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Gaming Laboratories International RNG Evaluation Report

Report N°	2015NOC002RNG332
Date	17 April 2015

**Issuing
Laboratory**

GLI Europe B.V.

**Evaluating
Laboratories**

GLI Europe B.V.

Recipient

Nolimit City Limited
Block A, Suite 3, 177 Skyway Offices, Marina Street
Pieta
PTA 9042
Malta

**Tested against
Requirements**

Remote Gaming Regulations, 2004 – Third Schedule Test Script

Jurisdiction

Malta LGA Remote

Manufacturer

Nolimit City Limited
Block A, Suite 3, 177 Skyway Offices, Marina Street
Pieta
PTA 9042
Malta

Submitter

Nolimit City Limited
Block A, Suite 3, 177 Skyway Offices, Marina Street
Pieta
PTA 9042
Malta

Product Name

Fortuna RNG Evaluation

Product Style

Random Number Generator

**Description of the
Product Tested**

AuditService-1.0.jar, RandomProvider-1.0.jar, Fortuna-1.0.jar
As requested per manufacturer's letter dated 20th January 2015.

**Date Received /
Date Completed**

5th February 2015 / 17th April 2015

Evaluation Period

10th February 2015 / 15th April 2015

Result

Recommended for approval (See Comments and Conditions on page 2)

Sections

- Comments/Conditions
- Hardware Product Details
- Software Product Details
- Applied Tests
- Product Characteristics
- RNG Analysis
- Appendix A
- Appendix B
- Terms and Conditions

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Comments/Conditions

Comments

As from 1st July 2006, it is the manufacturer's responsibility to ensure that their product is RoHS compliant with current EU directives.

GLI Verify® V7.0 has been used to generate the MD5 and SHA-1 signatures for the identified .jar Key Files.

This Report is issued for the evaluation of the RNG only and covers the game ranges included in the "RNG Analysis" section of this Report.

Please note that the numbering format used in this Report utilizes the comma symbol (,) for the thousands separator and the decimal point (.) as a fractional separator (example: 1,000.30 = one thousand point thirty).

Conditions

The tested RNG may only be used in connection to games which call the RNG with numbers within the ranges as specified in this Report.

LOOK



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Hardware Product Details

There are no Hardware Product Details applicable to this Report.

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Software Product Details

Product ID	Media Type	Function	CDCK	MD5 Signature	SHA-1 Signature	Report Number
AuditService-1.0.jar	File	RNG	8868	7876C14F 7A828B82 6F34FB05 D5738004	F58A2C63 951A25DA AD6D0C91 5DD4F38E 944A64DA	①
RandomProvider-1.0.jar	File	RNG	42DA	E177D742 3160283F 74D5E62F 8C5268BB	C8822807 AA450C80 11ECC25C C9A16441 D86C4042	①
Fortuna-1.0.jar	File	RNG	B0B3	158136DB 33D1E0BB 8A332EAE EC9CB106	BB72B47E 979F8379 227201BB F57B9CFB A4C35E2E	①

① The tests performed are listed in the Applied Tests section of this Report.

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Applied Tests

Product ID	Test Performed	Reference N°	Results	Additional Details
AuditService-1.0.jar RandomProvider-1.0.jar Fortuna-1.0.jar	Random Number Generator Analysis Source Code Review Jurisdictional Regulations Review	WI-MA-006 WI-MA-006 WI-MA-006	Pass Pass Pass	Internal Reference: RN-120-NOC-15-01

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Product Characteristics

Product ID	Characteristics
AuditService-1.0.jar RandomProvider-1.0.jar Fortuna-1.0.jar	These files contain the RNG under evaluation.

Tested by: Joost van 't Schip
Reviewed by: Margit de Kever

Technical Evaluation authorized by:

John van Schaijk
Technical Director

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RNG Analysis

RANDOMNESS REPORT FOR THE FORTUNA RNG

The intent of this Report is to indicate that **Gaming Laboratories International, LLC (GLI)** has completed its evaluation of the Fortuna Random Number Generator (RNG) provided by Nolimit City Limited.

SECTION I - SCOPE OF TESTING

Nolimit City Limited submitted the required materials to GLI in order to conduct a random number generator analysis on the Fortuna RNG. The scope of this analysis was limited to software verification, source code review, and data analysis. The RNG was tested for its ability to randomly produce outcomes for Casino games.

SECTION II - SOFTWARE VERIFICATION

The GLI Verify® V7.0 signatures for the Fortuna RNG are as follows:

File	Version	Type	Signature
RandomProvider-1.0.jar	1.0	SHA-1	C8822807AA450C8011ECC25CC9A16441D86C4042
Fortuna-1.0.jar	1.0	SHA-1	BB72B47E979F8379227201BBF57B9CFBA4C35E2E
AuditService-1.0.jar	1.0	SHA-1	F58A2C63951A25DAAD6D0C915DD4F38E944A64DA

Table 1. Digital Signatures

SECTION III - SOURCE CODE REVIEW

Nolimit City Limited submitted appropriate documentation and full source code which pertains to the generation of random numbers. GLI reviewed the source code provided by tracing the path of the RNG application from the initiation of the draw to the selected output of random numbers. GLI inspected the source code, where practicable, in an attempt to find any undisclosed switches or parameters having a possible influence on randomness and fair play. GLI assessed the ability of the RNG to produce all numbers within the desired range.

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SECTION IV - DATA ANALYSIS

The game configuration and parameters for the data obtained and tested are listed in Table 2. GLI performed a data format check on each data set listed in order to confirm that the game parameters were correctly represented in the data analyzed. A complete listing of the individual tests applied to each data set can be found in Appendix A.

A set of numbers is said to be drawn *with replacement* if a number can be selected multiple times within the same draw. A set of numbers is said to be drawn *without replacement* if a number can only be selected once within the same draw.

Data Set	Range	Positions	Replacement	Draws
Data Set 1	0-99	15	Yes	100,000,000
Data Set 2	0-99	1	N/A	1,500,000,000
Binary Data	byte	1	N/A	3*12,000,000

Table 2. Game Parameters

For a summary of the statistical tests applied to each data set, see *Appendix A*. For a description of the overall test methodology and a description of each test used, see *Appendix B*.

Overall, the RNG passed the battery of tests for each configuration at the 95%, 98% and 99% confidence levels.

SECTION V - SUMMARY

Overall Evaluation of the Random Number Generator

GLI's conclusion based upon the tests applied to the Fortuna RNG data is that this random number generator has exhibited random behavior and is suitable for the applications as described herein. If a game utilizes a different range or a different number of selections from the included ranges, the RNG should be resubmitted to test that set of parameters.



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APPENDIX A: Statistical Test Summary

Data Set	Range	Positions	Replacement	Draws	Test Names									
					Runs	Serial Corr.	Adj. Max-Min	Adj. High-Low	Coupon	Duplicates	Overlaps	Tot. Dist.	Diehard	Tot. Dist. by Pos.
Data Set 1	0-99	15	Yes	100,000,000	X	X	X	X	X	X	X	X		X
Data Set 2	0-99	1	N/A	1,500,000,000	X	X			X	X	X	X		
Binary Data	byte	1	N/A	3*12,000,000									X	

Table A 1. Tests Applied



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APPENDIX B: Test Descriptions

Definitions

The following terms apply to the below test descriptions. Randomness Device or Random Number Generator (RNG) output may be collected multiple numbers at a time. Each set of numbers is called a draw. Each individual number has a particular order within the draw. This is referred to as the number position.

Distribution Comparisons

Many of the tests compare an observed numerical distribution with an expected distribution. Unless otherwise specified, this is done by means of a statistical chi-square goodness-of-fit test. The value chi-square is computed in the standard way. If k is a possible value, o_k is the observed count of that value, and e_k is the expected count:

$$\chi^2 = \sum_k \frac{(o_k - e_k)^2}{e_k}$$

In the case where expected counts are too small for accurate use of the above formula, values are 'binned' together to ensure an appropriate minimum expected count. The resultant value for chi-square is compared against the distribution for the appropriate number of degrees of freedom. Unusually high (distribution mismatch) or unusually low (insufficient randomness) chi-square values can be causes for data failure.

Meta-testing

Evaluation of groups of p-values may include a meta-test for extremity of high or low p-values, a meta-test for frequency of high or low p-values, and a meta-test for uniformity of p-values, as appropriate.

Confidence Level

The statistical tests conducted by GLI are done at a particular confidence level. Common confidence levels used include 95%, 98% and 99%, depending on jurisdictional requirements, and intended use of the RNG. High confidence level testing has low risk of mistakenly failing a good RNG, but higher risk of passing a bad RNG. Lower confidence level testing has increased power of detecting bad RNGs, while also increasing the risk of false failures of good RNGs. Specifically, the confidence level represents the probability that an ideal source of randomness would pass the testing. If an RNG passes statistical tests at a given confidence level, passage at all higher confidence levels is implied.

Tests

Some tests are only applicable to certain types of data. Some tests may be applied only to a portion of the data. Some tests may require that the data be parsed, binned, or otherwise transformed, as necessitated by data format.

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Adjacency High-Low Test

For each draw, the number of local extrema ('highs' and 'lows') in the data is recorded and compared with the expected distribution. These are also referred to as 'turning points'. For example, if a draw consists of the numbers

1, 3, 5, 7, 2, 9

there would be one local maximum (7) and one local minimum (2). The resulting statistic would be 2.

Adjacency Max-Min Test

For each draw, the difference between the maximum and minimum values is calculated and recorded. This is compared with the expected theoretical distribution. For example, if a draw consists of the numbers

2, 3, 6, 7, 4

the resulting statistic would be 5, the difference between the maximum value (7) and the minimum value (2).

Coupon Collector's Test

The Coupon Collector's Test is applied positionally. The data is parsed until all possible values have been observed, then the number of values checked is recorded and the count is restarted. This is compared with the expected distribution. For example, if the set of all possible values is {0, 1, 2} and the first position of each draw is

1, 0, 1, 0, 2, 0, 1, 2, ...

then all values are observed in the first position by the fifth draw. All values are then observed within the next 3 draws, so the first two statistics for the first position would be 5 and 3.

Duplicates Test

The Duplicates Test counts the number of times a draw is exactly duplicated in the data. In the case that a particular draw is repeated more than twice, every possible way to generate a duplicate is counted. This is compared against the theoretical distribution to verify that the number of duplicate draws falls within expected bounds. For example, consider the dataset consisting of the following draws of two numbers each.

- a) 1, 3
- b) 4, 1
- c) 1, 3
- d) 1, 3
- e) 4, 1
- f) 3, 1

The duplicate pairs are (a,c), (a, d), (c, d), and (b, e), for a total of 4 duplicates. (f) is not counted as a duplicate since the draw must match in order as well as values.

Overlaps Test

The Overlaps Test compares consecutive draws for overlapping values. The number of overlapping values is recorded for each pair of draws. This observed distribution of overlaps is then compared against the expected distribution. For example, if the following draws are observed consecutively,

- a) 1, 4, 5, 6
- b) 4, 1, 7, 6

the number of overlaps would be 3, representing the values 1, 4, and 6.



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Runs Test

The Wald-Wolfowitz Runs Test is applied to each position within the draw. A center is established, typically the data median, and the number of 'runs' above and below the center are tallied. Values exactly equal to the center are discarded. This is compared to the expected distribution, which depends on the number of values above and below the center. For example, if the numbers drawn at a particular position were

2, 3, 1, 5, 4, 7, 3, 2, 3, 2, 3, 2, 6, 7, 3, 5

and the established center were the data median of 3, the data would be parsed for runs above 3 and runs below 3.

2, 3, 1, 5, 4, 7, 3, 2, 3, 2, 3, 2, 6, 7, 3, 5

This would be counted as 4 runs.

Serial Correlation Test

The Serial Correlation Test measures statistical correlation between consecutive draws of the same position. For each position, the sample Pearson correlation coefficient is calculated. If X represents the first number, and Y the number that follows, then the coefficient is

$$r = \frac{cov(X, Y)}{s_X s_Y}$$

where s denotes the sample standard deviation. The coefficients are used to generate a p-value for each position.

Total Distribution Test

The Total Distribution Test is a simple tally of all observed values throughout the data. This is compared with the expected distribution. Typically the expected distribution is a uniform distribution. In the case of unequal weighting of values, an appropriate discrete distribution is used.

Total Distribution by Position Test

The Total Distribution by Position Test tallies the observed distribution of values for each position within the draw. Each of these distributions is then compared with the expected.

DieHard Test

The DieHard Battery of Tests is a standard assessment of the randomness in raw outcomes generated from an RNG. The collection, designed by George Marsaglia, tests for a variety of patterns in the individual binary bits of RNG output. GLI uses a custom implementation to conduct DieHard testing.



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Sincerely,
GLI EUROPE BV

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