SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA
FACULTY OF ELECTRICAL ENGINEERING AND
INFORMATION TECHNOLOGY

PARANOYA

TEAM PROJECT

2020 Lóránt Boráros, Filip Budáč, Martin Cehelský, Silvia Holecová

SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA
FACULTY OF ELECTRICAL ENGINEERING AND
INFORMATION TECHNOLOGY

PARANOYA

TEAM PROJECT

Study Programme:	Applied Informatics
Course:	TP – Team project
Lecturer:	Mgr. Ing. Matúš Jókay, PhD.
Teaching assistant:	Mgr. Ing. Matúš Jókay, PhD.

Bratislava 2020 Lóránt Boráros, Filip Budáč, Martin Cehelský, Silvia Holecová

Contents

List of Figures and Tables

Introduction

The theme of team project is actualization of existing application called ParanoYa. This application was created on faculty of electrical engineering and information technology by students. ParanoYa was developed for statistical testing of pseudo random sequences. With this application is also possible to evaluate achieved results for testing sequences which are processed in Microsoft Excel.

In the first section is discussed the analysis for the given problem. There is described current state of the application, implemented test sets which are used in application, analysis of existing projects and solutions methods which we would like to use for the given problem.

The next section contains new graphical design interface for the application. There are also UML diagrams which describe whole functionality of the application. This section also contains acceptance tests for every application use case.

1 Analysis

This section describes complete analysis of the given problem. There are described existing programs which are similar as paranoYa, current status of the application, methods used in evaluate test and also test sets used in application with detailed description of each of them. There are also included functional requirements for the application.

1.1 Existing programs

Nowadays existing multiple applications which are similar as paranoYa. Analysing of these applications we found that none of them doesn't implement all of these test sets FIPS, NIST and Diehard, as paranoYa. ParanoYa was also designed for future extensions. But these existing applications don't have this possibility. Below are described applications which were analysed:

1. **Ent** is a console application, which is useful to test sequences of pseudo-random number generators for encryption, compression and statistical sampling. The application can run a variety of tests, including:

    - **Entropia**
    - **Chi-square Test**
    - **Arithmetic mean**
    - **Monte Carlo Value of Pi**
    - **Serial Correlational Coefficient**

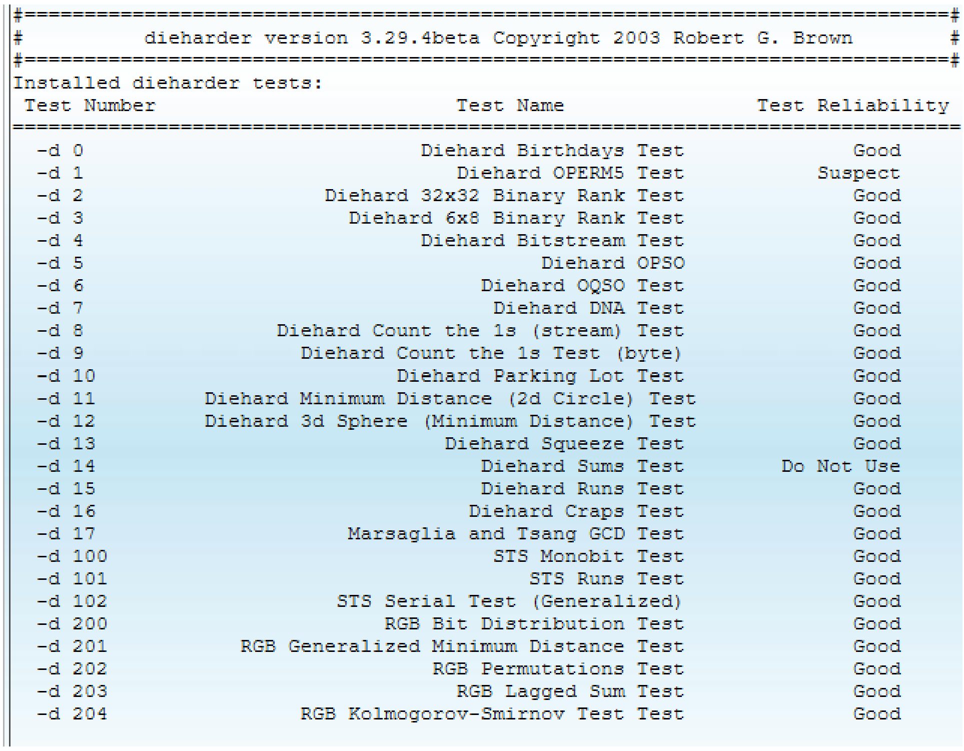
    Ent offers a number of options regarding input and output formats of the data:

    - **-b**

      Data input is treated as bit-stream instead of byte-stream.
    - **-c** A table of characters is printed to the standard output. The table includes the decimal value of each character paired with the corresponding printable character in ISO 8859-1 Latin-1.
    - **-f**

      Characters of upper-case letters are changed to lower-case.
    - **-t**

      Output format is changed to *terse mode* which means that the output values are seperated by a comma(CSV format).



```
#=============================================================================#
#          dieharder version 3.29.4beta Copyright 2003 Robert G. Brown        #
#=============================================================================#
Installed dieharder tests:
 Test Number                         Test Name                Test Reliability
===============================================================================
  -d 0                            Diehard Birthdays Test              Good
  -d 1                               Diehard OPERM5 Test           Suspect
  -d 2                    Diehard 32x32 Binary Rank Test              Good
  -d 3                      Diehard 6x8 Binary Rank Test              Good
  -d 4                            Diehard Bitstream Test              Good
  -d 5                                      Diehard OPSO              Good
  -d 6                                 Diehard OQSO Test              Good
  -d 7                                  Diehard DNA Test              Good
  -d 8                Diehard Count the 1s (stream) Test              Good
  -d 9                  Diehard Count the 1s Test (byte)              Good
  -d 10                         Diehard Parking Lot Test              Good
  -d 11       Diehard Minimum Distance (2d Circle) Test              Good
  -d 12       Diehard 3d Sphere (Minimum Distance) Test              Good
  -d 13                             Diehard Squeeze Test              Good
  -d 14                                Diehard Sums Test        Do Not Use
  -d 15                                Diehard Runs Test              Good
  -d 16                               Diehard Craps Test              Good
  -d 17                     Marsaglia and Tsang GCD Test              Good
  -d 100                                STS Monobit Test              Good
  -d 101                                   STS Runs Test              Good
  -d 102                     STS Serial Test (Generalized)             Good
  -d 200                         RGB Bit Distribution Test              Good
  -d 201             RGB Generalized Minimum Distance Test              Good
  -d 202                             RGB Permutations Test              Good
  -d 203                               RGB Lagged Sum Test              Good
  -d 204                  RGB Kolmogorov-Smirnov Test Test              Good
```

Figure 1: Dieharder test suite

- **-u**

  Prints manual.

2. **Dieharder** is an improved version of *Diehard battery of tests* with a cleaned up source code implemented in C programming language. Thanks to the improvements the tests run considerably faster. Furthermore the new structre enables the incorporation of new sets of tests in the future. It also enables to test generators directly by accepting a infinite stream of numbers.**Dieharder** is an open-source project available for free download in its website.

3. **Practically random** is a library implemented in the C++ programming language. It is suited for testing random number generators-*RNG*

4. **TestU01** is library implemented in ANSI C programming language. The library contains functions for empirical testing of random number generators. The application provides classical statistical test as well as some original ones. Basic plotting of the generated numbers is also available.

1.2 The current status of the application

Application named ParanoYa is used for statistical testing pseudo random sequences. In this application, are implemented various test sets like NIST, FIPS, Diehard. With this application it is also possible to evaluate each testing sequence. Using the application it is also possible to evaluate individual tested sequences based on two methodologies. Output of the application is processed in Microsoft Excel document. With this document we can evaluate the achieved results. Application was created with framework Qt and used test suites are implemented in C. Full description of the aplication ParanoYa can be found in attachment **A**.

1.3 Methods used in evaluate tests

The application using two methods for evaluate tests. In output file are saved results of testing sequences. Each of these values is called p-value and represents the probability that another randomly generated sequence is worse in a given test. The tests are evaluated at a confidence level of $\alpha = 0.01$. If some p-value is smaller than α than testing sequence did not pass the test. A generator has not passed a test if less than 96% of the sequences have passed that test. This limit is set for the number of 100 sequences using a confidence interval based on the probability of error of the second kind.

1.4 Used test sets

Testing is a process when is executed one or more test cases based on specified conditions. During this process is compared current and expected behavior. In the application are implemented different sets of tests, for example NIST, FIPS a Diehard.

1. **NIST**

   NIST is statistical package of tests which is used to testing randomness of arbitrarily long binary sequences. This sequences are generated using a random or pseudo-random sequence generator. This package is consists of the following 15 test:

   (a) **The Frequency (Monobit) Test**

   The aim of this test is determine whether the ratio of zeros and units in a given sequence corresponds to the expected ratio for a random sequence. The number of units and zeros in the sequence should be approximately equal, which is also examined by the test.

   (b) **Frequency Test within a Block**

This test considers the ratio of zeros and units in M-bit blocks. The aim of the test is to determine whether frequency of M-bit block is approximately M/2.

(c) **The Runs Test**

In this test is important the total number of zeros and units in runs in whole sequence, where the run represents a continuous sequence of equal bits. A run of length k means that it consists of k identical bits and is bounded before and after with a bit having the opposite value. The purpose of this test is to determine whether the number of runs of units and zeros of varying length is as expected for random sequences. This test is mainly used to assess whether the variation between such substrings is too slow or too fast.

(d) **Tests for the Longest-Run-of-Ones in a Block**

This test focuses on the longest run units within M-bit blocks. Its purpose is to determine whether the length of the longest run units in the test sequence is consistent with the length of the longest run units expected in random sequences. Irregularity in the expected length of the longest run of units means that there exists an irregularity in the expected length of the longest run of zeroes. Long zero runs are not evaluated separately because of concerns about statistical independence between tests.

(e) **The Binary Matrix Rank Test**

The test is aimed at the discontinuous order of the submatrices in the whole sequence. The purpose of this test is checking the linear dependence in the fixed length of the substrings of the original sequence.

(f) **The Discrete Fourier Transform (Spectral) Test**

The focus of this test are the heights of the peaks in the Fourier transform. The purpose of this test is detect periodic functions (for example, repeating patterns that are close together) in a test sequence that would indicate a deviation from the assumption of randomness.

(g) **The Non-overlapping Template Matching Test**

The random number sequence is divided into independent substrings of length M and the number of occurrences of template B, which represents the m-bit run units in each of the substrings. IfP-value chi-square of statistic is less than the significance level, the test concludes that the test sequence appears random. Otherwise, the test concludes that the retest appears to be random. The throughput is defined by the ratio of the sequences that passed the test.

(h) **The Overlapping Template Matching Test**

This test detects the number of occurrences in pre-specified target strings. The test uses an m-bit window to search for a specific m-bit pattern. If the pattern is not found, the window moves about one bit position. If the searched pattern is found, the window moves only one bit before resuming the search.

(i) **Maurer's "Universal Statistical" Test**

The purpose of this test is determine whether the sequence can be significantly compressed without losing information or not. A too compressed sequence is considered as non-random.

(j) **The Linear Complexity Test**

The purpose of this test is determine whether the sequence is sufficiently complex to be considered as random.

(k) **The Serial Test**

The purpose of this test is determine whether the number of occurrences of overlapping m-bit patterns is approximately the same as would be expected in a random sequence.

(l) **The Approximate Entropy Test**

The test focuses on the frequency of any possible overlap of m-bit patterns in the whole sequence. The purpose of this test is to compare the frequency of the overlapping blocks of two consecutive or adjacent lengths (m and m + 1) with the expected result for a random sequence.

(m) **The Cumulative Sums (Cusums) Test**

This test focuses on the maximum deviation (from zero) of the random walk (defined by the cumulative sum of the adjusted (-1, +1) digits in sequence). The aim of the test is determine whether the cumulative sum of the partial sequences occurring in the test sequence is too large or too small relative to the expected behavior of this cumulative sum for the random sequences. This cumulative sum can be considered as a random walk. The random walk deviation should be near zero for a random sequence. For certain types of random sequences, the deviations of this random walk will be greater than zero.

(n) **The Random Excursions Test**

The test is focused on the number of cycles that have exactly K occurrences in the cumulative sum of random steps. The cumulative sum can be found if the subtotals (0, 1) of the sequence are adjusted to (-1, +1). The random deviation of the random steps consists of a sequence of n steps of unit length. The purpose of the test is determine whether the number of occurrences of the state with random-step exceeds what is expected of the random sequence.

(o) **The Random Excursions Variant Test**

This test examines how many times is occurred specific status in a cumulative sum of random steps. The goal is detect deviations from the expected number of occurrences of different states in random steps.

These tests deal with the different types of randomness that might arise in sequence. Some of the tests could be broken down into different subtests. The order in which the tests are run is arbitrary, but it is recommended that the Frequency test be run first, because if this test fails, the probability of failing further tests is very high.

2. **FIPS** nist sp-822,fips 140-2 Test Federal Information Processing is the US government security standard used to validate cryptographic modules. FIPS provides different types of security based on a defined level of security. There are four such levels:

   (a) **Level 1** - the lowest security level that does not require specific physical security mechanisms but requires the use of at least one approved security algorithm or function

   (b) **Level 2** - this level requires role-based access control, as well as physical security

   (c) **Level 3** - in this level is provided identity-based authentication and physical security. It should include an attack detection mechanism. If the system were hacked, the system should be able to delete critical security parameters

   (d) **Level 4** - it is the highest level of security. In addition to the above-mentioned requirements for the system, the requirements of physical security are tighten, it is especially advantageous for working in a physically unprotected environment

FIPS validation involves intensive testing to identify specific deficiencies and weaknesses. For the system to meet FIPS validation, it needs to include cryptographic algorithms and hash functions. The three best known examples are AES, Triple DES, and HMAC SHA-1.

3. **Diehard**

   Diehard tests are statistical tests used to evaluate the quality of the random number generator. The Diehard test battery consists of various, independent statistical tests. The results of these assays are referred to as p-values. Diehard's tests include:

   (a) **The Birthday spacings test**

   This test first selects m birthdays in a year with n days, then it is a list of birthday gaps between birthdays. Finally, the Poisson asymptotically distribution of j value is assessed. The j value is the number of values that are in the list of spaces. If it is multiple times in the list, then j is asymptotically Poisson divided with diameter $m^3/(4n)$. n must be large enough to compare the results with the Poisson distribution.

   (b) **Overlapping permutations**

   This test follows a sequence of one million 32-bit random integers. Each set of five consecutive integers can be in one of 120 states for 5! possible arrangement of five numbers.

   (c) **Ranks of matrices**

   This test is performed by selecting a number of bits from a number of random numbers to form a matrix above [0,1] and then is determining the matrix order. The number of rows should follow a certain distribution.

   (d) **Monkey test**

   Also called as bitstream test. This test has its name from an endless "monkey theorem". It is best achieved by processing sequences of a certain number of bits as "words" and counting the overlapping words in the steam. The number of "words" that do not appear should follow the known distribution.

   (e) **Count the 1s**

   The test is done through counting the 1 bits in each of either successive or chosen bytes and converting the counts to "letters", and counting the occurrences of five-letter "words".

   (f) **Parking lot test**

   Randomly place unit circles in a 100 x 100 square. If the circle overlaps an existing one, try again. After 12,000 tries, the number of successfully "packed" circles should follow a certain normal distribution.

(g) **Minimum distance test**

Randomly place 8000 points in a 10,000 x 10,000 square and then find the minimum distance between the pairs. The square of this distance should be exponentially distributed with a certain mean.

(h) **Random spheres test**

Randomly choose 4000 points in a cube of edge 1000. Center a sphere on each point, whose radius is the minimum distance to another point. The smallest sphere s volume should be exponentially distributed with certain mean.

(i) **The squeeze test**

Multiply 231 by float random integers on [0,1) until you reach 1. Repeat this 100,000 times. The number of floats needed to reach 1 should follow a certain distribution.

(j) **Overlapping sums test**

Generate a long sequence of random floats on [0,1). Add sequence of 100 consecutive floats. The sums should be normally distributed with characteristic mean and sigma.

(k) **Runs test**

Generate a long sequence of random floats on [0,1). Count ascending and descending runs. The counts should follow a certain distribution.

(l) **The craps test**

Play 200,000 games of craps, counting the wins and the number of throws per game. Each count should follow a certain distribution.

1.5 Solution methods

The core of the application, test sets, are represented as C libraries. User interface is created using Qt framework and application output is currently presented within an *.xls* file, readable in spreadsheet editors. The solution design is divided into several steps:

1. **Project actualisation compatible with current design environments** We decided to use Python for developing user iterface. Using Cython library we created an python-c interface. A shared object file "*.so*" was created from the C libraries. The shared object enables us to dynamically connect library with different programs.

1.6 Functional requirements

- **Statistic pseudorandom sequence testing** - user will be able to statistically test pseudorandom sequences using implemented test sets
- **Adjusting of tests** - user will be able to adjust and edit tests by their criteria
- **Evaluation of testing sequences** - after sequence testing, user will be able to view test evaluation based on selected methodology

2 GUI - Graphical user interface

This sections contains new design for user interface of application paranoYa. There are displayed individual windows with their functionality.

2.1 Opening window

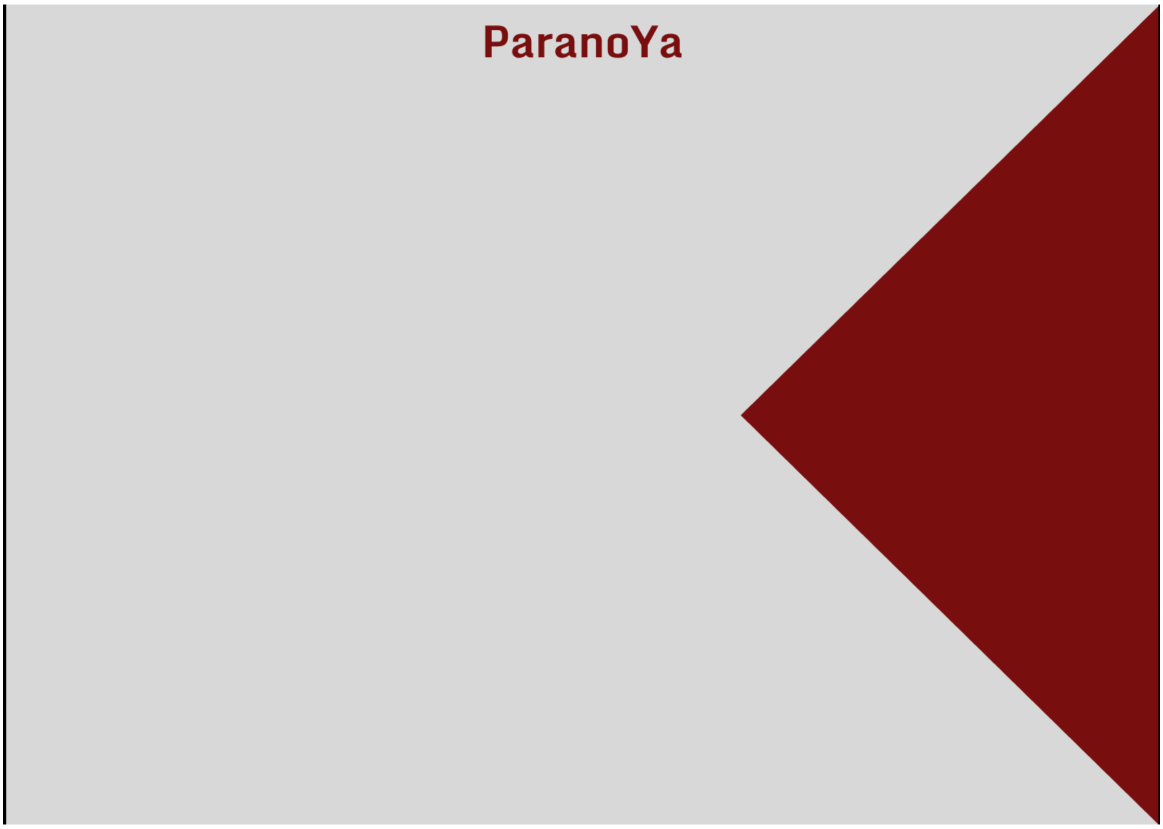


Figure 2: Opening window

Purpose:	The user is greeted with this opening window.
Navigation and User Interaction:	After opening the application this window is shown. When the application is use it is automatically redirected to the next window.

2.2 Main menu

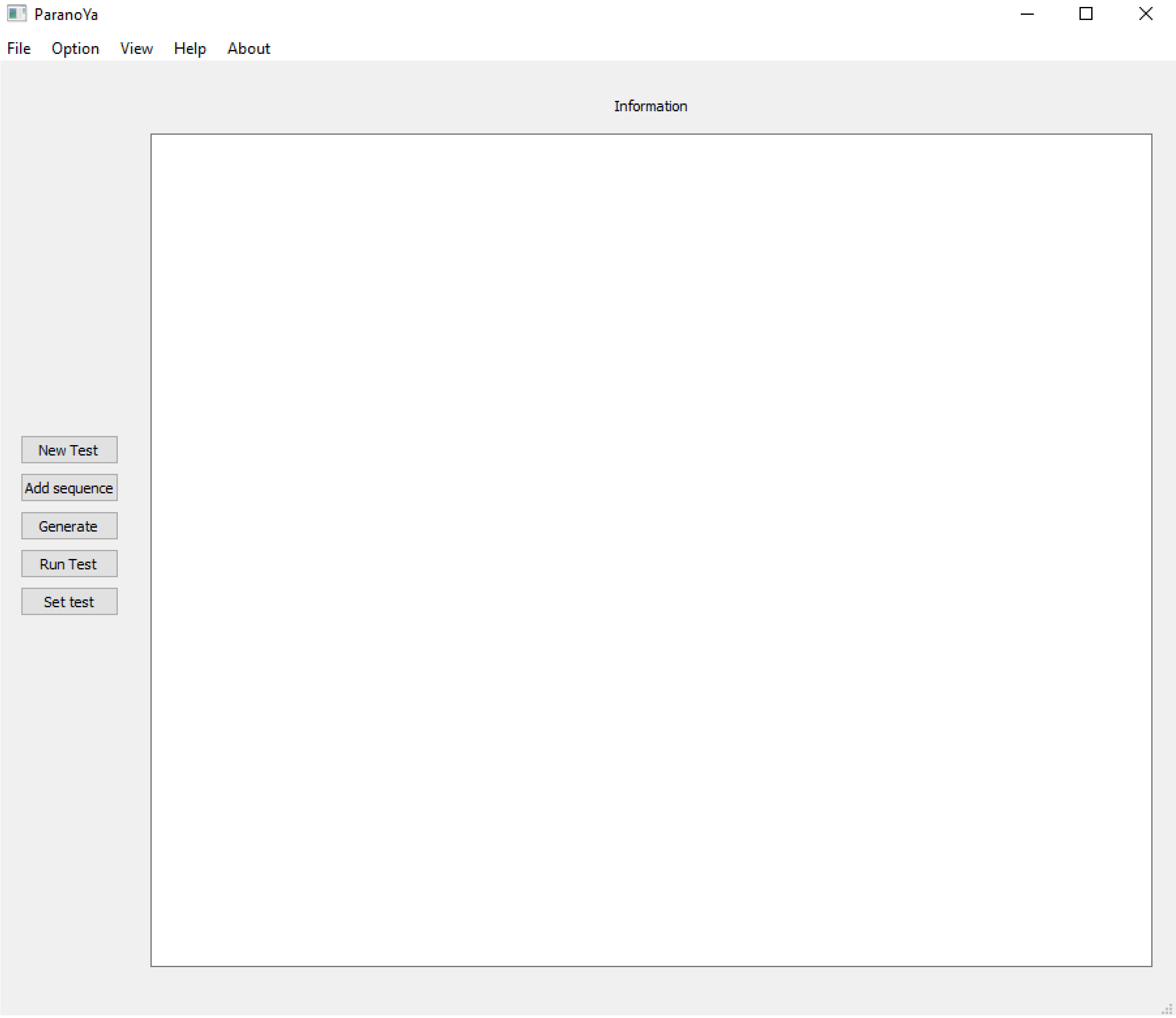
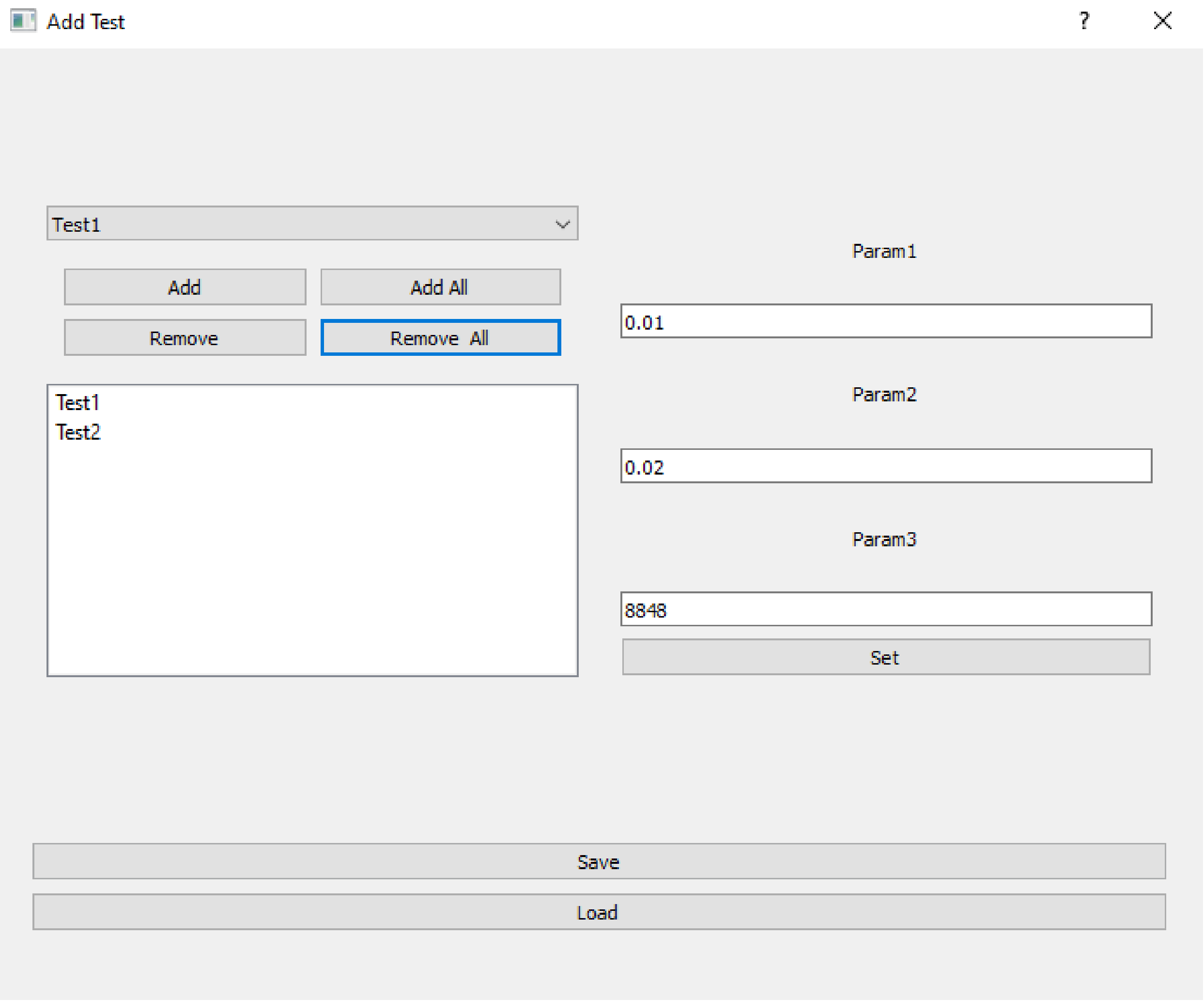


Figure 3: Main menu

Purpose:	Every function of the application is available from this window: • **New test** • **Add sequence** • **Generate sequence** • **Run test** • **Set test**
Navigation and User Interaction:	The user can choose an action by clicking the buttons. The corresponding windo appear immediately after that.

2.3 New Test



Add Test

Test1

Test1
Test2

Param1

0.01

Param2

0.02

Param3

8848

Figure 4: New Test

Purpose:	The user is able to create a new set of tests, save that set or load from an ex previously saved set.
Navigation and User Interaction:	By clicking the button **Add** the user is able to add a new test to the set. The ne will be chosen from a drop-down list containing all available test. Test parameters can be set on the right handside of the window and by clicking t button the changes will be saved. A selected test can be removed by clicking the **Remove** button. By clicking the **Add All** button the user is able to easily add all available tests t By clicking the **Remove All** button the user can remove all tests from the set. By clicking the button **Save** the user is able to save the current set of tests. By clicking the button **Load** the user is able load a previously save set of tests.

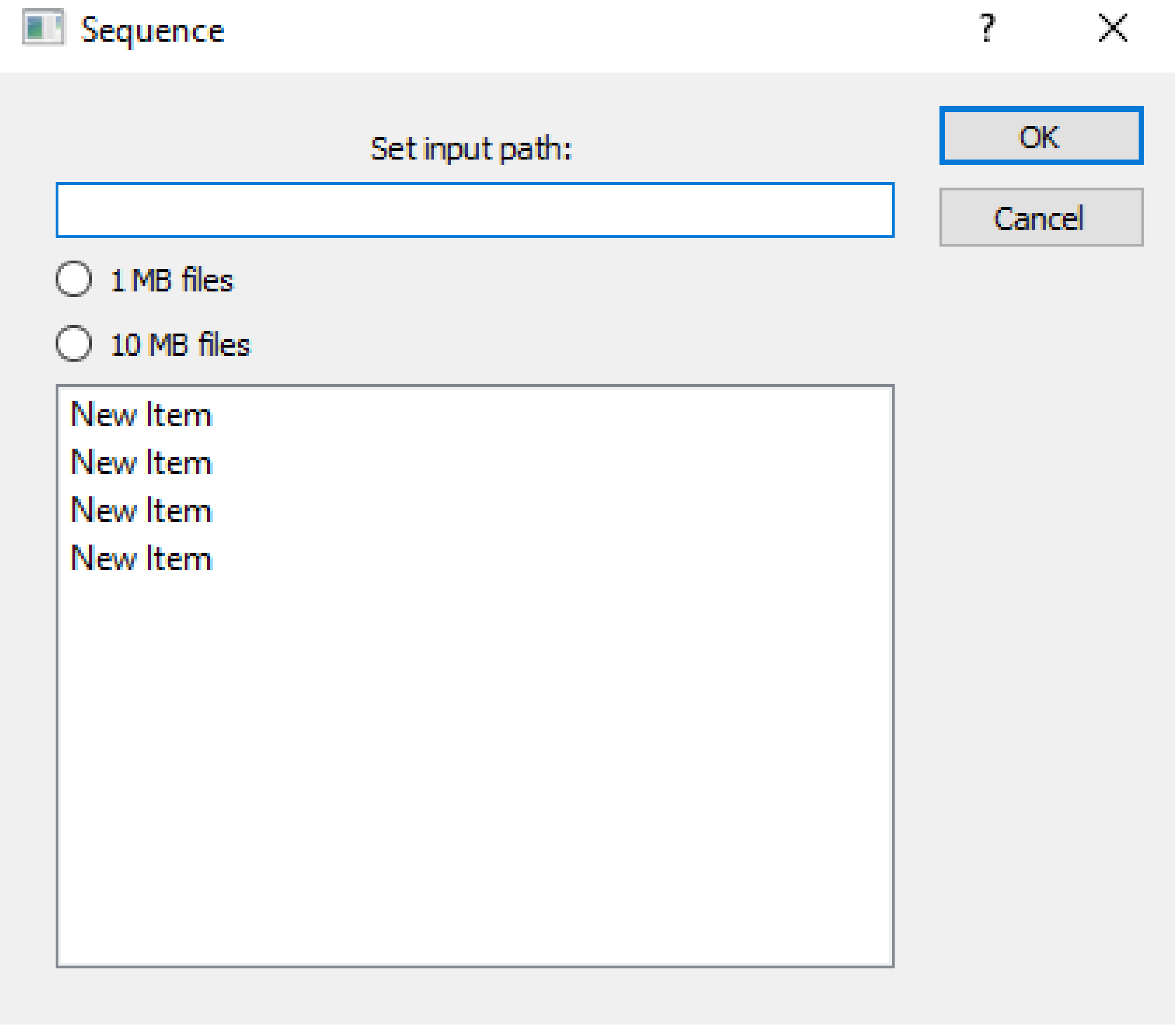


Figure 5: Add sequence

Purpose:	The user can add sequences for testing.
Navigation and User Interaction:	The user can specify the source folder which contains the sequences to be tested. have to specify the size of the source files. Currently ParanoYa support fixed s 1MB and 10MB. After clicking the button **Ok** the files in the specified folder imported. By clicking the **Cancel** button, the window is closed.

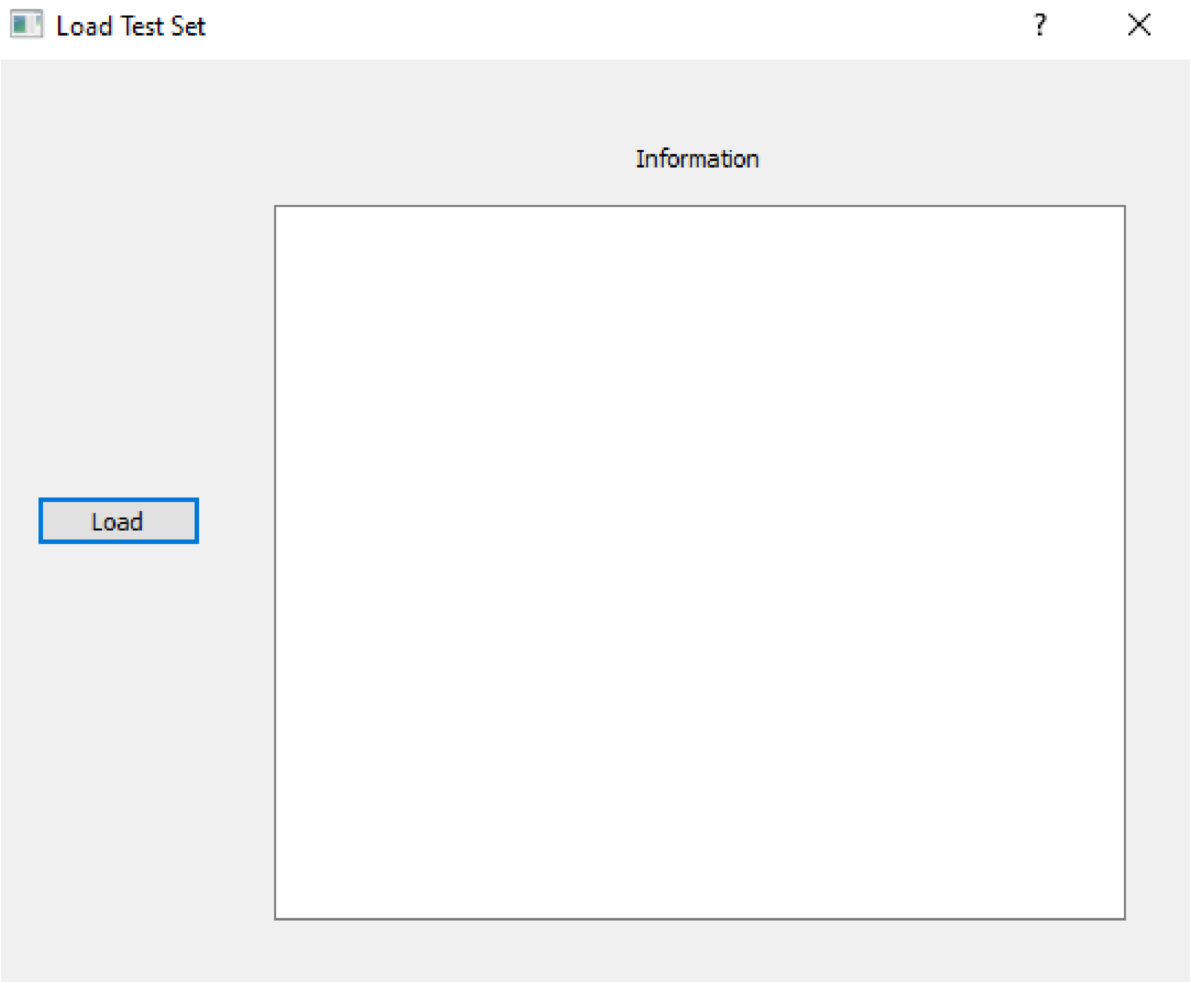
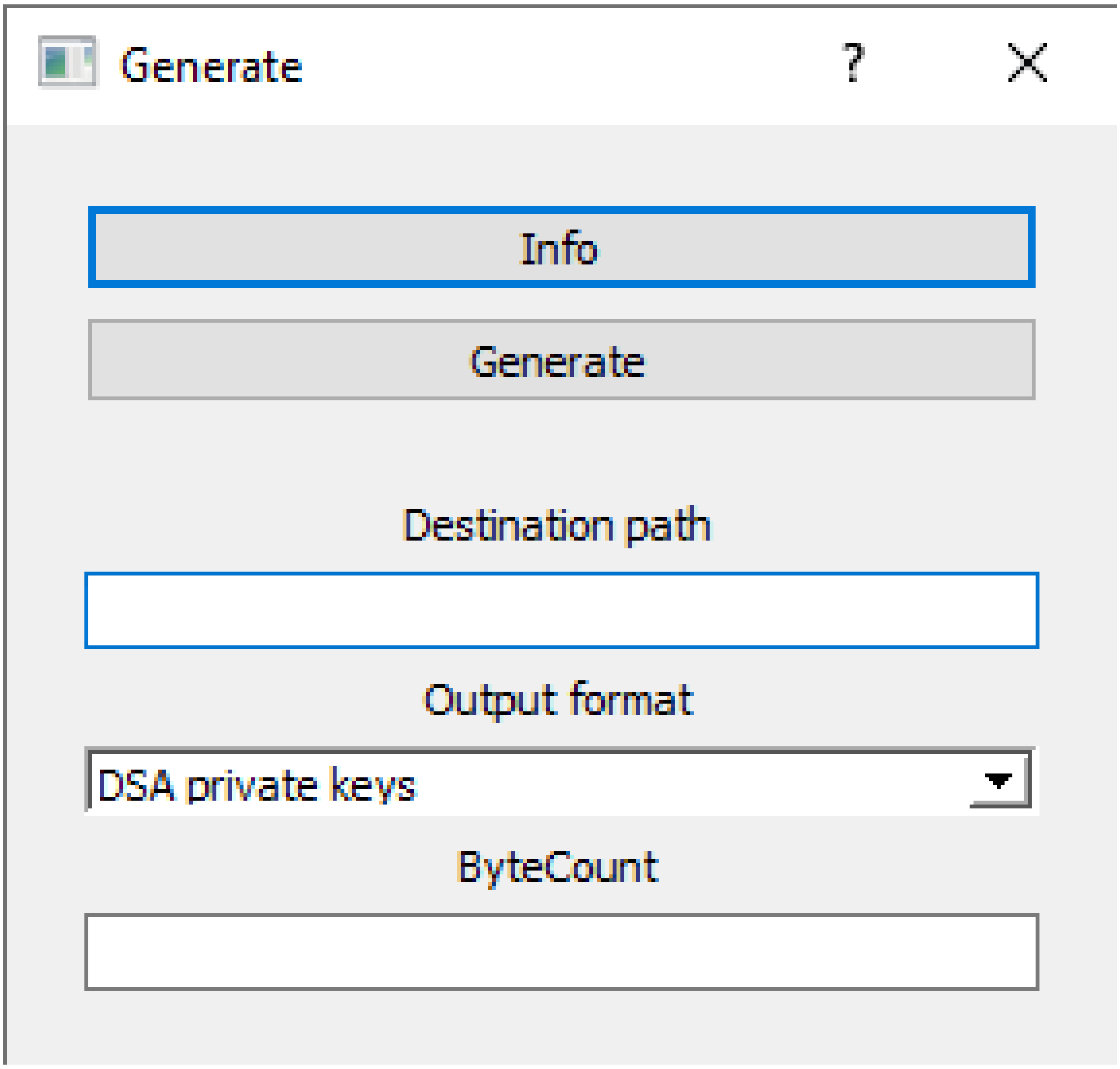


Figure 6: Set test

Purpose:	The user can choose from previously created test sets.
Navigation and User Interaction:	The user can choose from a list of predefined test set and load a selected set by c the **Load** button.

2.4 Generate



Output format

DSA private keys

Figure 7: Generate

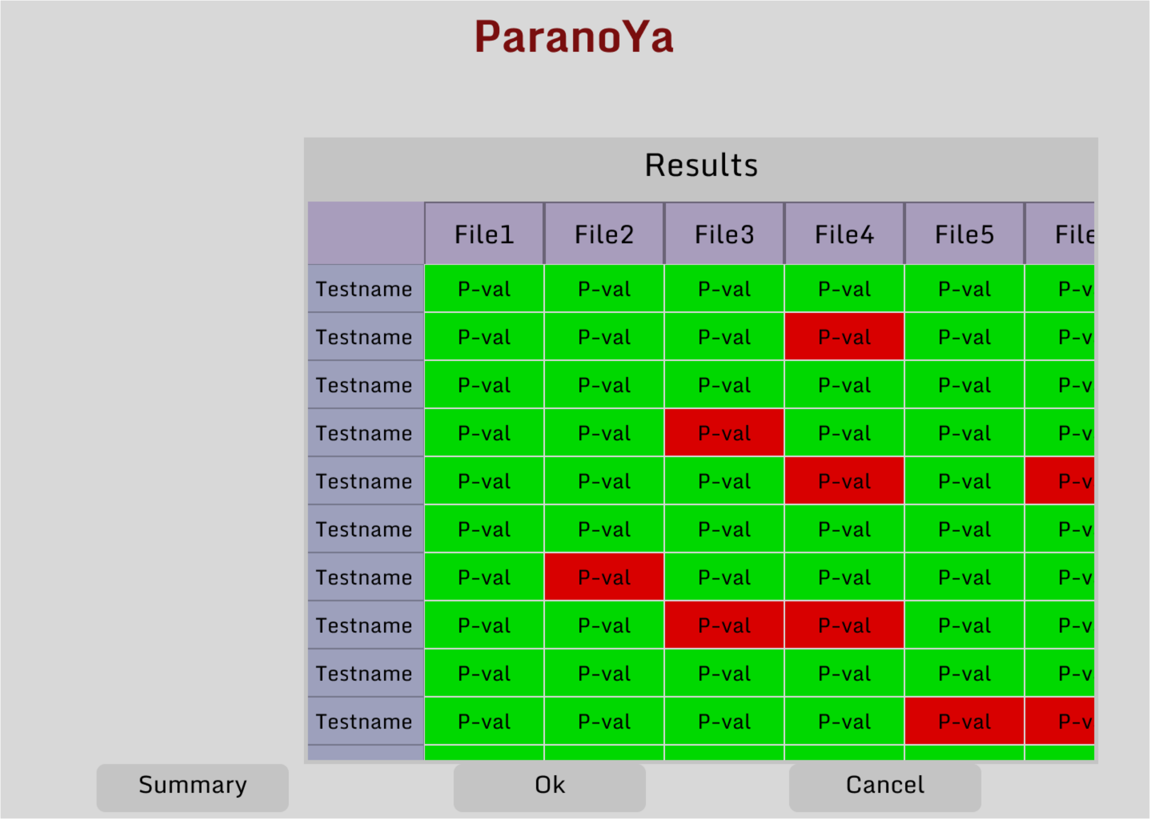
Purpose:	The user is able to generate sequences for testing
Navigation and User Interaction:	Some basic information is available for the parameters and their optimal value or of value. After the parameters are set the user can initiate the generation proc clicking the **Generate** button.

img/GUI/ShowTestInformation.png

Figure 8: Run Test

Purpose:	Checking the available information of the test.
Navigation and User Interaction:	For every test there is available some basic information together with the list parameters and their optimal value or range of value.

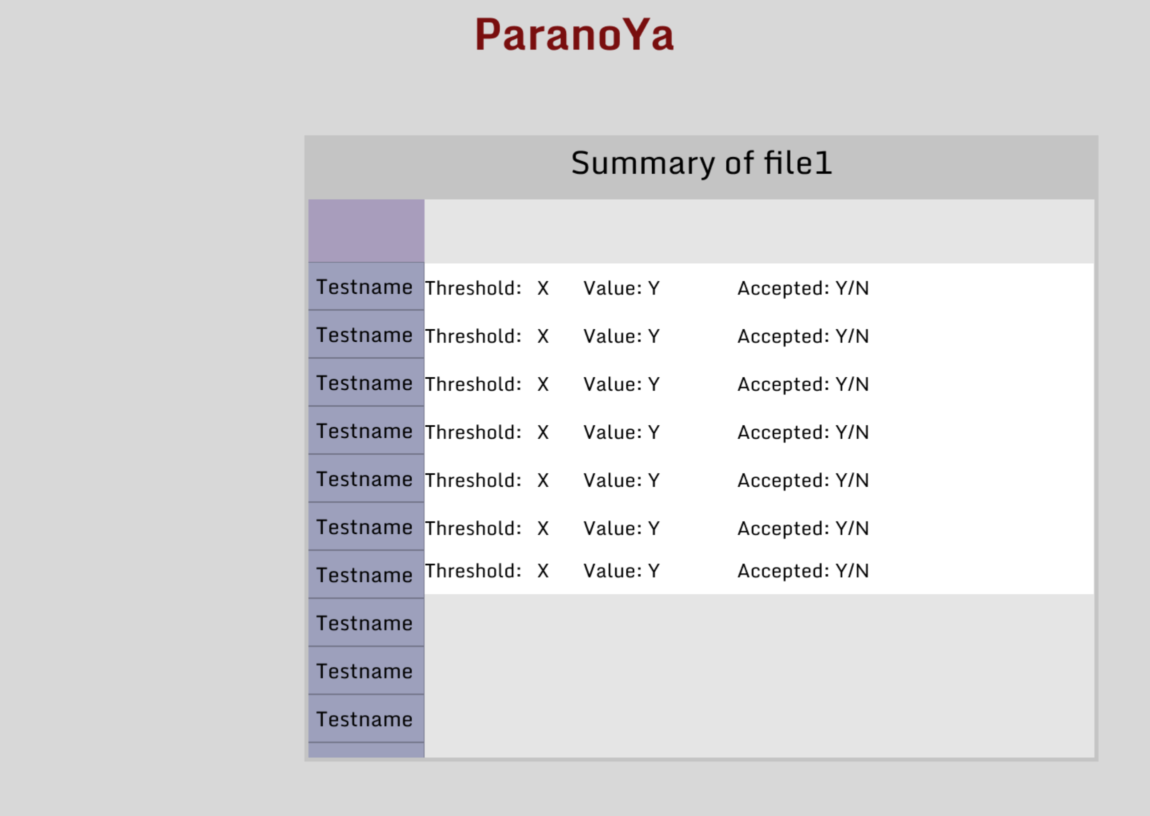
2.5 Results



	File1	File2	File3	File4	File5	File
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v
Testname	P-val	P-val	P-val	P-val	P-val	P-v

Figure 9: Results

Purpose:	The user is able to evaluate the results of the testing.
Navigation and User Interaction:	The result are summarized in a table. The rows represent the list of performed tes columns represent the tested sequences. The cells hold information about the suc the tests. The user can click on every cell to check why the chosen sequence fa passed the test.



ParanoYa

Summary of file1

Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname	Threshold: X	Value: Y	Accepted: Y/N
Testname			
Testname			
Testname			

Figure 10: Detailed results

Purpose:	The user is able to evaluate the results of performed tests by every sequence.
Navigation and User Interaction:	This table shows information about every test performed on the selected sequenc information includes the predefined threshold to pass the test, the actual value performed test and final verdict of the test.

3 UML Diagrams

This sections belongs UML diagrams which describe whole functionality of developing application.

3.1 Use Case Diagram

Each Use case describes a sequence of actions that provide something of measurable value to an Actor and is drawn as a horizontal ellipse. In our diagram are described actions, which are offered to the Actor operating with an app. Actor in our case is capable of several actions, to name a few, *File options*, *Selects tests*, *Tasks*, *Tests evaluation* etc. Each action has its respective Action and Sequence diagram, describing action more detaily in pages below.

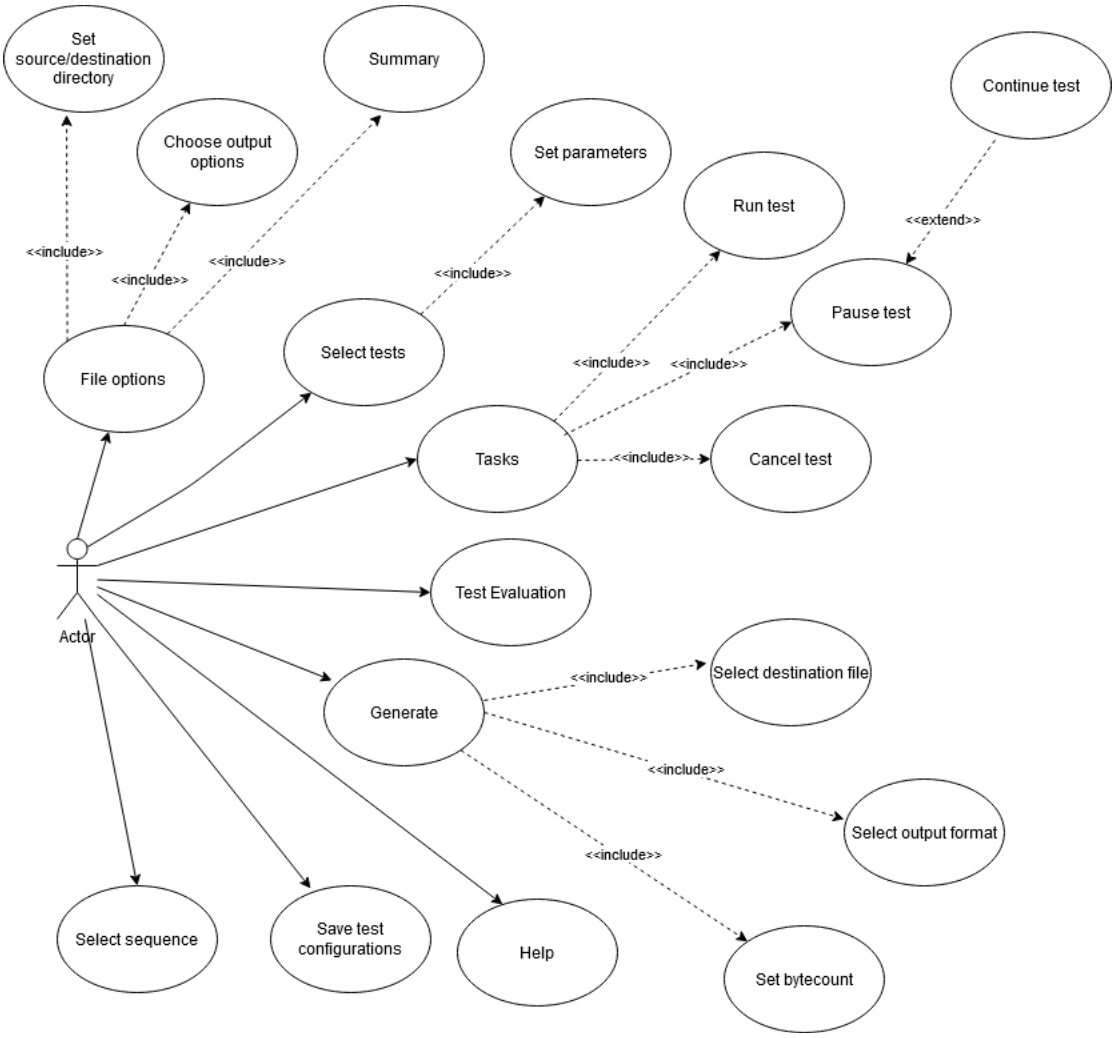


Figure 11: Use case diagram

3.2 Sequence Diagrams

In this subsections are belonged sequence diagrams. These diagrams displayed processes which are performed sequentially. With these diagrams we can examine behavior of the system.

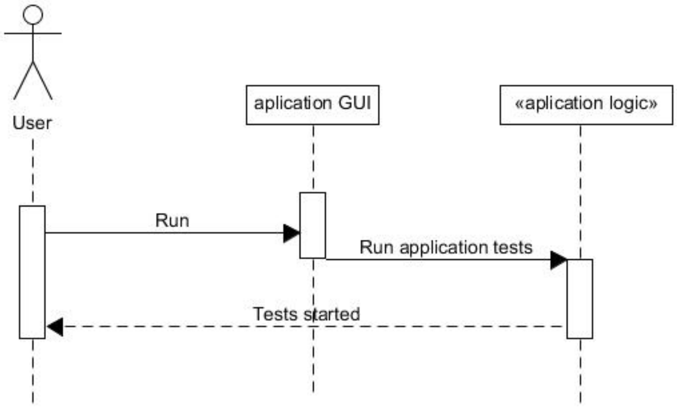


Figure 12: Sequence diagram - Run

The user interacts with the app's graphical interface. In the *Tasks* tab in the application navigation bar, selects *Run*. Pseudo-random sequence testing starts. Start-up is preceded by loading a sequence, selecting a methodology.

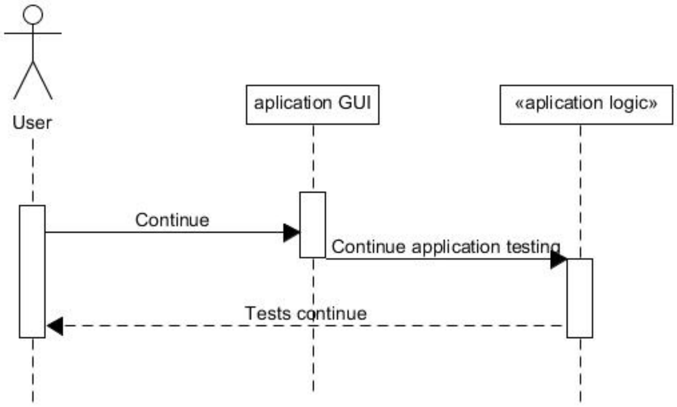


Figure 13: Sequence diagram - Continue

The user interacts with the app's graphical interface. In the *Tasks* tab in the application navigation bar, selects *Continue*. Pseudo-random sequence testing continues. Actions needed before that *Run* and *Pause* the testing.

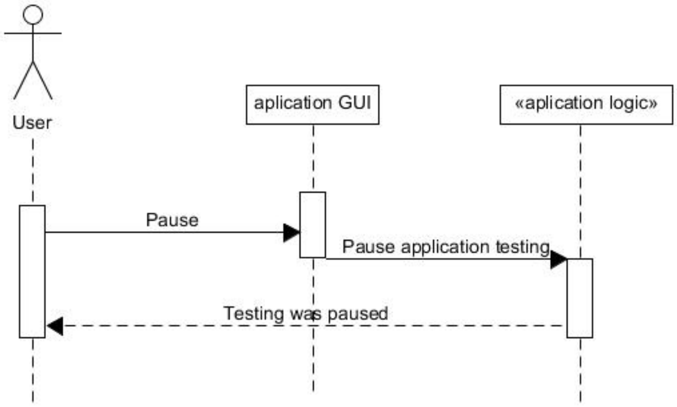


Figure 14: Sequence diagram - Pause

The user interacts with the app's graphical interface. In the *Tasks* tab in the application navigation bar, selects *Pause*. The pseudo-random sequence testing is discontinued. The interrupt is preceded by *Run* testing.

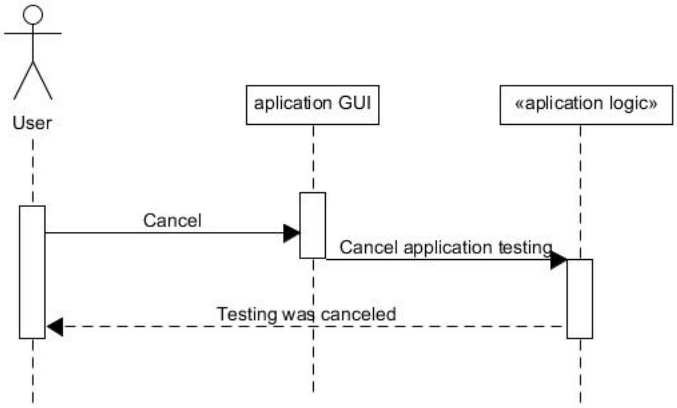


Figure 15: Sequence diagram - Cancel

The user interacts with the app's graphical interface. In the *Tasks* tab in the application navigation bar, selects *Cancel.* The pseudo-random sequence testing stops. Stopping is preceded by *Run* the testing.

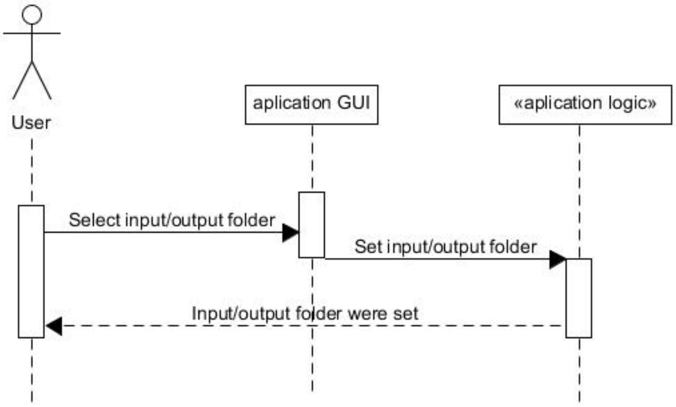


Figure 16: Sequence diagram - Set input/output folder

The user interacts with the app's graphical interface. In the *File* tab in the application navigation bar, selects *Batch process...*. Next window is shown. This window belongs Source directory, Destination directory, Output options and Summary. After clicking on the button *Set...*, the user selects Source directory in the option Source directory and then he clicks button *OK*. This directory is also set as Destination directory by default. If user would like to change destination directory, he sets it in a similar way like Source directory.

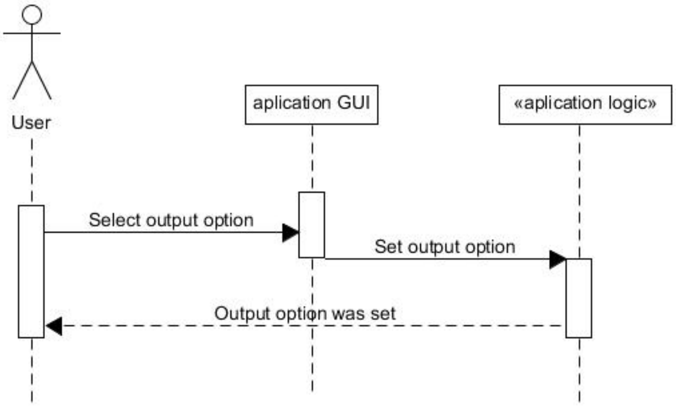


Figure 17: Sequence diagram - Select output option

The user interacts with the app's graphical interface. In the *File* tab in the application navigation bar, selects *Batch process....* Next window is shown. This window belongs Source directory, Destination directory, Output options and Summary. In the part Output options, the user selects one of the following options: XML, HTML, XML + HTML.

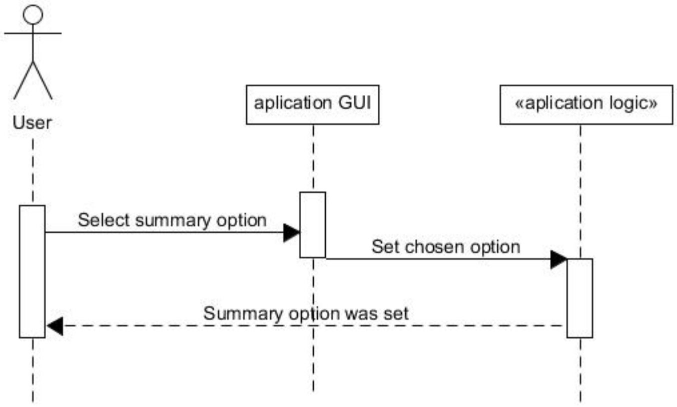


Figure 18: Sequence diagram - Select summary option

The user interacts with the app's graphical interface. In the *File* tab in the application navigation bar, selects *Batch process....* Next window is shown. This window belongs Source directory, Destination directory, Output options and Summary. In the part Summary, the user selects none, one or both of the following options: Generate summary HTML file, Prase P-values from all sequences..

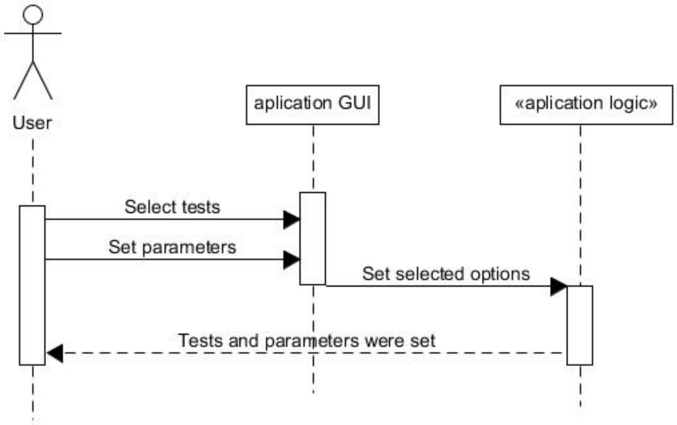


Figure 19: Sequence diagram - Set parameters for selected tests

The user interacts with the app's graphical interface. In the main menu selects test, which would like to run. Clicks button *Add new* and test is inserted. User can set parameters for inserted test by inscribing values, for example. N - length of input string or M - length in bits of each block.

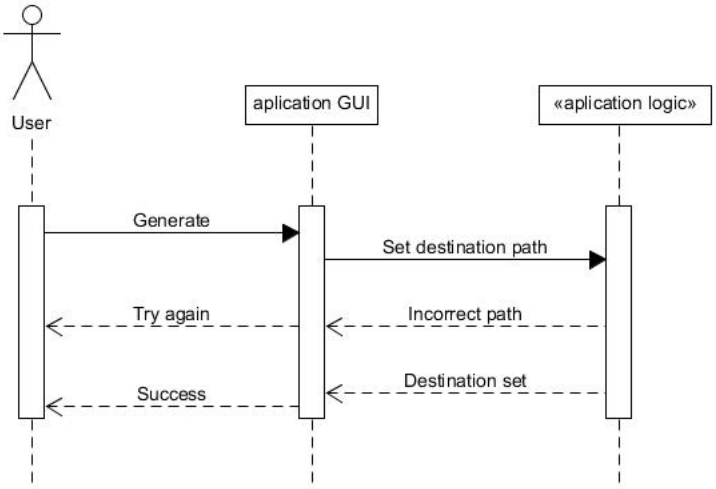


Figure 20: Sequence diagram - Generator-set destination file

The user interacts with the application GUI. In the main menu clicks Generate. A new window opens with three tasks. The User selects the path to a *Destination file*, where the generated sequence is going to be saved. If the User enters an incorrect path, he will be notified until a valid path is given.

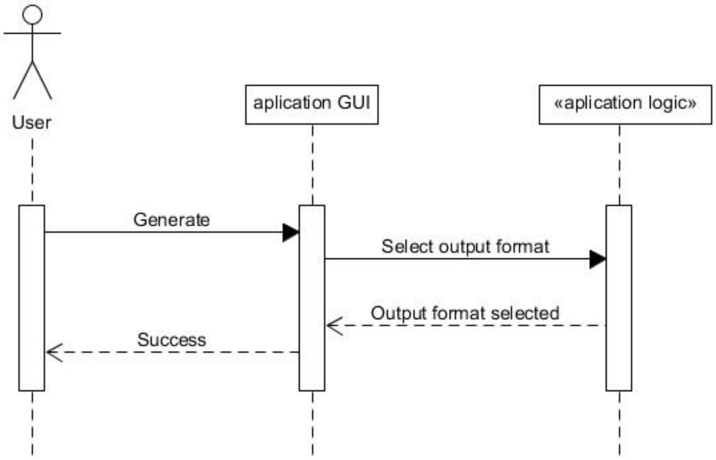


Figure 21: Sequence diagram - Generator-set output format

The user interacts with the application GUI. In the main menu clicks Generate. A new window opens with three tasks. The User has to choose an *output format* from a predefined list of available formats.

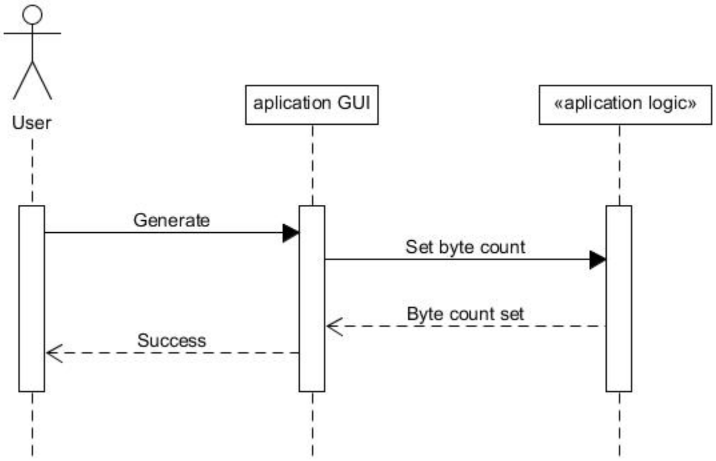


Figure 22: Sequence diagram - Generator-set bytecount

The user interacts with the application GUI. In the main menu clicks Generate. A new window opens with three tasks. The User has to provide a *byteCount*, which will be a number written to a text field.

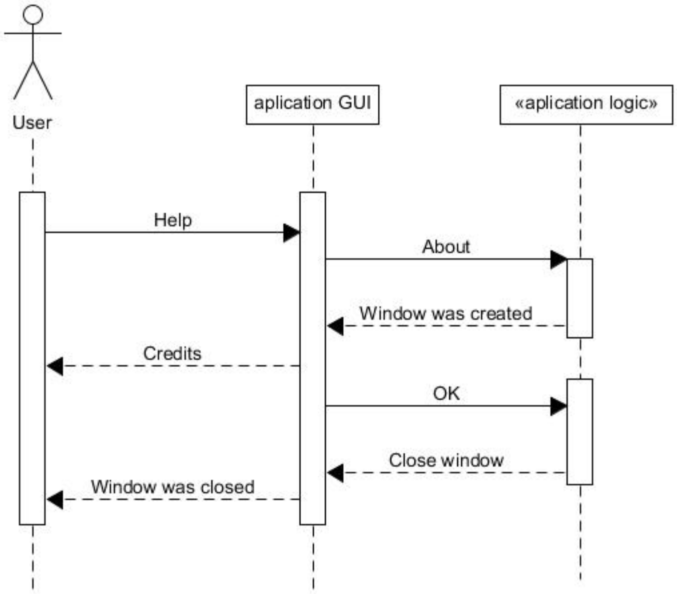


Figure 23: Sequence diagram - Help

The user interacts with the application GUI. In the main menu clicks Help. a submenu appears with one element named *About...* Clicking the *About...* button will open the Credits window. The Credit window can be closed with the ok button.

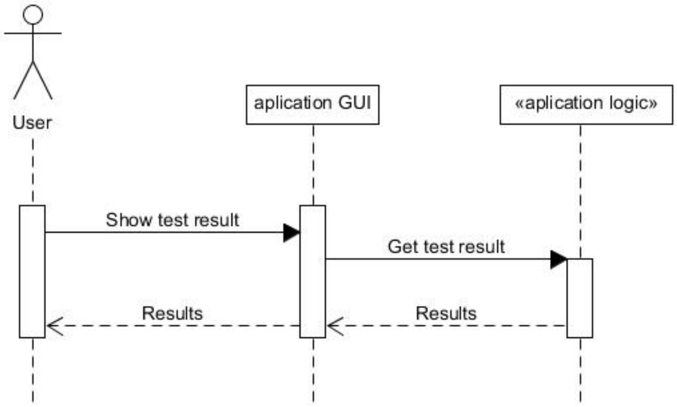


Figure 24: Sequence diagram - Show test results

After testing has ended, user has an option to show test results. When selected, it retrieves results from application logics and displays it to user via application GUI.

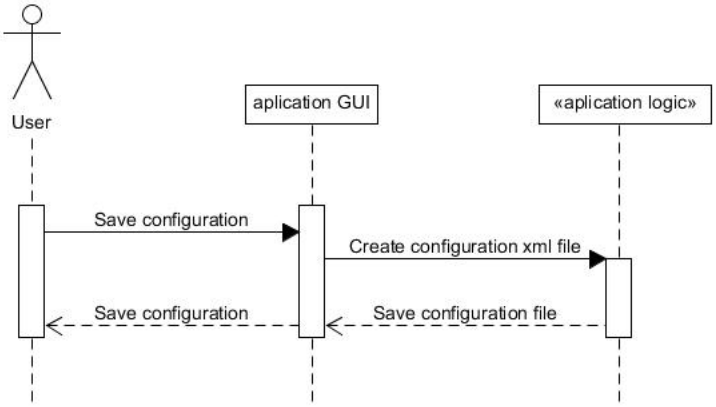


Figure 25: Sequence diagram - Save configuration

The user has an option to save current configuration in an XML file. The configuration is exported by application logics to an XML file which is sent back to user.

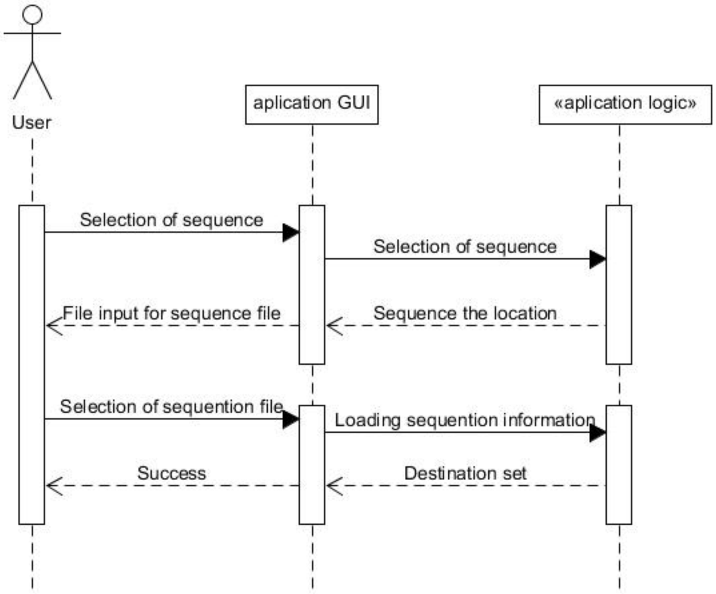


Figure 26: Sequence diagram - Load sequence

By selecting File -> Load Sequence, user is able to load a sequence into the program.

3.3 Activity Diagrams

This subsection contains all activity diagrams with pseudo codes corresponding to functionality of the application ParanoYa.

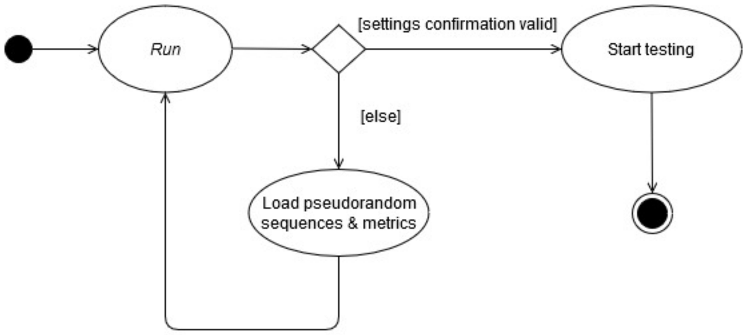
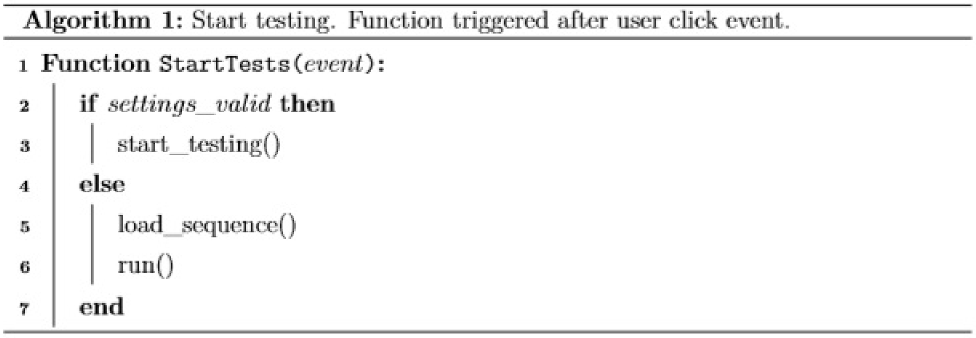

Run
[settings confirmation valid]
Start testing
[else]
Load pseudorandom sequences & metrics

Figure 27: Activity diagram - Run



Algorithm 1: Start testing. Function triggered after user click event.

```
Function StartTests(event):
    if settings_valid then
        start_testing()
    else
        load_sequence()
        run()
    end
```

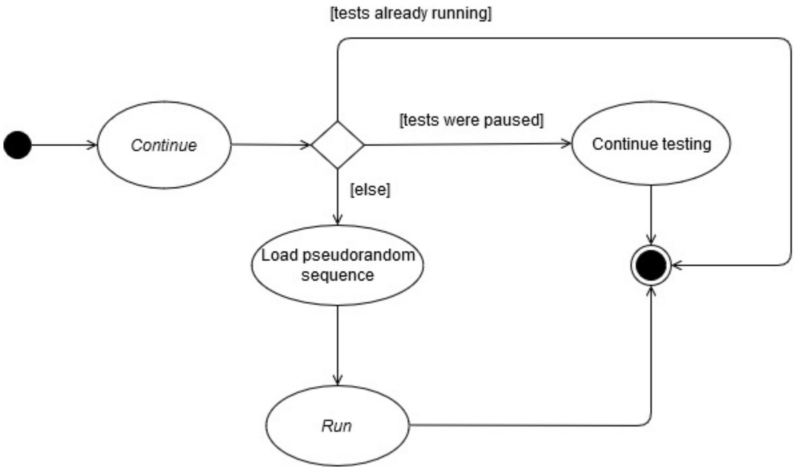


Figure 28: Activity diagram - Continue

Algorithm 2: Continue testing. Function triggered after user click event.

```
Function ContinueTests(event):
    if tests_running then
        return
    end
    if tests_paused then
        continue_testing()
    else
        load_sequence()
        run()
    end
```

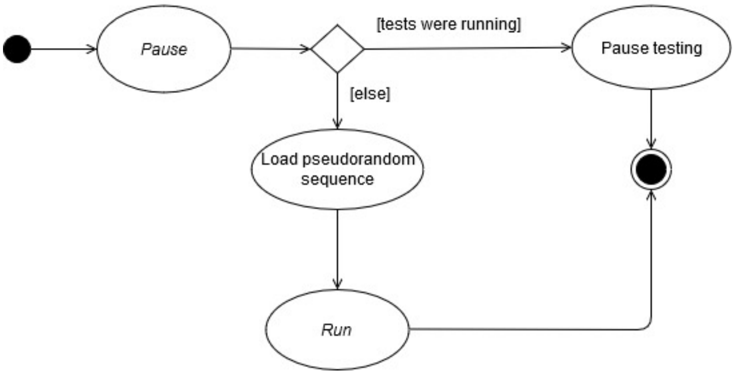


Figure 29: Activity diagram - Pause

Algorithm 3: Pause testing. Function triggered after user click event.

```
Function PauseTests(event):
    if tests_running then
        pause_testing()
    else
        load_sequence()
        run()
    end
```

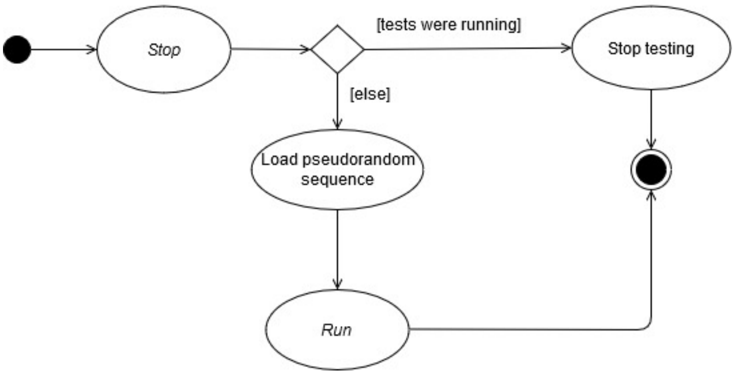


Figure 30: Activity diagram - Stop

Algorithm 4: Stop testing. Function triggered after user click event.

```
Function StopTests(event):
    if tests_paused then
        return
    end
    if tests_running then
        stop_testing()
    else
        load_sequence()
        run()
    end
```

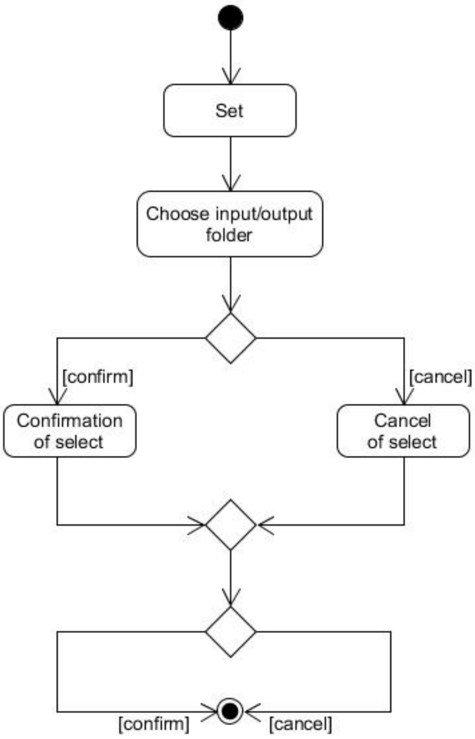
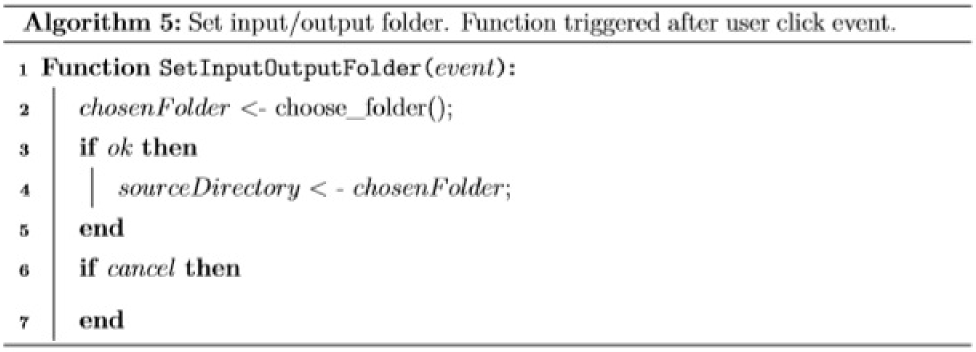


Figure 31: Activity diagram - Set input/output folder



Algorithm 5: Set input/output folder. Function triggered after user click event.

```
Function SetInputOutputFolder(event):
    chosenFolder <- choose_folder();
    if ok then
        sourceDirectory < - chosenFolder;
    end
    if cancel then
    end
```

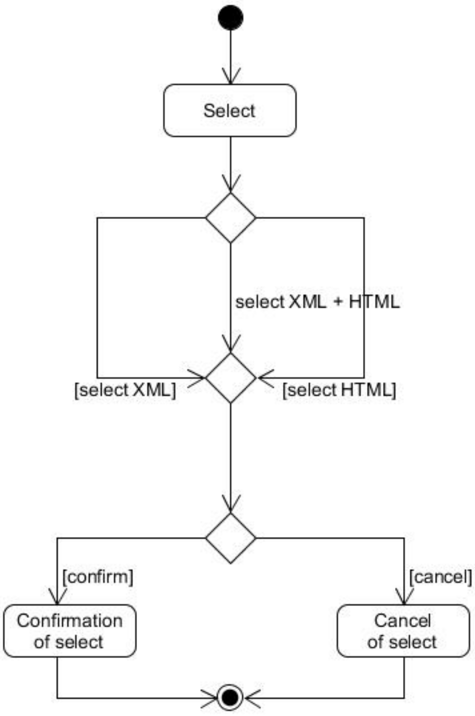


Figure 32: Activity diagram - Select output option

Algorithm 6: Select output option. Function triggered after user click event.

```
Function SelectOutputOption(event):
    if $XMLselected$ then
        $outputOption$ < - $XML$;
    end
    if $HTMLselected$ then
        $outputOption$ < - $HTML$;
    else
        $outputOption$ < - $XMLHTML$;
    end
```

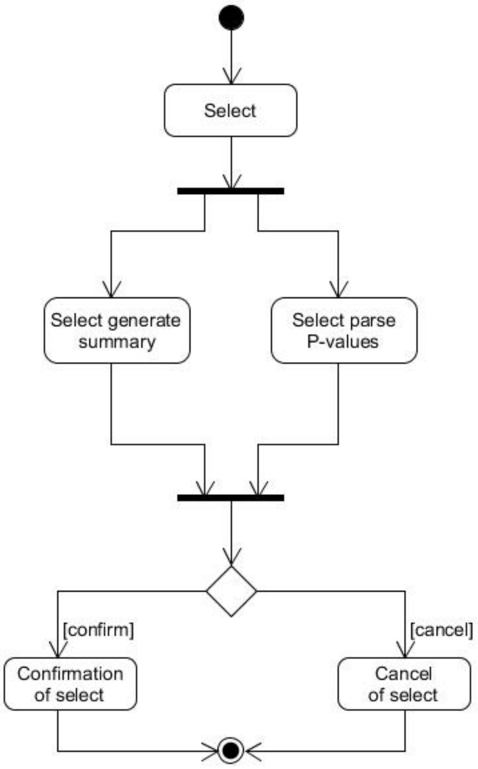
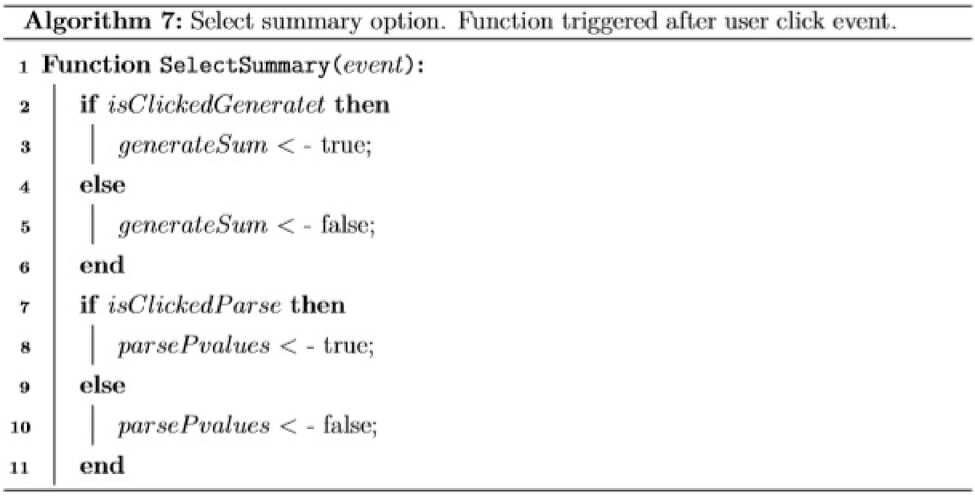


Figure 33: Activity diagram - Select summary option



Algorithm 7: Select summary option. Function triggered after user click event.

```
Function SelectSummary(event):
    if $isClickedGeneratet$ then
        $generateSum$ < - true;
    else
        $generateSum$ < - false;
    end
    if $isClickedParse$ then
        $parsePvalues$ < - true;
    else
        $parsePvalues$ < - false;
    end
```

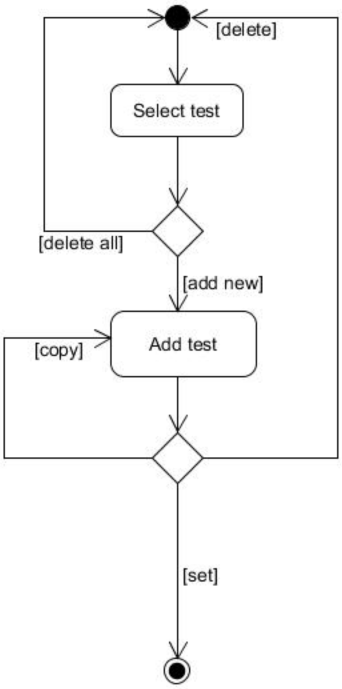
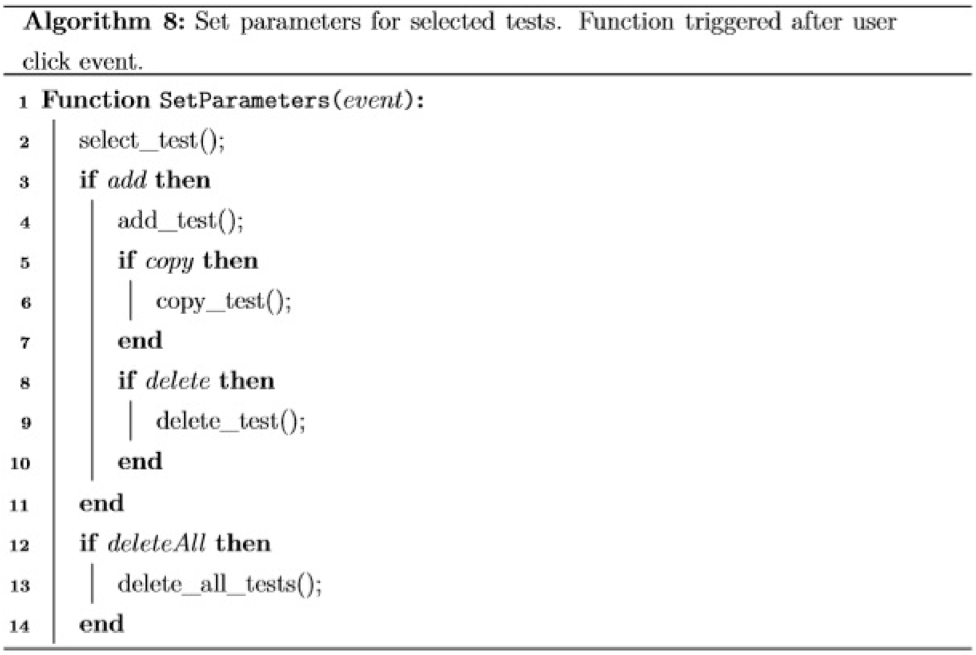


Figure 34: Activity diagram - Set parameters for selected tests



Algorithm 8: Set parameters for selected tests. Function triggered after user click event.

```
Function SetParameters(event):
    select_test();
    if add then
        add_test();
        if copy then
            copy_test();
        end
        if delete then
            delete_test();
        end
    end
    if deleteAll then
        delete_all_tests();
    end
```

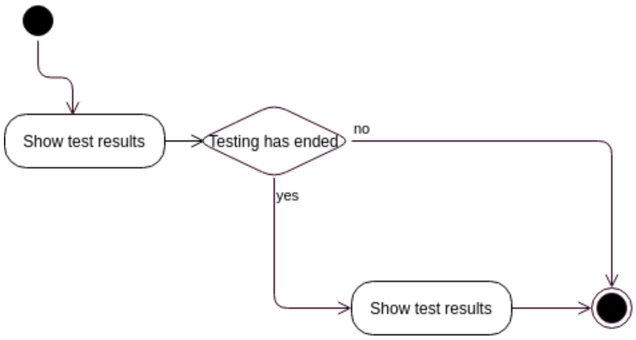


Figure 35: Activity diagram - Show test results

```
Algorithm 9: Show test results, after testing has ended, triggered after user click
Function ShowTestResults(event):
    if testing_has_ended then
        show_test_results()
    end
```

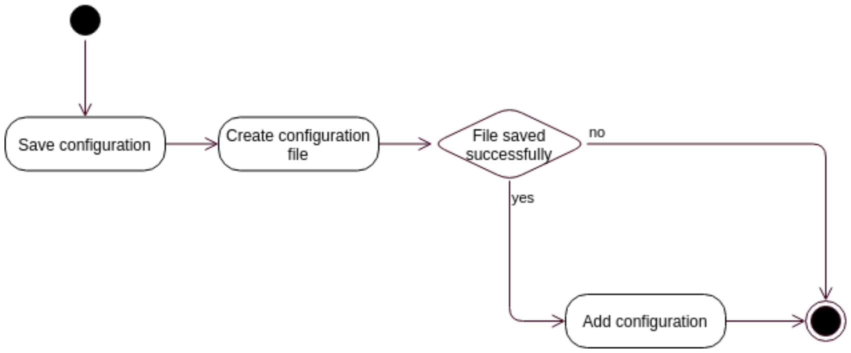


Figure 36: Activity diagram - Save configuration

```
Algorithm 10: Save configuration, triggered by selecting the option
Function SaveConfiguration(event):
    file < - create_configuration_file()
    if file then
        add_configuration()
        save_configuration()
    end
```

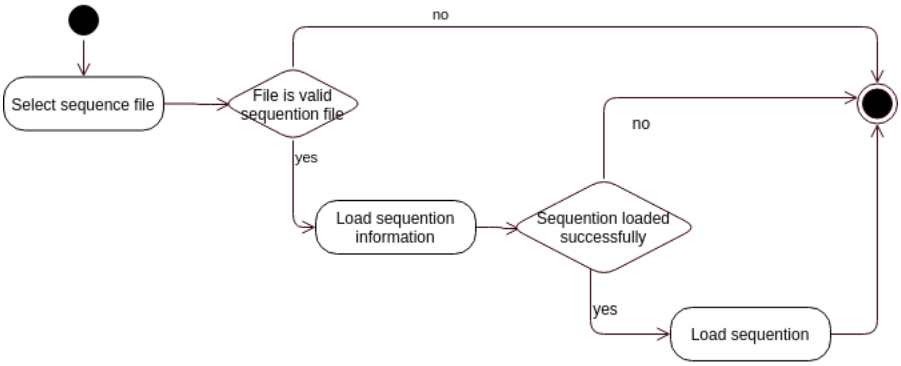

no
Select sequence file
File is valid sequention file
yes
no
Load sequention information
Sequention loaded successfully
yes
Load sequention

Figure 37: Activity diagram - Load sequence

Algorithm 11: Load sequence, triggered by selecting the option

```
Function LoadSequence(file):
    if is_valid_sequention_file(file) then
        sequention <- import_sequention(file)
        if sequention then
            load_sequention(sequention)
        end
    end
```

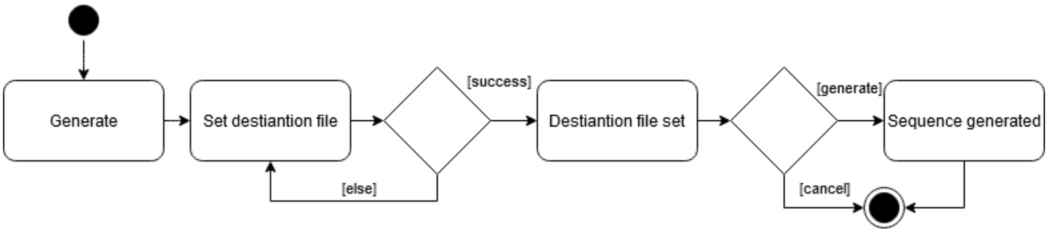


Figure 38: Activity diagram - Generate sequence/Set destination file

Algorithm 12: Generate sequence into file.

```
Function Generate(event):
    destinationFile_select();
    if success then
        destinationFile_set() ;
    else
        destinationFile_select() ;
    end
    generate();
```

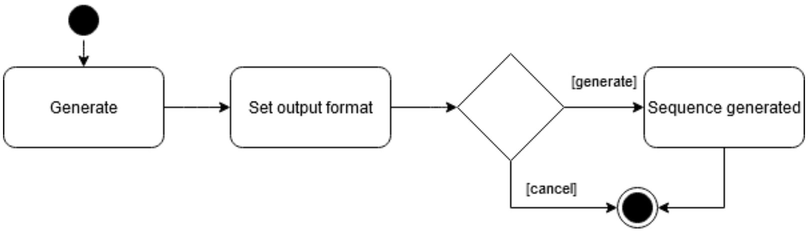


Figure 39: Activity diagram - Generate sequence/Set output format

Algorithm 13: Generate sequence into file.

```
Function Generate(event):
    OutputFormat_set();
    generate();
```

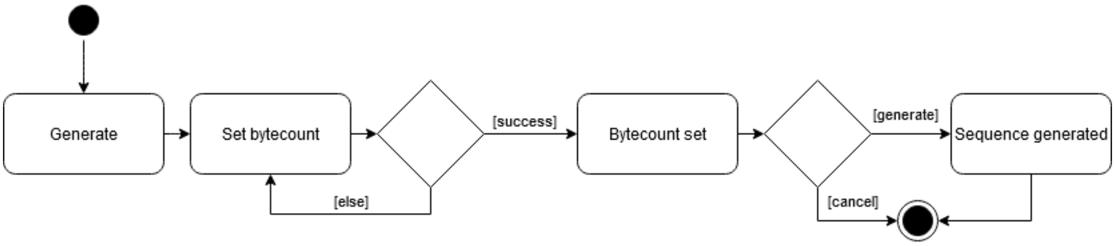


Figure 40: Activity diagram - Generate sequence/Set bytecount

Algorithm 14: Generate sequence into file.

```
Function Generate(event):
    byteCount_select();
    if success then
        byteCount_set() ;
    else
        byteCount_select() ;
    end
    generate();
```

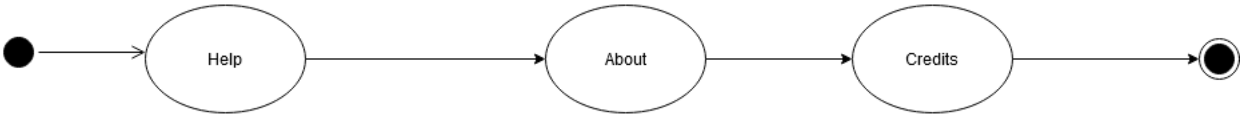


Figure 41: Activity diagram - Help

Algorithm 15: Open help for inforamtion

```
Function Help(event):
    help();
    About_click();
    Credits.show();
```

4 Acceptance tests

Section acceptance tests includes tables which describes these tests. Individually tables contain ID of acceptance test, name of test, interface for test, input, output, steps with action and expected reaction.

ID	1	**Name**	Show test results
Interface	Client / application GUI / application logics		
Input	Successfully ended testing		
Output	Test results are displayed to user in application GUI		
Step	**Action**	**Expected reaction**	
1	Testing ended	Application GUI shows an option to display test results	
2	Users selects to show test results	Test results are displayed to user	

ID	2	**Name**	Save configuration
Interface	Client / application GUI / application logics		
Input	-		
Output	Configuration is saved in a XML file		
Step	**Action**	**Expected reaction**	
1	User makes a change in a configuration	Application saves change for configuration	
2	Users selects to save configuration	Configuration is saved in a XML file	

ID	3	**Name**	Load sequence
Interface	Client / application GUI / application logics		
Input	-		
Output	Sequence is loaded into application		
Step	**Action**	**Expected reaction**	
1	User selects to load sequence	A file input is displayed to user	
2	Users selects valid configuration file	A sequence is loaded into application from the chosen file	

ID	4	**Name**	Run
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Tests started		
Step	**Action**	**Expected reaction**	
1	User enters tab Settings	Tab window is opened	
2	User selects option Run	Tests start running	

ID	5	**Name**	Continue
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Tests continue		
Step	**Action**	**Expected reaction**	
1	User enters tab Settings	Tab window is opened	
2	User selects option Continue	Stopped tests will run	

ID	6	**Name**	Pause
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Tests were paused		
Step	**Action**	**Expected reaction**	
1	User enters tab Settings	Tab window is opened	
2	User selects option Pause	Running tests will be paused	

ID	7	**Name**	Cancel
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Tests stopped		
Step	**Action**	**Expected reaction**	
1	User enters tab Settings	Tab window is opened	
2	User selects option Cancel	Running tests will stop	

ID	8	**Name**	Cancel
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Set input/output folder		
Step	**Action**	**Expected reaction**	
1	User chooses input/output folder	Input/output folder is chosen	
2	User selects option Cancel	Chosen folders are canceled	
3	User selects option OK	Chosen folders are set	
4	User selects option Cancel	Selected options are canceled	
5	User selects option OK	Selected options are successfully set	

ID	9	**Name**	Cancel
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Selected output option		
Step	**Action**	**Expected reaction**	
1	User selects one output option	Output option is selected	
2	User selects option Cancel	Selected options are canceled	
3	User selects option OK	Selected options are successfully set	

ID	10	**Name**	Cancel
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Selected summary option		
Step	**Action**	**Expected reaction**	
1	User selects one summary option	Summary option is selected	
2	User selects option Cancel	Selected options are canceled	
3	User selects option OK	Selected options are successfully set	

ID	11	**Name**	Cancel
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Set parameters for selected tests		
Step	**Action**	**Expected reaction**	
1	User selects test	Selected test is shown	
2	User selects option Add new	Advanced options are shown	
3	User set parameters for chosen test	Parameters are set	
4	User selects option Copy	Test is copied with set parameters	
5	User selects option Delete	Current test is deleted	
6	User selects option Delete All	All tests are deleted	

ID	12	**Name**	Gen-Set file path
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Selected summary option		
Step	**Action**	**Expected reaction**	
1	User provides path to destination file	Path saved	
2	User selects option OK	Path to destination file successfully set	

ID	13	**Name**	Gen-Set output
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Set output format		
Step	**Action**	**Expected reaction**	
1	User selects output format option	Ouptut format selected	
2	User selects option OK	Selected output format is successfully set	

ID	14	**Name**	Gen-Set bytecount
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Bytecount set		
Step	**Action**	**Expected reaction**	
1	User provides bytecount	Bytecount saved	
2	User selects option OK	Selected bytecount is successfully set	

ID	15	**Name**	Help
Interface	Client / application GUI / application logic		
Input	Click event		
Output	Shows credits window		
Step	**Action**	**Expected reaction**	
1	User enters help submenu	Help submenu appears	
2	User selects option About...	Credits window opens	
3	User selects option OK	Credits window closes	

5 Implementation

In this section are described tools which we used for development and detailed process of implementation.

5.1 Creation of shared object from Marek Sys libraries

Firstly, we created *.o* files from files in *src/* folder of Marek Sys library by command

```
gcc -c -fPIC utilities.c -o utilities.o
```

Secondly, we made shared object *.so* by command

```
gcc -shared -o liboutput.so library1.o library2.o library3.o
```

Which gave us shared object which can be implemented via Cython

Conclusion

The result of our work is complete analysis and design for future actualization of application ParanoYa. We also create prototype for new version of the application where are implemented basic test sets.

In the analysis is described original version of the application ParanoYa, created in Faculty of Electrical Engineering and Information Technology by students. There is detailed description of used test sets and comparison with existing applications that are similar as ParanoYa.

Design for new graphical interface was created with tool Figma. Entire functionality and behavior of the application is described by UML diagrams.

The prototype of new version of the application was created in programming language Python.

Possible extensions for further development:

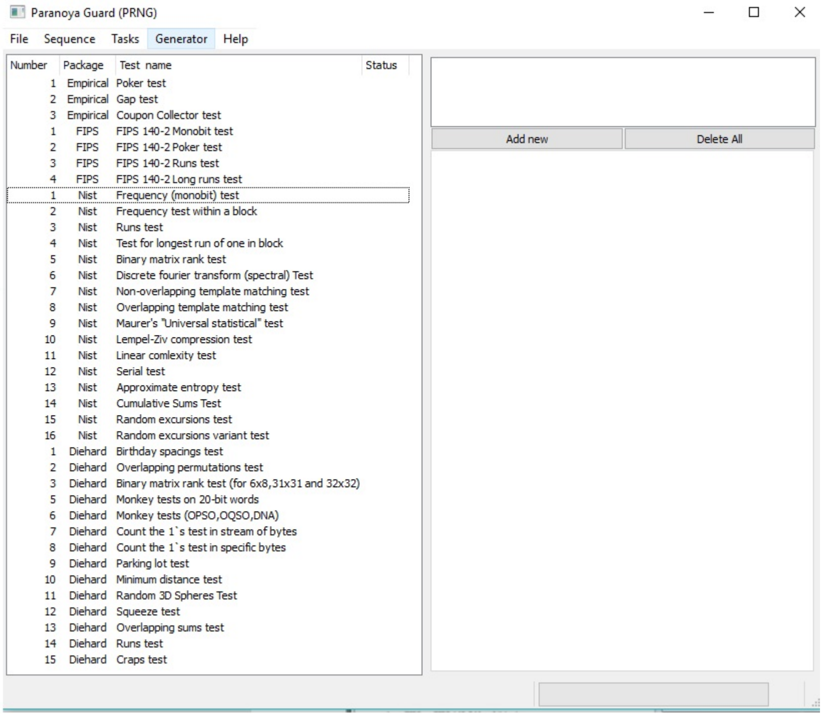
- Extension of methodologies by tests that have not yet been implemented in the application.
- Recasting the core of NIST tests according to Marek Sys's library.
- Extension of the application for evaluation of outputs (according to the Excel document model).
- Description of the methodology of testing for new implemented modifications in the application .

library.bib

Appendix

A Description of application

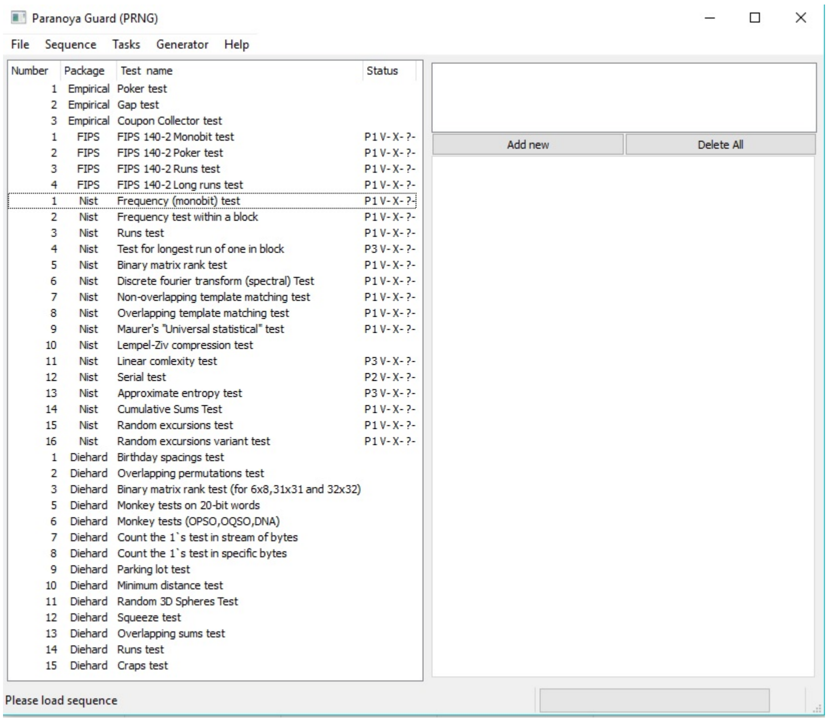
On the picture below we can see main window of application ParanoYa which will show after start the application. On the left side, there are all available tests and on the right side we can add new tests and set their parameters.



Number	Package	Test name	Status
1	Empirical	Poker test	
2	Empirical	Gap test	
3	Empirical	Coupon Collector test	
1	FIPS	FIPS 140-2 Monobit test	
2	FIPS	FIPS 140-2 Poker test	
3	FIPS	FIPS 140-2 Runs test	
4	FIPS	FIPS 140-2 Long runs test	
1	Nist	Frequency (monobit) test	
2	Nist	Frequency test within a block	
3	Nist	Runs test	
4	Nist	Test for longest run of one in block	
5	Nist	Binary matrix rank test	
6	Nist	Discrete fourier transform (spectral) Test	
7	Nist	Non-overlapping template matching test	
8	Nist	Overlapping template matching test	
9	Nist	Maurer's "Universal statistical" test	
10	Nist	Lempel-Ziv compression test	
11	Nist	Linear comlexity test	
12	Nist	Serial test	
13	Nist	Approximate entropy test	
14	Nist	Cumulative Sums Test	
15	Nist	Random excursions test	
16	Nist	Random excursions variant test	
1	Diehard	Birthday spacings test	
2	Diehard	Overlapping permutations test	
3	Diehard	Binary matrix rank test (for 6x8,31x31 and 32x32)	
5	Diehard	Monkey tests on 20-bit words	
6	Diehard	Monkey tests (OPSO,OQSO,DNA)	
7	Diehard	Count the 1`s test in stream of bytes	
8	Diehard	Count the 1`s test in specific bytes	
9	Diehard	Parking lot test	
10	Diehard	Minimum distance test	
11	Diehard	Random 3D Spheres Test	
12	Diehard	Squeeze test	
13	Diehard	Overlapping sums test	
14	Diehard	Runs test	
15	Diehard	Craps test	

Figure A.1: ParanoYa - Main window

When we would like to test some sequences we can insert our methodical template. In the File tab in the application navigation bar. There is necessary selects Open and choose template that we want to use. Needed tests are set based on which template was chosen. On the picture below we can see that some tests are set after inserting the template.

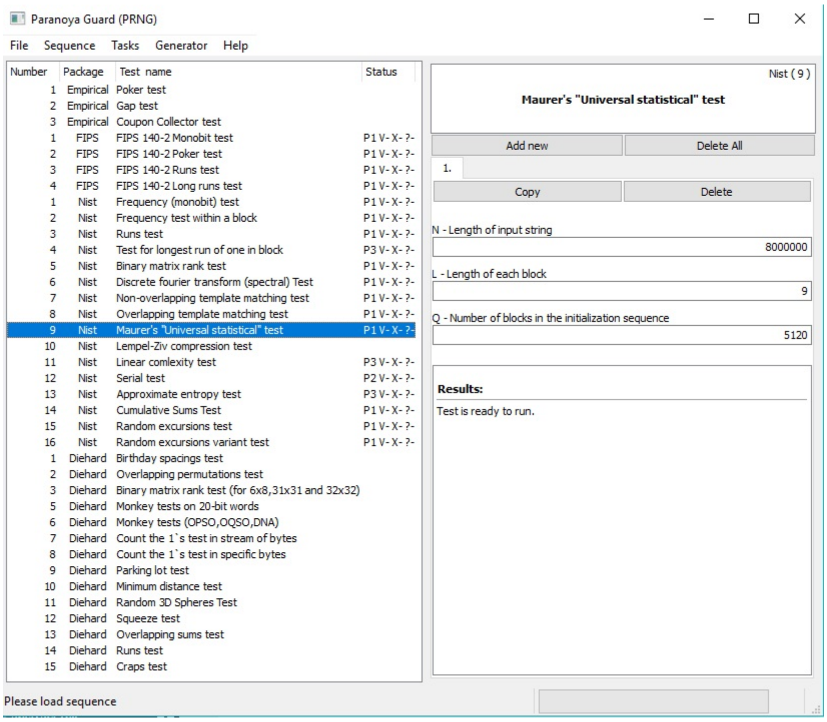


Number	Package	Test name	Status
1	Empirical	Poker test	
2	Empirical	Gap test	
3	Empirical	Coupon Collector test	
1	FIPS	FIPS 140-2 Monobit test	P1 V- X- ?-
2	FIPS	FIPS 140-2 Poker test	P1 V- X- ?-
3	FIPS	FIPS 140-2 Runs test	P1 V- X- ?-
4	FIPS	FIPS 140-2 Long runs test	P1 V- X- ?-
1	Nist	Frequency (monobit) test	P1 V- X- ?-
2	Nist	Frequency test within a block	P1 V- X- ?-
3	Nist	Runs test	P1 V- X- ?-
4	Nist	Test for longest run of one in block	P3 V- X- ?-
5	Nist	Binary matrix rank test	P1 V- X- ?-
6	Nist	Discrete fourier transform (spectral) Test	P1 V- X- ?-
7	Nist	Non-overlapping template matching test	P1 V- X- ?-
8	Nist	Overlapping template matching test	P1 V- X- ?-
9	Nist	Maurer's "Universal statistical" test	P1 V- X- ?-
10	Nist	Lempel-Ziv compression test	
11	Nist	Linear comlexity test	P3 V- X- ?-
12	Nist	Serial test	P2 V- X- ?-
13	Nist	Approximate entropy test	P3 V- X- ?-
14	Nist	Cumulative Sums Test	P1 V- X- ?-
15	Nist	Random excursions test	P1 V- X- ?-
16	Nist	Random excursions variant test	P1 V- X- ?-
1	Diehard	Birthday spacings test	
2	Diehard	Overlapping permutations test	
3	Diehard	Binary matrix rank test (for 6x8,31x31 and 32x32)	
5	Diehard	Monkey tests on 20-bit words	
6	Diehard	Monkey tests (OPSO,OQSO,DNA)	
7	Diehard	Count the 1`s test in stream of bytes	
8	Diehard	Count the 1`s test in specific bytes	
9	Diehard	Parking lot test	
10	Diehard	Minimum distance test	
11	Diehard	Random 3D Spheres Test	
12	Diehard	Squeeze test	
13	Diehard	Overlapping sums test	
14	Diehard	Runs test	
15	Diehard	Craps test	

Please load sequence

Figure A.2: ParanoYa - Tests are set

Some tests also contains various parameters that would be additionally modified on the right side of application what is displayed on the following picture.



Number	Package	Test name	Status
1	Empirical	Poker test	
2	Empirical	Gap test	
3	Empirical	Coupon Collector test	
1	FIPS	FIPS 140-2 Monobit test	P1 V- X- ?-
2	FIPS	FIPS 140-2 Poker test	P1 V- X- ?-
3	FIPS	FIPS 140-2 Runs test	P1 V- X- ?-
4	FIPS	FIPS 140-2 Long runs test	P1 V- X- ?-
1	Nist	Frequency (monobit) test	P1 V- X- ?-
2	Nist	Frequency test within a block	P1 V- X- ?-
3	Nist	Runs test	P1 V- X- ?-
4	Nist	Test for longest run of one in block	P3 V- X- ?-
5	Nist	Binary matrix rank test	P1 V- X- ?-
6	Nist	Discrete fourier transform (spectral) Test	P1 V- X- ?-
7	Nist	Non-overlapping template matching test	P1 V- X- ?-
8	Nist	Overlapping template matching test	P1 V- X- ?-
9	Nist	Maurer's "Universal statistical" test	P1 V- X- ?-
10	Nist	Lempel-Ziv compression test	
11	Nist	Linear comlexity test	P3 V- X- ?-
12	Nist	Serial test	P2 V- X- ?-
13	Nist	Approximate entropy test	P3 V- X- ?-
14	Nist	Cumulative Sums Test	P1 V- X- ?-
15	Nist	Random excursions test	P1 V- X- ?-
16	Nist	Random excursions variant test	P1 V- X- ?-
1	Diehard	Birthday spacings test	
2	Diehard	Overlapping permutations test	
3	Diehard	Binary matrix rank test (for 6x8,31x31 and 32x32)	
5	Diehard	Monkey tests on 20-bit words	
6	Diehard	Monkey tests (OPSO,OQSO,DNA)	
7	Diehard	Count the 1`s test in stream of bytes	
8	Diehard	Count the 1`s test in specific bytes	
9	Diehard	Parking lot test	
10	Diehard	Minimum distance test	
11	Diehard	Random 3D Spheres Test	
12	Diehard	Squeeze test	
13	Diehard	Overlapping sums test	
14	Diehard	Runs test	
15	Diehard	Craps test	

Nist (9)

Maurer's "Universal statistical" test

N - Length of input string: 8000000

L - Length of each block: 9

Q - Number of blocks in the initialization sequence: 5120

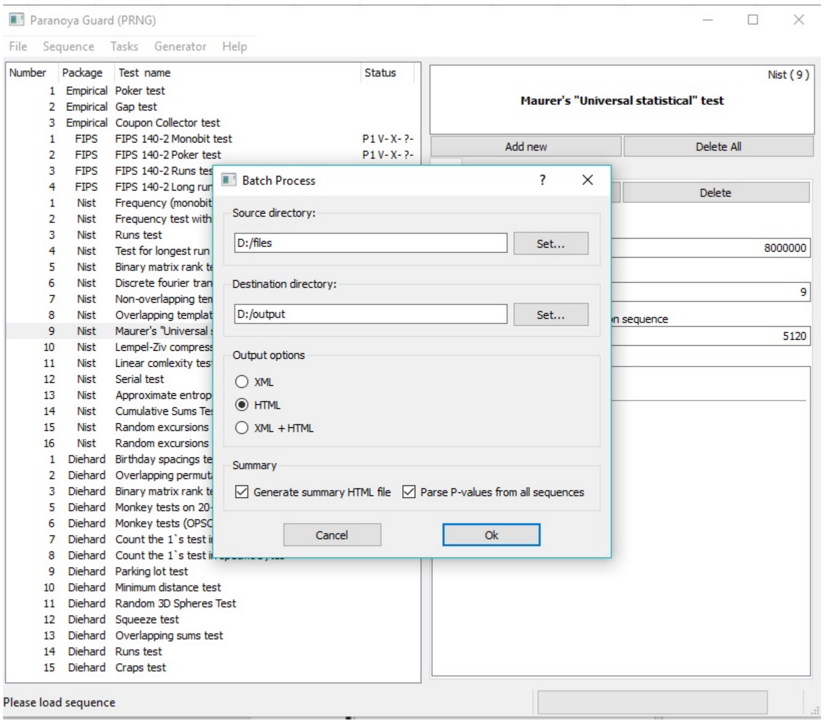
Results:

Test is ready to run.

Please load sequence

Figure A.3: ParanoYa - Additional modification of parameters

When all tests and parameters are set, there is also necessary to set source directory where are saved files with sequences, destination directory where ParanoYa will generate output files, output options and summary. These options we can see on the picture below. We can set these things after click the Batch process... in the File tab in the application navigation bar. After click the button Ok testing will start.



Number	Package	Test name	Status
1	Empirical	Poker test	
2	Empirical	Gap test	
3	Empirical	Coupon Collector test	
1	FIPS	FIPS 140-2 Monobit test	P1 V- X- ?-
2	FIPS	FIPS 140-2 Poker test	P1 V- X- ?-
3	FIPS	FIPS 140-2 Runs tes	
4	FIPS	FIPS 140-2 Long rur	
1	Nist	Frequency (monobit	
2	Nist	Frequency test with	
3	Nist	Runs test	
4	Nist	Test for longest run	
5	Nist	Binary matrix rank te	
6	Nist	Discrete fourier tran	
7	Nist	Non-overlapping ten	
8	Nist	Overlapping templat	
9	Nist	Maurer's "Universal s	
10	Nist	Lempel-Ziv compress	
11	Nist	Linear comlexity tes	
12	Nist	Serial test	
13	Nist	Approximate entrop	
14	Nist	Cumulative Sums Te	
15	Nist	Random excursions	
16	Nist	Random excursions	
1	Diehard	Birthday spacings te	
2	Diehard	Overlapping permut	
3	Diehard	Binary matrix rank te	
5	Diehard	Monkey tests on 20-	
6	Diehard	Monkey tests (OPSC	
7	Diehard	Count the 1`s test i	
8	Diehard	Count the 1`s test i	
9	Diehard	Parking lot test	
10	Diehard	Minimum distance test	
11	Diehard	Random 3D Spheres Test	
12	Diehard	Squeeze test	
13	Diehard	Overlapping sums test	
14	Diehard	Runs test	
15	Diehard	Craps test	

Source directory: D:/files

Destination directory: D:/output

Output options

○ XML
● HTML
○ XML + HTML

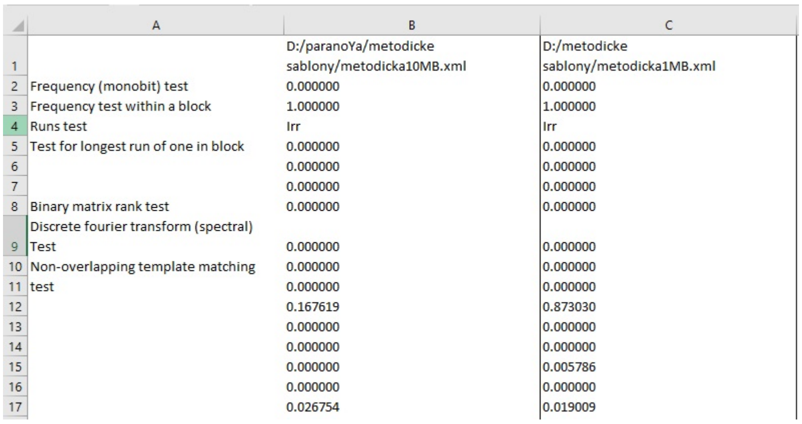
Summary

☑ Generate summary HTML file ☑ Parse P-values from all sequences

Please load sequence

Figure A.4: ParanoYa - Set the output options

ParanoYa generates files for every testing sequence and also two files: pval.html and summary.html into destination directory. We can open the file pval.html in Microsoft Excel and evaluate results of testing sequences. File pval.html opened in Microsoft Excel is displayed on the next picture.



	A	B	C
1		D:/paranoYa/metodicke sablony/metodicka10MB.xml	D:/metodicke sablony/metodicka1MB.xml
2	Frequency (monobit) test	0.000000	0.000000
3	Frequency test within a block	1.000000	1.000000
4	Runs test	Irr	Irr
5	Test for longest run of one in block	0.000000	0.000000
6		0.000000	0.000000
7		0.000000	0.000000
8	Binary matrix rank test	0.000000	0.000000
9	Discrete fourier transform (spectral) Test	0.000000	0.000000
10	Non-overlapping template matching	0.000000	0.000000
11	test	0.000000	0.000000
12		0.167619	0.873030
13		0.000000	0.000000
14		0.000000	0.000000
15		0.000000	0.005786
16		0.000000	0.000000
17		0.026754	0.019009

Figure A.5: ParanoYa - pval.html file