视觉*SLAM*

线性代数Eigen

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- Eigen Introduction
- Matrix Operations
- Eigen & Quaternion

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Eigen Introduction
Eigen简介

4 Eigen Introduction

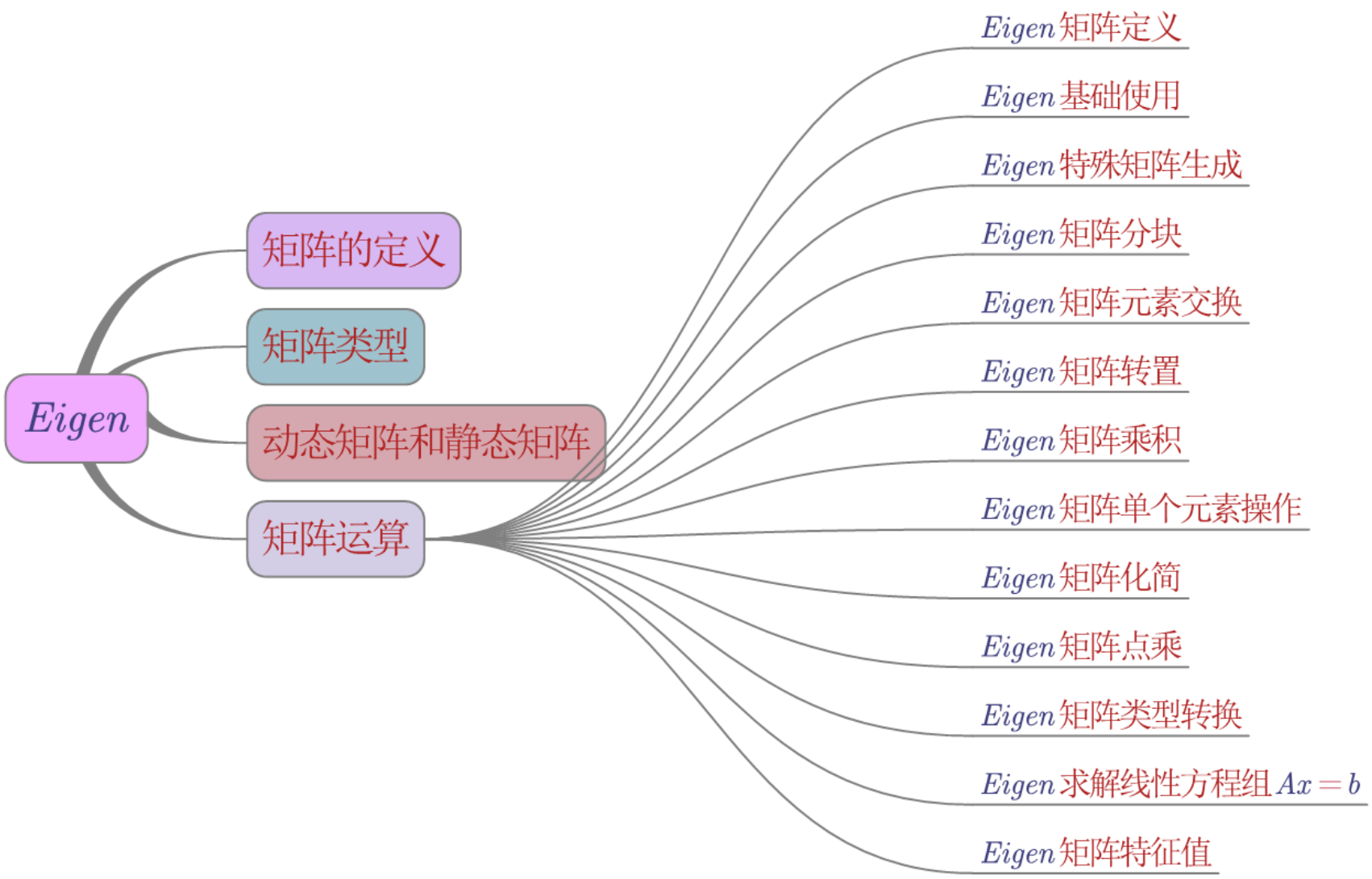
Module	Header file	Contents
Core	`#include <Eigen/Core>`	**Matrix** and **Array** classes, basic linear algebra (including triangular and selfadjoint products), array manipulation
Geometry	`#include <Eigen/Geometry>`	**Transform**, **Translation**, Scaling, **Rotation2D** and 3D rotations (**Quaternion**, **AngleAxis**)
LU	`#include <Eigen/LU>`	**Inverse**, determinant, LU decompositions with solver (**FullPivLU**, **PartialPivLU**)
Cholesky	`#include <Eigen/Cholesky>`	**LLT** and **LDLT** Cholesky factorization with solver
Householder	`#include <Eigen/Householder>`	Householder transformations; this module is used by several linear algebra modules
SVD	`#include <Eigen/SVD>`	SVD decompositions with least-squares solver (**JacobiSVD**, **BDCSVD**)
QR	`#include <Eigen/QR>`	QR decomposition with solver (**HouseholderQR**, **ColPivHouseholderQR**, **FullPivHouseholderQR**)
Eigenvalues	`#include <Eigen/Eigenvalues>`	Eigenvalue, eigenvector decompositions (**EigenSolver**, **SelfAdjointEigenSolver**, **ComplexEigenSolver**)
Sparse	`#include <Eigen/Sparse>`	Sparse matrix storage and related basic linear algebra (**SparseMatrix**, **SparseVector**) (see **Quick reference guide for sparse matrices** for details on sparse modules)
	`#include <Eigen/Dense>`	Includes Core, Geometry, LU, Cholesky, SVD, QR, and Eigenvalues header files
	`#include <Eigen/Eigen>`	Includes Dense and Sparse header files (the whole **Eigen** library)

- Eigen是可以用来进行线性代数、矩阵、向量操作等运算的C++库，它里面包含了很多算法
- Eigen采用源码的方式提供给用户使用，在使用时只需要包含Eigen的头文件即可进行使用

https://eigen.tuxfamily.org/index.php?title=Main_Page

https://eigen.tuxfamily.org/dox/group__QuickRefPage.html

5 Eigen Introduction



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Matrix Operations

矩阵运算

7 Eigen 矩阵定义

```
Matrix<double, 3, 3> A;                 // Fixed rows and cols. Same as Matrix3d.
Matrix<double, 3, Dynamic> B;           // Fixed rows, dynamic cols.
Matrix<double, Dynamic, Dynamic> C;     // Full dynamic. Same as MatrixXd.
Matrix<double, 3, 3, RowMajor> E;       // Row major; default is column-major.
Matrix3f P, Q, R;                       // 3x3 float matrix.
Vector3f x, y, z;                       // 3x1 float matrix.
RowVector3f a, b, c;                    // 1x3 float matrix.
VectorXd v;                             // Dynamic column vector of doubles
// Eigen            // Matlab           // comments
x.size()            // length(x)        // vector size
C.rows()            // size(C,1)        // number of rows
C.cols()            // size(C,2)        // number of columns
x(i)                // x(i+1)           // Matlab is 1-based
C(i,j)              // C(i+1,j+1)       //
```

8 Eigen 基础使用

```
// Basic usage
// Eigen         // Matlab           // comments
x.size()         // length(x)        // vector size
C.rows()         // size(C,1)        // number of rows
C.cols()         // size(C,2)        // number of columns
x(i)             // x(i+1)           // Matlab is 1-based
C(i, j)          // C(i+1,j+1)       //

A.resize(4, 4);   // Runtime error if assertions are on.
B.resize(4, 9);   // Runtime error if assertions are on.
A.resize(3, 3);   // Ok; size didn't change.
B.resize(3, 9);   // Ok; only dynamic cols changed.

A << 1, 2, 3,     // Initialize A. The elements can also be
     4, 5, 6,     // matrices, which are stacked along cols
     7, 8, 9;     // and then the rows are stacked.
B << A, A, A;     // B is three horizontally stacked A's.
A.fill(10);       // Fill A with all 10's.
```

9 Eigen 特殊矩阵生成

```
// Eigen                            // Matlab
MatrixXd::Identity(rows,cols)       // eye(rows,cols)
C.setIdentity(rows,cols)            // C = eye(rows,cols)
MatrixXd::Zero(rows,cols)           // zeros(rows,cols)
C.setZero(rows,cols)                // C = zeros(rows,cols)
MatrixXd::Ones(rows,cols)           // ones(rows,cols)
C.setOnes(rows,cols)                // C = ones(rows,cols)
MatrixXd::Random(rows,cols)         // rand(rows,cols)*2-1        // MatrixXd::Random returns uniform
random numbers in (-1, 1).
C.setRandom(rows,cols)              // C = rand(rows,cols)*2-1
VectorXd::LinSpaced(size,low,high)  // linspace(low,high,size)'
v.setLinSpaced(size,low,high)       // v = linspace(low,high,size)'
```

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Eigen 矩阵分块

```
// Matrix slicing and blocks. All expressions listed here are read/write.
// Templated size versions are faster. Note that Matlab is 1-based (a size N
// vector is x(1)...x(N)).
// Eigen                           // Matlab
x.head(n)                          // x(1:n)
x.head<n>()                        // x(1:n)
x.tail(n)                          // x(end - n + 1: end)
x.tail<n>()                        // x(end - n + 1: end)
x.segment(i, n)                    // x(i+1 : i+n)
x.segment<n>(i)                    // x(i+1 : i+n)
P.block(i, j, rows, cols)          // P(i+1 : i+rows, j+1 : j+cols)
P.block<rows, cols>(i, j)          // P(i+1 : i+rows, j+1 : j+cols)
P.row(i)                           // P(i+1, :)
P.col(j)                           // P(:, j+1)
P.leftCols<cols>()                 // P(:, 1:cols)
P.leftCols(cols)                   // P(:, 1:cols)
P.middleCols<cols>(j)              // P(:, j+1:j+cols)
P.middleCols(j, cols)              // P(:, j+1:j+cols)
P.rightCols<cols>()                // P(:, end-cols+1:end)
P.rightCols(cols)                  // P(:, end-cols+1:end)
P.topRows<rows>()                  // P(1:rows, :)
P.topRows(rows)                    // P(1:rows, :)
P.middleRows<rows>(i)              // P(i+1:i+rows, :)
P.middleRows(i, rows)              // P(i+1:i+rows, :)
P.bottomRows<rows>()               // P(end-rows+1:end, :)
P.bottomRows(rows)                 // P(end-rows+1:end, :)
P.topLeftCorner(rows, cols)        // P(1:rows, 1:cols)
P.topRightCorner(rows, cols)       // P(1:rows, end-cols+1:end)
P.bottomLeftCorner(rows, cols)     // P(end-rows+1:end, 1:cols)
P.bottomRightCorner(rows, cols)    // P(end-rows+1:end, end-cols+1:end)
P.topLeftCorner<rows,cols>()       // P(1:rows, 1:cols)
P.topRightCorner<rows,cols>()      // P(1:rows, end-cols+1:end)
P.bottomLeftCorner<rows,cols>()    // P(end-rows+1:end, 1:cols)
P.bottomRightCorner<rows,cols>()   // P(end-rows+1:end, end-cols+1:end)
```

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Eigen 矩阵元素交换

```
// Of particular note is Eigen's swap function which is highly optimized.
// Eigen                                  // Matlab
R.row(i) = P.col(j);                      // R(i, :) = P(:, i)
R.col(j1).swap(mat1.col(j2));             // R(:, [j1 j2]) = R(:, [j2, j1])
```

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Eigen 矩阵转置

```
// Views, transpose, etc; all read-write except for .adjoint().
// Eigen                                // Matlab
R.adjoint()                             // R'
R.transpose()                           // R.' or conj(R')
R.diagonal()                            // diag(R)
x.asDiagonal()                          // diag(x)
R.transpose().colwise().reverse();      // rot90(R)
R.conjugate()                           // conj(R)
```

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Eigen 矩阵乘积

```
// All the same as Matlab, but matlab doesn't have *= style operators.
// Matrix-vector.  Matrix-matrix.   Matrix-scalar.
y  = M*x;          R  = P*Q;        R  = P*s;
a  = b*M;          R  = P - Q;      R  = s*P;
a *= M;            R  = P + Q;      R  = P/s;
                   R *= Q;          R  = s*P;
                   R += Q;          R *= s;
                   R -= Q;          R /= s;
```

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Eigen 矩阵单个元素操作

```
// Vectorized operations on each element independently
// Eigen                    // Matlab
R = P.cwiseProduct(Q);      // R = P .* Q
R = P.array() * s.array();// R = P .* s
R = P.cwiseQuotient(Q);     // R = P ./ Q
R = P.array() / Q.array();// R = P ./ Q
R = P.array() + s.array();// R = P + s
R = P.array() - s.array();// R = P - s
R.array() += s;             // R = R + s
R.array() -= s;             // R = R - s
R.array() < Q.array();      // R < Q
R.array() <= Q.array();     // R <= Q
R.cwiseInverse();           // 1 ./ P
R.array().inverse();        // 1 ./ P
R.array().sin()             // sin(P)
R.array().cos()             // cos(P)
```

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Eigen 矩阵单个元素操作

```
R.array().pow(s)           // P .^ s
R.array().square()         // P .^ 2
R.array().cube()           // P .^ 3
R.cwiseSqrt()              // sqrt(P)
R.array().sqrt()           // sqrt(P)
R.array().exp()            // exp(P)
R.array().log()            // log(P)
R.cwiseMax(P)              // max(R, P)
R.array().max(P.array())   // max(R, P)
R.cwiseMin(P)              // min(R, P)
R.array().min(P.array())   // min(R, P)
R.cwiseAbs()               // abs(P)
R.array().abs()            // abs(P)
R.cwiseAbs2()              // abs(P.^2)
R.array().abs2()           // abs(P.^2)
(R.array() < s).select(P,Q);  // (R < s ? P : Q)
```

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Eigen 矩阵化简

```
// Reductions.
int r, c;
// Eigen                  // Matlab
R.minCoeff()              // min(R(:))
R.maxCoeff()              // max(R(:))
s = R.minCoeff(&r, &c)    // [s, i] = min(R(:)); [r, c] = ind2sub(size(R), i);
s = R.maxCoeff(&r, &c)    // [s, i] = max(R(:)); [r, c] = ind2sub(size(R), i);
R.sum()                   // sum(R(:))
R.colwise().sum()         // sum(R)
R.rowwise().sum()         // sum(R, 2) or sum(R')'
R.prod()                  // prod(R(:))
R.colwise().prod()        // prod(R)
R.rowwise().prod()        // prod(R, 2) or prod(R')'
R.trace()                 // trace(R)
R.all()                   // all(R(:))
R.colwise().all()         // all(R)
R.rowwise().all()         // all(R, 2)
R.any()                   // any(R(:))
R.colwise().any()         // any(R)
R.rowwise().any()         // any(R, 2)
```

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Eigen 矩阵点乘

```
// Dot products, norms, etc.
// Eigen                  // Matlab
x.norm()                  // norm(x).    Note that norm(R) doesn't work in Eigen.
x.squaredNorm()           // dot(x, x)   Note the equivalence is not true for complex
x.dot(y)                  // dot(x, y)
x.cross(y)                // cross(x, y) Requires #include <Eigen/Geometry>
```

Eigen 矩阵类型转换

```
//// Type conversion
// Eigen                                // Matlab
A.cast<double>();                       // double(A)
A.cast<float>();                        // single(A)
A.cast<int>();                          // int32(A)
A.real();                               // real(A)
A.imag();                               // imag(A)
// if the original type equals destination type, no work is done
```

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Eigen 求解线性方程组 Ax = b

```
// Solve Ax = b. Result stored in x. Matlab: x = A \ b.
x = A.ldlt().solve(b));  // A sym. p.s.d.    #include <Eigen/Cholesky>
x = A.llt() .solve(b));  // A sym. p.d.      #include <Eigen/Cholesky>
x = A.lu()  .solve(b));  // Stable and fast. #include <Eigen/LU>
x = A.qr()  .solve(b));  // No pivoting.     #include <Eigen/QR>
x = A.svd() .solve(b));  // Stable, slowest. #include <Eigen/SVD>
// .ldlt() -> .matrixL() and .matrixD()
// .llt()  -> .matrixL()
// .lu()   -> .matrixL() and .matrixU()
// .qr()   -> .matrixQ() and .matrixR()
// .svd()  -> .matrixU(), .singularValues(), and .matrixV()
```

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Eigen 矩阵特征值

```
// Eigenvalue problems
// Eigen                          // Matlab
A.eigenvalues();                  // eig(A);
EigenSolver<Matrix3d> eig(A);     // [vec val] = eig(A)
eig.eigenvalues();                // diag(val)
eig.eigenvectors();               // vec
// For self-adjoint matrices use SelfAdjointEigenSolver<>
```

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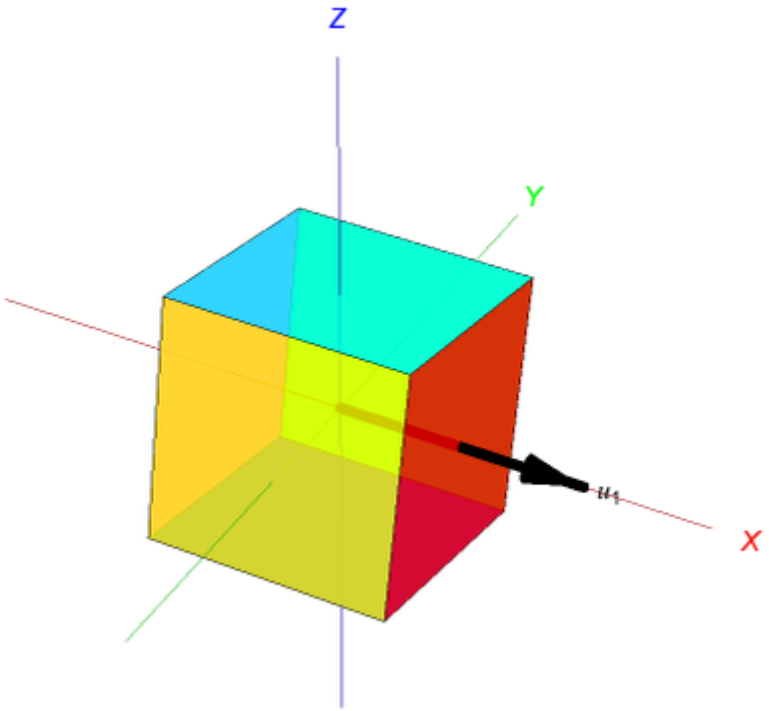
Eigen & Quaternion

矩阵 & 四元数



Eigen & Quaternion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