory to contain the results.

4.3.4 ZC_loadDataProperty

ZC_DataProperty* ZC_loadDataProperty(char* propResultFile);

Description: Load the data property from a property result file.

Arguments: char* propResultFile – the property analysis result file (*.prop).

Return: ZC_DataProperty* – the property analysis result

4.4 Data Comparison

4.4.1 ZC_compareData

ZC_CompareData* ZC_compareData(char* varName, int dataType, void *oriData, void *decData, size_t r5, size_t r4, size_t r3, size_t r2, size_t r1);

Description: Compare the original data and decompressed data and generate the comparison results.

Arguments: char* varName – variable name

Int dataType – the type of data (ZC_FLOAT or ZC_DOUBLE)

Void *oriData – the original data set

Void *decData – the decompressed data set

Size_t r5,r4,r3,r2,r1 – the sizes along each dimension (r1 changes fastest)

Return: ZC_CompareData* – the copmression result (the comparison between original data and decompressed data)

ZC_CompareData:

```
typedef struct ZC_CompareData
{
	ZC_DataProperty* property;

	double compressTime;
	double compressRate;
	int compressSize;
```

```
        double compressRatio; /*compression factor = orig_size/compressed_size*/
        double rate; /*# bits to be represented for each data point*/

        double decompressTime;
        double decompressRate;

        double minAbsErr;
        double avgAbsErr;
        double maxAbsErr;
        double* autoCorrAbsErr;
        double* absErrPDF; /*keep the distribution of errors (1000 elements)*/
        double* pwrErrPDF;
        double err_interval;
        double err_interval_rel;
        double err_minValue;
        double err_minValue_rel;

        double minRelErr;
        double avgRelErr;
        double maxRelErr;

        double minPWRErr;
        double avgPWRErr;
        double maxPWRErr;
        double snr;
        double rmse;
        double nrmse;
        double psnr;
        double valErrCorr;
        double pearsonCorr;

        complex *fftCoeff;
} ZC_CompareData;
```

4.4.2 ZC_printCompressionResult

void ZC_printCompressionResult(ZC_CompareData* compareResult);

Description: Print the compression results onto the screen.

Arguments: ZC_CompareData* compareResult – comparison results

4.4.3 ZC_writeCompressionResult

void ZC_writeCompressionResult(ZC_CompareData* compareResult, char* solution, char* varName, char* tgtWorkspaceDir);

Description: Write the comparison results to files.

Arguments: ZC_CompareData* compareResult – comparison results

Char* solution – the compression case, such as SZ_f(1E-3) or SZ_d(1E-3)

Char* varName – the name of the variable

Char* tgtWorkspaceDir – the target workspace directory to contain the results.

4.4.4 ZC_loadCompressionResult

ZC_CompareData* ZC_loadCompressionResult(char* cmpResultFile);

Description: Load the compression results into the memory (in order to for example generate the gnuplot figures)

Arguments: char* cmpResultFile – the compression result file, such as .cmp file in the ‘compressionResults’ directory.

4.5 Setting monitoring calls in compressor codes

4.5.1 ZC_startCmpr

ZC_DataProperty* ZC_startCmpr(char* varName, int dataType, void *oriData, size_t r5, size_t r4, size_t r3, size_t r2, size_t r1);

Description: ZC_startCmpr() function indicates a starting point of the compression. (You need to put this function right before calling a compression operation)

4.5.2 ZC_startCmpr_withDataAnalysis

ZC_DataProperty* ZC_startCmpr_withDataAnalysis(char* varName, int dataType, void *oriData, size_t r5, size_t r4, size_t r3, size_t r2, size_t r1);

Description: ZC_startCmpr_withDataAnalysis( ) integrates the data analysis.

Note:
This function includes the data analysis. That is, it will analyze the data and output the analysis results into the dataProperty/ directory. The analysis result includes auto-correlation of the data, spectrum result (based on FFT), distribution of the data, entropy, etc.

data analysis is costly, so we suggest to call ZC_startCmpr instead of ZC_startCmpr_withDataAnalysis in most cases.

4.5.2 ZC_endCmpr

ZC_CompareData* ZC_endCmpr(ZC_DataProperty* dataProperty, size_t cmprSize);

Description: This function indicates an ending point of the compression operation.

Arguments: ZC_DataProperty* dataProperty – the data property generated/returned by ZC_startCmpr.

size_t cmprSize – the compressed size

Return: ZC_CompareData* - the compression results.

4.5.3 ZC_startDec

void ZC_startDec();

Description: This function indicates the starting point of the decompression operations.

4.5.4 ZC_endDec

void ZC_endDec(ZC_CompareData* compareResult, char* solution, void *decData);

Description: This function specifies the ending point of the decompression.

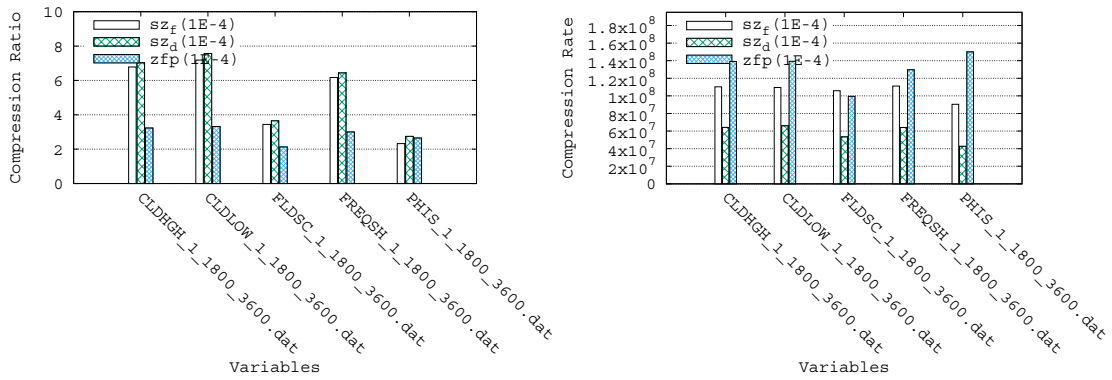
4.6 Plotting the analysis data suitable for Gnuplot

4.6.1 ZC_ plotHistogramResults

void ZC_plotHistogramResults(int cmpCount, char** compressorCases);

Description: Generate .eps files for histogram-style results, including compression ratios, compression rate, decompression rate, and PSNR.

Example output (in the directory ‘compareCompressors’) based on compression ratio and compression rate:



Arguments: int cmpCount – the number of compressor cases

Char** compressorCases – the compressor cases

4.6.2 ZC_plotComparisonCases

void ZC_plotComparisonCases();

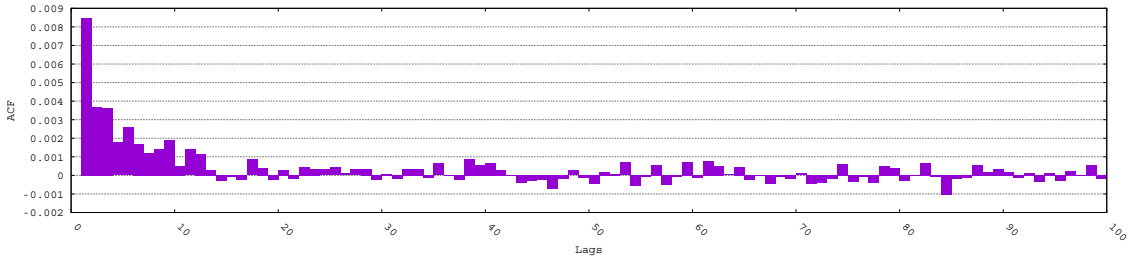
Description: Plot comparison cases. This function calls ZC_plotHistogramResults to complete the plotting work.

4.6.3 ZC_plotAutoCorr_CompressError

void ZC_plotAutoCorr_CompressError();

Description: Plot auto-correlation coefficients based on compression errors.

Example output:

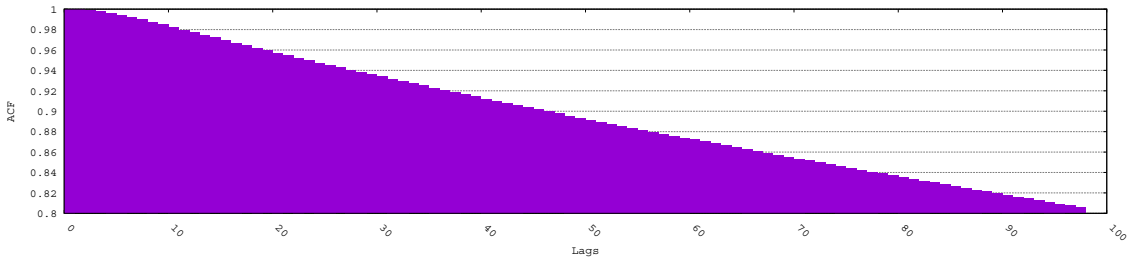


4.6.4 ZC_plotAutoCorr_DataProperty

void ZC_plotAutoCorr_DataProperty();

Description: Plot auto-correlation coefficients based on data set.

Example output:

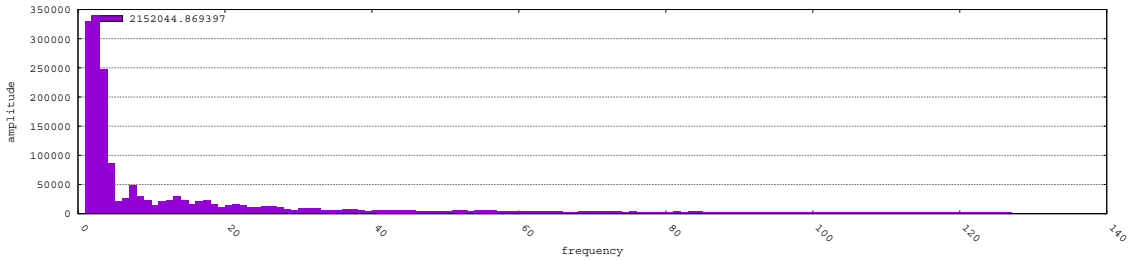


4.6.5 ZC_plotFFTAmplitude_OriginalData

void ZC_plotFFTAmplitude_OriginalData();

Description: Plot FFT amplitude for original data.

Example output:

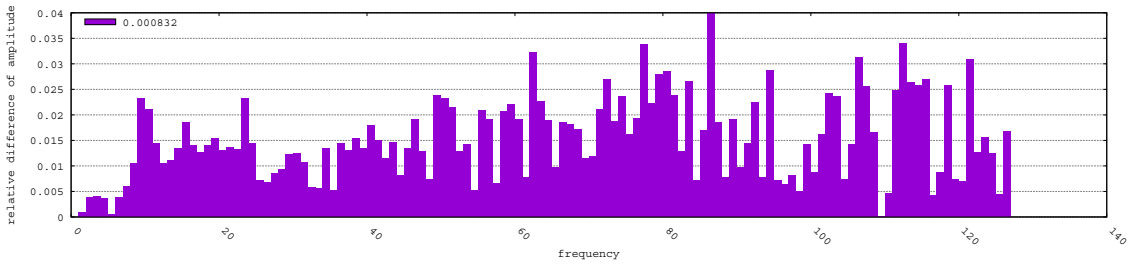


4.6.6 ZC_plotFFTAmplitude_DecompressData

void ZC_plotFFTAmplitude_DecompressData();

Description: Plot FFT amplitude difference between the original data and decompressed data.

Example output:

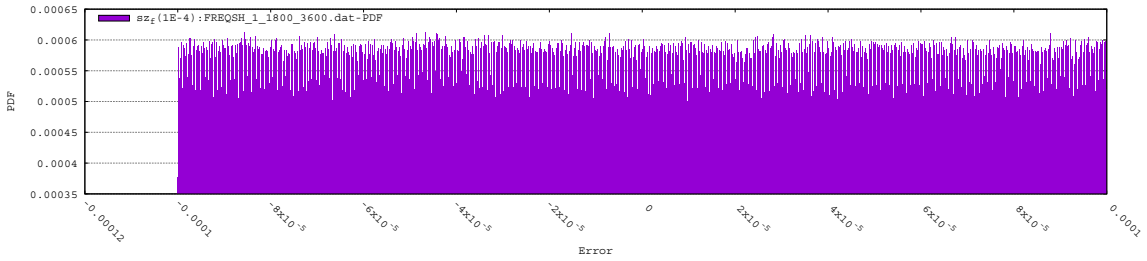


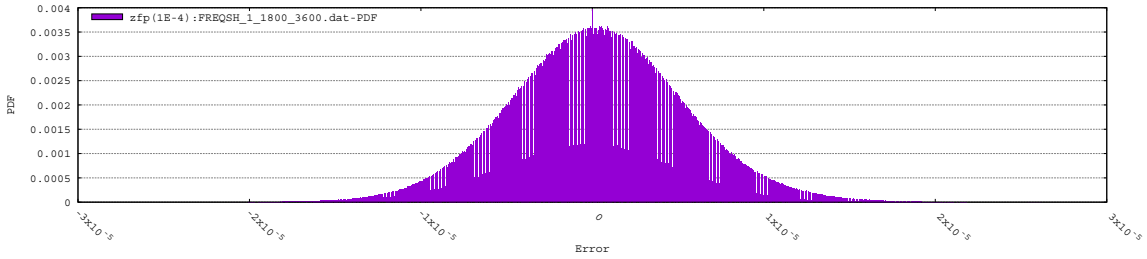
4.6.7 ZC_ plotErrDistribtion

void ZC_plotErrDistribtion();

Description: Plot the distribution of compression errors.

Example output (the first one is SZ and the second is based on ZFP)





4.7 Generating Gnuplot scripts

4.7.1 genGnuplotScript_linespoints

char** genGnuplotScript_linespoints(char* dataFileName, char* extension, int fontSize, int columns, char* xlabel, char* ylabel);

Description: Generate Gnuplot script based on lines-points format.

4.7.2 genGnuplotScript_histogram

char** genGnuplotScript_histogram(char* dataFileName, char* extension, int fontSize, int columns, char* xlabel, char* ylabel, long maxYValue);

Description: Generate Gnuplot script for histogram data.

4.7.3 genGnuplotScript_lines

char** genGnuplotScript_lines(char* dataFileName, char* extension, int fontSize, int columns, char* xlabel, char* ylabel);

Description: Generate Gnuplot script based on line-type format.

4.7.4 genGnuplotScript_fillsteps

char** genGnuplotScript_fillsteps(char* dataFileName, char* extension, int fontSize, int columns, char* xlabel, char* ylabel);

Description: Generate Gnuplot script based on fill-steps format.

4.8 Generating analysis report in PDF file format

Please see examples/generateReport.c for details.

4.9 Calling R script from Z-checker

The wrapper codes for calling R scripts from Z-checker can be found in [DOWNLOAD_PACKAGE]/R. You need to modify Makefile by setting the R installation path, before the compilation with “make”.
Specifically, the R installation path is set as follows:
R_BASE = [Your installation path of R] (e.g., /usr/lib64/R); hint: you could run the command "which Rscript" to check where it is.
For example, in my machine, R_Base=/usr/lib64/R.

After the compilation of R, you can use the executable called “zccallr” in the directory ./test/ to run any R script. It calls different functions such as ZC_callR_1_1d, SZ_callR_1_2d, to execute the function in a specific R script.

Before calling ZC_callR_x_xd, you need to initialize the environment as follows:

```
//Initialize an embedded R session
int r_argc = 2;
char *r_argv[] = { "R", "--silent" };
Rf_initEmbeddedR(r_argc, r_argv);

// Invoke a function in R
source(rscriptPath);    //rscriptPath is the file path of a R script
```

We describe the API as follows.

4.9.1 ZC_callR_1_1d

int ZC_callR_1_1d(char* rRuncName, int vecType, size_t inLen, void* in, size_t * outLen, double** out);

Description: This function calls an R function with one 1D data set (i.e., a vector) as input.

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the vector

size_t inLen – the number of elements in the vector

void* in – the pointer that points to the data set

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

4.9.2 ZC_callR_2_1d

int ZC_callR_2_1d(char* rFuncName, int vecType, size_t in1Len, void* in1, size_t in2Len, void* in2, size_t * outLen, double** out);

Description: This function calls an R function with two 1D data sets (i.e., two vectors).

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the vector

size_t in1Len – the number of elements in the first vector

void* in1 – the pointer that points to the first vector.

size_t in2Len – the number of elements in the second vector

void* in2 – the pointer that points to the second vector.

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

4.9.3 ZC_callR_1_2d

int ZC_callR_1_2d(char* rFuncName, int vecType, size_t in_n2, size_t in_n1, void* in, size_t * outLen, double** out);

Description: This function calls an R function with one 2D data set (i.e., a matrix) as input.

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the vector

size_t in_n2 – the size of the higher dimension for the matrix

size_t in_n1 – the size of the lower dimension for the matrix

void* in – the pointer that points to the matrix data

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

4.9.4 ZC_callR_2_2d

int ZC_callR_2_2d(char* rFuncName, int vecType, size_t in1_n2, size_t in1_n1, void* in1, size_t in2_n2, size_t in2_n1, void* in2, size_t* outLen, double** out);

Description: This function calls an R function with two 2D data sets (i.e., a matrices).

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the vector

size_t in1_n2 – the size of the higher dimension for the first matrix

size_t in1_n1 – the size of the lower dimension for the first matrix

void* in1 – the pointer that points to the first matrix data.

size_t in2_n2 – the size of the higher dimension for the second matrix

size_t in2_n1 – the size of the lower dimension for the second matrix

void* in2 – the pointer that points to the second matrix data.

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

4.9.5 ZC_callR_1_3d

int ZC_callR_1_3d(char* rFuncName, int vecType, size_t in_n3, size_t in_n2, size_t in_n1, void* in, size_t * outLen, double** out);

Description: This function calls an R function with one 3D data set (i.e., a matrix) as input.

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the vector

size_t in_n3 – the size of the highest dimension for the matrix

size_t in_n2 – the size of the middle dimension for the matrix

size_t in_n1 – the size of the lowest dimension for the matrix

void* in – the pointer that points to the matrix data

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

4.9.5 ZC_callR_2_3d

int ZC_callR_2_3d(char* rFuncName, int vecType, size_t in1_n3, size_t in1_n2, size_t in1_n1, void* in1, size_t in2_n3, size_t in2_n2, size_t in2_n1, void* in2, size_t * outLen, double** out);

Description: This function calls an R function with two 3D data sets (i.e., two matrices).

Arguments: char* rRuncName – the function name in the R script.

Int vecType – the data type of the two matrices

size_t in1_n3 – the size of the highest dimension for the first matrix

size_t in1_n2 – the size of the middle dimension for the first matrix

size_t in1_n1 – the size of the lowest dimension for the first matrix

void* in1 – the pointer that points to the first matrix data

size_t in2_n3 – the size of the highest dimension for the second matrix

size_t in2_n2 – the size of the middle dimension for the second matrix

size_t in2_n1 – the size of the lowest dimension for the second matrix

void* in2 – the pointer that points to the second matrix data

size_t* outLen – the number of elements in the output data set

double** out – the pointer pointing to the output data set. (new memory will be allocated in the function)

Return: status (either ZC_R_SUCCESS or ZC_R_ERROR)

5 Configuration file

You can switch on/off the metrics to check in the configuration file (zc.config) based on your demand. Please see the comments in the sz.config file for details.
In particular, there are two modes for running z-checker, “probe” mode and “analysis” mode. The former indicates the online checking by running the compressor, and the latter is to collect the compression results based on the previous probe-mode runs.

The configuration file actually is not a must when running a compressor with the z-checker as a probe/monitor. If configuration file is not used in the probe-mode running, all metrics will be switched on by default.

Note that if the z-checker is running in the “analysis” mode, please do remember to switch the checkingStatus parameter to “analysis” from “probe”.

6. Version history

The latest version (**version 0.1.x**) is the recommended one.

Version	**New features**
ZC 0.1.0	Prototype of Z-checker. It’s able to perform the data analysis for the original data set and compression quality analysis based on specific data compressors.
ZC 0.1.1	In the z-checker-installer, the users are able to set different error bounds for different compressors. It also supports using a configuration file (such as varInfo.txt) to specify the data files with the data having different dimension sizes.

7. Q&A and Trouble shooting

TBD

<END>