Matrix2D

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Chapter 1

Class Index

1.1 Class List

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

Chapter 2

File Index

2.1 File List

Here is a list of all files with brief descriptions:

Chapter 3

Class Documentation

3.1 Mat2D Struct Reference

Dense row-major matrix of doubles.

`#include <Matrix2D.h>`

Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- double * elements

3.1.1 Detailed Description

Dense row-major matrix of doubles.

- rows: number of rows (height)
- cols: number of columns (width)
- stride_r: number of elements between successive rows in memory (for contiguous storage, stride_r == cols)
- elements: pointer to contiguous storage of size rows * cols

Definition at line 81 of file Matrix2D.h.

3.1.2 Member Data Documentation

3.1.2.1 cols

```
size_t Mat2D::cols
```

Definition at line 83 of file Matrix2D.h.

Referenced by mat2D_add(), mat2D_add_col_to_col(), mat2D_add_row_time_factor_to_row(), mat2D_add_row_to_row(), mat2D_alloc(), mat2D_calc_norma(), mat2D_col_is_all_digit(), mat2D_copy(), mat2D_copy_mat_to_mat_at_window(), mat2D_cross(), mat2D_det(), mat2D_det_2x2_mat(), mat2D_dot(), mat2D_dot_product(), mat2D_fill(), mat2D_fill_sequence(), mat2D_get_col(), mat2D_get_row(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), mat2D_mat_is_all_digit(), mat2D_minor_alloc_fill_from_mat(), mat2D_mult(), mat2D_mult_row(), mat2D_offset2d(), mat2D_print(), mat2D_print_as_col(), mat2D_rand(), mat2D_row_is_all_digit(), mat2D_set_identity(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), mat2D_set_rot_mat_z(), mat2D_solve_linear_sys_LUP_decomposition(), mat2D_sub(), mat2D_sub_col_to_col(), mat2D_sub_row_time_factor_to_row(), mat2D_sub_row_to_row(), mat2D_swap_rows(), mat2D_transpose(), and mat2D_triangulate().

3.1.2.2 elements

```
double* Mat2D::elements
```

Definition at line 85 of file Matrix2D.h.

Referenced by mat2D_alloc(), mat2D_free(), and mat2D_print_as_col().

3.1.2.3 rows

```
size_t Mat2D::rows
```

Definition at line 82 of file Matrix2D.h.

Referenced by mat2D_add(), mat2D_add_col_to_col(), mat2D_add_row_to_row(), mat2D_alloc(), mat2D_calc_norma(), mat2D_copy(), mat2D_copy_mat_to_mat_at_window(), mat2D_cross(), mat2D_det(), mat2D_det_2x2_mat(), mat2D_dot(), mat2D_dot_product(), mat2D_fill(), mat2D_fill_sequence(), mat2D_get_col(), mat2D_get_row(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), mat2D_mat_is_all_digit(), mat2D_minor_alloc_fill_from_mat(), mat2D_mult(), mat2D_offset2d(), mat2D_print(), mat2D_print_as_col(), mat2D_rand(), mat2D_set_identity(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), mat2D_set_rot_mat_z(), mat2D_solve_linear_sys_LUP_decomposition(), mat2D_sub(), mat2D_sub_col_to_col(), mat2D_sub_row_to_row(), mat2D_transpose(), and mat2D_triangulate().

3.1.2.4 stride_r

```
size_t Mat2D::stride_r
```

Definition at line 84 of file Matrix2D.h.

Referenced by mat2D_alloc(), and mat2D_offset2d().

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

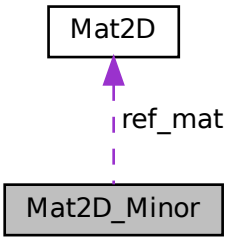
- Matrix2D.h

3.2 Mat2D_Minor Struct Reference

A minor "view" into a reference matrix.

`#include <Matrix2D.h>`

Collaboration diagram for Mat2D_Minor:



Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- size_t * rows_list
- size_t * cols_list
- Mat2D ref_mat

3.2.1 Detailed Description

A minor "view" into a reference matrix.

Represents a minor by excluding one row and one column of a reference matrix. It holds index lists mapping into the reference matrix, without owning the data of the reference matrix itself.

Memory ownership:

- rows_list and cols_list are heap-allocated by minor allocators and must be freed with mat2D_minor_free.
- The underlying matrix data (ref_mat.elements) is not owned by the minor and must not be freed by the minor functions.

Definition at line 119 of file Matrix2D.h.

3.2.2 Member Data Documentation

3.2.2.1 cols

```
size_t Mat2D_Minor::cols
```

Definition at line 121 of file Matrix2D.h.

Referenced by mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), mat2D_minor_det(), and mat2D_minor_print().

3.2.2.2 cols_list

```
size_t* Mat2D_Minor::cols_list
```

Definition at line 124 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), and mat2D_minor_free().

3.2.2.3 ref_mat

```
Mat2D Mat2D_Minor::ref_mat
```

Definition at line 125 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), and mat2D_minor_alloc_fill_from_mat_minor().

3.2.2.4 rows

```
size_t Mat2D_Minor::rows
```

Definition at line 120 of file Matrix2D.h.

Referenced by mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), mat2D_minor_det(), and mat2D_minor_print().

3.2.2.5 rows_list

```
size_t* Mat2D_Minor::rows_list
```

Definition at line 123 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), and mat2D_minor_free().

3.2.2.6 stride_r

```
size_t Mat2D_Minor::stride_r
```

Definition at line 122 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), and mat2D_minor_alloc_fill_from_mat_minor().

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

- Matrix2D.h

3.3 Mat2D_uint32 Struct Reference

Dense row-major matrix of uint32_t.

```
#include <Matrix2D.h>
```

Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- uint32_t * elements

3.3.1 Detailed Description

Dense row-major matrix of uint32_t.

- rows: number of rows (height)
- cols: number of columns (width)
- stride_r: number of elements between successive rows in memory (for contiguous storage, stride_r == cols)
- elements: pointer to contiguous storage of size rows * cols

Definition at line 98 of file Matrix2D.h.

3.3.2 Member Data Documentation

3.3.2.1 cols

```
size_t Mat2D_uint32::cols
```

Definition at line 100 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), mat2D_fill_uint32(), and mat2D_offset2d_uint32().

3.3.2.2 elements

```
uint32_t* Mat2D_uint32::elements
```

Definition at line 102 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), and mat2D_free_uint32().

3.3.2.3 rows

```
size_t Mat2D_uint32::rows
```

Definition at line 99 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), mat2D_fill_uint32(), and mat2D_offset2d_uint32().

3.3.2.4 stride_r

```
size_t Mat2D_uint32::stride_r
```

Definition at line 101 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), and mat2D_offset2d_uint32().

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

- Matrix2D.h

Chapter 4

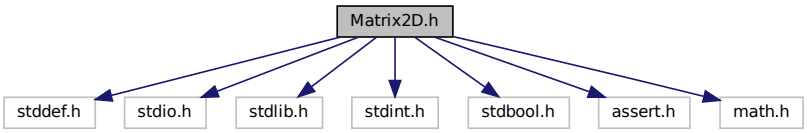
File Documentation

4.1 Matrix2D.h File Reference

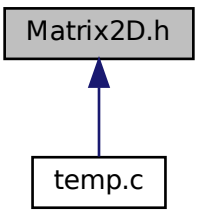
A single-header C library for simple 2D matrix operations on doubles and uint32_t, including allocation, basic arithmetic, linear algebra, and helpers (LUP, inverse, determinant, DCM, etc.).

```
#include <stddef.h>
#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <stdbool.h>
#include <assert.h>
#include <math.h>
```

Include dependency graph for Matrix2D.h:



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



Classes

- struct Mat2D

  Dense row-major matrix of doubles.
- struct Mat2D_uint32

  Dense row-major matrix of uint32_t.
- struct Mat2D_Minor

  A minor "view" into a reference matrix.

Macros

- #define MATRIX2D_MALLOC malloc

  Allocation function used by the library.
- #define MATRIX2D_ASSERT assert

  Assertion macro used by the library for parameter validation.
- #define MAT2D_AT(m, i, j) (m).elements[i ∗ m.stride_r + j]

  Access element (i, j) of a Mat2D (0-based).
- #define MAT2D_AT_UINT32(m, i, j) (m).elements[i ∗ m.stride_r + j]

  Access element (i, j) of a Mat2D_uint32 (0-based).
- #define __USE_MISC
- #define PI M_PI
- #define MAT2D_MINOR_AT(mm, i, j) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])

  Access element (i, j) of a Mat2D_Minor (0-based), dereferencing into the underlying reference matrix.
- #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)

  Convenience macro to print a matrix with its variable name.
- #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)

  Convenience macro to print a matrix as a single column with its name.
- #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)

  Convenience macro to print a minor with its variable name.
- #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))

  In-place normalization of all elements so that the Frobenius norm becomes 1.

Functions

- double mat2D_rand_double (void)

  Return a pseudo-random double in the range [0, 1].
- Mat2D mat2D_alloc (size_t rows, size_t cols)

  Allocate a rows x cols matrix of doubles.
- Mat2D_uint32 mat2D_alloc_uint32 (size_t rows, size_t cols)

  Allocate a rows x cols matrix of uint32_t.
- void mat2D_free (Mat2D m)

  Free the memory owned by a Mat2D (elements pointer).
- void mat2D_free_uint32 (Mat2D_uint32 m)

  Free the memory owned by a Mat2D_uint32 (elements pointer).
- size_t mat2D_offset2d (Mat2D m, size_t i, size_t j)

  Compute the linear offset of element (i, j) in a Mat2D.
- size_t mat2D_offset2d_uint32 (Mat2D_uint32 m, size_t i, size_t j)

  Compute the linear offset of element (i, j) in a Mat2D_uint32.
- void mat2D_fill (Mat2D m, double x)

  Fill all elements of a matrix of doubles with a scalar value.

- void mat2D_fill_sequence (Mat2D m, double start, double step)

  Fill a matrix with an arithmetic sequence laid out in row-major order.
- void mat2D_fill_uint32 (Mat2D_uint32 m, uint32_t x)

  Fill all elements of a matrix of uint32_t with a scalar value.
- void mat2D_rand (Mat2D m, double low, double high)

  Fill a matrix with random doubles in [low, high).
- void mat2D_dot (Mat2D dst, Mat2D a, Mat2D b)

  *Matrix product: dst = a * b.*
- double mat2D_dot_product (Mat2D a, Mat2D b)

  Dot product between two vectors.
- void mat2D_cross (Mat2D dst, Mat2D a, Mat2D b)

  3D cross product: dst = a x b for 3x1 vectors.
- void mat2D_add (Mat2D dst, Mat2D a)

  In-place addition: dst += a.
- void mat2D_add_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)

  *Row operation: row(des_r) += factor * row(src_r).*
- void mat2D_sub (Mat2D dst, Mat2D a)

  In-place subtraction: dst -= a.
- void mat2D_sub_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)

  *Row operation: row(des_r) -= factor * row(src_r).*
- void mat2D_mult (Mat2D m, double factor)

  *In-place scalar multiplication: m *= factor.*
- void mat2D_mult_row (Mat2D m, size_t r, double factor)

  *In-place row scaling: row(r) *= factor.*
- void mat2D_print (Mat2D m, const char *name, size_t padding)

  Print a matrix to stdout with a name and indentation padding.
- void mat2D_print_as_col (Mat2D m, const char *name, size_t padding)

  Print a matrix as a flattened column vector to stdout.
- void mat2D_set_identity (Mat2D m)

  Set a square matrix to the identity matrix.
- double mat2D_make_identity (Mat2D m)

  Reduce a matrix to identity via Gauss-Jordan elimination and return the cumulative scaling factor.
- void mat2D_set_rot_mat_x (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the X-axis.
- void mat2D_set_rot_mat_y (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the Y-axis.
- void mat2D_set_rot_mat_z (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the Z-axis.
- void mat2D_set_DCM_zyx (Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)

  Build a 3x3 direction cosine matrix (DCM) from Z-Y-X Euler angles.
- void mat2D_copy (Mat2D des, Mat2D src)

  Copy all elements from src to des.
- void mat2D_copy_mat_to_mat_at_window (Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)

  Copy a rectangular window from src into des.
- void mat2D_get_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Copy a column from src into a column of des.
- void mat2D_add_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Add a source column into a destination column: des[:, des_col] += src[:, src_col].
- void mat2D_sub_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Subtract a source column from a destination column: des[:, des_col] -= src[:, src_col].
- void mat2D_swap_rows (Mat2D m, size_t r1, size_t r2)

Swap two rows of a matrix in-place.

- void mat2D_get_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Copy a row from src into a row of des.
- void mat2D_add_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Add a source row into a destination row: des[des_row, :] += src[src_row, :].
- void mat2D_sub_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Subtract a source row from a destination row: des[des_row, :] -= src[src_row, :].
- double mat2D_calc_norma (Mat2D m)

  Compute the Frobenius norm of a matrix, sqrt(sum(m_ij^ 2)).
- bool mat2D_mat_is_all_digit (Mat2D m, double digit)

  Check if all elements of a matrix equal a given digit.
- bool mat2D_row_is_all_digit (Mat2D m, double digit, size_t r)

  Check if all elements of a row equal a given digit.
- bool mat2D_col_is_all_digit (Mat2D m, double digit, size_t c)

  Check if all elements of a column equal a given digit.
- double mat2D_det_2x2_mat (Mat2D m)

  Determinant of a 2x2 matrix.
- double mat2D_triangulate (Mat2D m)

  Forward elimination to transform a matrix to upper triangular form.
- double mat2D_det (Mat2D m)

  Determinant of an NxN matrix via Gaussian elimination.
- void mat2D_LUP_decomposition_with_swap (Mat2D src, Mat2D l, Mat2D p, Mat2D u)

  Compute LUP decomposition: P∗A = L∗U with L unit diagonal.
- void mat2D_transpose (Mat2D des, Mat2D src)

  Transpose a matrix: des = src^ T.
- void mat2D_invert (Mat2D des, Mat2D src)

  Invert a square matrix using Gauss-Jordan elimination.
- void mat2D_solve_linear_sys_LUP_decomposition (Mat2D A, Mat2D x, Mat2D B)

  Solve the linear system A x = B using LUP decomposition.
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat (Mat2D ref_mat, size_t i, size_t j)

  Allocate a minor view by excluding row i and column j of ref_mat.
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor (Mat2D_Minor ref_mm, size_t i, size_t j)

  Allocate a nested minor view from an existing minor by excluding row i and column j of the minor.
- void mat2D_minor_free (Mat2D_Minor mm)

  Free the index arrays owned by a minor.
- void mat2D_minor_print (Mat2D_Minor mm, const char ∗name, size_t padding)

  Print a minor matrix to stdout with a name and indentation padding.
- double mat2D_det_2x2_mat_minor (Mat2D_Minor mm)

  Determinant of a 2x2 minor.
- double mat2D_minor_det (Mat2D_Minor mm)

  Determinant of a minor via recursive expansion by minors.

4.1.1 Detailed Description

A single-header C library for simple 2D matrix operations on doubles and uint32_t, including allocation, basic arithmetic, linear algebra, and helpers (LUP, inverse, determinant, DCM, etc.).

- Storage is contiguous row-major (C-style). The element at row i, column j (0-based) is located at `elements[i * stride_r + j]`.

- Dense matrices of `double` are represented by Mat2D, and dense matrices of `uint32_t` are represented by Mat2D_uint32.
- Some routines assert shape compatibility using MATRIX2D_ASSERT.
- Random number generation uses the C library `rand()`; it is not cryptographically secure.
- Inversion is done via Gauss-Jordan elimination with partial pivoting only when a pivot is zero; this can be numerically unstable for ill-conditioned matrices. See notes below.
- To compile the implementation, define MATRIX2D_IMPLEMENTATION in exactly one translation unit before including this header.

Example: #define MATRIX2D_IMPLEMENTATION #include "matrix2d.h"

Note

This one-file library is heavily inspired by Tsoding's nn.h implementation of matrix creation and operations: https://github.com/tsoding/nn.h and the video: https://youtu.be/L1TbWe8bVOc?list=PLpM-Dvs8t0VZPZKggcql-MmjaBdZKeDMw

Warning

Numerical stability:

- There is a set of functions for minors that can be used to compute the determinant, but that approach is factorial in complexity and too slow for larger matrices. This library uses Gaussian elimination instead.
- The inversion function can fail or be unstable if pivot values become very small. Consider preconditioning or using a more robust decomposition (e.g., full pivoting, SVD) for ill-conditioned problems.

Definition in file Matrix2D.h.

4.1.2 Macro Definition Documentation

4.1.2.1 __USE_MISC

```
#define __USE_MISC
```

Definition at line 151 of file Matrix2D.h.

4.1.2.2 MAT2D_AT

```
#define MAT2D_AT(
                m,
                i,
                j ) (m).elements[i * m.stride_r + j]
```

Access element (i, j) of a Mat2D (0-based).

Warning

This macro does not perform bounds checking in the fast configuration. Use carefully.

Definition at line 145 of file Matrix2D.h.

4.1.2.3 MAT2D_AT_UINT32

```
#define MAT2D_AT_UINT32(
              m,
              i,
              j ) (m).elements[i * m.stride_r + j]
```

Access element (i, j) of a Mat2D_uint32 (0-based).

Warning

This macro does not perform bounds checking in the fast configuration. Use carefully.

Definition at line 146 of file Matrix2D.h.

4.1.2.4 MAT2D_MINOR_AT

```
#define MAT2D_MINOR_AT(
              mm,
              i,
              j ) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])
```

Access element (i, j) of a Mat2D_Minor (0-based), dereferencing into the underlying reference matrix.

Definition at line 162 of file Matrix2D.h.

4.1.2.5 MAT2D_MINOR_PRINT

```
#define MAT2D_MINOR_PRINT(
              mm ) mat2D_minor_print(mm, #mm, 0)
```

Convenience macro to print a minor with its variable name.

Definition at line 177 of file Matrix2D.h.

4.1.2.6 mat2D_normalize

```
#define mat2D_normalize(
              m ) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))
```

In-place normalization of all elements so that the Frobenius norm becomes 1.

Equivalent to: m *= 1.0 / mat2D_calc_norma(m).

Definition at line 184 of file Matrix2D.h.

4.1.2.7 MAT2D_PRINT

```
#define MAT2D_PRINT(
             m ) mat2D_print(m, #m, 0)
```

Convenience macro to print a matrix with its variable name.

Definition at line 167 of file Matrix2D.h.

4.1.2.8 MAT2D_PRINT_AS_COL

```
#define MAT2D_PRINT_AS_COL(
             m ) mat2D_print_as_col(m, #m, 0)
```

Convenience macro to print a matrix as a single column with its name.

Definition at line 172 of file Matrix2D.h.

4.1.2.9 MATRIX2D_ASSERT

```
#define MATRIX2D_ASSERT assert
```

Assertion macro used by the library for parameter validation.

Defaults to C `assert`. Override by defining MATRIX2D_ASSERT before including this header if you want custom behavior.

Definition at line 68 of file Matrix2D.h.

4.1.2.10 MATRIX2D_MALLOC

```
#define MATRIX2D_MALLOC malloc
```

Allocation function used by the library.

Defaults to `malloc`. Override by defining MATRIX2D_MALLOC before including this header if you want to use a custom allocator.

Definition at line 56 of file Matrix2D.h.

4.1.2.11 PI

```
#define PI M_PI
```

Definition at line 154 of file Matrix2D.h.

4.1.3 Function Documentation

4.1.3.1 mat2D_add()

```
void mat2D_add (
             Mat2D dst,
             Mat2D a )
```

In-place addition: dst += a.

Parameters

dst	Destination matrix to be incremented.
a	Summand of same shape as dst.

Precondition

Shapes match.

Definition at line 496 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.2 mat2D_add_col_to_col()

```
void mat2D_add_col_to_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Add a source column into a destination column: des[:, des_col] += src[:, src_col].

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 828 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.3 mat2D_add_row_time_factor_to_row()

```
void mat2D_add_row_time_factor_to_row (
            Mat2D m,
            size_t des_r,
            size_t src_r,
            double factor )
```

Row operation: row(des_r) += factor $*$ row(src_r).

Parameters

m	Matrix.

Parameters

des_r	Destination row index.
src_r	Source row index.
factor	Scalar multiplier.

Definition at line 514 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

4.1.3.4 mat2D_add_row_to_row()

```
void mat2D_add_row_to_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Add a source row into a destination row: des[des_row, :] += src[src_row, :].

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 897 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.5 mat2D_alloc()

```
Mat2D mat2D_alloc (
            size_t rows,
            size_t cols )
```

Allocate a rows x cols matrix of doubles.

Parameters

rows	Number of rows (>= 1).
cols	Number of columns (>= 1).

Returns

A Mat2D with contiguous storage; must be freed with mat2D_free.

Postcondition

m.stride_r == cols.

Definition at line 278 of file Matrix2D.h.

References Mat2D::cols, Mat2D::elements, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D::rows, and Mat2D::stride_r.

Referenced by main(), mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.1.3.6 mat2D_alloc_uint32()

```
Mat2D_uint32 mat2D_alloc_uint32 (
            size_t rows,
            size_t cols )
```

Allocate a rows x cols matrix of uint32_t.

Parameters

rows	Number of rows (>= 1).
cols	Number of columns (>= 1).

Returns

A Mat2D_uint32 with contiguous storage; free with mat2D_free_uint32.

Postcondition

m.stride_r == cols.

Definition at line 297 of file Matrix2D.h.

References Mat2D_uint32::cols, Mat2D_uint32::elements, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_uint32::rows, and Mat2D_uint32::stride_r.

4.1.3.7 mat2D_calc_norma()

```
double mat2D_calc_norma (
            Mat2D m )
```

Compute the Frobenius norm of a matrix, sqrt(sum(m_ij^2)).

Parameters

m	Matrix.

Returns

Frobenius norm.

Definition at line 931 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

Referenced by main().

4.1.3.8 mat2D_col_is_all_digit()

```
bool mat2D_col_is_all_digit (
            Mat2D m,
            double digit,
            size_t c )
```

Check if all elements of a column equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.
c	Column index.

Returns

true if every element equals digit, false otherwise.

Definition at line 985 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.1.3.9 mat2D_copy()

```
void mat2D_copy (
            Mat2D des,
            Mat2D src )
```

Copy all elements from src to des.

Parameters

des	Destination matrix.
src	Source matrix.

Precondition

Shapes match.

Definition at line 768 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by main(), mat2D_det(), mat2D_invert(), and mat2D_LUP_decomposition_with_swap().

4.1.3.10 mat2D_copy_mat_to_mat_at_window()

```
void mat2D_copy_mat_to_mat_at_window (
            Mat2D des,
            Mat2D src,
            size_t is,
            size_t js,
            size_t ie,
            size_t je )
```

Copy a rectangular window from src into des.

Parameters

des	Destination matrix. Must have size (ie - is + 1) x (je - js + 1).
src	Source matrix.
is	Start row index in src (inclusive).
js	Start column index in src (inclusive).
ie	End row index in src (inclusive).
je	End column index in src (inclusive).

Precondition

0 <= is <= ie < src.rows, 0 <= js <= je < src.cols.

Definition at line 790 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.11 mat2D_cross()

```
void mat2D_cross (
            Mat2D dst,
            Mat2D a,
            Mat2D b )
```

3D cross product: dst = a x b for 3x1 vectors.

Parameters

dst	3x1 destination vector.
a	3x1 input vector.
b	3x1 input vector.

Precondition

All matrices have shape 3x1.

Definition at line 479 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.12 mat2D_det()

```
double mat2D_det (
            Mat2D m )
```

Determinant of an NxN matrix via Gaussian elimination.

Parameters

m	Square matrix.

Returns

det(m).

Copies m internally, triangulates it, and returns the product of diagonal elements (adjusted by any scaling factor as implemented).

Definition at line 1052 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), MAT2D_AT, mat2D_col_is_all_digit(), mat2D_copy(), mat2D_free(), mat2D_row_is_all_digit(), mat2D_triangulate(), MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by mat2D_invert().

4.1.3.13 mat2D_det_2x2_mat()

```
double mat2D_det_2x2_mat (
            Mat2D m )
```

Determinant of a 2x2 matrix.

Parameters

m	Matrix (must be 2x2).

Returns

det(m) = a11 a22 - a12 a21.

Definition at line 1000 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.14 mat2D_det_2x2_mat_minor()

```
double mat2D_det_2x2_mat_minor (
            Mat2D_Minor mm )
```

Determinant of a 2x2 minor.

Parameters

mm	Minor (must be 2x2).

Returns

det(mm).

Definition at line 1383 of file Matrix2D.h.

References Mat2D_Minor::cols, MAT2D_MINOR_AT, MATRIX2D_ASSERT, and Mat2D_Minor::rows.

Referenced by mat2D_minor_det().

4.1.3.15 mat2D_dot()

```
void mat2D_dot (
            Mat2D dst,
            Mat2D a,
            Mat2D b )
```

Matrix product: dst = a $*$ b.

Parameters

dst	Destination matrix (size a.rows x b.cols).
a	Left matrix (size a.rows x a.cols).
b	Right matrix (size a.cols x b.cols).

Precondition

a.cols == b.rows, dst.rows == a.rows, dst.cols == b.cols.

Postcondition

dst is overwritten.

Definition at line 424 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by main(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.1.3.16 mat2D_dot_product()

```
double mat2D_dot_product (
            Mat2D a,
            Mat2D b )
```

Dot product between two vectors.

Parameters

a	Vector (shape n x 1 or 1 x n).
b	Vector (same shape as a).

Returns

The scalar dot product sum.

Precondition

a.rows == b.rows, a.cols == b.cols, and one dimension equals 1.

Definition at line 450 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.17 mat2D_fill()

```
void mat2D_fill (
            Mat2D m,
            double x )
```

Fill all elements of a matrix of doubles with a scalar value.

Parameters

m	Matrix to fill.
x	Value to assign to every element.

Definition at line 362 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

Referenced by main(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), and mat2D_solve_linear_sys_LUP_decomposition(

4.1.3.18 mat2D_fill_sequence()

```
void mat2D_fill_sequence (
            Mat2D m,
            double start,
            double step )
```

Fill a matrix with an arithmetic sequence laid out in row-major order.

Parameters

m	Matrix to fill.
start	First value in the sequence.
step	Increment between consecutive elements.

Element at linear index k gets value start + step $*$ k.

Definition at line 378 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_offset2d(), and Mat2D::rows.

Referenced by main().

4.1.3.19 mat2D_fill_uint32()

```
void mat2D_fill_uint32 (
            Mat2D_uint32 m,
            uint32_t x )
```

Fill all elements of a matrix of uint32_t with a scalar value.

Parameters

m	Matrix to fill.
x	Value to assign to every element.

Definition at line 391 of file Matrix2D.h.

References Mat2D_uint32::cols, MAT2D_AT_UINT32, and Mat2D_uint32::rows.

4.1.3.20 mat2D_free()

```
void mat2D_free (
            Mat2D m )
```

Free the memory owned by a Mat2D (elements pointer).

Parameters

m	Matrix whose elements were allocated via MATRIX2D_MALLOC.

Note

Safe to call with m.elements == NULL.

Definition at line 314 of file Matrix2D.h.

References Mat2D::elements.

Referenced by mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.1.3.21 mat2D_free_uint32()

```
void mat2D_free_uint32 (
            Mat2D_uint32 m )
```

Free the memory owned by a Mat2D_uint32 (elements pointer).

Parameters

m	Matrix whose elements were allocated via MATRIX2D_MALLOC.

Note

Safe to call with m.elements == NULL.

Definition at line 324 of file Matrix2D.h.

References Mat2D_uint32::elements.

4.1.3.22 mat2D_get_col()

```
void mat2D_get_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Copy a column from src into a column of des.

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 810 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.23 mat2D_get_row()

```
void mat2D_get_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Copy a row from src into a row of des.

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 879 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.24 mat2D_invert()

```
void mat2D_invert (
            Mat2D des,
            Mat2D src )
```

Invert a square matrix using Gauss-Jordan elimination.

Parameters

des	Destination matrix (same shape as src).
src	Source square matrix.

Precondition

src is square and nonsingular.

If det(src) == 0, prints an error and sets des to all zeros.

Warning

May be numerically unstable for ill-conditioned matrices.

Definition at line 1169 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), MAT2D_AT, mat2D_copy(), mat2D_det(), mat2D_fill(), mat2D_free(), mat2D_mult_row(), mat2D_set_identity(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by mat2D_solve_linear_sys_LUP_decomposition().

4.1.3.25 mat2D_LUP_decomposition_with_swap()

```
void mat2D_LUP_decomposition_with_swap (
            Mat2D src,
            Mat2D l,
            Mat2D p,
            Mat2D u )
```

Compute LUP decomposition: P∗A = L∗U with L unit diagonal.

Parameters

src	Input matrix A (not modified).
l	Lower triangular matrix with unit diagonal (output).
p	Permutation matrix (output).
u	Upper triangular matrix (output).

Precondition

l, p, u are allocated to match src shape; src is square.

Definition at line 1107 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_copy(), mat2D_fill(), mat2D_set_identity(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

Referenced by main(), and mat2D_solve_linear_sys_LUP_decomposition().

4.1.3.26 mat2D_make_identity()

```
double mat2D_make_identity (
            Mat2D m )
```

Reduce a matrix to identity via Gauss-Jordan elimination and return the cumulative scaling factor.

Parameters

m	Matrix reduced in-place to identity (if nonsingular).

Returns

The product of row scaling factors applied during elimination.

Note

Intended as a helper for determinant-related operations.

Warning

Not robust to singular or ill-conditioned matrices.

Definition at line 643 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_mult_row(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

4.1.3.27 mat2D_mat_is_all_digit()

```
bool mat2D_mat_is_all_digit (
            Mat2D m,
            double digit )
```

Check if all elements of a matrix equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.

Returns

true if every element equals digit, false otherwise.

Definition at line 949 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.1.3.28 mat2D_minor_alloc_fill_from_mat()

```
Mat2D_Minor mat2D_minor_alloc_fill_from_mat (
            Mat2D ref_mat,
            size_t i,
            size_t j )
```

Allocate a minor view by excluding row i and column j of ref_mat.

Parameters

ref_mat	Reference square matrix.
i	Excluded row index in ref_mat.
j	Excluded column index in ref_mat.

Returns

A Mat2D_Minor that references ref_mat.

Note

Free rows_list and cols_list with mat2D_minor_free when done.

Definition at line 1279 of file Matrix2D.h.

References Mat2D::cols, Mat2D_Minor::cols, Mat2D_Minor::cols_list, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_Minor::ref_mat, Mat2D::rows, Mat2D_Minor::rows, Mat2D_Minor::rows_list, and Mat2D_Minor::stride_r.

4.1.3.29 mat2D_minor_alloc_fill_from_mat_minor()

```
Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor (
            Mat2D_Minor ref_mm,
            size_t i,
            size_t j )
```

Allocate a nested minor view from an existing minor by excluding row i and column j of the minor.

Parameters

ref_mm	Reference minor.
i	Excluded row index in the minor.
j	Excluded column index in the minor.

Returns

A new Mat2D_Minor that references the same underlying matrix.

Note

Free rows_list and cols_list with mat2D_minor_free when done.

Definition at line 1318 of file Matrix2D.h.

References Mat2D_Minor::cols, Mat2D_Minor::cols_list, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_Minor::ref_mat, Mat2D_Minor::rows, Mat2D_Minor::rows_list, and Mat2D_Minor::stride_r.

Referenced by mat2D_minor_det().

4.1.3.30 mat2D_minor_det()

```
double mat2D_minor_det (
            Mat2D_Minor mm )
```

Determinant of a minor via recursive expansion by minors.

Parameters

mm	Square minor.

Returns

det(mm).

Warning

Exponential complexity (factorial). Intended for educational or very small matrices only.

Definition at line 1396 of file Matrix2D.h.

References Mat2D_Minor::cols, mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat_minor(), MAT2D_MINOR_AT, mat2D_minor_free(), MATRIX2D_ASSERT, and Mat2D_Minor::rows.

4.1.3.31 mat2D_minor_free()

```
void mat2D_minor_free (
            Mat2D_Minor mm )
```

Free the index arrays owned by a minor.

Parameters

mm	Minor to free.

Note

After this call, mm.rows_list and mm.cols_list are invalid.

Definition at line 1353 of file Matrix2D.h.

References Mat2D_Minor::cols_list, and Mat2D_Minor::rows_list.

Referenced by mat2D_minor_det().

4.1.3.32 mat2D_minor_print()

```
void mat2D_minor_print (
            Mat2D_Minor mm,
            const char * name,
            size_t padding )
```

Print a minor matrix to stdout with a name and indentation padding.

Parameters

mm	Minor to print.
name	Label to print.
padding	Left padding in spaces.

Definition at line 1365 of file Matrix2D.h.

References Mat2D_Minor::cols, MAT2D_MINOR_AT, and Mat2D_Minor::rows.

4.1.3.33 mat2D_mult()

```
void mat2D_mult (
            Mat2D m,
            double factor )
```

In-place scalar multiplication: m *= factor.

Parameters

m	Matrix.
factor	Scalar multiplier.

Definition at line 557 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

Referenced by main().

4.1.3.34 mat2D_mult_row()

```
void mat2D_mult_row (
            Mat2D m,
            size_t r,
            double factor )
```

In-place row scaling: row(r) ∗= factor.

Parameters

m	Matrix.
r	Row index.
factor	Scalar multiplier.

Definition at line 572 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), and mat2D_make_identity().

4.1.3.35 mat2D_offset2d()

```
size_t mat2D_offset2d (
            Mat2D m,
            size_t i,
            size_t j )
```

Compute the linear offset of element (i, j) in a Mat2D.

Parameters

m	Matrix.
i	Row index (0-based).
j	Column index (0-based).

Returns

The linear offset i * stride_r + j.

Precondition

0 <= i < rows, 0 <= j < cols (asserted).

Definition at line 337 of file Matrix2D.h.

References Mat2D::cols, MATRIX2D_ASSERT, Mat2D::rows, and Mat2D::stride_r.

Referenced by mat2D_fill_sequence().

4.1.3.36 mat2D_offset2d_uint32()

```
size_t mat2D_offset2d_uint32 (
            Mat2D_uint32 m,
            size_t i,
            size_t j )
```

Compute the linear offset of element (i, j) in a Mat2D_uint32.

Parameters

m	Matrix.
i	Row index (0-based).
j	Column index (0-based).

Returns

The linear offset i * stride_r + j.

Precondition

0 <= i < rows, 0 <= j < cols (asserted).

Definition at line 351 of file Matrix2D.h.

References Mat2D_uint32::cols, MATRIX2D_ASSERT, Mat2D_uint32::rows, and Mat2D_uint32::stride_r.

4.1.3.37 mat2D_print()

```
void mat2D_print (
            Mat2D m,
            const char * name,
            size_t padding )
```

Print a matrix to stdout with a name and indentation padding.

Parameters

m	Matrix to print.
name	Label to print.
padding	Left padding in spaces.

Definition at line 585 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.1.3.38 mat2D_print_as_col()

```
void mat2D_print_as_col (
            Mat2D m,
            const char * name,
            size_t padding )
```

Print a matrix as a flattened column vector to stdout.

Parameters

m	Matrix to print (flattened in row-major).
name	Label to print.
padding	Left padding in spaces.

Definition at line 604 of file Matrix2D.h.

References Mat2D::cols, Mat2D::elements, and Mat2D::rows.

4.1.3.39 mat2D_rand()

```
void mat2D_rand (
            Mat2D m,
            double low,
            double high )
```

Fill a matrix with random doubles in [low, high).

Parameters

m	Matrix to fill.
low	Lower bound (inclusive).
high	Upper bound (exclusive).

Precondition

high $>$ low.

Definition at line 407 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_rand_double(), and Mat2D::rows.

4.1.3.40 mat2D_rand_double()

```
double mat2D_rand_double (
            void  )
```

Return a pseudo-random double in the range [0, 1].

Note

Uses C library rand() and RAND_MAX. Not cryptographically secure.

Definition at line 266 of file Matrix2D.h.

Referenced by mat2D_rand().

4.1.3.41 mat2D_row_is_all_digit()

```
bool mat2D_row_is_all_digit (
            Mat2D m,
            double digit,
            size_t r )
```

Check if all elements of a row equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.
r	Row index.

Returns

true if every element equals digit, false otherwise.

Definition at line 968 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.1.3.42 mat2D_set_DCM_zyx()

```
void mat2D_set_DCM_zyx (
            Mat2D DCM,
            float yaw_deg,
            float pitch_deg,
            float roll_deg )
```

Build a 3x3 direction cosine matrix (DCM) from Z-Y-X Euler angles.

Parameters

DCM	3x3 destination matrix.
yaw_deg	Rotation about Z in degrees.
pitch_deg	Rotation about Y in degrees.
roll_deg	Rotation about X in degrees.

Computes DCM = R_x(roll) ∗ R_y(pitch) ∗ R_z(yaw).

Definition at line 743 of file Matrix2D.h.

References mat2D_alloc(), mat2D_dot(), mat2D_free(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), and mat2D_set_rot_mat_z().

4.1.3.43 mat2D_set_identity()

```
void mat2D_set_identity (
            Mat2D m )
```

Set a square matrix to the identity matrix.

Parameters

m	Matrix (must be square).

Precondition

m.rows == m.cols.

Definition at line 619 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by main(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), and mat2D_set_rot_mat_z().

4.1.3.44 mat2D_set_rot_mat_x()

```
void mat2D_set_rot_mat_x (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the X-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 689 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by mat2D_set_DCM_zyx().

4.1.3.45 mat2D_set_rot_mat_y()

```
void mat2D_set_rot_mat_y (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the Y-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 706 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by mat2D_set_DCM_zyx().

4.1.3.46 mat2D_set_rot_mat_z()

```
void mat2D_set_rot_mat_z (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the Z-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 723 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by mat2D_set_DCM_zyx().

4.1.3.47 mat2D_solve_linear_sys_LUP_decomposition()

```
void mat2D_solve_linear_sys_LUP_decomposition (
            Mat2D A,
            Mat2D x,
            Mat2D B )
```

Solve the linear system A x = B using LUP decomposition.

Parameters

A	Coefficient matrix (NxN).
x	Solution vector (N x 1) (output).
B	Right-hand side vector (N x 1).

Internally computes LUP and uses explicit inverses of L and U.

Warning

Forming inverses explicitly can be less stable; a forward/backward substitution would be preferable for production-quality code.

Definition at line 1236 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), mat2D_dot(), mat2D_fill(), mat2D_free(), mat2D_invert(), mat2D_LUP_decomposition_with_s
MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by main().

4.1.3.48 mat2D_sub()

```
void mat2D_sub (
            Mat2D dst,
            Mat2D a )
```

In-place subtraction: dst -= a.

Parameters

dst	Destination matrix to be decremented.
a	Subtrahend of same shape as dst.

Precondition

Shapes match.

Definition at line 527 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by main().

4.1.3.49 mat2D_sub_col_to_col()

```
void mat2D_sub_col_to_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Subtract a source column from a destination column: des[:, des_col] -= src[:, src_col].

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 846 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.50 mat2D_sub_row_time_factor_to_row()

```
void mat2D_sub_row_time_factor_to_row (
            Mat2D m,
            size_t des_r,
            size_t src_r,
            double factor )
```

Row operation: row(des_r) -= factor * row(src_r).

Parameters

m	Matrix.
des_r	Destination row index.
src_r	Source row index.
factor	Scalar multiplier.

Definition at line 545 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), and mat2D_triangulate().

4.1.3.51 mat2D_sub_row_to_row()

```
void mat2D_sub_row_to_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Subtract a source row from a destination row: des[des_row, :] -= src[src_row, :].

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 915 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.52 mat2D_swap_rows()

```
void mat2D_swap_rows (
            Mat2D m,
            size_t r1,
            size_t r2 )
```

Swap two rows of a matrix in-place.

Parameters

m	Matrix.
r1	First row index.
r2	Second row index.

Definition at line 863 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), and mat2D_triangulate().

4.1.3.53 mat2D_transpose()

```
void mat2D_transpose (
            Mat2D des,
            Mat2D src )
```

Transpose a matrix: des = src^T.

Parameters

des	Destination matrix (shape src.cols x src.rows).
src	Source matrix.

Definition at line 1149 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.1.3.54 mat2D_triangulate()

```
double mat2D_triangulate (
            Mat2D m )
```

Forward elimination to transform a matrix to upper triangular form.

Parameters

m	Matrix transformed in-place.

Returns

Product of row scaling factors (currently 1 in this implementation).

Note

Used as part of determinant computation via triangularization.

Warning

Not robust for linearly dependent rows or tiny pivots.

Definition at line 1013 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

Referenced by mat2D_det().

4.2 Matrix2D.h

```
00001
00039 #ifndef MATRIX2D_H_
00040 #define MATRIX2D_H_
00041
00042 #include <stddef.h>
00043 #include <stdio.h>
00044 #include <stdlib.h>
00045 #include <stdint.h>
00046 #include <stdbool.h>
00047
00055 #ifndef MATRIX2D_MALLOC
00056 #define MATRIX2D_MALLOC malloc
00057 #endif //MATRIX2D_MALLOC
00058
00066 #ifndef MATRIX2D_ASSERT
00067 #include <assert.h>
00068 #define MATRIX2D_ASSERT assert
00069 #endif //MATRIX2D_ASSERT
00070
00081 typedef struct {
00082     size_t rows;
00083     size_t cols;
00084     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00085     double *elements;
00086 } Mat2D;
00087
00098 typedef struct {
00099     size_t rows;
00100     size_t cols;
00101     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00102     uint32_t *elements;
00103 } Mat2D_uint32;
00104
00119 typedef struct {
00120     size_t rows;
00121     size_t cols;
00122     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00123     size_t *rows_list;
00124     size_t *cols_list;
00125     Mat2D ref_mat;
00126 } Mat2D_Minor;
00127
00141 #if 0
00142 #define MAT2D_AT(m, i, j) (m).elements[mat2D_offset2d((m), (i), (j))]
00143 #define MAT2D_AT_UINT32(m, i, j) (m).elements[mat2D_offset2d_uint32((m), (i), (j))]
00144 #else /* use this macro for batter performance but no assertion */
00145 #define MAT2D_AT(m, i, j) (m).elements[i * m.stride_r + j]
00146 #define MAT2D_AT_UINT32(m, i, j) (m).elements[i * m.stride_r + j]
00147 #endif
00148
00149 #ifndef PI
00150     #ifndef __USE_MISC
00151     #define __USE_MISC
00152     #endif
00153     #include <math.h>
00154     #define PI M_PI
00155 #endif
00156
```

```
00162 #define MAT2D_MINOR_AT(mm, i, j) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])
00167 #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)
00172 #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)
00177 #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)
00184 #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))
00185
00186 double mat2D_rand_double(void);
00187
00188 Mat2D mat2D_alloc(size_t rows, size_t cols);
00189 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols);
00190 void mat2D_free(Mat2D m);
00191 void mat2D_free_uint32(Mat2D_uint32 m);
00192 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j);
00193 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j);
00194
00195 void mat2D_fill(Mat2D m, double x);
00196 void mat2D_fill_sequence(Mat2D m, double start, double step);
00197 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x);
00198 void mat2D_rand(Mat2D m, double low, double high);
00199
00200 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b);
00201 double mat2D_dot_product(Mat2D a, Mat2D b);
00202 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b);
00203
00204 void mat2D_add(Mat2D dst, Mat2D a);
00205 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00206
00207 void mat2D_sub(Mat2D dst, Mat2D a);
00208 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00209
00210 void mat2D_mult(Mat2D m, double factor);
00211 void mat2D_mult_row(Mat2D m, size_t r, double factor);
00212
00213 void mat2D_print(Mat2D m, const char *name, size_t padding);
00214 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding);
00215
00216 void mat2D_set_identity(Mat2D m);
00217 double mat2D_make_identity(Mat2D m);
00218 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg);
00219 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg);
00220 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg);
00221 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg);
00222
00223 void mat2D_copy(Mat2D des, Mat2D src);
00224 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t
       je);
00225
00226 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00227 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00228 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00229
00230 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2);
00231 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00232 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00233 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00234
00235 double mat2D_calc_norma(Mat2D m);
00236
00237 bool mat2D_mat_is_all_digit(Mat2D m, double digit);
00238 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r);
00239 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c);
00240
00241 double mat2D_det_2x2_mat(Mat2D m);
00242 double mat2D_triangulate(Mat2D m);
00243 double mat2D_det(Mat2D m);
00244 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u);
00245 void mat2D_transpose(Mat2D des, Mat2D src);
00246 void mat2D_invert(Mat2D des, Mat2D src);
00247 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B);
00248
00249 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j);
00250 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j);
00251 void mat2D_minor_free(Mat2D_Minor mm);
00252 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding);
00253 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm);
00254 double mat2D_minor_det(Mat2D_Minor mm);
00255
00256 #endif // MATRIX2D_H_
00257
00258 #ifdef MATRIX2D_IMPLEMENTATION
00259 #undef MATRIX2D_IMPLEMENTATION
00260
00261
00266 double mat2D_rand_double(void)
00267 {
00268     return (double) rand() / (double) RAND_MAX;
00269 }
```

```
00270
00278 Mat2D mat2D_alloc(size_t rows, size_t cols)
00279 {
00280     Mat2D m;
00281     m.rows = rows;
00282     m.cols = cols;
00283     m.stride_r = cols;
00284     m.elements = (double*)MATRIX2D_MALLOC(sizeof(double)*rows*cols);
00285     MATRIX2D_ASSERT(m.elements != NULL);
00286
00287     return m;
00288 }
00289
00297 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols)
00298 {
00299     Mat2D_uint32 m;
00300     m.rows = rows;
00301     m.cols = cols;
00302     m.stride_r = cols;
00303     m.elements = (uint32_t*)MATRIX2D_MALLOC(sizeof(uint32_t)*rows*cols);
00304     MATRIX2D_ASSERT(m.elements != NULL);
00305
00306     return m;
00307 }
00308
00314 void mat2D_free(Mat2D m)
00315 {
00316     free(m.elements);
00317 }
00318
00324 void mat2D_free_uint32(Mat2D_uint32 m)
00325 {
00326     free(m.elements);
00327 }
00328
00337 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j)
00338 {
00339     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00340     return i * m.stride_r + j;
00341 }
00342
00351 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j)
00352 {
00353     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00354     return i * m.stride_r + j;
00355 }
00356
00362 void mat2D_fill(Mat2D m, double x)
00363 {
00364     for (size_t i = 0; i < m.rows; ++i) {
00365         for (size_t j = 0; j < m.cols; ++j) {
00366             MAT2D_AT(m, i, j) = x;
00367         }
00368     }
00369 }
00370
00378 void mat2D_fill_sequence(Mat2D m, double start, double step) {
00379     for (size_t i = 0; i < m.rows; i++) {
00380         for (size_t j = 0; j < m.cols; j++) {
00381             MAT2D_AT(m, i, j) = start + step * mat2D_offset2d(m, i, j);
00382         }
00383     }
00384 }
00385
00391 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x)
00392 {
00393     for (size_t i = 0; i < m.rows; ++i) {
00394         for (size_t j = 0; j < m.cols; ++j) {
00395             MAT2D_AT_UINT32(m, i, j) = x;
00396         }
00397     }
00398 }
00399
00407 void mat2D_rand(Mat2D m, double low, double high)
00408 {
00409     for (size_t i = 0; i < m.rows; ++i) {
00410         for (size_t j = 0; j < m.cols; ++j) {
00411             MAT2D_AT(m, i, j) = mat2D_rand_double()*(high - low) + low;
00412         }
00413     }
00414 }
00415
00424 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b)
00425 {
00426     MATRIX2D_ASSERT(a.cols == b.rows);
00427     MATRIX2D_ASSERT(a.rows == dst.rows);
00428     MATRIX2D_ASSERT(b.cols == dst.cols);
```

```
00429
00430     size_t i, j, k;
00431
00432     for (i = 0; i < dst.rows; i++) {
00433         for (j = 0; j < dst.cols; j++) {
00434             MAT2D_AT(dst, i, j) = 0;
00435             for (k = 0; k < a.cols; k++) {
00436                 MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, k)*MAT2D_AT(b, k, j);
00437             }
00438         }
00439     }
00440
00441 }
00442
00450 double mat2D_dot_product(Mat2D a, Mat2D b)
00451 {
00452     MATRIX2D_ASSERT(a.rows == b.rows);
00453     MATRIX2D_ASSERT(a.cols == b.cols);
00454     MATRIX2D_ASSERT((1 == a.cols && 1 == b.cols) || (1 == a.rows && 1 == b.rows));
00455
00456     double dot_product = 0;
00457
00458     if (1 == a.cols) {
00459         for (size_t i = 0; i < a.rows; i++) {
00460             dot_product += MAT2D_AT(a, i, 0) * MAT2D_AT(b, i, 0);
00461         }
00462     } else {
00463         for (size_t j = 0; j < a.cols; j++) {
00464             dot_product += MAT2D_AT(a, 0, j) * MAT2D_AT(b, 0, j);
00465         }
00466     }
00467
00468     return dot_product;
00469
00470 }
00471
00479 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b)
00480 {
00481     MATRIX2D_ASSERT(3 == dst.rows && 1 == dst.cols);
00482     MATRIX2D_ASSERT(3 == a.rows && 1 == a.cols);
00483     MATRIX2D_ASSERT(3 == b.rows && 1 == b.cols);
00484
00485     MAT2D_AT(dst, 0, 0) = MAT2D_AT(a, 1, 0) * MAT2D_AT(b, 2, 0) - MAT2D_AT(a, 2, 0) * MAT2D_AT(b, 1,
      0);
00486     MAT2D_AT(dst, 1, 0) = MAT2D_AT(a, 2, 0) * MAT2D_AT(b, 0, 0) - MAT2D_AT(a, 0, 0) * MAT2D_AT(b, 2,
      0);
00487     MAT2D_AT(dst, 2, 0) = MAT2D_AT(a, 0, 0) * MAT2D_AT(b, 1, 0) - MAT2D_AT(a, 1, 0) * MAT2D_AT(b, 0,
      0);
00488 }
00489
00496 void mat2D_add(Mat2D dst, Mat2D a)
00497 {
00498     MATRIX2D_ASSERT(dst.rows == a.rows);
00499     MATRIX2D_ASSERT(dst.cols == a.cols);
00500     for (size_t i = 0; i < dst.rows; ++i) {
00501         for (size_t j = 0; j < dst.cols; ++j) {
00502             MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, j);
00503         }
00504     }
00505 }
00506
00514 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00515 {
00516     for (size_t j = 0; j < m.cols; ++j) {
00517         MAT2D_AT(m, des_r, j) += factor * MAT2D_AT(m, src_r, j);
00518     }
00519 }
00520
00527 void mat2D_sub(Mat2D dst, Mat2D a)
00528 {
00529     MATRIX2D_ASSERT(dst.rows == a.rows);
00530     MATRIX2D_ASSERT(dst.cols == a.cols);
00531     for (size_t i = 0; i < dst.rows; ++i) {
00532         for (size_t j = 0; j < dst.cols; ++j) {
00533             MAT2D_AT(dst, i, j) -= MAT2D_AT(a, i, j);
00534         }
00535     }
00536 }
00537
00545 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00546 {
00547     for (size_t j = 0; j < m.cols; ++j) {
00548         MAT2D_AT(m, des_r, j) -= factor * MAT2D_AT(m, src_r, j);
00549     }
00550 }
00551
00557 void mat2D_mult(Mat2D m, double factor)
```

```
00558 {
00559     for (size_t i = 0; i < m.rows; ++i) {
00560         for (size_t j = 0; j < m.cols; ++j) {
00561             MAT2D_AT(m, i, j) *= factor;
00562         }
00563     }
00564 }
00565
00572 void mat2D_mult_row(Mat2D m, size_t r, double factor)
00573 {
00574     for (size_t j = 0; j < m.cols; ++j) {
00575         MAT2D_AT(m, r, j) *= factor;
00576     }
00577 }
00578
00585 void mat2D_print(Mat2D m, const char *name, size_t padding)
00586 {
00587     printf("%*s%s = [\n", (int) padding, "", name);
00588     for (size_t i = 0; i < m.rows; ++i) {
00589         printf("%*s    ", (int) padding, "");
00590         for (size_t j = 0; j < m.cols; ++j) {
00591             printf("%9.6f ", MAT2D_AT(m, i, j));
00592         }
00593         printf("\n");
00594     }
00595     printf("%*s]\n", (int) padding, "");
00596 }
00597
00604 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding)
00605 {
00606     printf("%*s%s = [\n", (int) padding, "", name);
00607     for (size_t i = 0; i < m.rows*m.cols; ++i) {
00608             printf("%*s    ", (int) padding, "");
00609             printf("%f\n", m.elements[i]);
00610     }
00611     printf("%*s]\n", (int) padding, "");
00612 }
00613
00619 void mat2D_set_identity(Mat2D m)
00620 {
00621     MATRIX2D_ASSERT(m.cols == m.rows);
00622     for (size_t i = 0; i < m.rows; ++i) {
00623         for (size_t j = 0; j < m.cols; ++j) {
00624             MAT2D_AT(m, i, j) = i == j ? 1 : 0;
00625             // if (i == j) {
00626             //     MAT2D_AT(m, i, j) = 1;
00627             // }
00628             // else {
00629             //     MAT2D_AT(m, i, j) = 0;
00630             // }
00631         }
00632     }
00633 }
00634
00643 double mat2D_make_identity(Mat2D m)
00644 {
00645     /* make identity matrix using Gauss elimination */
00646     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
00647     /* returns the factor multiplying the determinant */
00648
00649     double factor_to_return = 1;
00650
00651     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
00652         /* check if it is the biggest first number (absolute value) */
00653         size_t biggest_r = i;
00654         for (size_t index = i; index < m.rows; index++) {
00655             if (fabs(MAT2D_AT(m, index, index)) > fabs(MAT2D_AT(m, biggest_r, 0))) {
00656                 biggest_r = index;
00657             }
00658         }
00659         if (i != biggest_r) {
00660             mat2D_swap_rows(m, i, biggest_r);
00661             factor_to_return *= -1;
00662         }
00663         for (size_t j = i+1; j < m.cols; j++) {
00664             double factor = 1 / MAT2D_AT(m, i, i);
00665             mat2D_sub_row_time_factor_to_row(m, j, i, MAT2D_AT(m, j, i) * factor);
00666             mat2D_mult_row(m, i, factor);
00667             factor_to_return *= factor;
00668         }
00669     }
00670     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
00671     mat2D_mult_row(m, m.rows-1, factor);
00672     factor_to_return *= factor;
00673     for (size_t c = m.cols-1; c > 0; c--) {
00674         for (int r = c-1; r >= 0; r--) {
00675             double factor = 1 / MAT2D_AT(m, c, c);
```

```
00676             mat2D_sub_row_time_factor_to_row(m, r, c, MAT2D_AT(m, r, c) * factor);
00677         }
00678     }
00679
00680
00681     return factor_to_return;
00682 }
00683
00689 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg)
00690 {
00691     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00692
00693     float angle_rad = angle_deg * PI / 180;
00694     mat2D_set_identity(m);
00695     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00696     MAT2D_AT(m, 1, 2) =  sin(angle_rad);
00697     MAT2D_AT(m, 2, 1) = -sin(angle_rad);
00698     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00699 }
00700
00706 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg)
00707 {
00708     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00709
00710     float angle_rad = angle_deg * PI / 180;
00711     mat2D_set_identity(m);
00712     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00713     MAT2D_AT(m, 0, 2) = -sin(angle_rad);
00714     MAT2D_AT(m, 2, 0) =  sin(angle_rad);
00715     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00716 }
00717
00723 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg)
00724 {
00725     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00726
00727     float angle_rad = angle_deg * PI / 180;
00728     mat2D_set_identity(m);
00729     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00730     MAT2D_AT(m, 0, 1) =  sin(angle_rad);
00731     MAT2D_AT(m, 1, 0) = -sin(angle_rad);
00732     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00733 }
00734
00743 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)
00744 {
00745     Mat2D RotZ = mat2D_alloc(3,3);
00746     mat2D_set_rot_mat_z(RotZ, yaw_deg);
00747     Mat2D RotY = mat2D_alloc(3,3);
00748     mat2D_set_rot_mat_y(RotY, pitch_deg);
00749     Mat2D RotX = mat2D_alloc(3,3);
00750     mat2D_set_rot_mat_x(RotX, roll_deg);
00751     Mat2D temp = mat2D_alloc(3,3);
00752
00753     mat2D_dot(temp, RotY, RotZ);
00754     mat2D_dot(DCM, RotX, temp); /* I have a DCM */
00755
00756     mat2D_free(RotZ);
00757     mat2D_free(RotY);
00758     mat2D_free(RotX);
00759     mat2D_free(temp);
00760 }
00761
00768 void mat2D_copy(Mat2D des, Mat2D src)
00769 {
00770     MATRIX2D_ASSERT(des.cols == src.cols);
00771     MATRIX2D_ASSERT(des.rows == src.rows);
00772
00773     for (size_t i = 0; i < des.rows; ++i) {
00774         for (size_t j = 0; j < des.cols; ++j) {
00775             MAT2D_AT(des, i, j) = MAT2D_AT(src, i, j);
00776         }
00777     }
00778 }
00779
00790 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)
00791 {
00792     MATRIX2D_ASSERT(je > js && ie > is);
00793     MATRIX2D_ASSERT(je-js+1 == des.cols);
00794     MATRIX2D_ASSERT(ie-is+1 == des.rows);
00795
00796     for (size_t index = 0; index < des.rows; ++index) {
00797         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
00798             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, is+index, js+jndex);
00799         }
00800     }
00801 }
```

```
00802
00810 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00811 {
00812     MATRIX2D_ASSERT(src_col < src.cols);
00813     MATRIX2D_ASSERT(des.rows == src.rows);
00814     MATRIX2D_ASSERT(des_col < des.cols);
00815
00816     for (size_t i = 0; i < des.rows; i++) {
00817         MAT2D_AT(des, i, des_col) = MAT2D_AT(src, i, src_col);
00818     }
00819 }
00820
00828 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00829 {
00830     MATRIX2D_ASSERT(src_col < src.cols);
00831     MATRIX2D_ASSERT(des.rows == src.rows);
00832     MATRIX2D_ASSERT(des_col < des.cols);
00833
00834     for (size_t i = 0; i < des.rows; i++) {
00835         MAT2D_AT(des, i, des_col) += MAT2D_AT(src, i, src_col);
00836     }
00837 }
00838
00846 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00847 {
00848     MATRIX2D_ASSERT(src_col < src.cols);
00849     MATRIX2D_ASSERT(des.rows == src.rows);
00850     MATRIX2D_ASSERT(des_col < des.cols);
00851
00852     for (size_t i = 0; i < des.rows; i++) {
00853         MAT2D_AT(des, i, des_col) -= MAT2D_AT(src, i, src_col);
00854     }
00855 }
00856
00863 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2)
00864 {
00865     for (size_t j = 0; j < m.cols; j++) {
00866         double temp = MAT2D_AT(m, r1, j);
00867         MAT2D_AT(m, r1, j) = MAT2D_AT(m, r2, j);
00868         MAT2D_AT(m, r2, j) = temp;
00869     }
00870 }
00871
00879 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00880 {
00881     MATRIX2D_ASSERT(src_row < src.rows);
00882     MATRIX2D_ASSERT(des.cols == src.cols);
00883     MATRIX2D_ASSERT(des_row < des.rows);
00884
00885     for (size_t j = 0; j < des.cols; j++) {
00886         MAT2D_AT(des, des_row, j) = MAT2D_AT(src, src_row, j);
00887     }
00888 }
00889
00897 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00898 {
00899     MATRIX2D_ASSERT(src_row < src.rows);
00900     MATRIX2D_ASSERT(des.cols == src.cols);
00901     MATRIX2D_ASSERT(des_row < des.rows);
00902
00903     for (size_t j = 0; j < des.cols; j++) {
00904         MAT2D_AT(des, des_row, j) += MAT2D_AT(src, src_row, j);
00905     }
00906 }
00907
00915 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00916 {
00917     MATRIX2D_ASSERT(src_row < src.rows);
00918     MATRIX2D_ASSERT(des.cols == src.cols);
00919     MATRIX2D_ASSERT(des_row < des.rows);
00920
00921     for (size_t j = 0; j < des.cols; j++) {
00922         MAT2D_AT(des, des_row, j) -= MAT2D_AT(src, src_row, j);
00923     }
00924 }
00925
00931 double mat2D_calc_norma(Mat2D m)
00932 {
00933     double sum = 0;
00934
00935     for (size_t i = 0; i < m.rows; ++i) {
00936         for (size_t j = 0; j < m.cols; ++j) {
00937             sum += MAT2D_AT(m, i, j) * MAT2D_AT(m, i, j);
00938         }
00939     }
00940     return sqrt(sum);
00941 }
```

```
00942
00949 bool mat2D_mat_is_all_digit(Mat2D m, double digit)
00950 {
00951     for (size_t i = 0; i < m.rows; ++i) {
00952         for (size_t j = 0; j < m.cols; ++j) {
00953             if (MAT2D_AT(m, i, j) != digit) {
00954                 return false;
00955             }
00956         }
00957     }
00958     return true;
00959 }
00960
00968 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r)
00969 {
00970     for (size_t j = 0; j < m.cols; ++j) {
00971         if (MAT2D_AT(m, r, j) != digit) {
00972             return false;
00973         }
00974     }
00975     return true;
00976 }
00977
00985 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c)
00986 {
00987     for (size_t i = 0; i < m.cols; ++i) {
00988         if (MAT2D_AT(m, i, c) != digit) {
00989             return false;
00990         }
00991     }
00992     return true;
00993 }
00994
01000 double mat2D_det_2x2_mat(Mat2D m)
01001 {
01002     MATRIX2D_ASSERT(2 == m.cols && 2 == m.rows && "Not a 2x2 matrix");
01003     return MAT2D_AT(m, 0, 0) * MAT2D_AT(m, 1, 1) - MAT2D_AT(m, 0, 1) * MAT2D_AT(m, 1, 0);
01004 }
01005
01013 double mat2D_triangulate(Mat2D m)
01014 {
01015     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
01016     /* returns the factor multiplying the determinant */
01017
01018     double factor_to_return = 1;
01019
01020     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
01021         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
01022             /* finding biggest first number (absolute value) */
01023             size_t biggest_r = i;
01024             for (size_t index = i; index < m.rows; index++) {
01025                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
01026                     biggest_r = index;
01027                 }
01028             }
01029             if (i != biggest_r) {
01030                 mat2D_swap_rows(m, i, biggest_r);
01031             }
01032         }
01033         for (size_t j = i+1; j < m.cols; j++) {
01034             double factor = 1 / MAT2D_AT(m, i, i);
01035             if (!isfinite(factor)) {
01036                 printf("%s:%d: [Error] unable to transfrom into uperr triangular matrix. Probably some
      of the rows are not independent.\n", __FILE__, __LINE__);
01037             }
01038             double mat_value = MAT2D_AT(m, j, i);
01039             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
01040         }
01041     }
01042     return factor_to_return;
01043 }
01044
01052 double mat2D_det(Mat2D m)
01053 {
01054     MATRIX2D_ASSERT(m.cols == m.rows && "should be a square matrix");
01055
01056     /* checking if there is a row or column with all zeros */
01057     /* checking rows */
01058     for (size_t i = 0; i < m.rows; i++) {
01059         if (mat2D_row_is_all_digit(m, 0, i)) {
01060             return 0;
01061         }
01062     }
01063     /* checking cols */
01064     for (size_t j = 0; j < m.rows; j++) {
01065         if (mat2D_col_is_all_digit(m, 0, j)) {
01066             return 0;
```

```
01067         }
01068     }
01069
01070     /* This is an implementation of naive determinant calculation using minors. This is too slow */
01071
01072     // double det = 0;
01073     // /* TODO: finding beast row or col? */
01074     // for (size_t i = 0, j = 0; i < m.rows; i++) { /* first column */
01075     //     if (MAT2D_AT(m, i, j) < 1e-10) continue;
01076     //     Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat(m, i, j);
01077     //     int factor = (i+j)%2 ? -1 : 1;
01078     //     if (sub_mm.cols != 2) {
01079     //         MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
01080     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_minor_det(sub_mm);
01081     //     } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
01082     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
01083     //     }
01084     //     mat2D_minor_free(sub_mm);
01085     // }
01086
01087     Mat2D temp_m = mat2D_alloc(m.rows, m.cols);
01088     mat2D_copy(temp_m, m);
01089     double factor = mat2D_triangulate(temp_m);
01090     double diag_mul = 1;
01091     for (size_t i = 0; i < temp_m.rows; i++) {
01092         diag_mul *= MAT2D_AT(temp_m, i, i);
01093     }
01094     mat2D_free(temp_m);
01095
01096     return diag_mul / factor;
01097 }
01098
01107 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u)
01108 {
01109     /* performing LU decomposition Following the Wikipedia page:
      https://en.wikipedia.org/wiki/LU_decomposition */
01110
01111     mat2D_copy(u, src);
01112     mat2D_set_identity(p);
01113     mat2D_fill(l, 0);
01114
01115     for (size_t i = 0; i < (size_t)fmin(u.rows-1, u.cols); i++) {
01116         if (!MAT2D_AT(u, i, i)) {   /* swapping only if it is zero */
01117             /* finding biggest first number (absolute value) */
01118             size_t biggest_r = i;
01119             for (size_t index = i; index < u.rows; index++) {
01120                 if (fabs(MAT2D_AT(u, index, i)) > fabs(MAT2D_AT(u, biggest_r, i))) {
01121                     biggest_r = index;
01122                 }
01123             }
01124             if (i != biggest_r) {
01125                 mat2D_swap_rows(u, i, biggest_r);
01126                 mat2D_swap_rows(p, i, biggest_r);
01127                 mat2D_swap_rows(l, i, biggest_r);
01128             }
01129         }
01130         for (size_t j = i+1; j < u.cols; j++) {
01131             double factor = 1 / MAT2D_AT(u, i, i);
01132             if (!isfinite(factor)) {
01133                 printf("%s:%d: [Error] unable to transfrom into uper triangular matrix. Probably some
      of the rows are not independent.\n", __FILE__, __LINE__);
01134             }
01135             double mat_value = MAT2D_AT(u, j, i);
01136             mat2D_sub_row_time_factor_to_row(u, j, i, mat_value * factor);
01137             MAT2D_AT(l, j, i) = mat_value * factor;
01138         }
01139         MAT2D_AT(l, i, i) = 1;
01140     }
01141     MAT2D_AT(l, l.rows-1, l.cols-1) = 1;
01142 }
01143
01149 void mat2D_transpose(Mat2D des, Mat2D src)
01150 {
01151     MATRIX2D_ASSERT(des.cols == src.rows);
01152     MATRIX2D_ASSERT(des.rows == src.cols);
01153
01154     for (size_t index = 0; index < des.rows; ++index) {
01155         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
01156             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, jndex, index);
01157         }
01158     }
01159 }
01160
01169 void mat2D_invert(Mat2D des, Mat2D src)
01170 {
01171     MATRIX2D_ASSERT(src.cols == src.rows && "should be an NxN matrix");
01172     MATRIX2D_ASSERT(des.cols == src.cols && des.rows == des.cols);
```

```
01173
01174     Mat2D m = mat2D_alloc(src.rows, src.cols);
01175     mat2D_copy(m, src);
01176
01177     mat2D_set_identity(des);
01178
01179     if (!mat2D_det(m)) {
01180         mat2D_fill(des, 0);
01181         printf("%s:%d: [Error] Can't invert the matrix. Determinant is zero! Set the inverse matrix to
      all zeros\n", __FILE__, __LINE__);
01182         return;
01183     }
01184
01185     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
01186         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
01187             /* finding biggest first number (absolute value) */
01188             size_t biggest_r = i;
01189             for (size_t index = i; index < m.rows; index++) {
01190                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
01191                     biggest_r = index;
01192                 }
01193             }
01194             if (i != biggest_r) {
01195                 mat2D_swap_rows(m, i, biggest_r);
01196                 mat2D_swap_rows(des, i, biggest_r);
01197                 printf("%s:%d: [INFO] swapping row %zu with row %zu.\n", __FILE__, __LINE__, i,
      biggest_r);
01198             } else {
01199                 MATRIX2D_ASSERT(0 && "can't inverse");
01200             }
01201         }
01202         for (size_t j = i+1; j < m.cols; j++) {
01203             double factor = 1 / MAT2D_AT(m, i, i);
01204             double mat_value = MAT2D_AT(m, j, i);
01205             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
01206             mat2D_mult_row(m, i, factor);
01207
01208             mat2D_sub_row_time_factor_to_row(des, j, i, mat_value * factor);
01209             mat2D_mult_row(des, i, factor);
01210         }
01211     }
01212     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
01213     mat2D_mult_row(m, m.rows-1, factor);
01214     mat2D_mult_row(des, des.rows-1, factor);
01215     for (size_t c = m.cols-1; c > 0; c--) {
01216         for (int r = c-1; r >= 0; r--) {
01217             double factor = 1 / MAT2D_AT(m, c, c);
01218             double mat_value = MAT2D_AT(m, r, c);
01219             mat2D_sub_row_time_factor_to_row(m, r, c, mat_value * factor);
01220             mat2D_sub_row_time_factor_to_row(des, r, c, mat_value * factor);
01221         }
01222     }
01223
01224     mat2D_free(m);
01225 }
01226
01236 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B)
01237 {
01238     MATRIX2D_ASSERT(A.cols == x.rows);
01239     MATRIX2D_ASSERT(1 == x.cols);
01240     MATRIX2D_ASSERT(A.rows == B.rows);
01241     MATRIX2D_ASSERT(1 == B.cols);
01242
01243     Mat2D y     = mat2D_alloc(x.rows, x.cols);
01244     Mat2D l     = mat2D_alloc(A.rows, A.cols);
01245     Mat2D p     = mat2D_alloc(A.rows, A.cols);
01246     Mat2D u     = mat2D_alloc(A.rows, A.cols);
01247     Mat2D inv_l = mat2D_alloc(l.rows, l.cols);
01248     Mat2D inv_u = mat2D_alloc(u.rows, u.cols);
01249
01250     mat2D_LUP_decomposition_with_swap(A, l, p, u);
01251
01252     mat2D_invert(inv_l, l);
01253     mat2D_invert(inv_u, u);
01254
01255     mat2D_fill(x, 0);   /* x here is only a temp mat*/
01256     mat2D_fill(y, 0);
01257     mat2D_dot(x, p, B);
01258     mat2D_dot(y, inv_l, x);
01259
01260     mat2D_fill(x, 0);
01261     mat2D_dot(x, inv_u, y);
01262
01263     mat2D_free(y);
01264     mat2D_free(l);
01265     mat2D_free(p);
01266     mat2D_free(u);
```

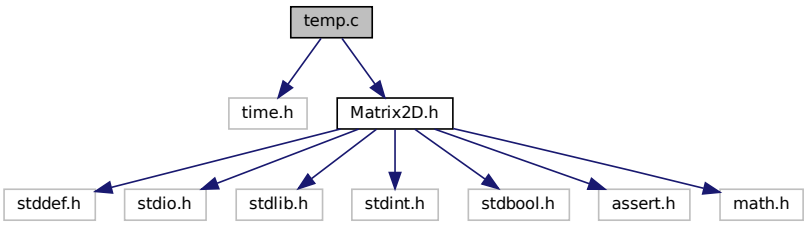
```
01267     mat2D_free(inv_l);
01268     mat2D_free(inv_u);
01269 }
01270
01279 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j)
01280 {
01281     MATRIX2D_ASSERT(ref_mat.cols == ref_mat.rows && "minor is defined only for square matrix");
01282
01283     Mat2D_Minor mm;
01284     mm.cols = ref_mat.cols-1;
01285     mm.rows = ref_mat.rows-1;
01286     mm.stride_r = ref_mat.cols-1;
01287     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.cols-1));
01288     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.rows-1));
01289     mm.ref_mat = ref_mat;
01290
01291     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
01292
01293     for (size_t index = 0, temp_index = 0; index < ref_mat.rows; index++) {
01294         if (index != i) {
01295             mm.rows_list[temp_index] = index;
01296             temp_index++;
01297         }
01298     }
01299     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mat.rows; jndex++) {
01300         if (jndex != j) {
01301             mm.cols_list[temp_jndex] = jndex;
01302             temp_jndex++;
01303         }
01304     }
01305
01306     return mm;
01307 }
01308
01318 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j)
01319 {
01320     MATRIX2D_ASSERT(ref_mm.cols == ref_mm.rows && "minor is defined only for square matrix");
01321
01322     Mat2D_Minor mm;
01323     mm.cols = ref_mm.cols-1;
01324     mm.rows = ref_mm.rows-1;
01325     mm.stride_r = ref_mm.cols-1;
01326     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.cols-1));
01327     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.rows-1));
01328     mm.ref_mat = ref_mm.ref_mat;
01329
01330     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
01331
01332     for (size_t index = 0, temp_index = 0; index < ref_mm.rows; index++) {
01333         if (index != i) {
01334             mm.rows_list[temp_index] = ref_mm.rows_list[index];
01335             temp_index++;
01336         }
01337     }
01338     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mm.rows; jndex++) {
01339         if (jndex != j) {
01340             mm.cols_list[temp_jndex] = ref_mm.cols_list[jndex];
01341             temp_jndex++;
01342         }
01343     }
01344
01345     return mm;
01346 }
01347
01353 void mat2D_minor_free(Mat2D_Minor mm)
01354 {
01355     free(mm.cols_list);
01356     free(mm.rows_list);
01357 }
01358
01365 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding)
01366 {
01367     printf("%*s%s = [\n", (int) padding, "", name);
01368     for (size_t i = 0; i < mm.rows; ++i) {
01369         printf("%*s    ", (int) padding, "");
01370         for (size_t j = 0; j < mm.cols; ++j) {
01371             printf("%f ", MAT2D_MINOR_AT(mm, i, j));
01372         }
01373         printf("\n");
01374     }
01375     printf("%*s]\n", (int) padding, "");
01376 }
01377
01383 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm)
01384 {
01385     MATRIX2D_ASSERT(2 == mm.cols && 2 == mm.rows && "Not a 2x2 matrix");
01386     return MAT2D_MINOR_AT(mm, 0, 0) * MAT2D_MINOR_AT(mm, 1, 1) - MAT2D_MINOR_AT(mm, 0, 1) *
```

```
      MAT2D_MINOR_AT(mm, 1, 0);
01387 }
01388
01396 double mat2D_minor_det(Mat2D_Minor mm)
01397 {
01398     MATRIX2D_ASSERT(mm.cols == mm.rows && "should be a square matrix");
01399
01400     double det = 0;
01401     /* TODO: finding beast row or col? */
01402     for (size_t i = 0, j = 0; i < mm.rows; i++) { /* first column */
01403         if (MAT2D_MINOR_AT(mm, i, j) < 1e-10) continue;
01404         Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat_minor(mm, i, j);
01405         int factor = (i+j)%2 ? -1 : 1;
01406         if (sub_mm.cols != 2) {
01407             MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
01408             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_minor_det(sub_mm);
01409         } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
01410             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
01411         }
01412         mat2D_minor_free(sub_mm);
01413     }
01414     return det;
01415 }
01416
01417
01418 #endif // MATRIX2D_IMPLEMENTATION
```

4.3 temp.c File Reference

```
#include "time.h"
#include "Matrix2D.h"
```

Include dependency graph for temp.c:



Macros

- #define MATRIX2D_IMPLEMENTATION

Functions

- int main (void)

4.3.1 Macro Definition Documentation

4.3.1.1 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 2 of file temp.c.

4.3.2 Function Documentation

4.3.2.1 main()

```
int main (
            void  )
```

Definition at line 5 of file temp.c.

References mat2D_alloc(), MAT2D_AT, mat2D_calc_norma(), mat2D_copy(), mat2D_dot(), mat2D_fill(), mat2D_fill_sequence(), mat2D_LUP_decomposition_with_swap(), mat2D_mult(), MAT2D_PRINT, mat2D_set_identity(), mat2D_solve_linear_sys_LUP_decomposition(), and mat2D_sub().

4.4 temp.c

```
00001 #include "time.h"
00002 #define MATRIX2D_IMPLEMENTATION
00003 #include "Matrix2D.h"
00004
00005 int main(void)
00006 {
00007     int n = 3;
00008     Mat2D a     = mat2D_alloc(n, n);
00009     Mat2D l     = mat2D_alloc(n, n);
00010     Mat2D p     = mat2D_alloc(n, n);
00011     Mat2D u     = mat2D_alloc(n, n);
00012     Mat2D current_A  = mat2D_alloc(n, n);
00013     Mat2D previous_A = mat2D_alloc(n, n);
00014     Mat2D diff       = mat2D_alloc(n, n);
00015     Mat2D x          = mat2D_alloc(n, 1);
00016     Mat2D B          = mat2D_alloc(n, 1);
00017
00018     // srand(time(0));
00019     // mat2D_rand(a, 0, 1);
00020     mat2D_fill_sequence(a, 1, 1);
00021     MAT2D_PRINT(a);
00022
00023     mat2D_LUP_decomposition_with_swap(a, l, p, u);
00024
00025     MAT2D_PRINT(l);
00026     MAT2D_PRINT(p);
00027     MAT2D_PRINT(u);
00028
00029     mat2D_dot(current_A, l, u);
00030     MAT2D_PRINT(current_A);
00031
00032     for (int i = 0; i < 25; i++) {
00033         mat2D_dot(current_A, l, u);
00034         mat2D_dot(previous_A, u, l);
00035         mat2D_LUP_decomposition_with_swap(previous_A, l, p, u);
00036         mat2D_copy(diff, current_A);
00037         mat2D_sub(diff, previous_A);
00038     }
00039     MAT2D_PRINT(diff);
00040     mat2D_copy(current_A, previous_A);
00041
00042     mat2D_set_identity(previous_A);
00043     mat2D_mult(previous_A, MAT2D_AT(current_A, 1, 1));
00044     mat2D_sub(a, previous_A);
```

```
00045
00046     mat2D_fill(B, 0);
00047     mat2D_solve_linear_sys_LUP_decomposition(a, x, B);
00048
00049     MAT2D_PRINT(a);
00050     MAT2D_PRINT(x);
00051     printf("\n%g\n", mat2D_calc_norma(diff));
00052
00053     return 0;
00054 }
```

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