Package ‘BosonSampling’

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Title Classical Boson Sampling

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Description Classical Boson Sampling using the algorithm of Clifford and Clifford (2017) <arXiv:1706.01260>. Also provides functions for generating random unitary matrices, evaluation of matrix permanents (both real and complex) and evaluation of complex permanent minors.

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BosonSampling-package *Classical Boson Sampling*

Description

Classical Boson Sampling using the algorithm of Clifford and Clifford (2017) <arXiv:1706.01260>. Also provides functions for generating random unitary matrices, evaluation of matrix permanents (both real and complex) and evaluation of complex permanent minors.

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bosonSampler *Function for independently sampling from the Boson Sampling distribution*

Description

The function implements the Boson Sampling algorithm defined in Clifford and Clifford (2017) https://arxiv.org/abs/1706.01260

Usage

```
bosonSampler(A, sampleSize, perm = FALSE)
```

Arguments

`A`	the first `n` columns of an (`m` x `m`) random unitary matrix, see `randomUnitary`
`sampleSize`	the number of independent sample values required for given `A`
`perm`	TRUE if the permanents and pmfs of each sample value are required

Details

Let the matrix `A` be the first `n` columns of an `(m x m)` random unitary matrix, then `X <- bosonSampler(A, sampleSize = N, perm = TRUE)` provides `X$values`, `X$perms` and `X$pmfs`,

The component `X$values` is an `(n x N)` matrix with columns that are independent sample values from the Boson Sampling distribution. Each sample value is a vector of `n` integer-valued output modes in random order. The elements of the vector can be sorted in increasing order to provide a multiset representation of the sample value.

The outputs `X$perms` and `X$pmfs` are vectors of the permanents and probability mass functions (pmfs) associated with the sample values. The permanent associated with a sample value `v = (v_1,...,v_n)` is the permanent of an `(n x n)` matrix constructed with rows `v_1,...,v_n` of `A`. Note the constructed matrix, `M`, may have repeated rows since `v_1,...,v_n` are not necessarily distinct. The pmf is calculated as `Mod(pM)^2/prod(factorial(tabulate(c))` where `pM` is the permanent of `M`.

Value

`X = bosonSampler(A, sampleSize = N, perm = TRUE)` provides `X$values`, `X$perms` and `X$pmfs`. See Details.

References

Clifford, P. and Clifford, R. (2017) The Classical Complexity of Boson Sampling, https://arxiv.org/abs/1706.01260

Examples

```
set.seed(7)
n <- 20  # number of photons
m <- 200 # number of output modes
A <- randomUnitary(m)[,1:n]
# sample of output vectors
valueList <- bosonSampler(A, sampleSize = 10)$values
valueList
# sample of output multisets
apply(valueList,2, sort)
#
set.seed(7)
n <- 12  # number of photons
m <- 30 # number of output modes
A <- randomUnitary(m)[,1:n]
# sample of output vectors
valueList = bosonSampler(A, sampleSize = 1000)$values
# Compare frequency of output modes at different
# positions in the output vectors
matplot(1:m,apply(valueList,1,tabulate), pch =20, t = "p",
xlab = "output modes", ylab = "frequency")
```

Permanent-functions *Functions for evaluating matrix permanents*

Description

These three functions are used in the classical Boson Sampling problem

Usage

```
cxPerm(A)
rePerm(B)
cxPermMinors(C)
```

Arguments

`A`	a square complex matrix.
`B`	a square real matrix.
`C`	a rectangular complex matrix where `nrow(C) = ncol(C) + 1`.

Details

Permanents are evaluated using Glynn's formula (equivalently that of Nijenhuis and Wilf (1978))

Value

`cxPerm(A)` returns a complex number: the permanent of the complex matrix `A`.
`rePerm(B)` returns a real number: the permanent of the real matrix `B`.
`cxPermMinors(C)` returns a complex vector of length `ncol(C)+1`: the permanents of all `ncol(C)`-dimensional square matrices constructed by removing individual rows from `C`.

References

Glynn, D.G. (2010) The permanent of a square matrix. *European Journal of Combinatorics*, **31**(7):1887–1891.
Nijenhuis, A. and Wilf, H. S. (1978). *Combinatorial algorithms: for computers and calculators.* Academic press.

Examples

```
set.seed(7)
n <- 20
A <- randomUnitary(n)
cxPerm(A)
#
B <- Re(A)
rePerm(B)
#
C <- A[,-n]
```

```
v <- cxPermMinors(C)
#
# Check Laplace expansion by sub-permanents
c(cxPerm(A),sum(v*A[,n]))
```

randomUnitary *Random unitary*

Description

Returns a square complex matrix sampled from the Haar random unitary distribution.

Usage

```
randomUnitary(size)
```

Arguments

`size`	dimension of matrix

Value

A square complex matrix.

Examples

```
m <- 25 # size of matrix (m x m)
set.seed(7)
U <- randomUnitary(m)
#
n <- 5 # First n columns
A <- U[,1:n]
```

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