

Employing online quantum random number generators for generating truly random quantum states in *Mathematica*

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Abstract

We present a new version of **TRQS** package for *Mathematica* computing system. The package allows harnessing quantum random number generators (QRNG) for investigating the statistical properties of quantum states. It implements a number of functions for generating random states. The new version of the package adds the ability to use the on-line quantum random number generator service and implements new functions for retrieving lists of random numbers. Thanks to the introduced improvements, the new version provides faster access to high-quality sources of random numbers and can be used in simulations requiring large amount of random data.

Keywords: random density matrices ;quantum information ;quantum random number generator ;on-line quantum random number generator service

PACS numbers: 03.67.-a ;02.70.Wz ;07.05.Tp

New Version Program Summary

Program title: TRQS

Program author: Jarosław A. Mischczak

Program web page: <http://www.iitis.pl/mischczak/trqs>

Distribution format: tar.gz

No. of bytes in distributed program, including test data, etc.: 218 618

No. of lines in distributed program, including test data, etc.: 16 479

Programming language: Mathematica, C

Computer: any supporting Mathematica in version 7 or higher

Operating system: any platform supporting Mathematica; tested with GNU/Linux

(32 and 64 bit)

RAM: case-dependent

Classification: 4.15

Catalogue identifier of previous version: AEKA_v1.0

Reference in CPC: Comput. Phys. Commun. 183 (2012) 118 [1]

Does the new version supersede the previous version?: Yes.

Nature of problem: Generation of random density matrices and utilization of high-quality random numbers for the purpose of computer simulation.

Method of solution: Use of a physical quantum random number generator and an on-line service providing access to the source of true random numbers generated by quantum real number generator.

Running time: Depends on the used source of randomness and the amount of random data used in the experiment.

Reasons for new version: Added support for the high-speed on-line quantum random number generator and improved methods for retrieving lists of random numbers.

1 Summary of revisions

The presented version provides two significant improvements.

The first one is the ability to use on-line Quantum Random Number Generation service developed by PicoQuant GmbH and the Nano-Optics groups at the Department of Physics of Humboldt University. The on-line service supported in the version 2.0 of the **TRQS** package provides faster access to true randomness sources constructed using the laws of quantum physics. The service is freely available at [?]. The use of this service allows using the presented package with the need of a physical quantum random number generator.

The second improvement introduced in this version is the ability to retrieve arrays of random data directly for the used source. This increases the speed of the random number generation, especially in the case of an on-line service, where it reduces the time necessary to establish the connection. Thanks to the speed improvement of the presented version, the package can now be used in simulations requiring larger amount of random data. Moreover, the functions for generating random numbers provided by current version of the package more closely follow the pattern of functions for generating pseudo-random numbers provided in *Mathematica*.

2 Speed comparison

The implementation of the support for QRNG on-line service provides a noticeable improvement in the speed of random number generation. For

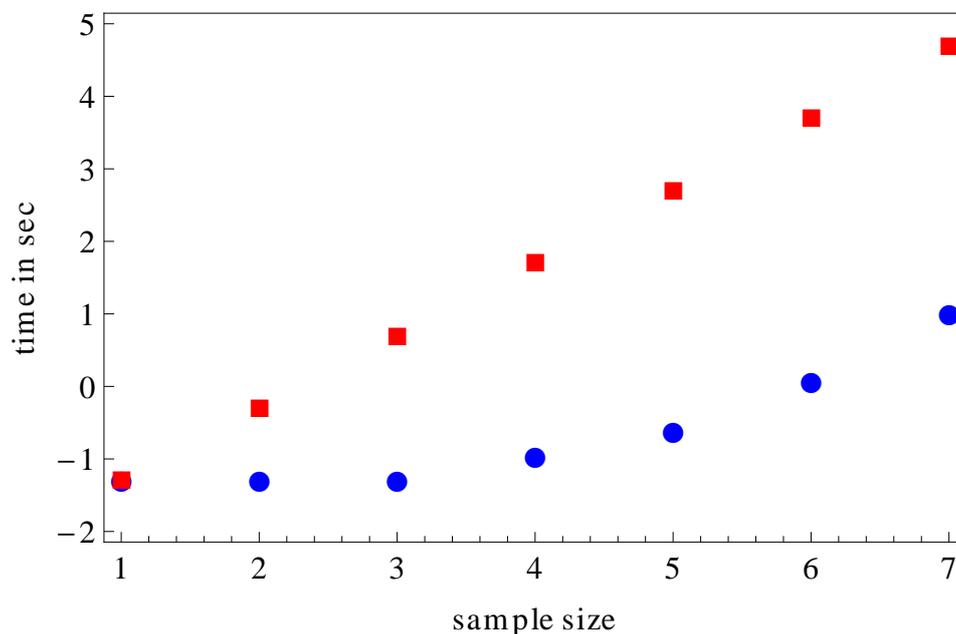


Figure 1: Comparison of the times required to generate a sample of random numbers using Quantis device (red squares) and QRNG service (blue dots) in log-log scale. In the case of the QRNG service the plot presents time averaged over three experiments. In both cases the results were obtained by generating matrices of random real numbers from $[0, 1]$ using TrueRandomReal function.

the samples of real numbers of size $10^1, 10^2, \dots, 10^7$ the times required to generate these samples using Quantis USB device and QRNG service are compared in Fig. 1. The presented results show that the use of on-line service provides faster access to random numbers. One should note, however, that the speed gain can increase or decrease depending on the connection speed between the computer and the server providing random numbers.

Acknowledgements

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References

- [1] J.A. Miszczak, *Generating and using truly random quantum states in Mathematica*, Computer Physics Communications, Vol. 183, No. 1 (2012), pp. 118-124. arXiv:1102.4598 DOI:10.1016/j.cpc.2011.08.002
- [2] QRNG Service available on-line at <https://qrng.physik.hu-berlin.de/>.
- [3] M. Wahl, M. Leifgen, M. Berlin, T. Röhlicke, H.-J. Rahn, O. Benson O., *An ultrafast quantum random number generator with provably bounded output bias based on photon arrival time measurements*, Applied Physics Letters, Vol. 098, 171105 (2011). DOI:10.1063/1.3578456