quantum++

0.1

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Contents

Chapter 1

quantum++ - A C++11 quantum computing library

Version

0.1

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A simple example:

```
#include "qpp.h"

//#include "matlab.h" // support for MATLAB

using namespace std;
using namespace qpp;

cplx pow3(const cplx& z) // a test function
{
    return std::pow(z, 3);
}

int main()
{
    cout << "Starting qpp..." << endl;
    // output format
    //cout << std::scientific;
    cout << std::fixed; // use fixed format for nice formatting
    cout << std::setprecision(4); // only for fixed or scientific modes

    // TESTING
    // testing channel and Gates::apply
    cout << endl << "Testing channel(...) and Gates::apply(...)." << endl;
    cmat rho = randrho(16);
    cmat K = kron(gt.Id2, gt.X, gt.Y, gt.Z);
    vector<std::size_t> p = randperm(4); // permutation
    cout << "Permutation: ";
    displn(p, ", ");
    vector<std::size_t> invp = invperm(p); // inverse permutation
    cout << "Inverse permutation: ";
    displn(invp, ", ");
    cmat r1 = channel(rho, { K }, p, { 2, 2, 2, 2 });
    cmat r2 = syspermute(channel(syspermute(rho, p, { 2, 2, 2, 2 }), { K },
      { 0,
            1, 2, 3 }, { 2, 2, 2, 2 }), invp, { 2, 2, 2, 2 });
    cout << norm(r1 - r2) << endl << endl;

    r1 = gt.apply(rho, K, p, { 2, 2, 2, 2 });
    r2 = syspermute(
            gt.apply(syspermute(rho, p, { 2, 2, 2, 2 }), K, { 0, 1, 2, 3 }, { 2,
                    2, 2, 2 }), invp, { 2, 2, 2, 2 });
    cout << norm(r1 - r2) << endl << endl;
```

```
displn(channel(prj(mket( { 0, 1 })), { gt.CNOTab }, { 1, 0 }, { 2, 2 }));
cout << endl;
displn(gt.apply(mket( { 0, 0 }), gt.CNOTab, { 0, 1 }, { 2, 2 }));

// quantum teleportation
cout << endl << "Qudit teleportation." << endl;
ket psi = randket(2); // a random state;
cout << "|psi><psi|:" << endl;
displn(prj(psi));
cmat telecircuit = expandout(gt.H, { 0 }, { 2, 2, 2 })
          gt.CTRL(gt.X, { 0 }, { 1 }, 3);
ket psiin = kron(psi, st.b00); // input state
ket psiout = telecircuit * psiin; // output state before measurement
// measure Alice's qubits, measurement results are 1 0
psiout = kron(prj(st.z1), prj(st.z0), gt.Id2) * psiout;
// apply correction
psiout = expandout(powm(gt.Z, 1) * powm(gt.X, 0), { 2 }, { 2, 2, 2 })
          psiout;
// not necessary to normalize, prj() takes care of it below
cmat rhoout = ptrace(prj(psiout), { 0, 1 }, { 2, 2, 2 });
cout << endl << "Teleported state:" << endl;
displn(rhoout);
cout << "Difference in norm: " << norm(prj(psi) - rhoout) << endl;

// qudit measurements
cout << endl << "Qudit measurements." << endl;
cout << "Initially in state |0><0|." << endl;
ket zd0(3);
zd0 << 1, 0, 0;
Qudit q(prj(zd0));
cout << "Measuring Z operator non-destructively. Results:" << endl;
cout << q.measure() << endl;
cout << q.measure() << endl;
cout << q.measure() << endl;
cout << "Measuring X operator non-destructively. Results:" << endl;
cout << q.measure(gt.Xd(3)) << endl;
cout << q.measure(gt.Xd(3)) << endl;
cout << q.measure(gt.Xd(3)) << endl;
// von Neumann projective measurement
cout << "Measuring X operator destructively (collapse). Results:" << endl;
cout << q.measure(gt.Xd(3), true) << endl;
cout << q.measure(gt.Xd(3)) << endl;
cout << q.measure(gt.Xd(3)) << endl;
cout << "Finally measuring Z operator destructively. Results:" << endl;
cout << q.measure(true) << endl;
cout << q.measure() << endl;
cout << q.measure() << endl;
cout << "Final state of qudit:" << endl;
displn(q.getRho());

// Bell state generator
cout << endl << "Bell state generator: " << endl;
cmat circuit;
circuit = gt.CTRL(gt.X, { 0 }, { 1 }, 2) * expandout(gt.
  H, 0, { 2, 2 });
cmat input = kron(st.z0, st.z0);
cmat output = circuit * input;
cout << "Circuit matrix representation: " << endl;
displn(circuit);
cout << endl << "Output (|Bell_0> state) of the circuit on |00>: " << endl;
displn(output);

// 3-qubit repetion code
cout << endl << "3-qubit repetition code: " << endl;
cmat rep;
rep = gt.CTRL(gt.X, { 0 }, { 2 }, 3) * gt.CTRL(gt.X, { 0 }, { 1 }, 3);
input = kron(st.z1, st.z0, st.z0);
output = rep * input;
cout << "Circuit acting on |000> produces |111>. Check: " << endl;
displn(output);

// functor test
cout << endl << "Functor z^3 acting on:" << endl;
cmat a(2, 2);
a << 1, 2, 3, 4;
displn(a);
cout << "Result (with lambda):" << endl;
// functor z^3 componentwise, specify OutputScalar and Derived for lambdas
displn(cwise<cplx, cmat>(a, [](const cplx& z)->cplx
{   return z*z*z;}));
cout << "Result (with proper function):" << endl;
// automatic type deduction for proper functions
displn(cwise(a, &pow3));

// Gram-Schmidt
cout << endl << "Gram-Schmidt on matrix:" << endl;
```

```
cmat A(3, 3);
A << 1, 1, 0, 0, 2, 0, 0, 0, 0;
displn(A);
cmat Ags = grams(A);
cout << endl << "Result:" << endl;
displn(Ags);
cout << endl << "Projector is:" << endl;
displn(Ags * adjoint(Ags));

// spectral decomposition test
cout << endl << "Spectral decomposition tests." << endl;
std::size_t D = 4;
cmat rH = randH(D);
dmat evalsH = hevals(rH);
cmat evectsH = hevects(rH);
cmat spec = cmat::Zero(D, D);
for (std::size_t i = 0; i < D; i++)
    spec += evalsH(i) * prj((cmat) evectsH.col(i));
cout << "Original matrix: " << endl;
displn(rH);
cout << endl << "Reconstructed from spectral decomposition: " << endl;
displn(spec);
cout << "Difference in norm: " << norm(spec - rH) << endl;

// channel tests
cout << endl << "Channel tests." << endl;
std::size_t nk = 10, d = 2; // nk Kraus on d-dimensional system
cout << "Generating a random channel with " << nk
        << " Kraus operators on a " << d << " dimensional space..." << endl;
std::vector<cmat> Ks = randkraus(nk, d);

cmat rho_in = randrho(d); // input state
cmat rho_out = channel(rho_in, Ks); // output state

cout << "Computing its Choi matrix..." << endl;
cmat choim = choi(Ks);
cout << "Choi matrix:" << endl;
displn(choim);
cout << endl << "The eigenvalues of the Choi matrix are: " << endl;
displn(transpose(hevals(choim)));
cout << endl << "Their sum is: " << sum(hevals(choim)) << endl;
std::vector<cmat> Kperps = choi2kraus(choim);
cout << endl << "The Kraus rank of the channel is: " << Kperps.size()
        << endl;
cmat rho_out1 = channel(rho_in, Kperps);
cout << endl << "Difference in norm on output states: "
        << norm(rho_out1 - rho_out) << endl;
cout << endl << "Superoperator matrix:" << endl;
cmat smat = super(Ks);
displn(smat);
cout << endl << "The eigenvalues of the superoperator matrix are: " << endl;
cmat evalsupop = evals(smat);
displn(transpose(evalsupop));
cout << endl << "Their absolute values are: " << endl;
for (std::size_t i = 0; i < (std::size_t) evalsupop.size(); i++)
    cout << std::abs((cplx) evalsupop(i)) << " ";
cout << endl << endl << "Diference in norm for superoperator action: ";
cmat rho_out2 = transpose(
        (cmat) reshape(smat * reshape(transpose(rho_in), d * d, 1), d, d));
cout << norm(rho_out - rho_out2) << endl;

// statistics tests
cout << endl << "Statistics tests." << endl;
std::vector<cplx> ampl = { 1. + 1_i, 1. - 1_i };
cmat va(1, 4);
va << 0.1, 1, 1. + 1_i, 1. + 2_i;
DiscreteDistributionAbsSquare dc(va);
cout << "The probabilities are: ";
displn(dc.probabilities(), ", ", "{", "}");

//  // TIMING tests
cout << endl << "Timing tests..." << endl;
std::size_t n = 12; // number of qubits
std::size_t N = std::pow(2, n);
vector<std::size_t> dims(n, 2); // local dimensions
cout << "n = " << n << " qubits, matrix size " << N << " x " << N << "."
        << endl;

// matrix initialization
cout << endl << "Matrix initialization timing." << endl;
// start the timer, automatic tic() in the constructor
Timer t, total;
cmat randcmat = cmat::Random(N, N);
t.toc(); // read the time
cout << "Took " << t << " seconds." << endl;

// lazy matrix product
```

```
    cout << endl << "Lazy matrix product timing." << endl;
    t.tic();
    auto lazyprod = randcmat * randcmat; // lazyprod has type GenMatProduct
    t.toc(); // read the time
    cout << "Took " << t << " seconds." << endl;

    // ptrace1 timing
    cout << endl << "ptrace1 timing." << endl;
    t.tic(); // reset the chronometer
    // trace away half of the qubits
    ptrace1(randcmat,
            { (std::size_t) std::sqrt(N), (std::size_t) std::sqrt(N) });
    t.toc(); // read the time
    cout << "Took " << t << " seconds." << endl;

    // ptrace2 timing
    cout << endl << "ptrace2 timing." << endl;
    t.tic(); // reset the chronometer
    // trace away half of the qubits
    ptrace2(randcmat,
            { (std::size_t) std::sqrt(N), (std::size_t) std::sqrt(N) });
    t.toc(); // read the time
    cout << "Took " << t << " seconds." << endl;

    // ptrace
    cout << endl << "ptrace timing." << endl;
    vector<std::size_t> subsys_ptrace = { 0 };
    cout << "Subsytem(s): ";
    displn(subsys_ptrace, ", ");
    t.tic();
    ptrace(randcmat, subsys_ptrace, dims);
    t.toc();
    cout << "Took " << t << " seconds." << endl;

    // ptranspose
    cout << endl << "ptranspose timing." << endl;
    vector<std::size_t> subsys_ptranspose; // partially transpose n-1 subsystems
    for (std::size_t i = 0; i < n - 1; i++)
        subsys_ptranspose.push_back(i);
    cout << "Subsytem(s): ";
    displn(subsys_ptranspose, ", ");
    t.tic();
    ptranspose(randcmat, subsys_ptranspose, dims);
    t.toc();
    cout << "Took " << t << " seconds." << endl;

    // syspermute
    cout << endl << "syspermute timing." << endl;
    vector<std::size_t> perm; // left-shift all subsystems by 1
    for (std::size_t i = 0; i < n; i++)
        perm.push_back((i + 1) % n);
    cout << "Subsytem(s): ";
    displn(perm, ", ");
    t.tic();
    syspermute(randcmat, perm, dims);
    t.toc();
    cout << "Took " << t << " seconds." << endl;

    //   // matrix product
    //   cout << endl << "Matrix product timing." << endl;
    //   t.tic(); // reset the chronometer
    //   cmat prodmat = randcmat * randcmat; // explicit cmat now
    //   t.toc(); // read the time
    //   cout << "Took " << t << " seconds." << endl;

    // END TIMING
    total.toc(); // read the total running time
    cout << endl << "Total time: " << total.seconds() << " seconds.";
    cout << endl << "Exiting qpp..." << endl;
}
```

Chapter 2

Namespace Index

2.1 Namespace List

Here is a list of all namespaces with brief descriptions:

Chapter 3

Hierarchical Index

3.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 4

Class Index

4.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 5

File Index

5.1 File List

Here is a list of all files with brief descriptions:

Chapter 6

Namespace Documentation

6.1 qpp Namespace Reference

Namespaces

- internal

Classes

- class DiscreteDistribution
- class DiscreteDistributionAbsSquare
- class Exception
- class Gates
- class NormalDistribution
- class Qudit
- class RandomDevices
- class Singleton
- class States
- class Timer
- class UniformIntDistribution
- class UniformRealDistribution

Typedefs

- using cplx = std::complex< double >

  Complex number in double precision.
- using cmat = Eigen::MatrixXcd

  Complex (double precision) dynamic Eigen matrix.
- using dmat = Eigen::MatrixXd

  Real (double precision) dynamic Eigen matrix.
- using ket = Eigen::Matrix< cplx, Eigen::Dynamic, 1 >

  Complex (double precision) dynamic Eigen column matrix.
- using bra = Eigen::Matrix< cplx, 1, Eigen::Dynamic >

  Complex (double precision) dynamic Eigen row matrix.
- template<typename Scalar >
  using DynMat = Eigen::Matrix< Scalar, Eigen::Dynamic, Eigen::Dynamic >

  Dynamic Eigen matrix over the field specified by Scalar.

Functions

- cmat super (const std::vector< cmat > &Ks)

    Superoperator matrix representation.
- cmat choi (const std::vector< cmat > &Ks)

    Choi matrix representation.
- std::vector< cmat > choi2kraus (const cmat &A)

    Extracts orthogonal Kraus operators from Choi matrix.
- template<typename Derived >
  cmat channel (const Eigen::MatrixBase< Derived > &rho, const std::vector< cmat > &Ks)

    Applies the channel specified by the set of Kraus operators Ks to the density matrix rho.
- template<typename Derived >
  cmat channel (const Eigen::MatrixBase< Derived > &rho, const std::vector< cmat > &Ks, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

    Applies the channel specified by the set of Kraus operators Ks to the part of the density matrix rho specified by subsys.
- constexpr std::complex< double > operator""_i (unsigned long long int x)

    User-defined literal for complex $i = \sqrt{-1}$ *(integer overload)*
- constexpr std::complex< double > operator""_i (long double x)

    User-defined literal for complex $i = \sqrt{-1}$ *(real overload)*
- std::complex< double > omega (std::size_t D)

    D-th root of unity.
- template<typename Derived >
  cmat schmidtcoeff (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

    Schmidt coefficients of the bi-partite pure state A.
- template<typename Derived >
  cmat schmidtU (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

    Schmidt basis on Alice's side.
- template<typename Derived >
  cmat schmidtV (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

    Schmidt basis on Bob's side.
- template<typename Derived >
  cmat schmidtprob (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

    Schmidt probabilities of the bi-partite pure state A.
- template<typename Derived >
  double entanglement (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

    Entanglement of the bi-partite pure state A.
- template<typename Derived >
  double gconcurrence (const Eigen::MatrixBase< Derived > &A)

    G-concurrence of the bi-partite pure state A.
- template<typename Derived >
  double shannon (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double renyi (const double alpha, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double renyi_inf (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double tsallis (const double alpha, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double qmutualinfo (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)
- template<typename Derived >
  DynMat< typename Derived::Scalar > transpose (const Eigen::MatrixBase< Derived > &A)

    Transpose.

- template< typename Derived >
  DynMat< typename Derived::Scalar > conjugate (const Eigen::MatrixBase< Derived > &A)

  Complex conjugate.
- template< typename Derived >
  DynMat< typename Derived::Scalar > adjoint (const Eigen::MatrixBase< Derived > &A)

  Adjoint.
- template< typename Derived >
  DynMat< typename Derived::Scalar > inverse (const Eigen::MatrixBase< Derived > &A)

  Inverse.
- template< typename Derived >
  Derived::Scalar trace (const Eigen::MatrixBase< Derived > &A)

  Trace.
- template< typename Derived >
  Derived::Scalar det (const Eigen::MatrixBase< Derived > &A)

  Determinant.
- template< typename Derived >
  Derived::Scalar logdet (const Eigen::MatrixBase< Derived > &A)

  Logarithm of the determinant.
- template< typename Derived >
  Derived::Scalar sum (const Eigen::MatrixBase< Derived > &A)

  Element-wise sum.
- template< typename Derived >
  double norm (const Eigen::MatrixBase< Derived > &A)

  Trace norm.
- template< typename Derived >
  cmat evals (const Eigen::MatrixBase< Derived > &A)

  Eigenvalues.
- template< typename Derived >
  cmat evects (const Eigen::MatrixBase< Derived > &A)

  Eigenvectors.
- template< typename Derived >
  dmat hevals (const Eigen::MatrixBase< Derived > &A)

  Hermitian eigenvalues.
- template< typename Derived >
  cmat hevects (const Eigen::MatrixBase< Derived > &A)

  Hermitian eigenvectors.
- template< typename Derived >
  cmat funm (const Eigen::MatrixBase< Derived > &A, cplx(∗f)(const cplx &))

  Functional calculus f(A)
- template< typename Derived >
  cmat sqrtm (const Eigen::MatrixBase< Derived > &A)

  Matrix square root.
- template< typename Derived >
  cmat absm (const Eigen::MatrixBase< Derived > &A)

  Matrix absolut value.
- template< typename Derived >
  cmat expm (const Eigen::MatrixBase< Derived > &A)

  Matrix exponential.
- template< typename Derived >
  cmat logm (const Eigen::MatrixBase< Derived > &A)

  Matrix logarithm.
- template< typename Derived >
  cmat sinm (const Eigen::MatrixBase< Derived > &A)

Matrix sin.

- template<typename Derived >
  cmat cosm (const Eigen::MatrixBase< Derived > &A)

  Matrix cos.
- template<typename Derived >
  cmat spectralpowm (const Eigen::MatrixBase< Derived > &A, const cplx z)

  Matrix power.
- template<typename Derived >
  DynMat< typename Derived::Scalar > powm (const Eigen::MatrixBase< Derived > &A, std::size_t n)

  Matrix power.
- template<typename OutputScalar , typename Derived >
  DynMat< OutputScalar > cwise (const Eigen::MatrixBase< Derived > &A, OutputScalar(*f)(const typename Derived::Scalar &))

  Functor.
- template<typename T >
  DynMat< typename T::Scalar > kron (const T &head)

  Kronecker product (variadic overload)
- template<typename T , typename... Args>
  DynMat< typename T::Scalar > kron (const T &head, const Args &...tail)

  Kronecker product (variadic overload)
- template<typename Derived >
  DynMat< typename Derived::Scalar > kron (const std::vector< Derived > &As)

  Kronecker product (std::vector overload)
- template<typename Derived >
  DynMat< typename Derived::Scalar > kron (const std::initializer_list< Derived > &As)

  Kronecker product (std::initializer_list overload)
- template<typename Derived >
  DynMat< typename Derived::Scalar > kronpow (const Eigen::MatrixBase< Derived > &A, std::size_t n)

  Kronecker power.
- template<typename Derived >
  DynMat< typename Derived::Scalar > reshape (const Eigen::MatrixBase< Derived > &A, std::size_t rows, std::size_t cols)

  Reshape.
- template<typename Derived >
  DynMat< typename Derived::Scalar > syspermute (const Eigen::MatrixBase< Derived > &A, const std↩ ::vector< std::size_t > &perm, const std::vector< std::size_t > &dims)

  System permutation.
- template<typename Derived >
  DynMat< typename Derived::Scalar > ptrace1 (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Partial trace.
- template<typename Derived >
  DynMat< typename Derived::Scalar > ptrace2 (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Partial trace.
- template<typename Derived >
  DynMat< typename Derived::Scalar > ptrace (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

  Partial trace.
- template<typename Derived >
  DynMat< typename Derived::Scalar > ptranspose (const Eigen::MatrixBase< Derived > &A, const std↩ ::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

  Partial transpose.

- template< typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > comm (const Eigen::MatrixBase< Derived1 > &A, const Eigen::↩ MatrixBase< Derived2 > &B)

  Commutator.
- template< typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > anticomm (const Eigen::MatrixBase< Derived1 > &A, const Eigen↩ ::MatrixBase< Derived2 > &B)

  Anti-commutator.
- template< typename Derived >
  DynMat< typename Derived::Scalar > prj (const Eigen::MatrixBase< Derived > &V)

  Projector.
- template< typename Derived >
  DynMat< typename Derived::Scalar > expandout (const Eigen::MatrixBase< Derived > &A, std::size_t pos, const std::vector< std::size_t > &dims)

  Expand out.
- template< typename Derived >
  DynMat< typename Derived::Scalar > grams (const std::vector< Derived > &Vs)

  Gram-Schmidt orthogonalization (std::vector overload)
- template< typename Derived >
  DynMat< typename Derived::Scalar > grams (const std::initializer_list< Derived > &Vs)

  Gram-Schmidt orthogonalization (std::initializer_list overload)
- template< typename Derived >
  DynMat< typename Derived::Scalar > grams (const Eigen::MatrixBase< Derived > &A)

  Gram-Schmidt orthogonalization (Eigen expression (matrix) overload)
- std::vector< std::size_t > n2multiidx (std::size_t n, const std::vector< std::size_t > &dims)

  Non-negative integer index to multi-index.
- std::size_t multiidx2n (const std::vector< std::size_t > &midx, const std::vector< std::size_t > &dims)

  Multi-index to non-negative integer index.
- ket mket (const std::vector< std::size_t > &mask)

  Multi-partite qubit ket.
- ket mket (const std::vector< std::size_t > &mask, const std::vector< std::size_t > &dims)

  Multi-partite qudit ket (different dimensions overload)
- ket mket (const std::vector< std::size_t > &mask, std::size_t d)

  Multi-partite qudit ket (same dimensions overload)
- std::vector< std::size_t > invperm (const std::vector< std::size_t > &perm)

  Inverse permutation.
- std::vector< std::size_t > compperm (const std::vector< std::size_t > &perm, const std::vector< std::size_t > &sigma)

  Compose permutations.
- template< typename T >
  void disp (const T &x, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template< typename T >
  void displn (const T &x, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template< typename T >
  void disp (const T ∗x, const std::size_t n, const std::string &separator, const std::string &start="[", const std↩ ::string &end="]", std::ostream &os=std::cout)
- template< typename T >
  void displn (const T ∗x, const std::size_t n, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template< typename Derived >
  void disp (const Eigen::MatrixBase< Derived > &A, double chop=chop, std::ostream &os=std::cout)

- template<typename Derived >
  void displn (const Eigen::MatrixBase< Derived > &A, double chop=chop, std::ostream &os=std::cout)
- void disp (const cplx c, double chop=chop, std::ostream &os=std::cout)
- void displn (const cplx c, double chop=chop, std::ostream &os=std::cout)
- template<typename Derived >
  void save (const Eigen::MatrixBase< Derived > &A, const std::string &fname)
- template<typename Derived >
  DynMat< typename Derived::Scalar > load (const std::string &fname)
- template<typename Derived >
  Derived loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<>
  dmat loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<>
  cmat loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<typename Derived >
  void saveMATLABmatrix (const Eigen::MatrixBase< Derived > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)
- template<>
  void saveMATLABmatrix (const Eigen::MatrixBase< dmat > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)
- template<>
  void saveMATLABmatrix (const Eigen::MatrixBase< cmat > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)
- template<typename Derived >
  Derived rand (std::size_t rows, std::size_t cols, double a=0, double b=1)
- template<>
  dmat rand (std::size_t rows, std::size_t cols, double a, double b)
- template<>
  cmat rand (std::size_t rows, std::size_t cols, double a, double b)
- double rand (double a=0, double b=1)
- long long randint (long long a, long long b)
- template<typename Derived >
  Derived randn (std::size_t rows, std::size_t cols, double mean=0, double sigma=1)
- template<>
  dmat randn (std::size_t rows, std::size_t cols, double mean, double sigma)
- template<>
  cmat randn (std::size_t rows, std::size_t cols, double mean, double sigma)
- double randn (double mean=0, double sigma=1)
- cmat randU (std::size_t D)
- cmat randV (std::size_t Din, std::size_t Dout)
- std::vector< cmat > randkraus (std::size_t n, std::size_t D)
- cmat randH (std::size_t D)
- ket randket (std::size_t D)
- cmat randrho (std::size_t D)
- std::vector< std::size_t > randperm (std::size_t n)

Variables

- constexpr double chop = 1e-10

  Used in qpp::disp() and qpp::displn() for setting to zero numbers that have their absolute value smaller than qpp::ct::chop.
- constexpr double eps = 1e-12

  Used to decide whether a number or expression in double precision is zero or not.
- constexpr std::size_t maxn = 64

  Maximum number of qubits.

- constexpr double pi = 3.141592653589793238462643383279502884

  π
- constexpr double ee = 2.718281828459045235360287471352662497

  Base of natural logarithm, e.
- RandomDevices & rdevs = RandomDevices::get_instance()

  qpp::RandomDevices Singleton
- const Gates & gt = Gates::get_instance()

  qpp::Gates const Singleton
- const States & st = States::get_instance()

  qpp::States const Singleton

6.1.1 Typedef Documentation

6.1.1.1 using **qpp::bra** = typedef Eigen::Matrix<**cplx**, 1, Eigen::Dynamic>

Complex (double precision) dynamic Eigen row matrix.

6.1.1.2 using **qpp::cmat** = typedef Eigen::MatrixXcd

Complex (double precision) dynamic Eigen matrix.

6.1.1.3 using **qpp::cplx** = typedef std::complex<double>

Complex number in double precision.

6.1.1.4 using **qpp::dmat** = typedef Eigen::MatrixXd

Real (double precision) dynamic Eigen matrix.

6.1.1.5 template<typename Scalar > using **qpp::DynMat** = typedef Eigen::Matrix<Scalar, Eigen::Dynamic, Eigen::Dynamic>

Dynamic Eigen matrix over the field specified by *Scalar*.

Example:

```
auto mat = DynMat<float>(2,3); // type of mat is Eigen::Matrix<float, Eigen::Dynamic, Eigen::Dynamic>
```

6.1.1.6 using **qpp::ket** = typedef Eigen::Matrix<**cplx**, Eigen::Dynamic, 1>

Complex (double precision) dynamic Eigen column matrix.

6.1.2 Function Documentation

6.1.2.1 template<typename Derived > **cmat** qpp::absm (const Eigen::MatrixBase< Derived > & *A*)

Matrix absolut value.

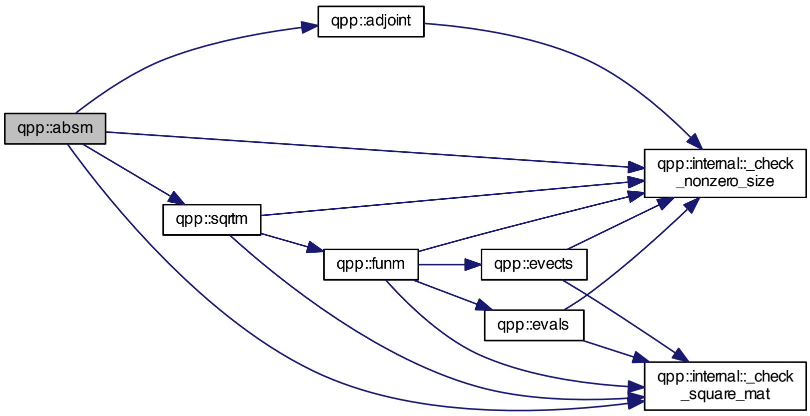
Parameters

A	Eigen expression

Returns

Matrix absolut value of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.2 template<typename Derived > DynMat<typename Derived::Scalar> qpp::adjoint (const Eigen::MatrixBase< Derived > & *A*)

Adjoint.

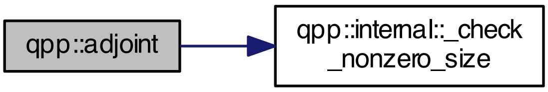
Parameters

A	Eigen expression

Returns

Adjoint (Hermitian conjugate) of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.3 template< typename Derived1 , typename Derived2 > DynMat<typename Derived1::Scalar> qpp::anticomm (const Eigen::MatrixBase< Derived1 > & *A*, const Eigen::MatrixBase< Derived2 > & *B*)

Anti-commutator.

Anti-commutator $\{A,B\} = AB + BA$
Both *A* and *B* must be Eigen expressions over the same scalar field

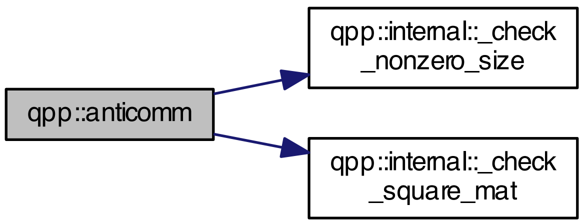
Parameters

A	Eigen expression
B	Eigen expression

Returns

Anti-commutator $AB+BA$, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.4 template< typename Derived > cmat qpp::channel (const Eigen::MatrixBase< Derived > & *rho*, const std::vector< cmat > & *Ks*)

Applies the channel specified by the set of Kraus operators *Ks* to the density matrix *rho*.

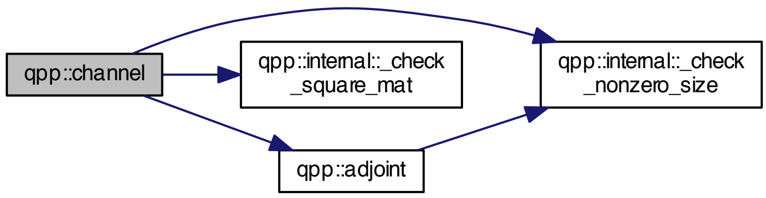
Parameters

rho	Eigen expression
Ks	std::vector of Eigen expressions representing the set of Kraus operators

Returns

Output density matrix, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.5 template< typename Derived > cmat qpp::channel (const Eigen::MatrixBase< Derived > & *rho*, const std::vector< cmat > & *Ks*, const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*)

Applies the channel specified by the set of Kraus operators *Ks* to the part of the density matrix *rho* specified by *subsys*.

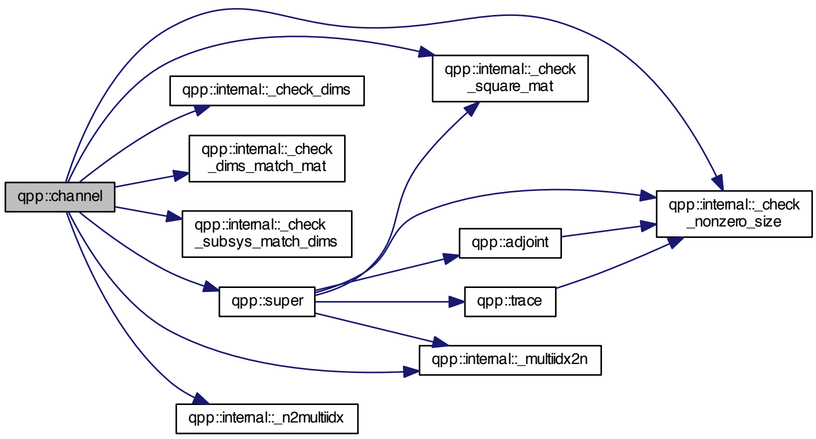
Parameters

rho	Eigen expression
Ks	std::vector of Eigen expressions representing the set of Kraus operators
subsys	Subsystems' indexes
dims	Dimensions of the multi-partite system

Returns

Output density matrix, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.6 cmat qpp::choi (const std::vector< cmat > & *Ks*)

Choi matrix representation.

Constructs the Choi matrix of the channel specified by the set of Kraus operators *Ks* in the standard operator basis $\{|i\rangle\langle j|\}$ ordered in lexicographical order, i.e. $|0\rangle\langle 0|$, $|0\rangle\langle 1|$ etc.

Note

the superoperator matrix S and the Choi matrix C are related by $S_{ab,mn} = C_{ma,nb}$

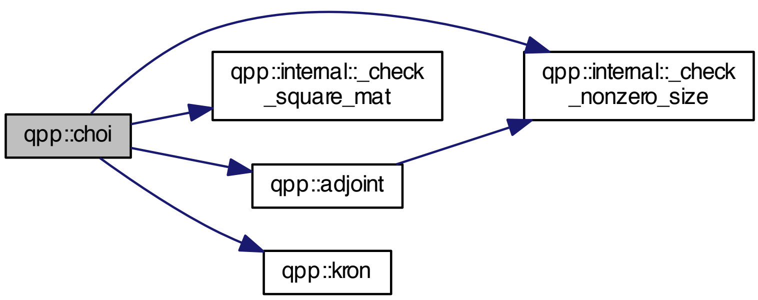
Parameters

Ks	std::vector of Eigen expressions representing the set of Kraus operators

Returns

Choi matrix representation, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.7 std::vector<cmat> qpp::choi2kraus (const cmat & *A*)

Extracts orthogonal Kraus operators from Choi matrix.

Extracts a set of orthogonal (under Hilbert-Schmidt operator norm) Kraus operators from the Choi representation *A* of the channel

Note

The Kraus operators satisfy $Tr(K_i^\dagger K_j) = \delta_{ij}$ for all $i \neq j$

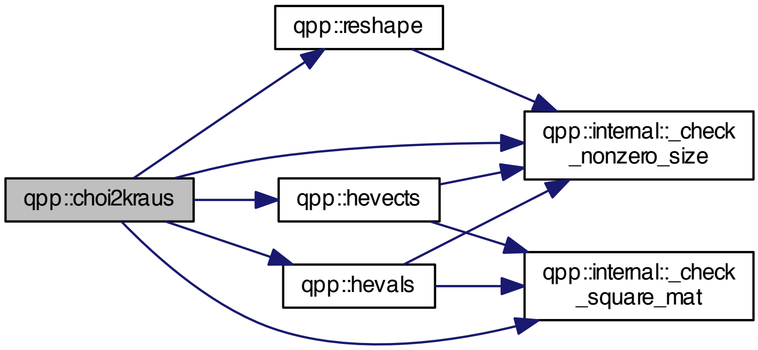
Parameters

A	Choi matrix

Returns

std::vector of dynamic matrices over the complex field representing the set of Kraus operators

Here is the call graph for this function:



6.1.2.8 template< typename Derived1 , typename Derived2 > DynMat<typename Derived1::Scalar> qpp::comm (const Eigen::MatrixBase< Derived1 > & *A*, const Eigen::MatrixBase< Derived2 > & *B*)

Commutator.

Commutator $[A,B] = AB - BA$
Both *A* and *B* must be Eigen expressions over the same scalar field

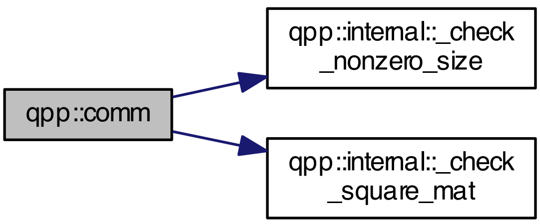
Parameters

A	Eigen expression
B	Eigen expression

Returns

Commutator $AB - BA$, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.9 std::vector<std::size_t> qpp::compperm (const std::vector< std::size_t > & *perm*, const std::vector< std::size_t > & *sigma*)

Compose permutations.

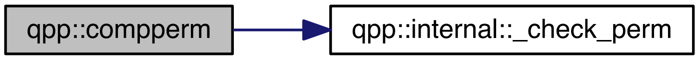
Parameters

perm	Permutation
sigma	Permutation

Returns

Composition of the permutations *perm* ∘ *sigma* = perm(sigma)

Here is the call graph for this function:



6.1.2.10 template<typename Derived > DynMat<typename Derived::Scalar> qpp::conjugate (const Eigen::MatrixBase< Derived > & *A*)

Complex conjugate.

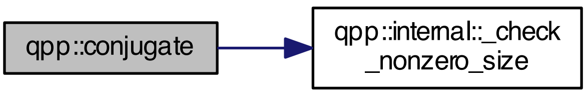
Parameters

A	Eigen expression

Returns

Complex conjugate of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.11 template<typename Derived > cmat qpp::cosm (const Eigen::MatrixBase< Derived > & *A*)

Matrix cos.

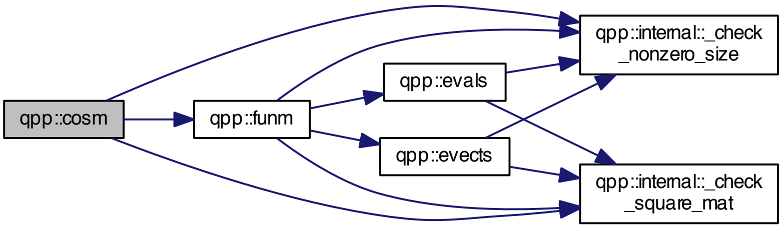
Parameters

A	Eigen expression

Returns

Matrix cosine of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.12 template< typename OutputScalar , typename Derived > DynMat< OutputScalar> qpp::cwise (const Eigen::MatrixBase< Derived > & *A*, OutputScalar(∗)(const typename Derived::Scalar &) *f*)

Functor.

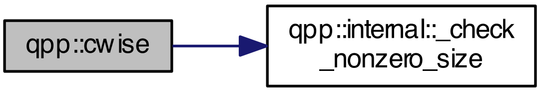
Parameters

A	Eigen expression
f	Pointer-to-function from scalars of *A* to *OutputScalar*

Returns

Component-wise $f(A)$, as a dynamic matrix over the *OutputScalar* scalar field

Here is the call graph for this function:



6.1.2.13 template< typename Derived > Derived::Scalar qpp::det (const Eigen::MatrixBase< Derived > & *A*)

Determinant.

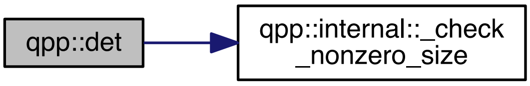
Parameters

A	Eigen expression

Returns

Determinant of *A*, as a dynamic matrix over the same scalar field
Returns $\pm\infty$ when the determinant overflows/underflows

Here is the call graph for this function:



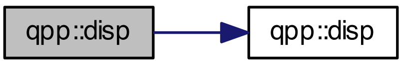
6.1.2.14 template< typename T > void qpp::disp (const T & *x*, const std::string & *separator*, const std::string & *start* = "[", const std::string & *end* = "]", std::ostream & *os* = `std::cout`)

6.1.2.15 template< typename T > void qpp::disp (const T ∗ *x*, const std::size_t *n*, const std::string & *separator*, const std::string & *start* = "[", const std::string & *end* = "]", std::ostream & *os* = `std::cout`)

6.1.2.16 template< typename Derived > void qpp::disp (const Eigen::MatrixBase< Derived > & *A*, double *chop* = `chop`, std::ostream & *os* = `std::cout`)

6.1.2.17 void qpp::disp (const cplx *c*, double *chop* = `chop`, std::ostream & *os* = `std::cout`)

Here is the call graph for this function:



6.1.2.18 template<typename T > void qpp::dispIn (const T & *x*, const std::string & *separator*, const std::string & *start* = "[", const std::string & *end* = "]", std::ostream & *os* = `std::cout`)

Here is the call graph for this function:

6.1.2.19 template<typename T > void qpp::dispIn (const T * *x*, const std::size_t *n*, const std::string & *separator*, const std::string & *start* = "[", const std::string & *end* = "]", std::ostream & *os* = `std::cout`)

Here is the call graph for this function:

6.1.2.20 template<typename Derived > void qpp::dispIn (const Eigen::MatrixBase< Derived > & *A*, double *chop* = `chop`, std::ostream & *os* = `std::cout`)

Here is the call graph for this function:

6.1.2.21 void qpp::dispIn (const cplx *c*, double *chop* = `chop`, std::ostream & *os* = `std::cout`)

Here is the call graph for this function:

6.1.2.22 template< typename Derived > double qpp::entanglement (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Entanglement of the bi-partite pure state *A*.

Note

Defined as the von-Neumann entropy of the reduced density matrix of one of the subsystems

See also

qpp::shannon()

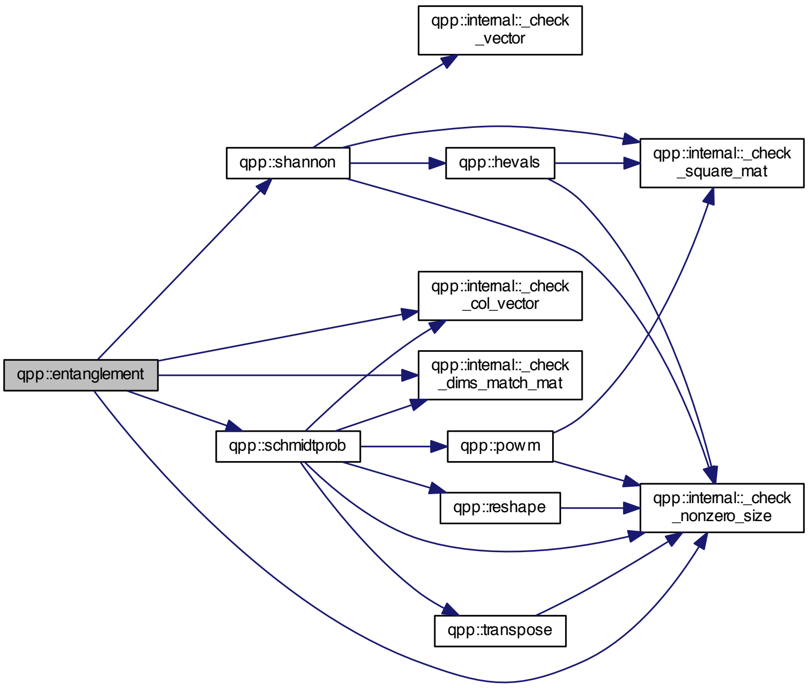
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

Entanglement, with the logarithm in base 2

Here is the call graph for this function:



6.1.2.23 template< typename Derived > cmat qpp::evals (const Eigen::MatrixBase< Derived > & *A*)

Eigenvalues.

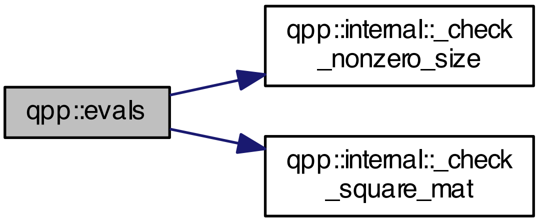
Parameters

A	Eigen expression

Returns

Eigenvalues of *A*, as a diagonal dynamic matrix over the complex field, with the eigenvalues on the diagonal

Here is the call graph for this function:



6.1.2.24 template< typename Derived > cmat qpp::evects (const Eigen::MatrixBase< Derived > & *A*)

Eigenvectors.

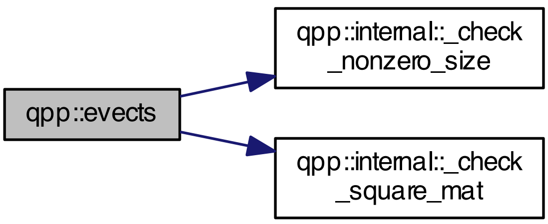
Parameters

A	Eigen expression

Returns

Eigenvectors of *A*, as columns of a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.25 template< typename Derived > DynMat< typename Derived::Scalar> qpp::expandout (const Eigen::MatrixBase< Derived > & *A*, std::size_t *pos*, const std::vector< std::size_t > & *dims*)

Expand out.

Expand out *A* as a matrix in a multi-partite system
Faster than using *qpp::kron*(I, I, ..., I, A, I, ..., I)

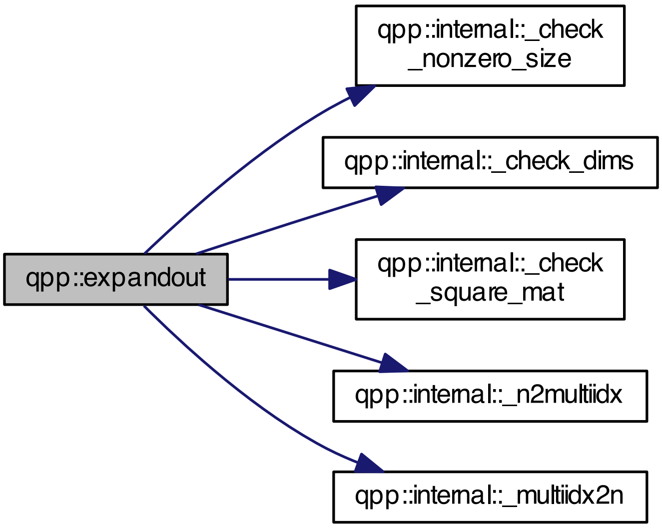
Parameters

A	Eigen expression
pos	Position
dims	Dimensions of the multi-partite system

Returns

Tensor product $I \otimes \cdots \otimes I \otimes A \otimes I \otimes \cdots \otimes I$, with *A* on position *pos*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.26 template<typename Derived > cmat qpp::expm (const Eigen::MatrixBase< Derived > & *A*)

Matrix exponential.

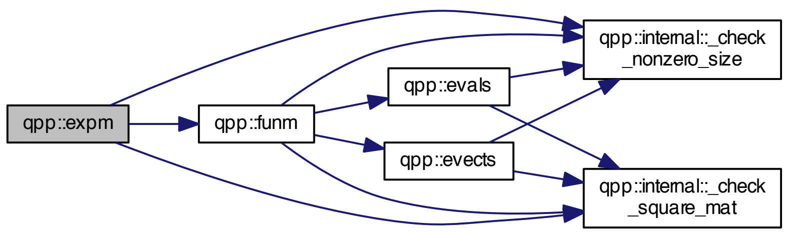
Parameters

A	Eigen expression

Returns

Matrix exponential of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.27 template< typename Derived > cmat qpp::funm (const Eigen::MatrixBase< Derived > & *A*, cplx(∗)(const cplx &) *f*)

Functional calculus f(A)

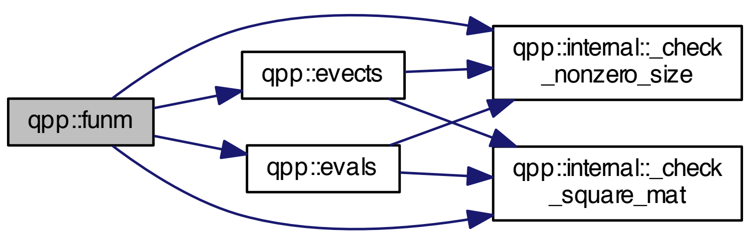
Parameters

A	Eigen expression
f	Pointer-to-function from complex to complex

Returns

f(A), as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.28 template< typename Derived > double qpp::gconcurrence (const Eigen::MatrixBase< Derived > & *A*)

G-concurrence of the bi-partite pure state *A*.

Note

Uses *qpp::logdet()* to avoid overflows

See also

qpp::logdet()

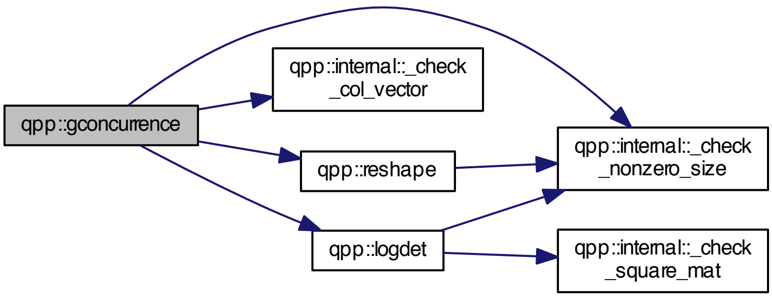
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

G-concurrence

Here is the call graph for this function:



6.1.2.29 template<typename Derived > DynMat<typename Derived::Scalar> qpp::grams (const std::vector< Derived > & *Vs*)

Gram-Schmidt orthogonalization (std::vector overload)

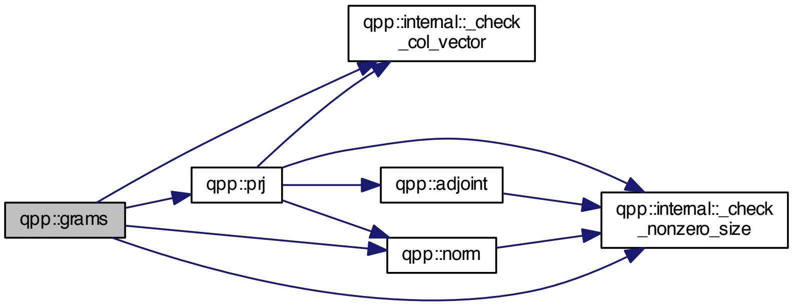
Parameters

Vs	std::vector of Eigen expressions as column vectors

Returns

Gram-Schmidt vectors of *Vs* as columns of a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.30 template<typename Derived > DynMat<typename Derived::Scalar> qpp::grams (const std::initializer_list< Derived > & *Vs*)

Gram-Schmidt orthogonalization (std::initializer_list overload)

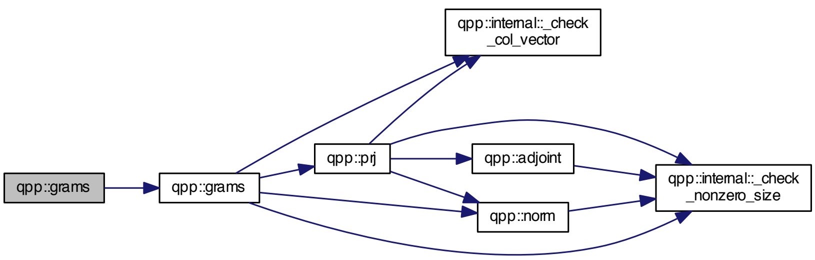
Parameters

Vs	std::initializer_list of Eigen expressions as column vectors

Returns

Gram-Schmidt vectors of *Vs* as columns of a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.31 template<typename Derived > DynMat<typename Derived::Scalar> qpp::grams (const Eigen::MatrixBase< Derived > & *A*)

Gram-Schmidt orthogonalization (Eigen expression (matrix) overload)

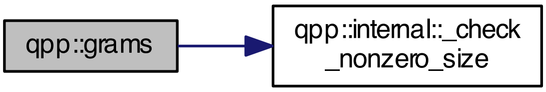
Parameters

A	Eigen expression, the input vectors are the columns of *A*

Returns

Gram-Schmidt vectors of the columns of *A*, as columns of a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.32 template< typename Derived > dmat qpp::hevals (const Eigen::MatrixBase< Derived > & *A*)

Hermitian eigenvalues.

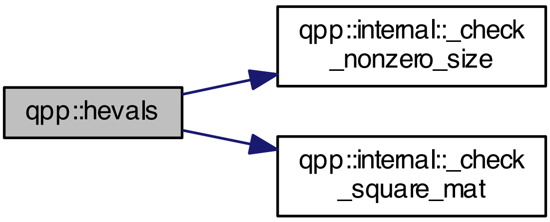
Parameters

A	Eigen expression

Returns

Eigenvalues of Hermitian *A*, as a diagonal dynamic matrix over the real field, with eigenvalues on the diagonal

Here is the call graph for this function:



6.1.2.33 template< typename Derived > cmat qpp::hevects (const Eigen::MatrixBase< Derived > & *A*)

Hermitian eigenvectors.

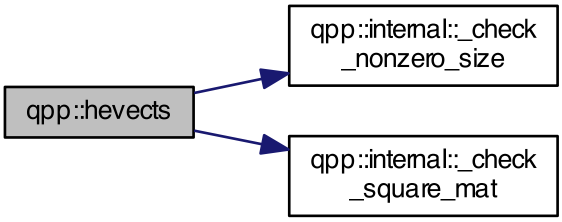
Parameters

A	Eigen expression

Returns

Eigenvectors of Hermitian *A*, as columns of a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.34 template<typename Derived > DynMat<typename Derived::Scalar> qpp::inverse (const Eigen::MatrixBase< Derived > & *A*)

Inverse.

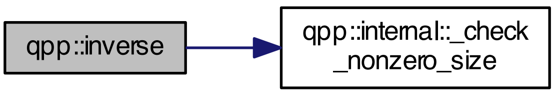
Parameters

A	Eigen expression

Returns

Inverse of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.35 std::vector<std::size_t> qpp::invperm (const std::vector< std::size_t > & *perm*)

Inverse permutation.

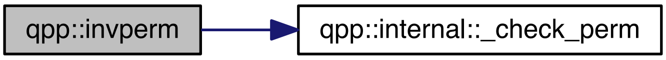
Parameters

perm	Permutation

Returns

Inverse of the permutation *perm*

Here is the call graph for this function:



6.1.2.36 template<typename T > DynMat<typename T::Scalar> qpp::kron (const T & *head*)

Kronecker product (variadic overload)

Used to stop the recursion for the variadic template version of *qpp::kron()*

Parameters

head	Eigen expression

Returns

Its argument *head*

6.1.2.37 template<typename T , typename... Args> DynMat<typename T::Scalar> qpp::kron (const T & *head*, const Args &... *tail*)

Kronecker product (variadic overload)

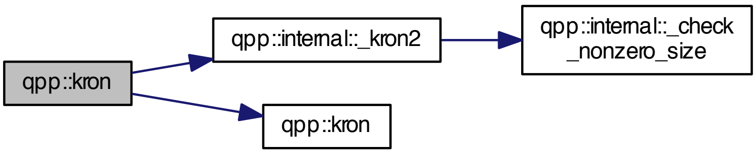
Parameters

head	Eigen expression
tail	Variadic Eigen expression (zero or more parameters)

Returns

Kronecker product of all input parameters, evaluated from left to right, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.38 template<typename Derived > DynMat<typename Derived::Scalar> qpp::kron (const std::vector< Derived > & *As*)

Kronecker product (std::vector overload)

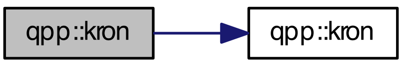
Parameters

As	std::vector of Eigen expressions

Returns

Kronecker product of all elements in *As*, evaluated from left to right, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.39 template<typename Derived > DynMat<typename Derived::Scalar> qpp::kron (const std::initializer_list< Derived > & *As*)

Kronecker product (std::initializer_list overload)

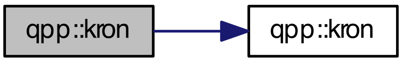
Parameters

As	std::initializer_list of Eigen expressions, such as *{A1*, A2, ... ,Ak}

Returns

Kronecker product of all elements in *As*, evaluated from left to right, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.40 template<typename Derived > DynMat<typename Derived::Scalar> qpp::kronpow (const Eigen::MatrixBase< Derived > & *A,* std::size_t *n*)

Kronecker power.

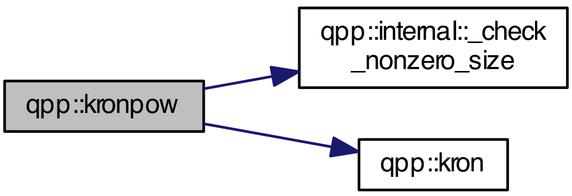
Parameters

A	Eigen expression
n	Non-negative integer

Returns

Kronecker product of *A* with itself *n* times $A^{\otimes n}$, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.41 template<typename Derived > DynMat<typename Derived::Scalar> qpp::load (const std::string & *fname*)

6.1.2.42 template<typename Derived > Derived qpp::loadMATLABmatrix (const std::string & *mat_file,* const std::string & *var_name*)

6.1.2.43 template<> dmat qpp::loadMATLABmatrix (const std::string & *mat_file*, const std::string & *var_name*)

6.1.2.44 template<> cmat qpp::loadMATLABmatrix (const std::string & *mat_file*, const std::string & *var_name*)

6.1.2.45 template<typename Derived > Derived::Scalar qpp::logdet (const Eigen::MatrixBase< Derived > & *A*)

Logarithm of the determinant.

Especially useful when the determinant overflows/underflows

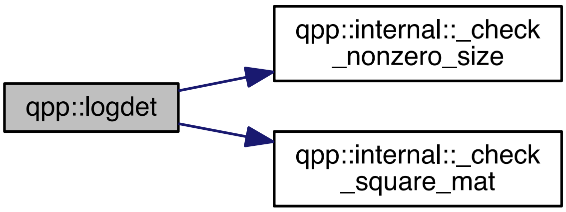
Parameters

A	Eigen expression

Returns

Logarithm of the determinant of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.46 template<typename Derived > cmat qpp::logm (const Eigen::MatrixBase< Derived > & *A*)

Matrix logarithm.

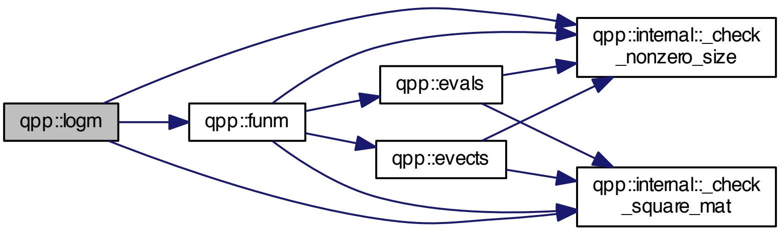
Parameters

A	Eigen expression

Returns

Matrix logarithm of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.47 ket qpp::mket (const std::vector< std::size_t > & *mask*)

Multi-partite qubit ket.

Constructs the multi-partite qubit ket $|\mathrm{mask}\rangle$, where *mask* is a std::vector of 0's and 1's

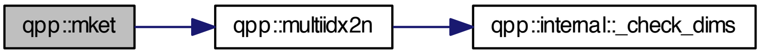
Parameters

mask	std::vector of 0's and 1's

Returns

Multi-partite qubit state vector, as a dynamic column vector over the complex field

Here is the call graph for this function:



6.1.2.48 ket qpp::mket (const std::vector< std::size_t > & *mask*, const std::vector< std::size_t > & *dims*)

Multi-partite qudit ket (different dimensions overload)

Constructs the multi-partite qudit ket $|\mathrm{mask}\rangle$, where *mask* is a std::vector of non-negative integers
Each element in *mask* has to be smaller than the corresponding element in *dims*

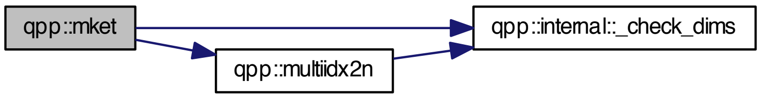
Parameters

mask	std::vector of non-negative integers
dims	Dimensions of the multi-partite system

Returns

Multi-partite qudit state vector, as a dynamic column vector over the complex field

Here is the call graph for this function:



6.1.2.49 ket qpp::mket (const std::vector< std::size_t > & *mask*, std::size_t *d*)

Multi-partite qudit ket (same dimensions overload)

Constructs the multi-partite qudit ket $|\mathrm{mask}\rangle$ in a multi-partite system, all subsystem having equal dimension *d* *mask* is a std::vector of non-negative integers, and each element in *mask* has to be strictly smaller than *d*

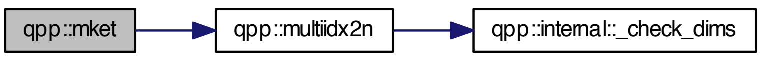
Parameters

mask	std::vector of non-negative integers
d	Subsystems' dimension

Returns

Multi-partite qudit state vector, as a dynamic column vector over the complex field

Here is the call graph for this function:



6.1.2.50 std::size_t qpp::multiidx2n (const std::vector< std::size_t > & *midx*, const std::vector< std::size_t > & *dims*)

Multi-index to non-negative integer index.

Uses standard lexicographical order, i.e. 00...0, 00...1 etc.

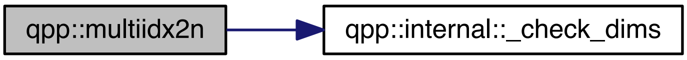
Parameters

midx	Multi-index
dims	Dimensions of the multi-partite system

Returns

Non-negative integer index

Here is the call graph for this function:



6.1.2.51 std::vector<std::size_t> qpp::n2multiidx (std::size_t *n*, const std::vector< std::size_t > & *dims*)

Non-negative integer index to multi-index.

Uses standard lexicographical order, i.e. 00...0, 00...1 etc.

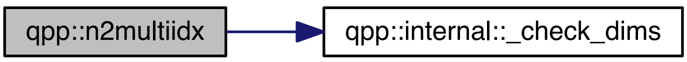
Parameters

n	Non-negative integer index
dims	Dimensions of the multi-partite system

Returns

Multi-index of the same size as *dims*

Here is the call graph for this function:



6.1.2.52 template<typename Derived > double qpp::norm (const Eigen::MatrixBase< Derived > & *A*)

Trace norm.

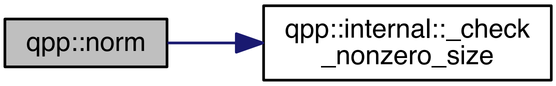
Parameters

A	Eigen expression

Returns

Trace norm (Frobenius norm) of *A*, as a real number

Here is the call graph for this function:



6.1.2.53 std::complex<double> qpp::omega (std::size_t *D*)

D-th root of unity.

Parameters

D	Non-negative integer

Returns

D-th root of unity $\exp(2\pi i/D)$

6.1.2.54 constexpr std::complex<double> qpp::operator"" _i (unsigned long long int *x*)

User-defined literal for complex $i = \sqrt{-1}$ (integer overload)

Example:

```
auto z = 4_i; // type of z is std::complex<double>
```

6.1.2.55 constexpr std::complex<double> qpp::operator"" _i (long double *x*)

User-defined literal for complex $i = \sqrt{-1}$ (real overload)

Example:

```
auto z = 4.5_i; // type of z is std::complex<double>
```

6.1.2.56 template<typename Derived > DynMat<typename Derived::Scalar> qpp::powm (const Eigen::MatrixBase< Derived > & *A*, std::size_t *n*)

Matrix power.

Explicitly multiplies the matrix *A* with itself *n* times
By convention $A^0 = I$

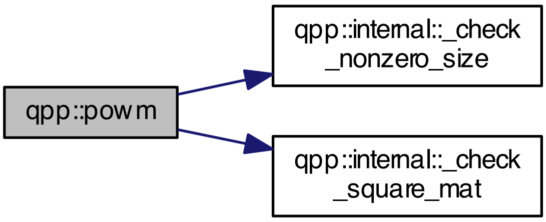
Parameters

A	Eigen expression
n	Non-negative integer

Returns

Matrix power A^n, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.57 template<typename Derived > DynMat<typename Derived::Scalar> qpp::prj (const Eigen::MatrixBase< Derived > & *V*)

Projector.

Normalized projector onto state vector

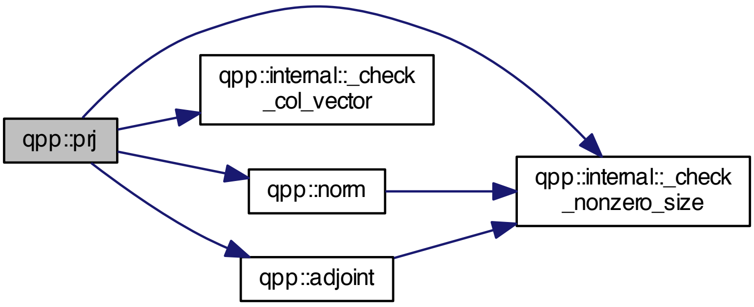
Parameters

V	Eigen expression

Returns

Projector onto the state vector *V*, or the matrix *Zero* if *V* has norm zero (i.e. smaller than *qpp::eps*), as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.58 template<typename Derived > DynMat<typename Derived::Scalar> qpp::ptrace (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*)

Partial trace.

Partial trace of the multi-partite density matrix over a list of subsystems

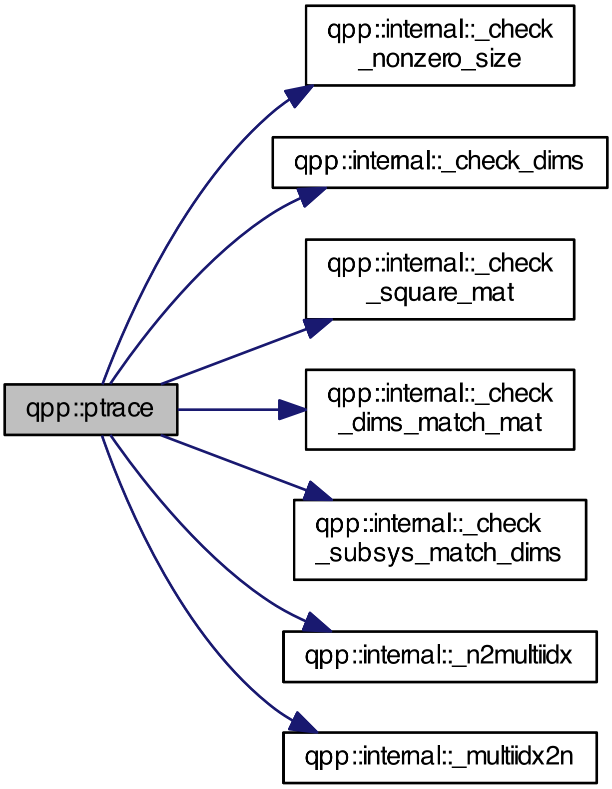
Parameters

A	Eigen expression
subsys	Subsystems' indexes
dims	Dimensions of the multi-partite system

Returns

Partial trace $Tr_{subsys}(\cdot)$ over the subsytems *subsys* in a multi-partite system, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.59 template< typename Derived > DynMat< typename Derived::Scalar> qpp::ptrace1 (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Partial trace.

Partial trace of density matrix over the first subsystem in a bi-partite system

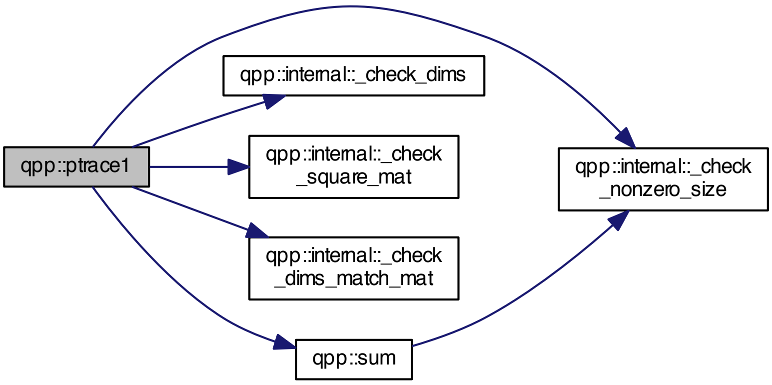
Parameters

A	Eigen expression
dims	Dimensions of bi-partite system (must be a std::vector with 2 elements)

Returns

Partial trace $Tr_A(\cdot)$ over the first subsytem A in a bi-partite system $A \otimes B$, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.60 template< typename Derived > DynMat< typename Derived::Scalar > qpp::ptrace2 (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Partial trace.

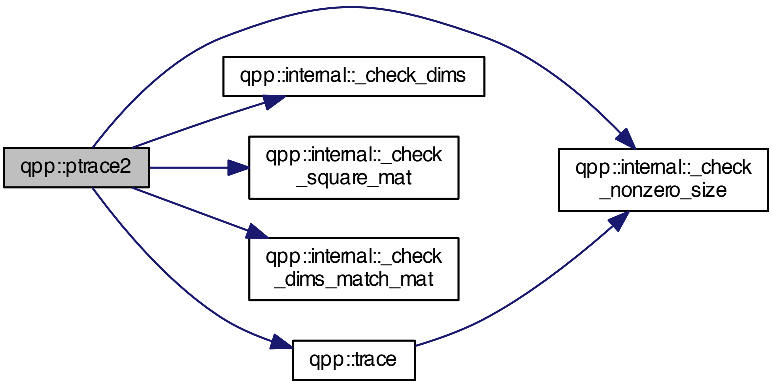
Parameters

A	Eigen expression
dims	Dimensions of bi-partite system (must be a std::vector with 2 elements)

Returns

Partial trace $Tr_B(\cdot)$ over the second subsytem B in a bi-partite system $A \otimes B$, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.61 template< typename Derived > DynMat< typename Derived::Scalar> qpp::ptranspose (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*)

Partial transpose.

Partial transpose of the multi-partite density matrix over a list of subsystems

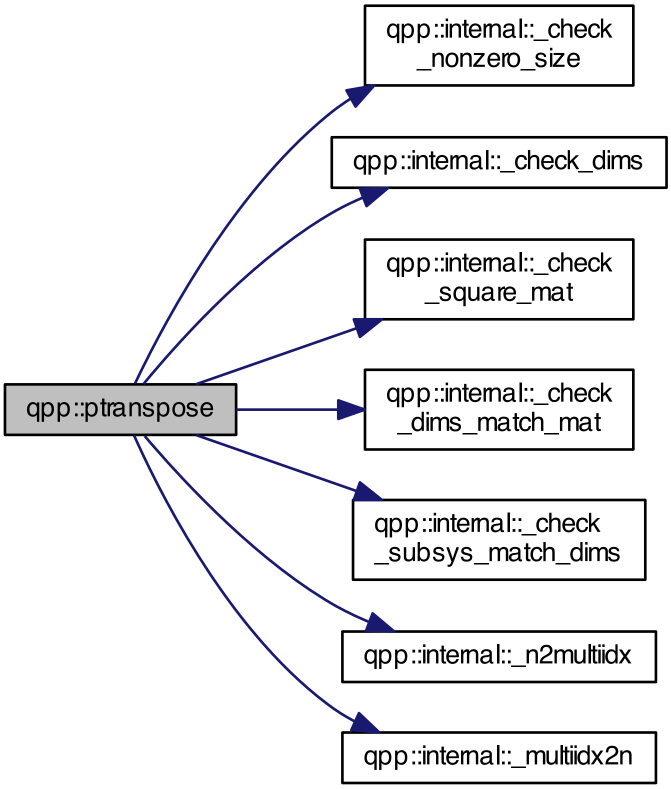
Parameters

A	Eigen expression
subsys	Subsystems' indexes
dims	Dimensions of the multi-partite system

Returns

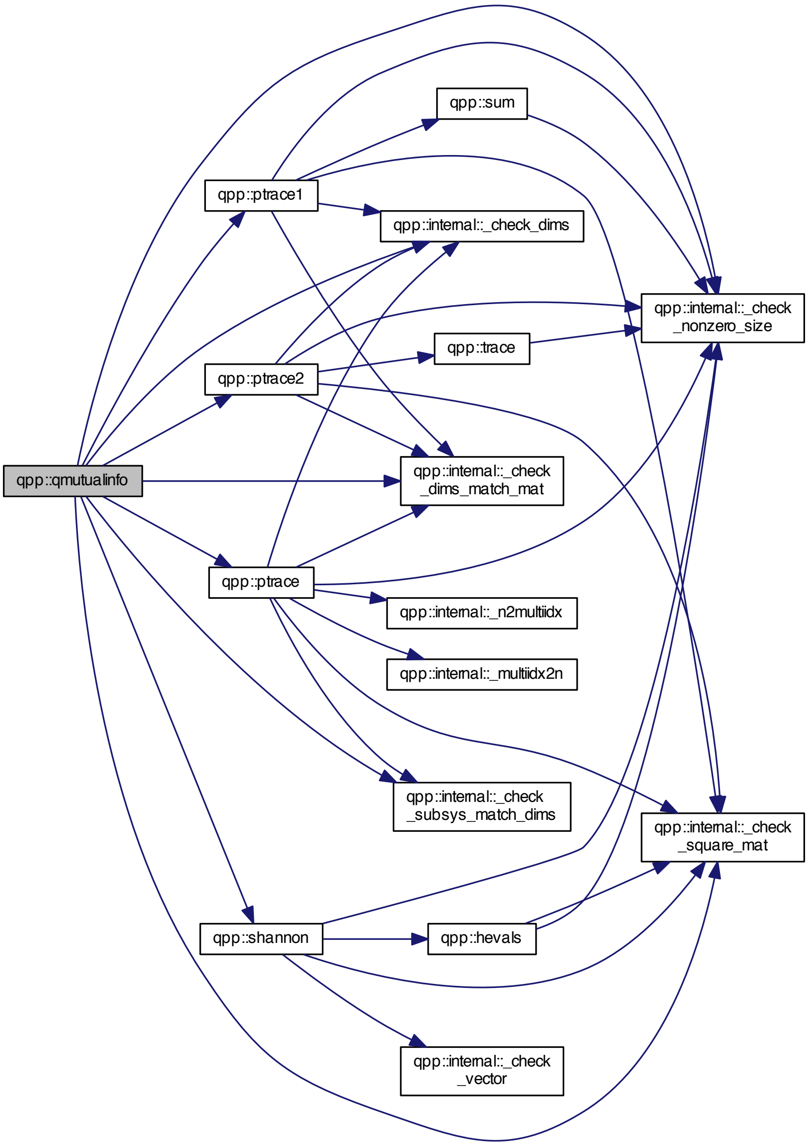
Partial transpose $(\cdot)^{T_{subsys}}$ over the subsytems *subsys* in a multi-partite system, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.62 template< typename Derived > double qpp::qmutualinfo (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*)

Here is the call graph for this function:

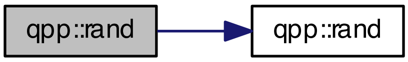


6.1.2.63 template< typename Derived > Derived qpp::rand (std::size_t *rows*, std::size_t *cols*, double *a* = 0, double *b* = 1)

6.1.2.64 template<> dmat qpp::rand (std::size_t *rows*, std::size_t *cols*, double *a*, double *b*)

6.1.2.65 template<> cmat qpp::rand (std::size_t *rows*, std::size_t *cols*, double *a*, double *b*)

Here is the call graph for this function:

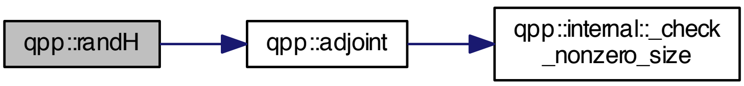


6.1.2.66 double qpp::rand (double *a* = 0, double *b* = 1)

Here is the call graph for this function:

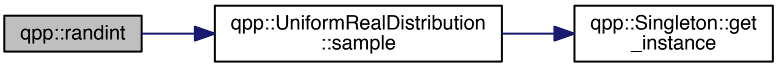
6.1.2.67 cmat qpp::randH (std::size_t *D*)

Here is the call graph for this function:



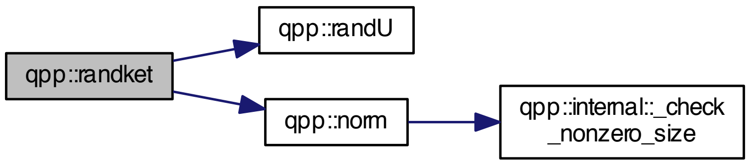
6.1.2.68 long long qpp::randint (long long *a*, long long *b*)

Here is the call graph for this function:



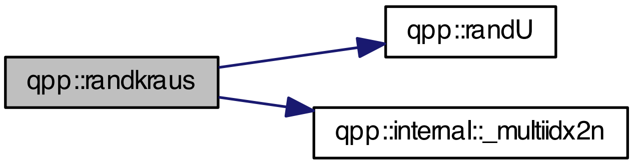
6.1.2.69 ket qpp::randket (std::size_t *D*)

Here is the call graph for this function:



6.1.2.70 std::vector<cmat> qpp::randkraus (std::size_t *n*, std::size_t *D*)

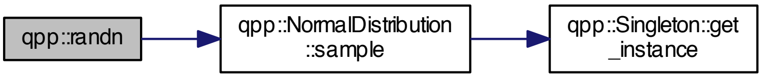
Here is the call graph for this function:



6.1.2.71 template<typename Derived > Derived qpp::randn (std::size_t *rows*, std::size_t *cols*, double *mean* = 0, double *sigma* = 1)

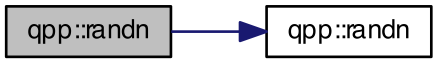
6.1.2.72 template<> dmat qpp::randn (std::size_t *rows*, std::size_t *cols*, double *mean*, double *sigma*)

Here is the call graph for this function:



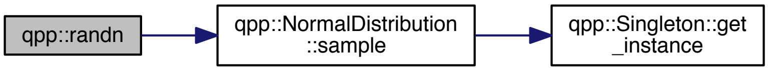
6.1.2.73 template<> cmat qpp::randn (std::size_t *rows*, std::size_t *cols*, double *mean*, double *sigma*)

Here is the call graph for this function:



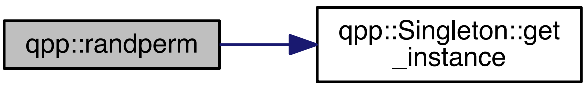
6.1.2.74 double qpp::randn (double *mean* = 0, double *sigma* = 1)

Here is the call graph for this function:



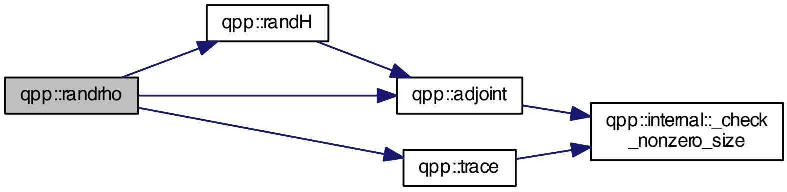
6.1.2.75 std::vector<std::size_t> qpp::randperm (std::size_t *n*)

Here is the call graph for this function:



6.1.2.76 cmat qpp::randrho (std::size_t *D*)

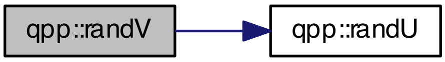
Here is the call graph for this function:



6.1.2.77 cmat qpp::randU (std::size_t *D*)

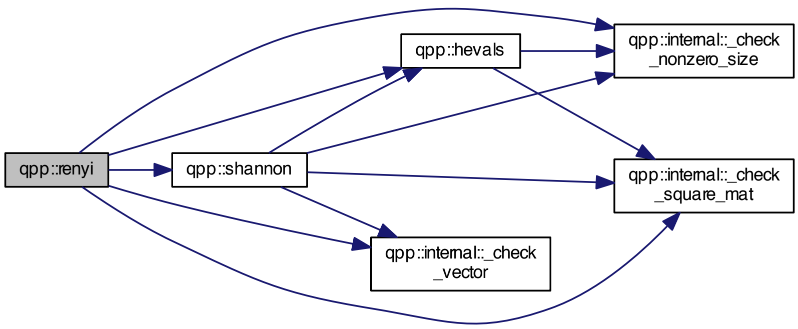
6.1.2.78 cmat qpp::randV (std::size_t *Din,* std::size_t *Dout*)

Here is the call graph for this function:



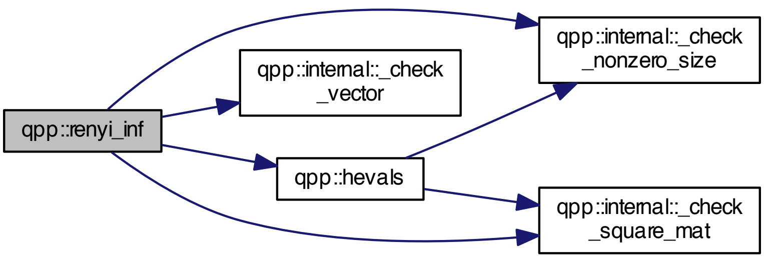
6.1.2.79 template< typename Derived > double qpp::renyi (const double *alpha,* const Eigen::MatrixBase< Derived > & *A*)

Here is the call graph for this function:



6.1.2.80 template<typename Derived > double qpp::renyi_inf (const Eigen::MatrixBase< Derived > & *A*)

Here is the call graph for this function:



6.1.2.81 template<typename Derived > DynMat<typename Derived::Scalar> qpp::reshape (const Eigen::MatrixBase< Derived > & *A,* std::size_t *rows,* std::size_t *cols*)

Reshape.

Uses column-major order when reshaping (same as MATLAB)

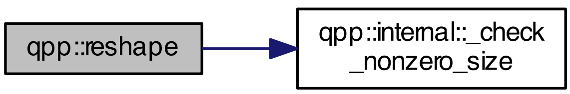
Parameters

A	Eigen expression
rows	Number of rows of the reshaped matrix
cols	Number of columns of the reshaped matrix

Returns

Reshaped matrix with *rows* rows and *cols* columns, as a dynamic matrix over the same scalar field

Here is the call graph for this function:

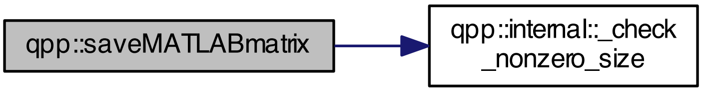


6.1.2.82 template<typename Derived > void qpp::save (const Eigen::MatrixBase< Derived > & *A,* const std::string & *fname*)

6.1.2.83 template<typename Derived > void qpp::saveMATLABmatrix (const Eigen::MatrixBase< Derived > & *A,* const std::string & *mat_file,* const std::string & *var_name,* const std::string & *mode*)

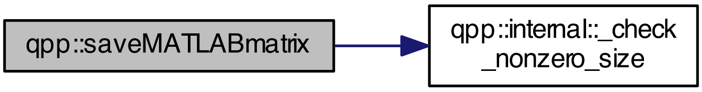
6.1.2.84 template<> void qpp::saveMATLABmatrix (const Eigen::MatrixBase< dmat > & *A*, const std::string & *mat_file*, const std::string & *var_name*, const std::string & *mode*)

Here is the call graph for this function:



6.1.2.85 template<> void qpp::saveMATLABmatrix (const Eigen::MatrixBase< cmat > & *A*, const std::string & *mat_file*, const std::string & *var_name*, const std::string & *mode*)

Here is the call graph for this function:



6.1.2.86 template<typename Derived > cmat qpp::schmidtcoeff (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Schmidt coefficients of the bi-partite pure state *A*.

Note

The sum of the squares of the Schmidt coefficients equals 1

See also

qpp::schmidtprob()

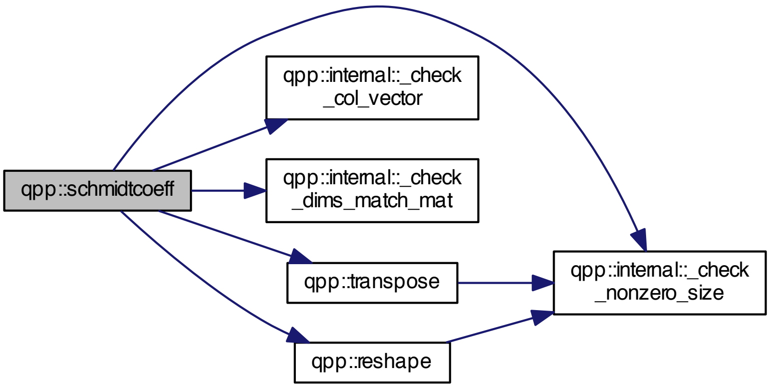
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

Schmidt coefficients of *A*, as a dynamic matrix over the complex field, with the Schmidt coefficients on the diagonal

Here is the call graph for this function:



6.1.2.87 template< typename Derived > cmat qpp::schmidtprob (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Schmidt probabilities of the bi-partite pure state *A*.

Note

Defined as the squares of the Schmidt coefficients
The sum of the Schmidt probabilities equals 1

See also

qpp::schmidtcoeff()

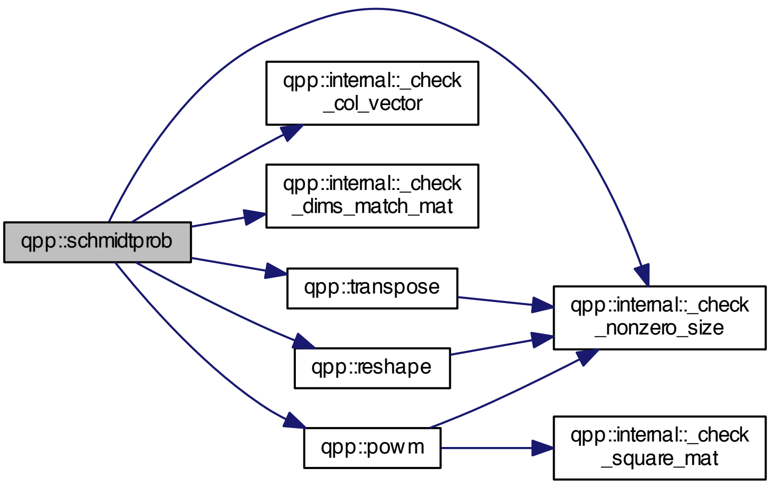
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

Schmidt probabilites of *A*, as a dynamic matrix over the complex field, with the Schmidt probabilities on the diagonal

Here is the call graph for this function:



6.1.2.88 template< typename Derived > cmat qpp::schmidtU (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Schmidt basis on Alice's side.

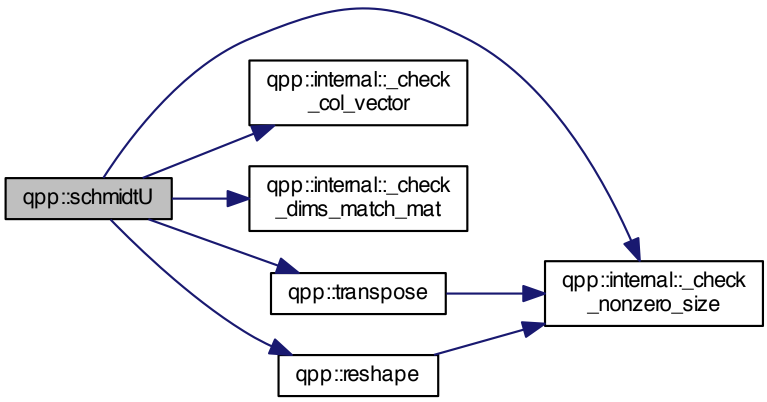
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

Unitary matrix U representing the Schmidt basis on Alice's side, as a dynamic matrix over the complex field, acting on the computational basis as $U|j\rangle = |\bar{j}\rangle$ (Schmidt vector)

Here is the call graph for this function:



6.1.2.89 template< typename Derived > cmat qpp::schmidtV (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *dims*)

Schmidt basis on Bob's side.

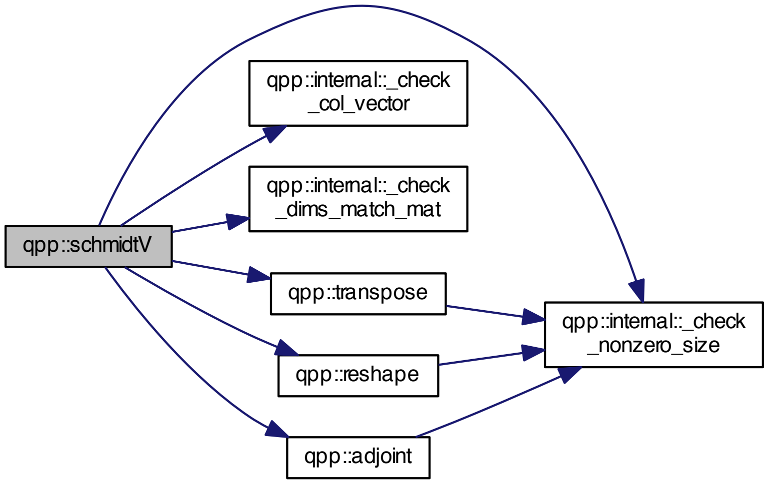
Parameters

A	Eigen expression
dims	Subsystems' dimensions

Returns

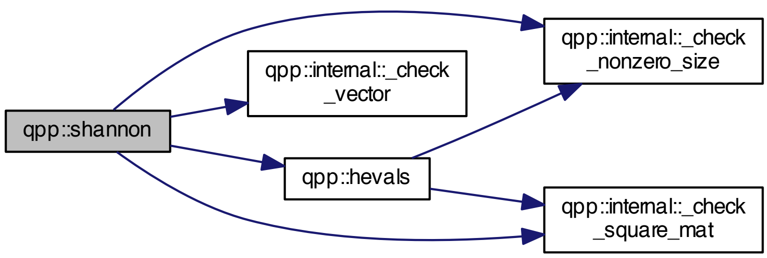
Unitary matrix V representing the Schmidt basis on Bob's side, as a dynamic matrix over the complex field, acting on the computational basis as $V|j\rangle = |\bar{j}\rangle$ (Schmidt vector)

Here is the call graph for this function:



6.1.2.90 template< typename Derived > double qpp::shannon (const Eigen::MatrixBase< Derived > & *A*)

Here is the call graph for this function:



6.1.2.91 template< typename Derived > cmat qpp::sinm (const Eigen::MatrixBase< Derived > & *A*)

Matrix sin.

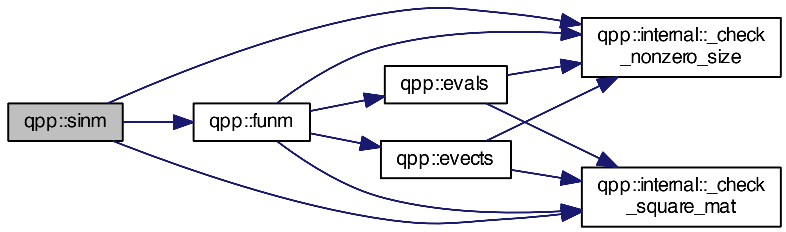
Parameters

A	Eigen expression

Returns

Matrix sine of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.92 template< typename Derived > cmat qpp::spectralpowm (const Eigen::MatrixBase< Derived > & *A*, const cplx *z*)

Matrix power.

Uses the spectral decomposition of *A* to compute the matrix power
By convention $A^0 = I$

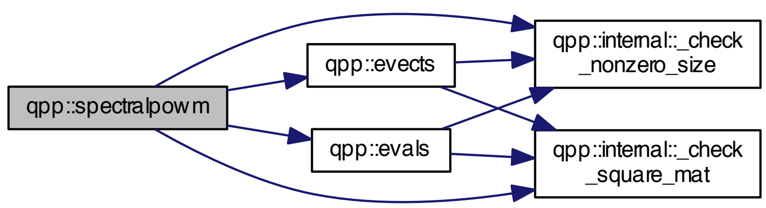
Parameters

A	Eigen expression
z	Complex number

Returns

Matrix power A^z, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.93 template< typename Derived > cmat qpp::sqrtm (const Eigen::MatrixBase< Derived > & *A*)

Matrix square root.

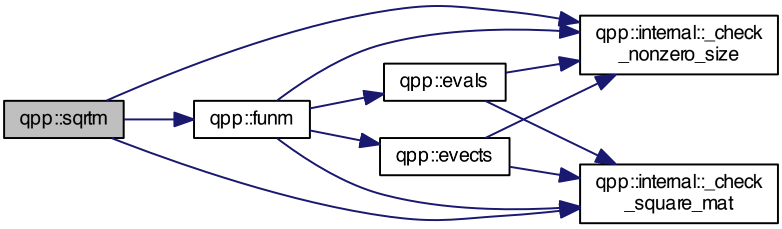
Parameters

A	Eigen expression

Returns

Matrix square root of *A*, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.94 template< typename Derived > Derived::Scalar qpp::sum (const Eigen::MatrixBase< Derived > & *A*)

Element-wise sum.

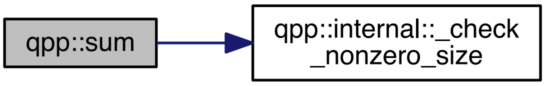
Parameters

A	Eigen expression

Returns

Element-wise sum of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.95 cmat qpp::super (const std::vector< cmat > & *Ks*)

Superoperator matrix representation.

Constructs the superoperator matrix of the channel specified by the set of Kraus operators *Ks* in the standard operator basis $\{|i\rangle\langle j|\}$ ordered in lexicographical order, i.e. $|0\rangle\langle 0|$, $|0\rangle\langle 1|$ etc.

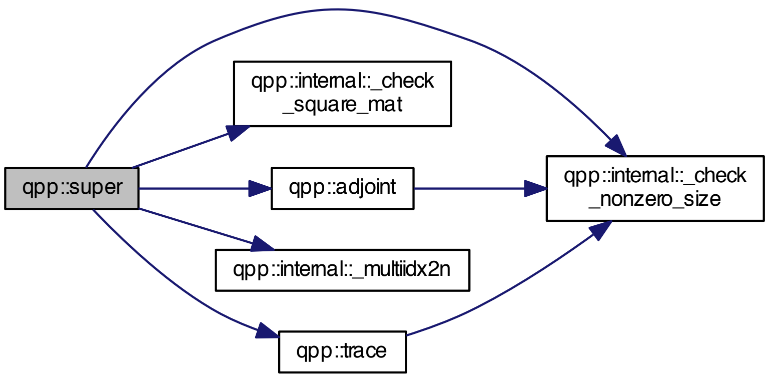
Parameters

Ks	std::vector of Eigen expressions representing the set of Kraus operators

Returns

Superoperator matrix representation, as a dynamic matrix over the complex field

Here is the call graph for this function:



6.1.2.96 template<typename Derived > DynMat<typename Derived::Scalar> qpp::syspermute (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *perm*, const std::vector< std::size_t > & *dims*)

System permutation.

Permutes the subsystems in a state vector or density matrix
The qubit *perm*[*i*] is permuted to the location *i*

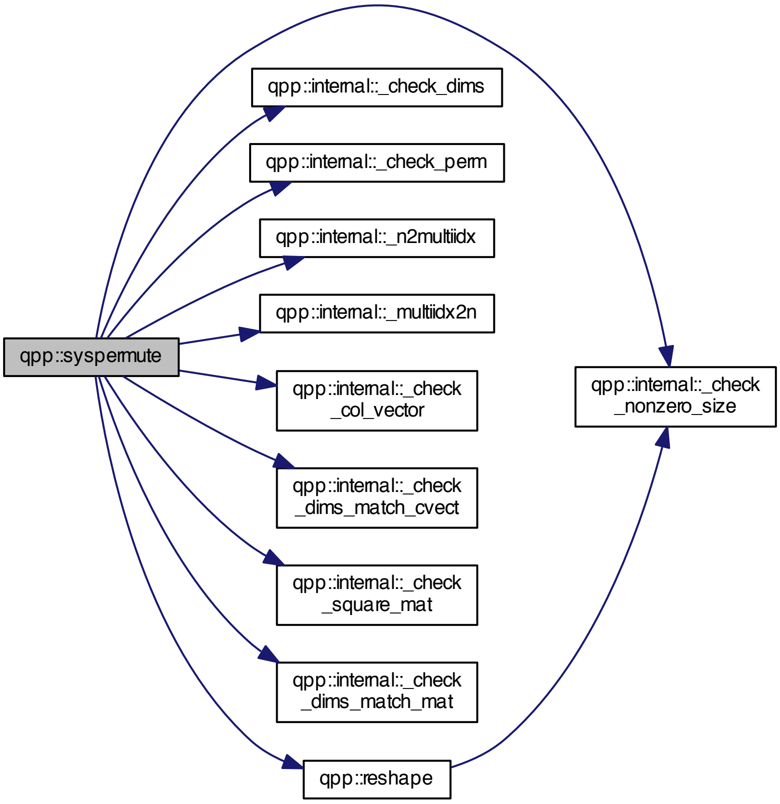
Parameters

A	Eigen expression
perm	Permutation
dims	Subsystems' dimensions

Returns

Permuted system, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.97 template< typename Derived > Derived::Scalar qpp::trace (const Eigen::MatrixBase< Derived > & *A*)

Trace.

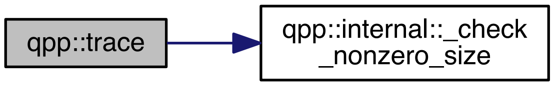
Parameters

A	Eigen expression

Returns

Trace of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.98 template<typename Derived > DynMat<typename Derived::Scalar> qpp::transpose (const Eigen::MatrixBase< Derived > & *A*)

Transpose.

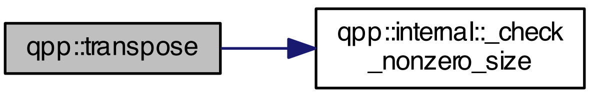
Parameters

A	Eigen expression

Returns

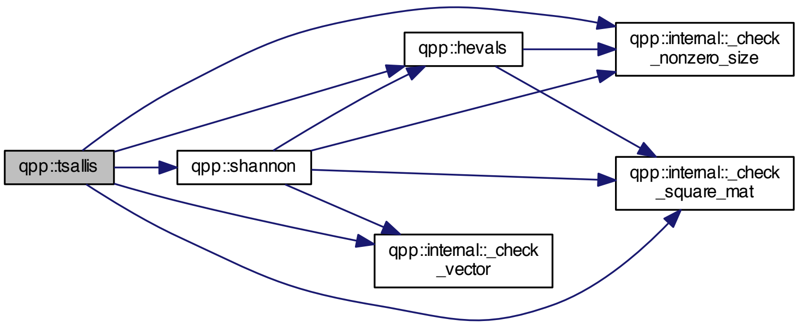
Transpose of *A*, as a dynamic matrix over the same scalar field

Here is the call graph for this function:



6.1.2.99 template< typename Derived > double qpp::tsallis (const double *alpha,* const Eigen::MatrixBase< Derived > & *A*)

Here is the call graph for this function:



6.1.3 Variable Documentation

6.1.3.1 constexpr double qpp::chop = 1e-10

Used in *qpp::disp()* and *qpp::displn()* for setting to zero numbers that have their absolute value smaller than *qpp::ct::chop*.

6.1.3.2 constexpr double qpp::ee = 2.718281828459045235360287471352662497

Base of natural logarithm, e.

6.1.3.3 constexpr double qpp::eps = 1e-12

Used to decide whether a number or expression in double precision is zero or not.

Example:

```
if(std::abs(x) < qpp::ct::eps) // x is zero
```

6.1.3.4 const Gates& qpp::gt = Gates::get_instance()

qpp::Gates const Singleton

Initializes the gates, see the class *qpp::Gates*

6.1.3.5 constexpr std::size_t qpp::maxn = 64

Maximum number of qubits.

Used internally to statically allocate arrays (for speed reasons)

6.1.3.6 constexpr double qpp::pi = 3.141592653589793238462643383279502884

π

6.1.3.7 RandomDevices& qpp::rdevs = RandomDevices::get_instance()

qpp::RandomDevices Singleton

Initializes the random devices, see the class *qpp::RandomDevices*

6.1.3.8 const States& qpp::st = States::get_instance()

qpp::States const Singleton

Initializes the states, see the class *qpp::States*

6.2 qpp::internal Namespace Reference

Functions

- void _n2multiidx (std::size_t n, std::size_t numdims, const std::size_t ∗dims, std::size_t ∗result)
- std::size_t _multiidx2n (const std::size_t ∗midx, std::size_t numdims, const std::size_t ∗dims)
- template<typename Derived >
  bool _check_square_mat (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool _check_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool _check_row_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool _check_col_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename T >
  bool _check_nonzero_size (const T &x)
- bool _check_dims (const std::vector< std::size_t > &dims)
- template<typename Derived >
  bool _check_dims_match_mat (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool _check_dims_match_cvect (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &V)
- template<typename Derived >
  bool _check_dims_match_rvect (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &V)
- bool _check_eq_dims (const std::vector< std::size_t > &dims, std::size_t dim)
- bool _check_subsys_match_dims (const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)
- bool _check_perm (const std::vector< std::size_t > &perm)
- template<typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > _kron2 (const Eigen::MatrixBase< Derived1 > &A, const Eigen::↩ MatrixBase< Derived2 > &B)
- template<typename T >
  void variadic_vector_emplace (std::vector< T > &)
- template<typename T , typename First , typename... Args>
  void variadic_vector_emplace (std::vector< T > &v, First &&first, Args &&...args)

6.2.1 Detailed Description

Internal functions, do not modify or use directly

6.2.2 Function Documentation

6.2.2.1 template< typename Derived > bool qpp::internal::_check_col_vector (const Eigen::MatrixBase< Derived > & *A*)

6.2.2.2 bool qpp::internal::_check_dims (const std::vector< std::size_t > & *dims*)

6.2.2.3 template< typename Derived > bool qpp::internal::_check_dims_match_cvect (const std::vector< std::size_t > & *dims*, const Eigen::MatrixBase< Derived > & *V*)

6.2.2.4 template< typename Derived > bool qpp::internal::_check_dims_match_mat (const std::vector< std::size_t > & *dims*, const Eigen::MatrixBase< Derived > & *A*)

6.2.2.5 template< typename Derived > bool qpp::internal::_check_dims_match_rvect (const std::vector< std::size_t > & *dims*, const Eigen::MatrixBase< Derived > & *V*)

6.2.2.6 bool qpp::internal::_check_eq_dims (const std::vector< std::size_t > & *dims*, std::size_t *dim*)

6.2.2.7 template< typename T > bool qpp::internal::_check_nonzero_size (const T & *x*)

6.2.2.8 bool qpp::internal::_check_perm (const std::vector< std::size_t > & *perm*)

6.2.2.9 template< typename Derived > bool qpp::internal::_check_row_vector (const Eigen::MatrixBase< Derived > & *A*)

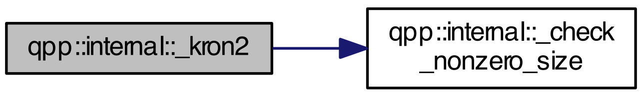
6.2.2.10 template< typename Derived > bool qpp::internal::_check_square_mat (const Eigen::MatrixBase< Derived > & *A*)

6.2.2.11 bool qpp::internal::_check_subsys_match_dims (const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*)

6.2.2.12 template< typename Derived > bool qpp::internal::_check_vector (const Eigen::MatrixBase< Derived > & *A*)

6.2.2.13 template< typename Derived1 , typename Derived2 > DynMat<typename Derived1::Scalar> qpp::internal::_kron2 (const Eigen::MatrixBase< Derived1 > & *A*, const Eigen::MatrixBase< Derived2 > & *B*)

Here is the call graph for this function:



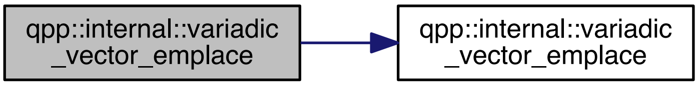
6.2.2.14 std::size_t qpp::internal::_multiidx2n (const std::size_t ∗ *midx*, std::size_t *numdims*, const std::size_t ∗ *dims*)

6.2.2.15 void qpp::internal::_n2multiidx (std::size_t *n*, std::size_t *numdims*, const std::size_t ∗ *dims*, std::size_t ∗ *result*)

6.2.2.16 template< typename T > void qpp::internal::variadic_vector_emplace (std::vector< T > &)

6.2.2.17 template< typename T , typename First , typename... Args > void qpp::internal::variadic_vector_emplace (std::vector< T > & *v,* First && *first,* Args &&... *args*)

Here is the call graph for this function:



Chapter 7

Class Documentation

7.1 qpp::DiscreteDistribution Class Reference

```
#include <stat.h>
```

Public Member Functions

- template< typename InputIterator >
  DiscreteDistribution (InputIterator first, InputIterator last)
- DiscreteDistribution (std::initializer_list< double > weights)
- DiscreteDistribution (std::vector< double > weights)
- std::size_t sample ()
- std::vector< double > probabilities () const

Protected Attributes

- std::discrete_distribution
  < std::size_t > _d

7.1.1 Constructor & Destructor Documentation

7.1.1.1 template< typename InputIterator > qpp::DiscreteDistribution::DiscreteDistribution (InputIterator *first,* InputIterator *last*) `[inline]`

7.1.1.2 qpp::DiscreteDistribution::DiscreteDistribution (std::initializer_list< double > *weights*) `[inline]`

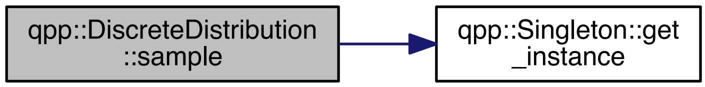
7.1.1.3 qpp::DiscreteDistribution::DiscreteDistribution (std::vector< double > *weights*) `[inline]`

7.1.2 Member Function Documentation

7.1.2.1 std::vector<double> qpp::DiscreteDistribution::probabilities ( ) const `[inline]`

7.1.2.2 std::size_t qpp::DiscreteDistribution::sample ( ) [inline]

Here is the call graph for this function:



7.1.3 Member Data Documentation

7.1.3.1 std::discrete_distribution<std::size_t> qpp::DiscreteDistribution::_d [protected]

The documentation for this class was generated from the following file:

- include/classes/stat.h

7.2 qpp::DiscreteDistributionAbsSquare Class Reference

```
#include <stat.h>
```

Public Member Functions

- template<typename InputIterator >
  DiscreteDistributionAbsSquare (InputIterator first, InputIterator last)
- DiscreteDistributionAbsSquare (std::initializer_list< cplx > amplitudes)
- DiscreteDistributionAbsSquare (std::vector< cplx > amplitudes)
- template<typename Derived >
  DiscreteDistributionAbsSquare (const Eigen::MatrixBase< Derived > &V)
- std::size_t sample ()
- std::vector< double > probabilities () const

Protected Member Functions

- template<typename InputIterator >
  std::vector< double > cplx2weights (InputIterator first, InputIterator last) const

Protected Attributes

- std::discrete_distribution
  < std::size_t > _d

7.2.1 Constructor & Destructor Documentation

7.2.1.1 template< typename InputIterator > qpp::DiscreteDistributionAbsSquare::DiscreteDistributionAbsSquare (InputIterator *first*, InputIterator *last*) [inline]

7.2.1.2 qpp::DiscreteDistributionAbsSquare::DiscreteDistributionAbsSquare (std::initializer_list< cplx > *amplitudes*) [inline]

7.2.1.3 qpp::DiscreteDistributionAbsSquare::DiscreteDistributionAbsSquare (std::vector< cplx > *amplitudes*) [inline]

7.2.1.4 template< typename Derived > qpp::DiscreteDistributionAbsSquare::DiscreteDistributionAbsSquare (const Eigen::MatrixBase< Derived > & *V*) [inline]

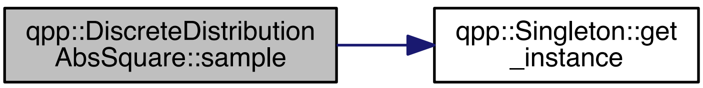
7.2.2 Member Function Documentation

7.2.2.1 template< typename InputIterator > std::vector<double> qpp::DiscreteDistributionAbsSquare::cplx2weights (InputIterator *first*, InputIterator *last*) const [inline], [protected]

7.2.2.2 std::vector<double> qpp::DiscreteDistributionAbsSquare::probabilities ( ) const [inline]

7.2.2.3 std::size_t qpp::DiscreteDistributionAbsSquare::sample ( ) [inline]

Here is the call graph for this function:



7.2.3 Member Data Documentation

7.2.3.1 std::discrete_distribution<std::size_t> qpp::DiscreteDistributionAbsSquare::_d [protected]

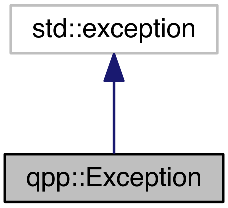
The documentation for this class was generated from the following file:

- include/classes/stat.h

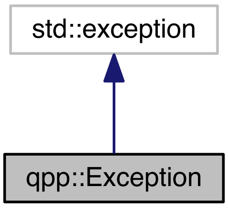
7.3 qpp::Exception Class Reference

```
#include <exception.h>
```

Inheritance diagram for qpp::Exception:



Collaboration diagram for qpp::Exception:



Public Types

- enum Type {
  Type::UNKNOWN_EXCEPTION = 1, Type::ZERO_SIZE, Type::MATRIX_NOT_SQUARE, Type::MATRIX_↩
  NOT_CVECTOR,
  Type::MATRIX_NOT_RVECTOR, Type::MATRIX_NOT_VECTOR, Type::MATRIX_NOT_SQUARE_OR_C↩
  VECTOR, Type::MATRIX_NOT_SQUARE_OR_RVECTOR,
  Type::MATRIX_NOT_SQUARE_OR_VECTOR, Type::DIMS_INVALID, Type::DIMS_NOT_EQUAL, Type::D↩
  IMS_MISMATCH_MATRIX,
  Type::DIMS_MISMATCH_CVECTOR, Type::DIMS_MISMATCH_RVECTOR, Type::DIMS_MISMATCH_VE↩
  CTOR, Type::SUBSYS_MISMATCH_DIMS,
  Type::PERM_INVALID, Type::NOT_QUBIT_GATE, Type::NOT_QUBIT_SUBSYS, Type::NOT_BIPARTITE,
  Type::OUT_OF_RANGE, Type::TYPE_MISMATCH, Type::UNDEFINED_TYPE, Type::CUSTOM_EXCEPT↩
  ION }

Public Member Functions

- Exception (const std::string &where, const Type &type)
- Exception (const std::string &where, const std::string &custom)
- virtual const char * what () const noexceptoverride

Private Member Functions

- std::string _construct_exception_msg ()

Private Attributes

- std::string _where
- std::string _msg
- Type _type
- std::string _custom

7.3.1 Member Enumeration Documentation

7.3.1.1 enum qpp::Exception::Type [strong]

Enumerator

UNKNOWN_EXCEPTION Unknown exception

ZERO_SIZE Zero sized object, e.g. empty Eigen::Matrix or std::vector with no elements

MATRIX_NOT_SQUARE Eigen::Matrix is not square

MATRIX_NOT_CVECTOR Eigen::Matrix is not a column vector

MATRIX_NOT_RVECTOR Eigen::Matrix is not a row vector

MATRIX_NOT_VECTOR Eigen::Matrix is not a row/column vector

MATRIX_NOT_SQUARE_OR_CVECTOR Eigen::Matrix is not square nor a column vector

MATRIX_NOT_SQUARE_OR_RVECTOR Eigen::Matrix is not square nor a row vector

MATRIX_NOT_SQUARE_OR_VECTOR Eigen::Matrix is not square nor a row/column vector

DIMS_INVALID std::vector<std::size_t> representing the dimensions has zero size or contains zeros

DIMS_NOT_EQUAL std::vector<std::size_t> representing the dimensions contains non-equal elements

DIMS_MISMATCH_MATRIX Product of the dimenisons' std::vector<std::size_t> is not equal to the number of rows of Eigen::Matrix (assumed to be square)

DIMS_MISMATCH_CVECTOR Product of the dimenisons' std::vector<std::size_t> is not equal to the number of cols of Eigen::Matrix (assumed to be a column vector)

DIMS_MISMATCH_RVECTOR Product of the dimenisons' std::vector<std::size_t> is not equal to the number of cols of Eigen::Matrix (assumed to be a row vector)

DIMS_MISMATCH_VECTOR Product of the dimenisons' std::vector<std::size_t> is not equal to the number of cols of Eigen::Matrix (assumed to be a row/column vector)

SUBSYS_MISMATCH_DIMS std::vector<std::size_t> representing the subsystems' labels has duplicatates, or has entries that are larger than the size of the std::vector<std::size_t> representing the dimensions

PERM_INVALID Invalid std::vector<std::size_t> permutation

NOT_QUBIT_GATE Eigen::Matrix is not 2 x 2

NOT_QUBIT_SUBSYS Subsystems are not 2-dimensional

NOT_BIPARTITE std::vector<std::size_t> representing the dimensions has size different from 2

OUT_OF_RANGE Parameter out of range

TYPE_MISMATCH Types do not match (i.e. Matrix<double> vs Matrix<cplx>)

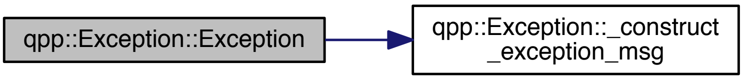
UNDEFINED_TYPE Templated function not defined for this type

CUSTOM_EXCEPTION Custom exception, user must provide a custom message

7.3.2 Constructor & Destructor Documentation

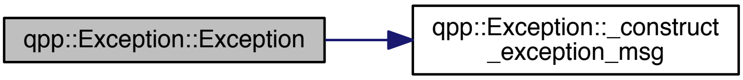
7.3.2.1 qpp::Exception::Exception (const std::string & *where*, const Type & *type*) [inline]

Here is the call graph for this function:



7.3.2.2 qpp::Exception::Exception (const std::string & *where*, const std::string & *custom*) [inline]

Here is the call graph for this function:



7.3.3 Member Function Documentation

7.3.3.1 std::string qpp::Exception::_construct_exception_msg ( ) [inline], [private]

7.3.3.2 virtual const char∗ qpp::Exception::what ( ) const [inline], [override], [virtual], [noexcept]

7.3.4 Member Data Documentation

7.3.4.1 std::string qpp::Exception::_custom [private]

7.3.4.2 std::string qpp::Exception::_msg [private]

7.3.4.3 Type qpp::Exception::_type [private]

7.3.4.4 std::string qpp::Exception::_where [private]

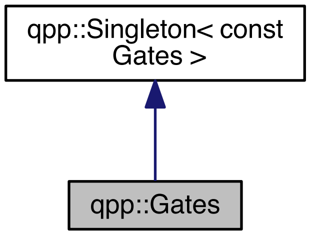
The documentation for this class was generated from the following file:

- include/classes/exception.h

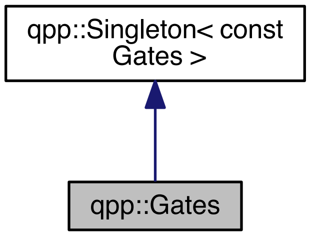
7.4 qpp::Gates Class Reference

```
#include <gates.h>
```

Inheritance diagram for qpp::Gates:



Collaboration diagram for qpp::Gates:



Public Member Functions

- cmat Rn (double theta, std::vector< double > n) const
- cmat Zd (std::size_t D) const
- cmat Fd (std::size_t D) const
- cmat Xd (std::size_t D) const
- template<typename Derived = Eigen::MatrixXcd>
  Derived Id (std::size_t D) const
- template<typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > applyCTRL (const Eigen::MatrixBase< Derived1 > &state, const Eigen::MatrixBase< Derived2 > &A, const std::vector< std::size_t > &ctrl, const std::vector< std::size_t > &subsys, std::size_t n, std::size_t d=2) const
- template<typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > apply (const Eigen::MatrixBase< Derived1 > &state, const Eigen::MatrixBase< Derived2 > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims) const
- template<typename Derived >
  DynMat< typename Derived::Scalar > CTRL (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &ctrl, const std::vector< std::size_t > &subsys, std::size_t n, std::size_t d=2) const

Public Attributes

- cmat Id2 { cmat::Identity(2, 2) }
- cmat H { cmat::Zero(2, 2) }
- cmat X { cmat::Zero(2, 2) }
- cmat Y { cmat::Zero(2, 2) }
- cmat Z { cmat::Zero(2, 2) }
- cmat S { cmat::Zero(2, 2) }
- cmat T { cmat::Zero(2, 2) }
- cmat CNOTab { cmat::Identity(4, 4) }
- cmat CZ { cmat::Identity(4, 4) }
- cmat CNOTba { cmat::Zero(4, 4) }
- cmat SWAP { cmat::Identity(4, 4) }
- cmat TOF { cmat::Identity(8, 8) }
- cmat FRED { cmat::Identity(8, 8) }

Private Member Functions

- Gates ()

Friends

- class Singleton< const Gates >

Additional Inherited Members

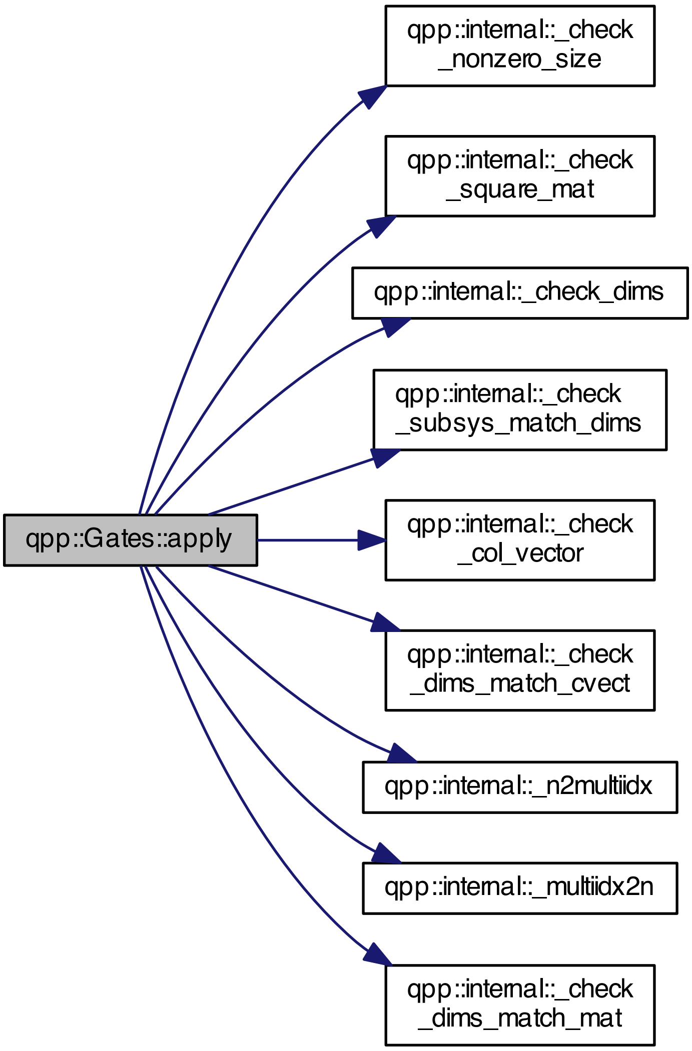
7.4.1 Constructor & Destructor Documentation

7.4.1.1 qpp::Gates::Gates ( ) [inline], [private]

7.4.2 Member Function Documentation

7.4.2.1 template<typename Derived1 , typename Derived2 > DynMat<typename Derived1::Scalar> qpp::Gates::apply (const Eigen::MatrixBase< Derived1 > & *state*, const Eigen::MatrixBase< Derived2 > & *A*, const std::vector< std::size_t > & *subsys*, const std::vector< std::size_t > & *dims*) const [inline]

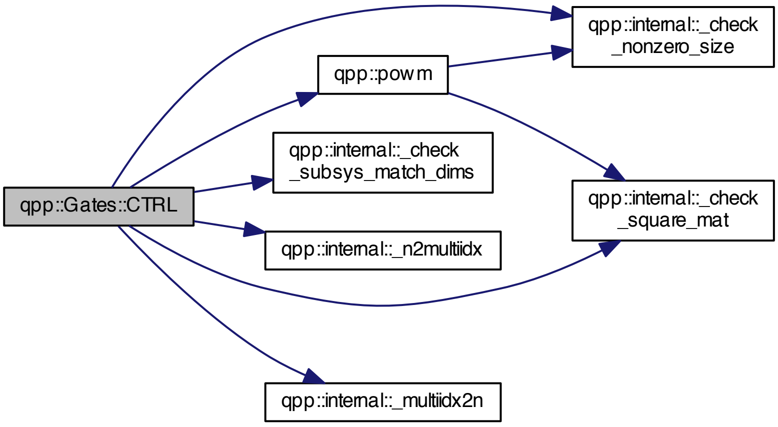
Here is the call graph for this function:



7.4.2.2 template<typename Derived1 , typename Derived2 > DynMat<typename Derived1::Scalar> qpp::Gates::applyCTRL (const Eigen::MatrixBase< Derived1 > & *state*, const Eigen::MatrixBase< Derived2 > & *A*, const std::vector< std::size_t > & *ctrl*, const std::vector< std::size_t > & *subsys*, std::size_t *n*, std::size_t *d* = 2) const [inline]

7.4.2.3 template<typename Derived > DynMat<typename Derived::Scalar> qpp::Gates::CTRL (const Eigen::MatrixBase< Derived > & *A*, const std::vector< std::size_t > & *ctrl*, const std::vector< std::size_t > & *subsys*, std::size_t *n*, std::size_t *d* = 2) const [inline]

Here is the call graph for this function:



7.4.2.4 cmat qpp::Gates::Fd (std::size_t *D*) const [inline]

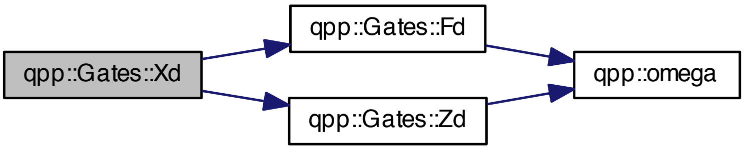
Here is the call graph for this function:

7.4.2.5 template<typename Derived = Eigen::MatrixXcd> Derived qpp::Gates::Id (std::size_t *D*) const [inline]

7.4.2.6 cmat qpp::Gates::Rn (double *theta*, std::vector< double > *n*) const [inline]

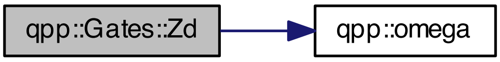
7.4.2.7 cmat qpp::Gates::Xd (std::size_t *D*) const [inline]

Here is the call graph for this function:



7.4.2.8 cmat qpp::Gates::Zd (std::size_t *D*) const [inline]

Here is the call graph for this function:



7.4.3 Friends And Related Function Documentation

7.4.3.1 friend class Singleton< const Gates > [friend]

7.4.4 Member Data Documentation

7.4.4.1 cmat qpp::Gates::CNOTab { cmat::Identity(4, 4) }

7.4.4.2 cmat qpp::Gates::CNOTba { cmat::Zero(4, 4) }

7.4.4.3 cmat qpp::Gates::CZ { cmat::Identity(4, 4) }

7.4.4.4 cmat qpp::Gates::FRED { cmat::Identity(8, 8) }

7.4.4.5 cmat qpp::Gates::H { cmat::Zero(2, 2) }

7.4.4.6 cmat qpp::Gates::Id2 { cmat::Identity(2, 2) }

7.4.4.7 cmat qpp::Gates::S { cmat::Zero(2, 2) }

7.4.4.8 cmat qpp::Gates::SWAP { cmat::Identity(4, 4) }

7.4.4.9 cmat qpp::Gates::T { cmat::Zero(2, 2) }

7.4.4.10 cmat qpp::Gates::TOF { cmat::Identity(8, 8) }

7.4.4.11 cmat qpp::Gates::X { cmat::Zero(2, 2) }

7.4.4.12 cmat qpp::Gates::Y { cmat::Zero(2, 2) }

7.4.4.13 cmat qpp::Gates::Z { cmat::Zero(2, 2) }

The documentation for this class was generated from the following file:

- include/classes/gates.h

7.5 qpp::NormalDistribution Class Reference

```
#include <stat.h>
```

Public Member Functions

- NormalDistribution (double mean=0, double sigma=1)
- double sample ()

Protected Attributes

- std::normal_distribution _d

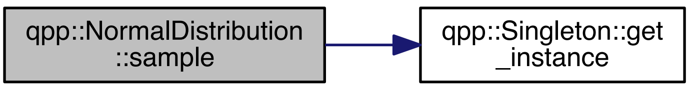
7.5.1 Constructor & Destructor Documentation

7.5.1.1 qpp::NormalDistribution::NormalDistribution (double *mean* = 0, double *sigma* = 1) [inline]

7.5.2 Member Function Documentation

7.5.2.1 double qpp::NormalDistribution::sample ( ) [inline]

Here is the call graph for this function:



7.5.3 Member Data Documentation

7.5.3.1 std::normal_distribution qpp::NormalDistribution::_d [protected]

The documentation for this class was generated from the following file:

- include/classes/stat.h

7.6 qpp::Qudit Class Reference

`#include <qudit.h>`

Public Member Functions

- Qudit (const cmat &rho=States::get_instance().pz0)
- std::size_t measure (const cmat &U, bool destructive=false)
- std::size_t measure (bool destructive=false)
- cmat getRho () const
- std::size_t getD () const

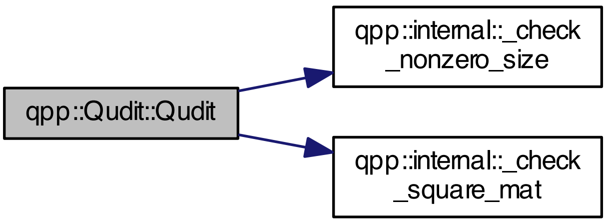
Private Attributes

- cmat _rho
- std::size_t _D

7.6.1 Constructor & Destructor Documentation

7.6.1.1 qpp::Qudit::Qudit (const cmat & *rho* = States::get_instance().pz0) [inline]

Here is the call graph for this function:



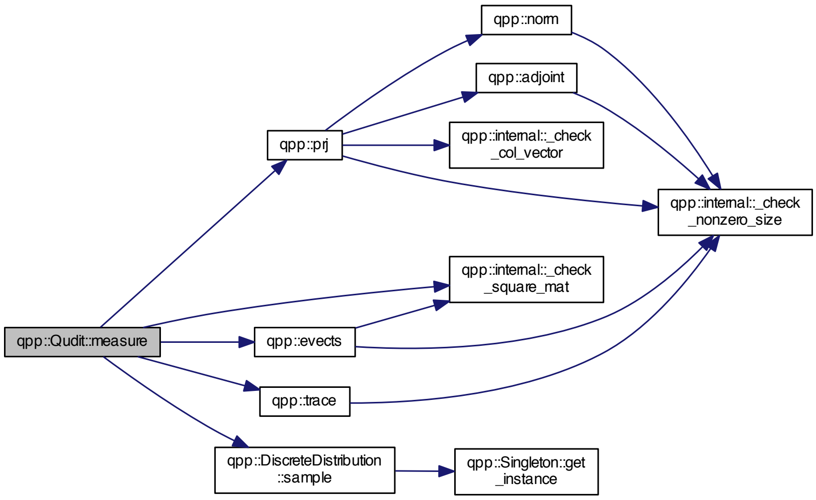
7.6.2 Member Function Documentation

7.6.2.1 std::size_t qpp::Qudit::getD ( ) const [inline]

7.6.2.2 cmat qpp::Qudit::getRho ( ) const [inline]

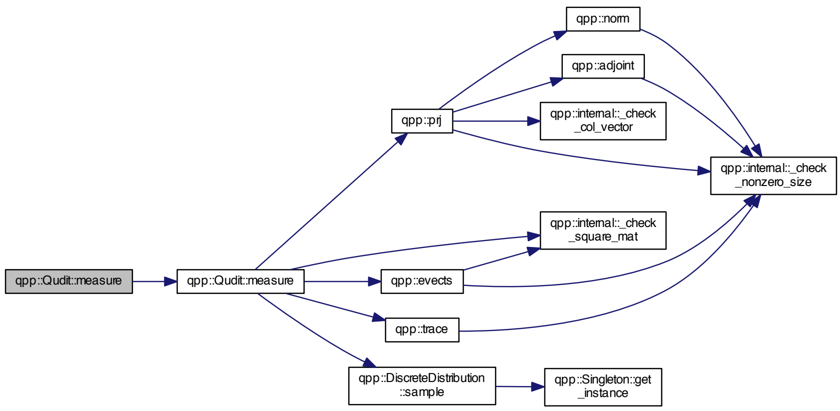
7.6.2.3 std::size_t qpp::Qudit::measure (const cmat & *U*, bool *destructive* = false) [inline]

Here is the call graph for this function:



7.6.2.4 std::size_t qpp::Qudit::measure (bool *destructive* = false) [inline]

Here is the call graph for this function:



7.6.3 Member Data Documentation

7.6.3.1 std::size_t qpp::Qudit::_D [private]

7.6.3.2 cmat qpp::Qudit::_rho [private]

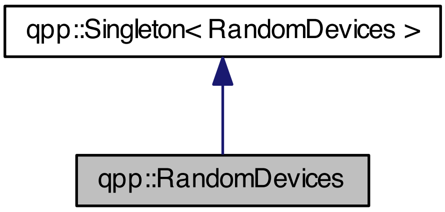
The documentation for this class was generated from the following file:

- include/classes/qudit.h

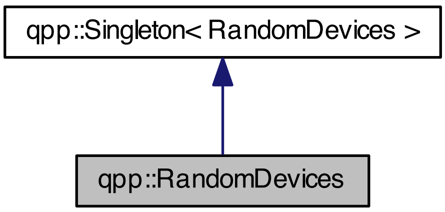
7.7 qpp::RandomDevices Class Reference

```
#include <randevs.h>
```

Inheritance diagram for qpp::RandomDevices:



Collaboration diagram for qpp::RandomDevices:



Public Attributes

- std::mt19937 _rng

Private Member Functions

- RandomDevices ()

Private Attributes

- std::random_device _rd

Friends

- class Singleton< RandomDevices >

Additional Inherited Members

7.7.1 Constructor & Destructor Documentation

7.7.1.1 qpp::RandomDevices::RandomDevices ( ) [inline], [private]

7.7.2 Friends And Related Function Documentation

7.7.2.1 friend class Singleton< RandomDevices > [friend]

7.7.3 Member Data Documentation

7.7.3.1 std::random_device qpp::RandomDevices::_rd [private]

7.7.3.2 std::mt19937 qpp::RandomDevices::_rng

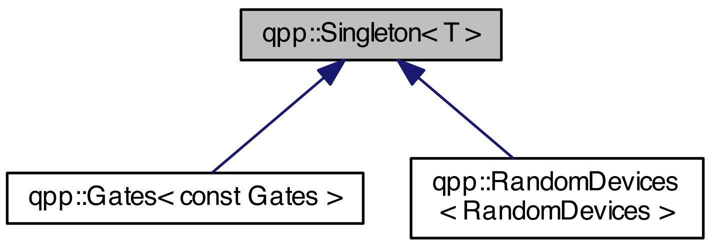
The documentation for this class was generated from the following file:

- include/classes/randevs.h

7.8 qpp::Singleton< T > Class Template Reference

```
#include <singleton.h>
```

Inheritance diagram for qpp::Singleton< T >:



Static Public Member Functions

- static T & get_instance ()

Protected Member Functions

- Singleton ()=default
- virtual ∼Singleton ()
- Singleton (const Singleton &)=delete
- Singleton & operator= (const Singleton &)=delete

7.8.1 Constructor & Destructor Documentation

7.8.1.1 template< typename T > qpp::Singleton< T >::Singleton ( ) [protected], [default]

7.8.1.2 template< typename T > virtual qpp::Singleton< T >::~Singleton ( ) [inline], [protected], [virtual]

7.8.1.3 template< typename T > qpp::Singleton< T >::Singleton (const Singleton< T > &) [protected], [delete]

7.8.2 Member Function Documentation

7.8.2.1 template< typename T > static T& qpp::Singleton< T >::get_instance ( ) [inline], [static]

7.8.2.2 template< typename T > Singleton& qpp::Singleton< T >::operator= (const Singleton< T > &) [protected], [delete]

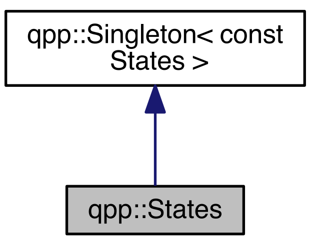
The documentation for this class was generated from the following file:

- include/classes/singleton.h

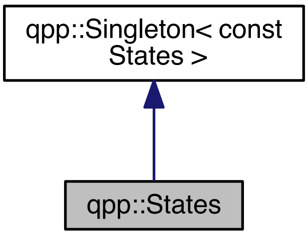
7.9 qpp::States Class Reference

```
#include <states.h>
```

Inheritance diagram for qpp::States:



Collaboration diagram for qpp::States:



Public Attributes

- ket x0 { ket::Zero(2) }
- ket x1 { ket::Zero(2) }
- ket y0 { ket::Zero(2) }
- ket y1 { ket::Zero(2) }
- ket z0 { ket::Zero(2) }
- ket z1 { ket::Zero(2) }
- cmat px0 { cmat::Zero(2, 2) }
- cmat px1 { cmat::Zero(2, 2) }
- cmat py0 { cmat::Zero(2, 2) }
- cmat py1 { cmat::Zero(2, 2) }
- cmat pz0 { cmat::Zero(2, 2) }
- cmat pz1 { cmat::Zero(2, 2) }
- ket b00 { ket::Zero(4) }
- ket b01 { ket::Zero(4) }
- ket b10 { ket::Zero(4) }
- ket b11 { ket::Zero(4) }
- cmat pb00 { cmat::Zero(4, 4) }
- cmat pb01 { cmat::Zero(4, 4) }
- cmat pb10 { cmat::Zero(4, 4) }
- cmat pb11 { cmat::Zero(4, 4) }
- ket GHZ { ket::Zero(8) }
- ket W { ket::Zero(8) }
- cmat pGHZ { cmat::Zero(8, 8) }
- cmat pW { cmat::Zero(8, 8) }

Private Member Functions

- States ()

Friends

- class Singleton< const States >

Additional Inherited Members

7.9.1 Constructor & Destructor Documentation

7.9.1.1 qpp::States::States ( ) [inline], [private]

7.9.2 Friends And Related Function Documentation

7.9.2.1 friend class Singleton< const States > [friend]

7.9.3 Member Data Documentation

7.9.3.1 ket qpp::States::b00 { ket::Zero(4) }

7.9.3.2 ket qpp::States::b01 { ket::Zero(4) }

7.9.3.3 ket qpp::States::b10 { ket::Zero(4) }

7.9.3.4 ket qpp::States::b11 { ket::Zero(4) }

7.9.3.5 ket qpp::States::GHZ { ket::Zero(8) }

7.9.3.6 cmat qpp::States::pb00 { cmat::Zero(4, 4) }

7.9.3.7 cmat qpp::States::pb01 { cmat::Zero(4, 4) }

7.9.3.8 cmat qpp::States::pb10 { cmat::Zero(4, 4) }

7.9.3.9 cmat qpp::States::pb11 { cmat::Zero(4, 4) }

7.9.3.10 cmat qpp::States::pGHZ { cmat::Zero(8, 8) }

7.9.3.11 cmat qpp::States::pW { cmat::Zero(8, 8) }

7.9.3.12 cmat qpp::States::px0 { cmat::Zero(2, 2) }

7.9.3.13 cmat qpp::States::px1 { cmat::Zero(2, 2) }

7.9.3.14 cmat qpp::States::py0 { cmat::Zero(2, 2) }

7.9.3.15 cmat qpp::States::py1 { cmat::Zero(2, 2) }

7.9.3.16 cmat qpp::States::pz0 { cmat::Zero(2, 2) }

7.9.3.17 cmat qpp::States::pz1 { cmat::Zero(2, 2) }

7.9.3.18 ket qpp::States::W { ket::Zero(8) }

7.9.3.19 ket qpp::States::x0 { ket::Zero(2) }

7.9.3.20 ket qpp::States::x1 { ket::Zero(2) }

7.9.3.21 ket qpp::States::y0 { ket::Zero(2) }

7.9.3.22 ket qpp::States::y1 { ket::Zero(2) }

7.9.3.23 ket qpp::States::z0 { ket::Zero(2) }

7.9.3.24 ket qpp::States::z1 { ket::Zero(2) }

The documentation for this class was generated from the following file:

- include/classes/states.h

7.10 qpp::Timer Class Reference

```
#include <timer.h>
```

Public Member Functions

- Timer ()
- void tic ()
- void toc ()
- double seconds () const

Protected Attributes

- std::chrono::steady_clock::time_point _start
- std::chrono::steady_clock::time_point _end

Friends

- std::ostream & operator<< (std::ostream &os, const Timer &rhs)

7.10.1 Constructor & Destructor Documentation

7.10.1.1 qpp::Timer::Timer ( ) [inline]

7.10.2 Member Function Documentation

7.10.2.1 double qpp::Timer::seconds ( ) const [inline]

7.10.2.2 void qpp::Timer::tic ( ) [inline]

7.10.2.3 void qpp::Timer::toc ( ) [inline]

7.10.3 Friends And Related Function Documentation

7.10.3.1 std::ostream& operator<< (std::ostream & *os*, const Timer & *rhs*) [friend]

7.10.4 Member Data Documentation

7.10.4.1 std::chrono::steady_clock::time_point qpp::Timer::_end [protected]

7.10.4.2 std::chrono::steady_clock::time_point qpp::Timer::_start [protected]

The documentation for this class was generated from the following file:

- include/classes/timer.h

7.11 qpp::UniformIntDistribution Class Reference

`#include <stat.h>`

Public Member Functions

- UniformIntDistribution (int a=0, int b=1)
- int sample ()

Protected Attributes

- std::uniform_int_distribution _d

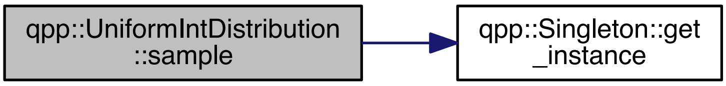
7.11.1 Constructor & Destructor Documentation

7.11.1.1 qpp::UniformIntDistribution::UniformIntDistribution (int *a* = 0, int *b* = 1) [inline]

7.11.2 Member Function Documentation

7.11.2.1 int qpp::UniformIntDistribution::sample ( ) [inline]

Here is the call graph for this function:



7.11.3 Member Data Documentation

7.11.3.1 std::uniform_int_distribution qpp::UniformIntDistribution::_d [protected]

The documentation for this class was generated from the following file:

- include/classes/stat.h

7.12 qpp::UniformRealDistribution Class Reference

`#include <stat.h>`

Public Member Functions

- UniformRealDistribution (double a=0, double b=1)
- double sample ()

Protected Attributes

- std::uniform_real_distribution _d

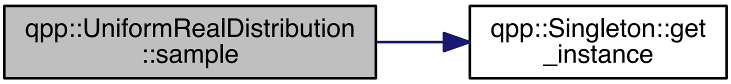
7.12.1 Constructor & Destructor Documentation

7.12.1.1 qpp::UniformRealDistribution::UniformRealDistribution (double *a* = 0, double *b* = 1) [inline]

7.12.2 Member Function Documentation

7.12.2.1 double qpp::UniformRealDistribution::sample ( ) [inline]

Here is the call graph for this function:



7.12.3 Member Data Documentation

7.12.3.1 std::uniform_real_distribution qpp::UniformRealDistribution::_d [protected]

The documentation for this class was generated from the following file:

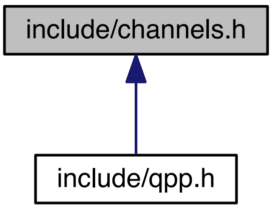
- include/classes/stat.h

Chapter 8

File Documentation

8.1 include/channels.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Functions

- cmat qpp::super (const std::vector< cmat > &Ks)

    Superoperator matrix representation.
- cmat qpp::choi (const std::vector< cmat > &Ks)

    Choi matrix representation.
- std::vector< cmat > qpp::choi2kraus (const cmat &A)

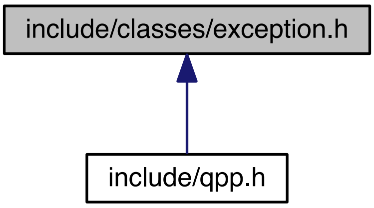
    Extracts orthogonal Kraus operators from Choi matrix.
- template<typename Derived >
  cmat qpp::channel (const Eigen::MatrixBase< Derived > &rho, const std::vector< cmat > &Ks)

    Applies the channel specified by the set of Kraus operators Ks to the density matrix rho.
- template<typename Derived >
  cmat qpp::channel (const Eigen::MatrixBase< Derived > &rho, const std::vector< cmat > &Ks, const std↩ ::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

    Applies the channel specified by the set of Kraus operators Ks to the part of the density matrix rho specified by subsys.

8.2 include/classes/exception.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

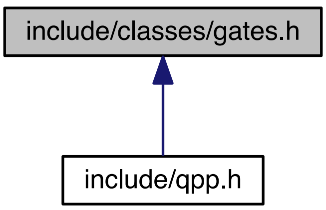
- class qpp::Exception

Namespaces

- qpp

8.3 include/classes/gates.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

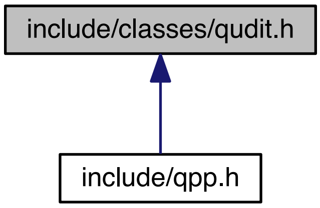
- class qpp::Gates

Namespaces

- qpp

8.4 include/classes/qudit.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

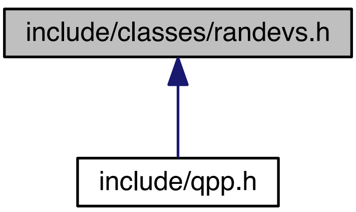
- class qpp::Qudit

Namespaces

- qpp

8.5 include/classes/randevs.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

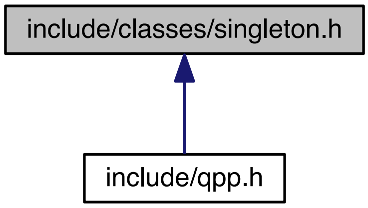
- class qpp::RandomDevices

Namespaces

- qpp

8.6 include/classes/singleton.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

- class qpp::Singleton< T >

Namespaces

- qpp

Macros

- #define CLASS_SINGLETON(Foo)
- #define CLASS_CONST_SINGLETON(Foo)

8.6.1 Macro Definition Documentation

8.6.1.1 #define CLASS_CONST_SINGLETON(*Foo*)

Value:

```
class Foo: public Singleton<const Foo>\
{\
    friend class Singleton<const Foo>;
```

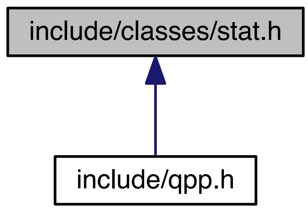
8.6.1.2 #define CLASS_SINGLETON(*Foo*)

Value:

```
class Foo: public Singleton<Foo>\
{\
    friend class Singleton<Foo>;
```

8.7 include/classes/stat.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

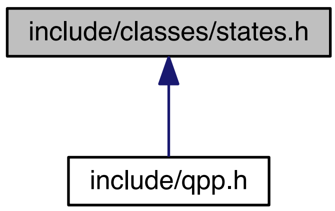
- class qpp::NormalDistribution
- class qpp::UniformRealDistribution
- class qpp::UniformIntDistribution
- class qpp::DiscreteDistribution
- class qpp::DiscreteDistributionAbsSquare

Namespaces

- qpp

8.8 include/classes/states.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

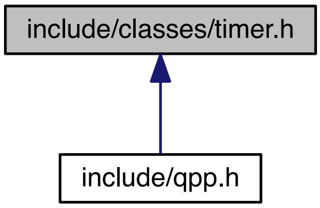
- class qpp::States

Namespaces

- qpp

8.9 include/classes/timer.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

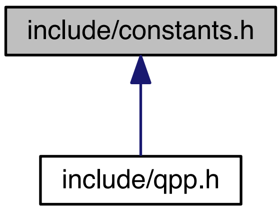
- class qpp::Timer

Namespaces

- qpp

8.10 include/constants.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Functions

- constexpr std::complex< double > qpp::operator""_i (unsigned long long int x)

  User-defined literal for complex $i = \sqrt{-1}$ *(integer overload)*
- constexpr std::complex< double > qpp::operator""_i (long double x)

  User-defined literal for complex $i = \sqrt{-1}$ *(real overload)*
- std::complex< double > qpp::omega (std::size_t D)

  D-th root of unity.

Variables

- constexpr double qpp::chop = 1e-10

  Used in qpp::disp() and qpp::displn() for setting to zero numbers that have their absolute value smaller than qpp::ct←
  ::chop.
- constexpr double qpp::eps = 1e-12

  Used to decide whether a number or expression in double precision is zero or not.
- constexpr std::size_t qpp::maxn = 64

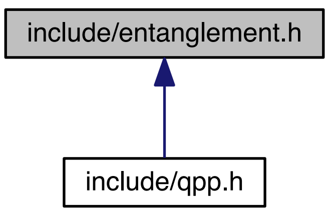
  Maximum number of qubits.
- constexpr double qpp::pi = 3.141592653589793238462643383279502884

  π
- constexpr double qpp::ee = 2.718281828459045235360287471352662497

  Base of natural logarithm, e.

8.11 include/entanglement.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Functions

- template<typename Derived >
  cmat qpp::schmidtcoeff (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Schmidt coefficients of the bi-partite pure state A.

- template<typename Derived >
  cmat qpp::schmidtU (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Schmidt basis on Alice's side.
- template<typename Derived >
  cmat qpp::schmidtV (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Schmidt basis on Bob's side.
- template<typename Derived >
  cmat qpp::schmidtprob (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

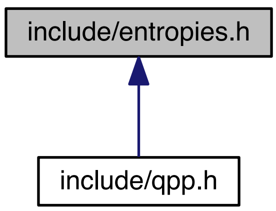
  Schmidt probabilities of the bi-partite pure state A.
- template<typename Derived >
  double qpp::entanglement (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Entanglement of the bi-partite pure state A.
- template<typename Derived >
  double qpp::gconcurrence (const Eigen::MatrixBase< Derived > &A)

  G-concurrence of the bi-partite pure state A.

8.12 include/entropies.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

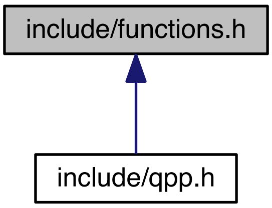
- qpp

Functions

- template<typename Derived >
  double qpp::shannon (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double qpp::renyi (const double alpha, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double qpp::renyi_inf (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double qpp::tsallis (const double alpha, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  double qpp::qmutualinfo (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

8.13 include/functions.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Functions

- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::transpose (const Eigen::MatrixBase< Derived > &A)

  Transpose.
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::conjugate (const Eigen::MatrixBase< Derived > &A)

  Complex conjugate.
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::adjoint (const Eigen::MatrixBase< Derived > &A)

  Adjoint.
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::inverse (const Eigen::MatrixBase< Derived > &A)

  Inverse.
- template<typename Derived >
  Derived::Scalar qpp::trace (const Eigen::MatrixBase< Derived > &A)

  Trace.
- template<typename Derived >
  Derived::Scalar qpp::det (const Eigen::MatrixBase< Derived > &A)

  Determinant.
- template<typename Derived >
  Derived::Scalar qpp::logdet (const Eigen::MatrixBase< Derived > &A)

  Logarithm of the determinant.
- template<typename Derived >
  Derived::Scalar qpp::sum (const Eigen::MatrixBase< Derived > &A)

  Element-wise sum.
- template<typename Derived >
  double qpp::norm (const Eigen::MatrixBase< Derived > &A)

  Trace norm.
- template<typename Derived >
  cmat qpp::evals (const Eigen::MatrixBase< Derived > &A)

Eigenvalues.

- template<typename Derived >
  cmat qpp::evects (const Eigen::MatrixBase< Derived > &A)

  Eigenvectors.
- template<typename Derived >
  dmat qpp::hevals (const Eigen::MatrixBase< Derived > &A)

  Hermitian eigenvalues.
- template<typename Derived >
  cmat qpp::hevects (const Eigen::MatrixBase< Derived > &A)

  Hermitian eigenvectors.
- template<typename Derived >
  cmat qpp::funm (const Eigen::MatrixBase< Derived > &A, cplx(∗f)(const cplx &))

  Functional calculus f(A)
- template<typename Derived >
  cmat qpp::sqrtm (const Eigen::MatrixBase< Derived > &A)

  Matrix square root.
- template<typename Derived >
  cmat qpp::absm (const Eigen::MatrixBase< Derived > &A)

  Matrix absolut value.
- template<typename Derived >
  cmat qpp::expm (const Eigen::MatrixBase< Derived > &A)

  Matrix exponential.
- template<typename Derived >
  cmat qpp::logm (const Eigen::MatrixBase< Derived > &A)

  Matrix logarithm.
- template<typename Derived >
  cmat qpp::sinm (const Eigen::MatrixBase< Derived > &A)

  Matrix sin.
- template<typename Derived >
  cmat qpp::cosm (const Eigen::MatrixBase< Derived > &A)

  Matrix cos.
- template<typename Derived >
  cmat qpp::spectralpowm (const Eigen::MatrixBase< Derived > &A, const cplx z)

  Matrix power.
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::powm (const Eigen::MatrixBase< Derived > &A, std::size_t n)

  Matrix power.
- template<typename OutputScalar , typename Derived >
  DynMat< OutputScalar > qpp::cwise (const Eigen::MatrixBase< Derived > &A, OutputScalar(∗f)(const typename Derived::Scalar &))

  Functor.
- template<typename T >
  DynMat< typename T::Scalar > qpp::kron (const T &head)

  Kronecker product (variadic overload)
- template<typename T , typename... Args>
  DynMat< typename T::Scalar > qpp::kron (const T &head, const Args &...tail)

  Kronecker product (variadic overload)
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::kron (const std::vector< Derived > &As)

  Kronecker product (std::vector overload)
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::kron (const std::initializer_list< Derived > &As)

  Kronecker product (std::initializer_list overload)

- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::kronpow (const Eigen::MatrixBase< Derived > &A, std::size_t n)

  Kronecker power.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::reshape (const Eigen::MatrixBase< Derived > &A, std::size_t rows, std::size_t cols)

  Reshape.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::syspermute (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &perm, const std::vector< std::size_t > &dims)

  System permutation.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::ptrace1 (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Partial trace.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::ptrace2 (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &dims)

  Partial trace.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::ptrace (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

  Partial trace.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::ptranspose (const Eigen::MatrixBase< Derived > &A, const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)

  Partial transpose.
- template< typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > qpp::comm (const Eigen::MatrixBase< Derived1 > &A, const Eigen::MatrixBase< Derived2 > &B)

  Commutator.
- template< typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > qpp::anticomm (const Eigen::MatrixBase< Derived1 > &A, const Eigen::MatrixBase< Derived2 > &B)

  Anti-commutator.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::prj (const Eigen::MatrixBase< Derived > &V)

  Projector.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::expandout (const Eigen::MatrixBase< Derived > &A, std::size_t pos, const std::vector< std::size_t > &dims)

  Expand out.
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::grams (const std::vector< Derived > &Vs)

  Gram-Schmidt orthogonalization (std::vector overload)
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::grams (const std::initializer_list< Derived > &Vs)

  Gram-Schmidt orthogonalization (std::initializer_list overload)
- template< typename Derived >
  DynMat< typename Derived::Scalar > qpp::grams (const Eigen::MatrixBase< Derived > &A)

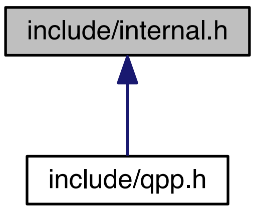
  Gram-Schmidt orthogonalization (Eigen expression (matrix) overload)
- std::vector< std::size_t > qpp::n2multiidx (std::size_t n, const std::vector< std::size_t > &dims)

  Non-negative integer index to multi-index.

- std::size_t qpp::multiidx2n (const std::vector< std::size_t > &midx, const std::vector< std::size_t > &dims)
  Multi-index to non-negative integer index.
- ket qpp::mket (const std::vector< std::size_t > &mask)
  Multi-partite qubit ket.
- ket qpp::mket (const std::vector< std::size_t > &mask, const std::vector< std::size_t > &dims)
  Multi-partite qudit ket (different dimensions overload)
- ket qpp::mket (const std::vector< std::size_t > &mask, std::size_t d)
  Multi-partite qudit ket (same dimensions overload)
- std::vector< std::size_t > qpp::invperm (const std::vector< std::size_t > &perm)
  Inverse permutation.
- std::vector< std::size_t > qpp::compperm (const std::vector< std::size_t > &perm, const std::vector< std↩ ::size_t > &sigma)
  Compose permutations.

8.14 include/internal.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp::internal
- qpp

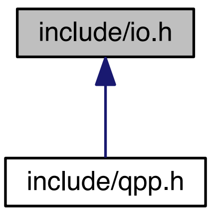
Functions

- void qpp::internal::_n2multiidx (std::size_t n, std::size_t numdims, const std::size_t ∗dims, std::size_t ∗result)
- std::size_t qpp::internal::_multiidx2n (const std::size_t ∗midx, std::size_t numdims, const std::size_t ∗dims)
- template<typename Derived >
  bool qpp::internal::_check_square_mat (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool qpp::internal::_check_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool qpp::internal::_check_row_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool qpp::internal::_check_col_vector (const Eigen::MatrixBase< Derived > &A)
- template<typename T >
  bool qpp::internal::_check_nonzero_size (const T &x)
- bool qpp::internal::_check_dims (const std::vector< std::size_t > &dims)

- template<typename Derived >
  bool qpp::internal::_check_dims_match_mat (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &A)
- template<typename Derived >
  bool qpp::internal::_check_dims_match_cvect (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &V)
- template<typename Derived >
  bool qpp::internal::_check_dims_match_rvect (const std::vector< std::size_t > &dims, const Eigen::MatrixBase< Derived > &V)
- bool qpp::internal::_check_eq_dims (const std::vector< std::size_t > &dims, std::size_t dim)
- bool qpp::internal::_check_subsys_match_dims (const std::vector< std::size_t > &subsys, const std::vector< std::size_t > &dims)
- bool qpp::internal::_check_perm (const std::vector< std::size_t > &perm)
- template<typename Derived1 , typename Derived2 >
  DynMat< typename Derived1::Scalar > qpp::internal::_kron2 (const Eigen::MatrixBase< Derived1 > &A, const Eigen::MatrixBase< Derived2 > &B)
- template<typename T >
  void qpp::internal::variadic_vector_emplace (std::vector< T > &)
- template<typename T , typename First , typename... Args>
  void qpp::internal::variadic_vector_emplace (std::vector< T > &v, First &&first, Args &&...args)

8.15 include/io.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Functions

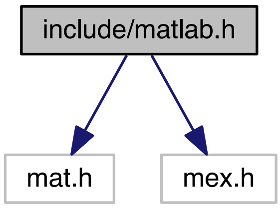
- template<typename T >
  void qpp::disp (const T &x, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template<typename T >
  void qpp::displn (const T &x, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template<typename T >
  void qpp::disp (const T ∗x, const std::size_t n, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)

- template<typename T >
  void qpp::displn (const T *x, const std::size_t n, const std::string &separator, const std::string &start="[", const std::string &end="]", std::ostream &os=std::cout)
- template<typename Derived >
  void qpp::disp (const Eigen::MatrixBase< Derived > &A, double chop=chop, std::ostream &os=std::cout)
- template<typename Derived >
  void qpp::displn (const Eigen::MatrixBase< Derived > &A, double chop=chop, std::ostream &os=std::cout)
- void qpp::disp (const cplx c, double chop=chop, std::ostream &os=std::cout)
- void qpp::displn (const cplx c, double chop=chop, std::ostream &os=std::cout)
- template<typename Derived >
  void qpp::save (const Eigen::MatrixBase< Derived > &A, const std::string &fname)
- template<typename Derived >
  DynMat< typename Derived::Scalar > qpp::load (const std::string &fname)

8.16 include/matlab.h File Reference

```
#include "mat.h"
#include "mex.h"
```

Include dependency graph for matlab.h:



Namespaces

- qpp

Functions

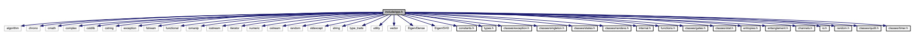
- template<typename Derived >
  Derived qpp::loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<>
  dmat qpp::loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<>
  cmat qpp::loadMATLABmatrix (const std::string &mat_file, const std::string &var_name)
- template<typename Derived >
  void qpp::saveMATLABmatrix (const Eigen::MatrixBase< Derived > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)
- template<>
  void qpp::saveMATLABmatrix (const Eigen::MatrixBase< dmat > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)

- template<>
  void qpp::saveMATLABmatrix (const Eigen::MatrixBase< cmat > &A, const std::string &mat_file, const std::string &var_name, const std::string &mode)

8.17 include/qpp.h File Reference

```
#include <algorithm>
#include <chrono>
#include <cmath>
#include <complex>
#include <cstdlib>
#include <cstring>
#include <exception>
#include <fstream>
#include <functional>
#include <iomanip>
#include <iostream>
#include <iterator>
#include <numeric>
#include <ostream>
#include <random>
#include <stdexcept>
#include <string>
#include <type_traits>
#include <utility>
#include <vector>
#include <Eigen/Dense>
#include <Eigen/SVD>
#include "constants.h"
#include "types.h"
#include "classes/exception.h"
#include "classes/singleton.h"
#include "classes/states.h"
#include "classes/randevs.h"
#include "internal.h"
#include "functions.h"
#include "classes/gates.h"
#include "classes/stat.h"
#include "entropies.h"
#include "entanglement.h"
#include "channels.h"
#include "io.h"
#include "random.h"
#include "classes/qudit.h"
#include "classes/timer.h"
```

Include dependency graph for qpp.h:



Namespaces

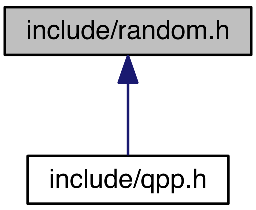
- qpp

Variables

- RandomDevices & qpp::rdevs = RandomDevices::get_instance()
    qpp::RandomDevices Singleton
- const Gates & qpp::gt = Gates::get_instance()
    qpp::Gates const Singleton
- const States & qpp::st = States::get_instance()
    qpp::States const Singleton

8.18 include/random.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

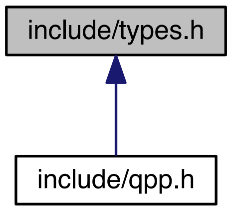
Functions

- template<typename Derived >
  Derived qpp::rand (std::size_t rows, std::size_t cols, double a=0, double b=1)
- template<>
  dmat qpp::rand (std::size_t rows, std::size_t cols, double a, double b)
- template<>
  cmat qpp::rand (std::size_t rows, std::size_t cols, double a, double b)
- double qpp::rand (double a=0, double b=1)
- long long qpp::randint (long long a, long long b)
- template<typename Derived >
  Derived qpp::randn (std::size_t rows, std::size_t cols, double mean=0, double sigma=1)
- template<>
  dmat qpp::randn (std::size_t rows, std::size_t cols, double mean, double sigma)
- template<>
  cmat qpp::randn (std::size_t rows, std::size_t cols, double mean, double sigma)
- double qpp::randn (double mean=0, double sigma=1)
- cmat qpp::randU (std::size_t D)
- cmat qpp::randV (std::size_t Din, std::size_t Dout)
- std::vector< cmat > qpp::randkraus (std::size_t n, std::size_t D)
- cmat qpp::randH (std::size_t D)

- ket qpp::randket (std::size_t D)
- cmat qpp::randrho (std::size_t D)
- std::vector< std::size_t > qpp::randperm (std::size_t n)

8.19 include/types.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- qpp

Typedefs

- using qpp::cplx = std::complex< double >

  Complex number in double precision.
- using qpp::cmat = Eigen::MatrixXcd

  Complex (double precision) dynamic Eigen matrix.
- using qpp::dmat = Eigen::MatrixXd

  Real (double precision) dynamic Eigen matrix.
- using qpp::ket = Eigen::Matrix< cplx, Eigen::Dynamic, 1 >

  Complex (double precision) dynamic Eigen column matrix.
- using qpp::bra = Eigen::Matrix< cplx, 1, Eigen::Dynamic >

  Complex (double precision) dynamic Eigen row matrix.
- template<typename Scalar >
  using qpp::DynMat = Eigen::Matrix< Scalar, Eigen::Dynamic, Eigen::Dynamic >

  Dynamic Eigen matrix over the field specified by Scalar.

Index