
matrix_decomposition Documentation

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Contents

1	Release info	3
1.1	Conda	3
1.2	pip	3
1.3	GitHub	4
1.4	Zenodo	4
2	Documentation	5
3	Test status	7
4	Contents	9
4.1	Functions	9
4.2	Matrix decompositions	18
4.3	Errors	37
4.4	Changelog	40
5	Indices and tables	43
6	Copyright	45
	Index	47

This is *matrix-decomposition*, a library to approximate Hermitian (dense and sparse) matrices by positive definite matrices. Furthermore it allows to decompose (factorize) positive definite matrices and solve associated systems of linear equations.

There are several ways to obtain and install this package.

1.1 Conda

To install this package with *conda* run:

```
conda install -c jore matrix-decomposition
```

<https://anaconda.org/jore/matrix-decomposition>

1.2 pip

To install this package with *pip* run:

```
pip install 'matrix-decomposition'
```

<https://pypi.python.org/pypi/matrix-decomposition>

1.3 GitHub

To clone this package with *git* run:

```
git clone https://github.com/jor-/matrix-decomposition.git
```

To install this package after that with *python* run:

```
cd matrix-decomposition; python setup.py install
```

<https://github.com/jor-/matrix-decomposition>

1.4 Zenodo

CHAPTER 2

Documentation

<https://matrix-decomposition.readthedocs.io>

CHAPTER 3

Test status

4.1 Functions

Several functions are included in this package. The most important ones are summarized here.

4.1.1 Positive semidefinite approximation of a matrix

`matrix.approximation.positive_semidefinite.positive_semidefinite_matrix` (*A*,
min_diag_B=None,
max_diag_B=None,
min_diag_D=None,
max_diag_D=None,
min_abs_value_D=None,
per-
mu-
ta-
tion=None,
over-
write_A=False)

Computes an approximation of A which has a LDL^H decomposition with the specified properties.

Returns A if A has such a decomposition and otherwise an approximation of A .

Parameters

- **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be approximated. A must be Hermitian.
- **min_diag_B** (*numpy.ndarray* or *float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.

- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^H decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be greater or equal to 0. optional, default : Is chosen by the algorithm.
- **max_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^H decomposition of the returned matrix is forced to be lower or equal to *max_diag_D*. optional, default : No maximal value is forced.
- **min_abs_value_D** (*float*) – Absolute values below *min_abs_value_D* are considered as zero in the matrix *D* in a LDL^H decomposition of the returned matrix. *min_abs_value_D* must be greater or equal to 0. optional, default : The square root of the resolution of the underlying data type.
- **permutation** (*str or numpy.ndarray*) – The symmetric permutation method that is applied to the matrix before it is decomposed. It has to be a value in `matrix.UNIVERSAL_PERMUTATION_METHODS` or `APPROXIMATION_ONLY_PERMUTATION_METHODS`. If *A* is sparse, it can also be a value in `matrix.SPARSE_ONLY_PERMUTATION_METHODS`. It is also possible to directly pass a permutation vector. optional, default: The permutation is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns B – An approximation of *A* which has a LDL^H decomposition.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix` (same type as *A*)

Raises

- `matrix.errors.MatrixNotSquareError` – If *A* is not a square matrix.
- `matrix.errors.MatrixComplexDiagonalValueError` – If *A* has complex diagonal values.

```
matrix.approximation.positive_semidefinite.decomposition(A, min_diag_B=None,
                                                         max_diag_B=None,
                                                         min_diag_D=None,
                                                         max_diag_D=None,
                                                         min_abs_value_D=None,
                                                         permutation=None,
                                                         overwrite_A=False,
                                                         return_type=None)
```

Computes an approximative decomposition of a matrix with the specified properties.

Returns a decomposition of *A* if has such a decomposition and otherwise a decomposition of an approximation of *A*.

Parameters

- **A** (*numpy.ndarray or scipy.sparse.spmatrix*) – The matrix that should be approximated by a decomposition. *A* must be Hermitian.
- **min_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the composed matrix *B* of an approximated LDL^H decomposition is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.

- **max_diag_B** (*numpy.ndarray* or *float*) – Each component of the diagonal of the composed matrix B of an approximated LDL^H decomposition is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix D in an approximated LDL^H decomposition is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be greater or equal to 0. optional, default : Is chosen by the algorithm.
- **max_diag_D** (*float*) – Each component of the diagonal of the matrix D in an approximated LDL^H decomposition is forced to be lower or equal to *max_diag_D*. optional, default : No maximal value is forced.
- **min_abs_value_D** (*float*) – Absolute values below *min_abs_value_D* are considered as zero in the matrix D of an approximated LDL^H decomposition. *min_abs_value_D* must be greater or equal to 0. optional, default : The square root of the resolution of the underlying data type.
- **permutation** (*str* or *numpy.ndarray*) – The symmetric permutation method that is applied to the matrix before it is decomposed. It has to be a value in *matrix.UNIVERSAL_PERMUTATION_METHODS* or *APPROXIMATION_ONLY_PERMUTATION_METHODS*. If A is sparse, it can also be a value in *matrix.SPARSE_ONLY_PERMUTATION_METHODS*. It is also possible to directly pass a permutation vector. optional, default: The permutation is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite A . Enabling may result in performance gain. optional, default: False
- **return_type** (*str*) – The type of the decomposition that should be returned. It has to be a value in *matrix.DECOMPOSITION_TYPES*. optional, default : The type of the decomposition is chosen by the function itself.

Returns An (approximative) decomposition of A of type *return_type*.

Return type *matrix.decompositions.DecompositionBase*

Raises

- *matrix.errors.MatrixNotSquareError* – If A is not a square matrix.
- *matrix.errors.MatrixComplexDiagonalValueError* – If A has complex diagonal values.

```
matrix.approximation.positive_semidefinite.APPROXIMATION_ONLY_PERMUTATION_METHODS = ('min'
```

Permutation methods supported only by the decomposition and the positive_semidefinite_matrix algorithm.

```
matrix.approximation.positive_semidefinite.GMW_81(A, min_diag_B=None,
max_diag_B=None,
min_diag_D=None, overwrite_A=False)
```

Computes a positive definite approximation of A .

Returns A if A is positive definite and meets the constrains and otherwise a positive definite approximation of A .

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. A must be symmetric.
- **min_diag_B** (*numpy.ndarray* or *float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.

- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns *B* – An approximation of *A* which is positive definite.

Return type *numpy.ndarray*

Raises *matrix.errors.MatrixNotSquareError* – If *A* is not a square matrix.

Notes

The algorithm is introduced in [1]. Is is also described in [2]. This discription has been used for this implementation. The implementation has been extended to allow restrictions on the diagonal values.

References

[1] Gill, P. E.; Murray, W. & Wright, M. H., Practical optimization, Academic press, 1981

[2] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349

```
matrix.approximation.positive_semidefinite.GMW_T1 (A, min_diag_B=None,
                                                    max_diag_B=None,
                                                    min_diag_D=None,      over-
                                                    write_A=False)
```

Computes a positive definite approximation of *A*.

Returns *A* if *A* is positive definite and meets the constrains and otherwise a positive definite approximation of *A*.

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. *A* must be symmetric.
- **min_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.
- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns *B* – An approximation of *A* which is positive definite.

Return type *numpy.ndarray*

Raises *matrix.errors.MatrixNotSquareError* – If *A* is not a square matrix.

Notes

The algorithm is introduced in [1]. This discription has been used for this implementation. The algorithm is based on [2]. The implementation has been extended to allow restrictions on the diagonal values.

References

- [1] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349
- [2] Gill, P. E.; Murray, W. & Wright, M. H., Practical optimization, Academic press, 1981

```
matrix.approximation.positive_semidefinite.GMW_T2(A, min_diag_B=None,
                                                    max_diag_B=None,
                                                    min_diag_D=None, over-
                                                    write_A=False)
```

Computes a positive definite approximation of A.

Returns A if A is positive definite and meets the constrains and otherwise a positive definite approximation of A.

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. A must be symmetric.
- **min_diag_B** (*numpy.ndarray* or *float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.
- **max_diag_B** (*numpy.ndarray* or *float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite A. Enabling may result in performance gain. optional, default: False

Returns B – An approximation of A which is positive definite.

Return type *numpy.ndarray*

Raises *matrix.errors.MatrixNotSquareError* – If A is not a square matrix.

Notes

The algorithm is introduced in [1]. This discription has been used for this implementation. The algorithm is based on [2]. The implementation has been extended to allow restrictions on the diagonal values.

References

- [1] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349
- [2] Gill, P. E.; Murray, W. & Wright, M. H., Practical optimization, Academic press, 1981

```
matrix.approximation.positive_semidefinite.SE_90(A, min_diag_B=None,
max_diag_B=None,
min_diag_D=None, over-
write_A=False)
```

Computes a positive definite approximation of A .

Returns A if A is positive definite and meets the constraints and otherwise a positive definite approximation of A .

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. A must be symmetric.
- **min_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.
- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix D in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite A . Enabling may result in performance gain. optional, default: False

Returns B – An approximation of A which is positive definite.

Return type *numpy.ndarray*

Raises *matrix.errors.MatrixNotSquareError* – If A is not a square matrix.

Notes

The algorithm is introduced in [1]. It is also described in [2]. This description has been used for this implementation. The implementation has been extended to allow restrictions on the diagonal values.

References

- [1] Schnabel, R. & Eskow, E., A New Modified Cholesky Factorization, SIAM Journal on Scientific and Statistical Computing, 1990, 11, 1136-1158
- [2] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349

```
matrix.approximation.positive_semidefinite.SE_99(A, min_diag_B=None,
max_diag_B=None,
min_diag_D=None, over-
write_A=False)
```

Computes a positive definite approximation of A .

Returns A if A is positive definite and meets the constraints and otherwise a positive definite approximation of A .

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. A must be symmetric.
- **min_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.

- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns **B** – An approximation of *A* which is positive definite.

Return type `numpy.ndarray`

Raises `matrix.errors.MatrixNotSquareError` – If *A* is not a square matrix.

Notes

The algorithm is introduced in [1]. Is is also described in [2]. This discription has been used for this implementation. The algorithm is based on [3]. The implementation has been extended to allow restrictions on the diagonal values.

References

- [1] Schnabel, R. & Eskow, E., A Revised Modified Cholesky Factorization Algorithm, SIAM Journal on Optimization, 1999, 9, 1135-1148
- [2] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349
- [3] Schnabel, R. & Eskow, E., A New Modified Cholesky Factorization, SIAM Journal on Scientific and Statistical Computing, 1990, 11, 1136-1158

```
matrix.approximation.positive_semidefinite.SE_T1(A, min_diag_B=None,
max_diag_B=None,
min_diag_D=None,
write_A=False)
```

Computes a positive definite approximation of *A*.

Returns *A* if *A* is positive definite and meets the constrains and otherwise a positive definite approximation of *A*.

Parameters

- **A** (*numpy.ndarray*) – The matrix that should be approximated. *A* must be symmetric.
- **min_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be greater or equal to *min_diag_B*. optional, default : No minimal value is forced.
- **max_diag_B** (*numpy.ndarray or float*) – Each component of the diagonal of the returned matrix is forced to be lower or equal to *max_diag_B*. optional, default : No maximal value is forced.
- **min_diag_D** (*float*) – Each component of the diagonal of the matrix *D* in a LDL^T decomposition of the returned matrix is forced to be greater or equal to *min_diag_D*. *min_diag_D* must be positive. optional, default : Is chosen by the algorithm.
- **overwrite_A** (*bool*) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns **B** – An approximation of *A* which is positive definite.

Return type `numpy.ndarray`

Raises `matrix.errors.MatrixNotSquareError` – If *A* is not a square matrix.

Notes

The algorithm is introduced in [1]. This description has been used for this implementation. The algorithm is based on [2]. The implementation has been extended to allow restrictions on the diagonal values.

References

- [1] Fang, H.-r. & O’Leary, D. P., Modified Cholesky algorithms: a catalog with new approaches, Mathematical Programming, 2008, 115, 319-349
- [2] Schnabel, R. & Eskow, E., A Revised Modified Cholesky Factorization Algorithm, SIAM Journal on Optimization, 1999, 9, 1135-1148
- [3] Schnabel, R. & Eskow, E., A New Modified Cholesky Factorization, SIAM Journal on Scientific and Statistical Computing, 1990, 11, 1136-1158

4.1.2 Decompose a matrix

`matrix.decompose` (*A*, *permutation*=None, *return_type*=None, *check_finite*=True, *overwrite_A*=False)

Computes a decomposition of a matrix.

Parameters

- **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Matrix to be decomposed. *A* must be Hermitian.
- **permutation** (`str` or `numpy.ndarray`) – The symmetric permutation method that is applied to the matrix before it is decomposed. It has to be a value in `matrix.UNIVERSAL_PERMUTATION_METHODS`. If *A* is sparse, it can also be a value in `matrix.SPARSE_ONLY_PERMUTATION_METHODS`. It is also possible to directly pass a permutation vector. optional, default: no permutation
- **return_type** (`str`) – The type of the decomposition that should be calculated. It has to be a value in `matrix.DECOMPOSITION_TYPES`. If *return_type* is None the type of the returned decomposition is chosen by the function itself. optional, default: the type of the decomposition is chosen by the function itself
- **check_finite** (`bool`) – Whether to check that *A* contains only finite numbers. Disabling may result in problems (crashes, non-termination) if the inputs do contain infinities or NaNs. Disabling gives a performance gain. optional, default: True
- **overwrite_A** (`bool`) – Whether it is allowed to overwrite *A*. Enabling may result in performance gain. optional, default: False

Returns A decomposition of *A* of type *return_type*.

Return type `matrix.decompositions.DecompositionBase`

Raises

- `matrix.errors.NoDecompositionPossibleError` – If the decomposition of *A* is not possible.

- `matrix.errors.MatrixNotSquareError` – If A is not a square matrix.
- `matrix.errors.MatrixNotFiniteError` – If A is not a finite matrix and `check_finite` is True.

`matrix.UNIVERSAL_PERMUTATION_METHODS = ('none', 'decreasing_diagonal_values', 'increasing_`
Supported permutation methods for decompose dense and sparse matrices.

`matrix.SPARSE_ONLY_PERMUTATION_METHODS = ()`
Supported permutation methods only for sparse matrices.

`matrix.DECOMPOSITION_TYPES = ('LDL', 'LDL_compressed', 'LL')`
Supported types of decompositions.

4.1.3 Examine a matrix

`matrix.is_positive_semidefinite(A, check_finite=True)`
Returns whether the passed matrix is positive semi-definite.

Parameters

- **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be checked. A must be Hermitian.
- **check_finite** (`bool`) – Whether to check that A contain only finite numbers. Disabling may result in problems (crashes, non-termination) if they contain infinities or NaNs. Disabling gives a performance gain. optional, default: True

Returns Whether A is positive semi-definite.

Return type `bool`

Raises `matrix.errors.MatrixNotFiniteError` – If A is not a finite matrix and `check_finite` is True.

`matrix.is_positive_definite(A, check_finite=True)`
Returns whether the passed matrix is positive definite.

Parameters

- **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be checked. A must be Hermitian.
- **check_finite** (`bool`) – Whether to check that A contain only finite numbers. Disabling may result in problems (crashes, non-termination) if they contain infinities or NaNs. Disabling gives a performance gain. optional, default: True

Returns Whether A is positive definite.

Return type `bool`

Raises `matrix.errors.MatrixNotFiniteError` – If A is not a finite matrix and `check_finite` is True.

`matrix.is_invertible(A, check_finite=True)`
Returns whether the passed matrix is an invertible matrix.

Parameters

- **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be checked. A must be Hermitian and positive semidefinite.

- **check_finite** (*bool*) – Whether to check that A contain only finite numbers. Disabling may result in problems (crashes, non-termination) if they contain infinities or NaNs. Disabling gives a performance gain. optional, default: True

Returns Whether A is invertible.

Return type `bool`

Raises `matrix.errors.MatrixNotFiniteError` – If A is not a finite matrix and `check_finite` is True.

4.1.4 Solve system of linear equations

`matrix.solve(A, b, overwrite_b=False, check_finite=True)`

Solves the equation $Ax = b$ regarding x .

Parameters

- **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be checked. A must be Hermitian and positive definite.
- **b** (`numpy.ndarray`) – Right-hand side vector or matrix in equation $Ax = b$. It must hold `b.shape[0] == A.shape[0]`.
- **overwrite_b** (*bool*) – Allow overwriting data in b . Enabling gives a performance gain. optional, default: False
- **check_finite** (*bool*) – Whether to check that A and b^* contain only finite numbers. Disabling may result in problems (crashes, non-termination) if they contain infinities or NaNs. Disabling gives a performance gain. optional, default: True

Returns An x so that $Ax = b$. The shape of x matches the shape of b .

Return type `numpy.ndarray`

Raises

- `matrix.errors.MatrixNotSquareError` – If A is not a square matrix.
- `matrix.errors.MatrixNotFiniteError` – If A is not a finite matrix and `check_finite` is True.
- `matrix.errors.MatrixSingularError` – If A is singular.

4.2 Matrix decompositions

Several matrix decompositions are supported. They are available in `matrix.decompositions`:

4.2.1 LL decomposition

class `matrix.decompositions.LLDecomposition` ($L=None, p=None$)

Bases: `matrix.decompositions.DecompositionBase`

A matrix decomposition where LL^H is the decomposed (permuted) matrix.

L is a lower triangle matrix with ones on the diagonal. This decomposition is also called Cholesky decomposition.

Parameters

- **L** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix L of the decomposition. optional, If it is not set yet, it must be set later.
- **p** (*numpy.ndarray*) – The permutation vector used for the decomposition. This decomposition is of $A[p[:, np.newaxis], p[np.newaxis, :]]$ where A is a matrix. optional, default: no permutation

L

The matrix L of the decomposition.

Type *numpy.matrix* or *scipy.sparse.spmatrix*

P

The permutation matrix. $P @ A @ P.T$ is the matrix A permuted by the permutation of the decomposition

Type *scipy.sparse.dok_matrix*

as_LDL_Decomposition()

as_any_type (**type_strs*, *copy=False*)

Convert decomposition to any of the passed types.

Parameters

- ***type_strs** (*str*) – The decomposition types to any of them this this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not in *type_strs*, a decomposition of type *type_str[0]* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

as_type (*type_str*, *copy=False*)

Convert decomposition to passed type.

Parameters

- **type_str** (*str*) – The decomposition type to which this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not *type_str*, a decomposition of type *type_str* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

check_finite (*check_finite=True*)

Check if this is a decomposition representing a finite matrix.

Parameters **check_finite** (*bool*) – Whether to perform this check. default: True

Raises *matrix.errors.DecompositionNotFiniteError* – If this is a decomposition representing a non-finite matrix.

check_invertible ()

Check if this is a decomposition representing an invertible matrix.

Raises *matrix.errors.DecompositionSingularError* – If this is a decomposition representing a singular matrix.

composed_matrix

The composed matrix represented by this decomposition.

Type `numpy.matrix` or `scipy.sparse.spmatrix`

copy()

Copy this decomposition.

Returns A copy of this decomposition.

Return type `matrix.decompositions.DecompositionBase`

inverse_matrix_both_sides_multiplication(*x*, *y=None*)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters

- **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == x.shape[0]`.
- **y** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == y.shape[0]`. optional, default: If *y* is not passed, *x* is used as *y*.

Returns The result of $x.H @ A @ y$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

inverse_matrix_right_side_multiplication(*x*)

Calculates the right side (matrix-matrix or matrix-vector) product $B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product in the matrix-matrix or matrix-vector $B @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $B @ x$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

is_almost_equal(*other*, *rtol=0.0001*, *atol=1e-06*)

Whether this decomposition is close to passed decomposition.

Parameters

- **other** (`str`) – The decomposition which to compare to this decomposition.
- **rtol** (`float`) – The relative tolerance parameter.
- **atol** (`float`) – The absolute tolerance parameter.

Returns Whether this decomposition is close to passed decomposition.

Return type `bool`

is_equal(*other*)

Whether this decomposition is equal to passed decomposition.

Parameters **other** (`str`) – The decomposition which to compare to this decomposition.

Returns Whether this decomposition is equal to passed decomposition.

Return type `bool`

`is_finite()`

Returns whether this is a decomposition representing a finite matrix.

Returns Whether this is a decomposition representing a finite matrix.

Return type `bool`

`is_invertible()`

Returns whether this is a decomposition representing an invertible matrix.

Returns Whether this is a decomposition representing an invertible matrix.

Return type `bool`

`is_permuted`

Whether this is a decompositon with permutation.

Type `bool`

`is_positive_definite()`

Returns whether this is a decomposition of a positive definite matrix.

Returns Whether this is a decomposition of a positive definite matrix.

Return type `bool`

`is_positive_semidefinite()`

Returns whether this is a decomposition of a positive semi-definite matrix.

Returns Whether this is a decomposition of a positive semi-definite matrix.

Return type `bool`

`is_singular()`

Returns whether this is a decomposition representing a singular matrix.

Returns Whether this is a decomposition representing a singular matrix.

Return type `bool`

`is_sparse()`

Returns whether this is a decomposition of a sparse matrix.

Returns Whether this is a decomposition of a sparse matrix.

Return type `bool`

`is_type(type_str)`

Whether this is a decomposition of the passed type.

Parameters `type_str` (*str*) – The decomposition type according to which is checked.

Returns Whether this is a decomposition of the passed type.

Return type `bool`

`load(filename)`

Loads a decomposition of this type.

Parameters `filename` (*str*) – Where the decomposition is saved.

Raises

- `FileNotFoundError` – If the files are not found in the passed directory.

- `DecompositionInvalidDecompositionTypeFile` – If the files contains another decomposition type.

matrix_both_sides_multiplication (*x*, *y=None*)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ A @ x$, where A is the composed matrix represented by this decomposition.

Parameters

- **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold `self.n == x.shape[0]`.
- **y** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold `self.n == y.shape[0]`. optional, default: If *y* is not passed, *x* is used as *y*.

Returns The result of $x.H @ A @ y$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

matrix_right_side_multiplication (*x*)

Calculates the right side (matrix-matrix or matrix-vector) product $A @ x$, where A is the composed matrix represented by this decomposition.

Parameters **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product in the matrix-matrix or matrix-vector $A @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $A @ x$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

n

The dimension of the squared decomposed matrix.

Type *int*

P

The permutation vector. $A[p[:, np.newaxis], p[np.newaxis, :]]$ is the matrix A permuted by the permutation of the decomposition

Type *numpy.ndarray*

p_inverse

The permutation vector that undoes the permutation.

Type *numpy.ndarray*

permute_matrix (*A*)

Permute a matrix by the permutation of the decomposition.

Parameters **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be permuted.

Returns The matrix A permuted by the permutation of the decomposition.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

save (*filename*)

Saves this decomposition.

Parameters **filename** (*str*) – Where this decomposition should be saved.

solve (*b*)

Solves the equation $A x = b$ regarding x , where A is the composed matrix represented by this decomposition.

Parameters **b** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Right-hand side vector or matrix in equation $Ax = b$. It must hold `self.n == b.shape[0]`.

Returns An x so that $Ax = b$. The shape of x matches the shape of b .

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

Raises *matrix.errors.DecompositionSingularError* – If this is a decomposition representing a singular matrix.

type_str = 'LL'

The type of this decomposition represented as string.

Type *str*

unpermute_matrix(*A*)

Unpermute a matrix permuted by the permutation of the decomposition.

Parameters **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be unpermuted.

Returns The matrix A unpermuted by the permutation of the decomposition.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

4.2.2 LDL decomposition

class *matrix.decompositions.LDL_Decomposition* (*L=None, d=None, p=None*)

Bases: *matrix.decompositions.DecompositionBase*

A matrix decomposition where LDL^H is the decomposed (permuted) matrix.

L is a lower triangle matrix with ones on the diagonal. D is a diagonal matrix. Only the diagonal values of D are stored.

Parameters

- **L** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix L of the decomposition. optional, If it is not set yet, it must be set later.
- **d** (*numpy.ndarray*) – The vector of the diagonal components of D of the decomposition. optional, If it is not set yet, it must be set later.
- **p** (*numpy.ndarray*) – The permutation vector used for the decomposition. This decomposition is of $A[p[:, np.newaxis], p[np.newaxis, :]]$ where A is a matrix. optional, default: no permutation

D

The permutation matrix.

Type *scipy.sparse.dia_matrix*

L

The matrix L of the decomposition.

Type *numpy.matrix* or *scipy.sparse.spmatrix*

LD

A matrix whose diagonal values are the diagonal values of D and whose off-diagonal values are those of L .

Type *numpy.matrix* or *scipy.sparse.spmatrix*

P

The permutation matrix. $P @ A @ P.T$ is the matrix A permuted by the permutation of the decomposition

Type `scipy.sparse.dok_matrix`

as_LDL_DecompositionCompressed()

as_LL_Decomposition()

as_any_type (*type_strs, copy=False)

Convert decomposition to any of the passed types.

Parameters

- ***type_strs** (*str*) – The decomposition types to any of them this this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not in *type_strs*, a decomposition of type *type_str*[0] is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type `matrix.decompositions.DecompositionBase`

as_type (type_str, copy=False)

Convert decomposition to passed type.

Parameters

- **type_str** (*str*) – The decomposition type to which this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not *type_str*, a decomposition of type *type_str* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type `matrix.decompositions.DecompositionBase`

check_finite (check_finite=True)

Check if this is a decomposition representing a finite matrix.

Parameters **check_finite** (*bool*) – Whether to perform this check. default: True

Raises `matrix.errors.DecompositionNotFiniteError` – If this is a decomposition representing a non-finite matrix.

check_invertible ()

Check if this is a decomposition representing an invertible matrix.

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

composed_matrix

The composed matrix represented by this decomposition.

Type `numpy.matrix` or `scipy.sparse.spmatrix`

copy ()

Copy this decomposition.

Returns A copy of this decomposition.

Return type `matrix.decompositions.DecompositionBase`

d

The diagonal vector of the matrix D of the decomposition.

Type `numpy.ndarray`

inverse_matrix_both_sides_multiplication (x , $y=None$)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters

- **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == x.shape[0]`.
- **y** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == y.shape[0]`. optional, default: If y is not passed, x is used as y .

Returns The result of $x.H @ A @ y$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

inverse_matrix_right_side_multiplication (x)

Calculates the right side (matrix-matrix or matrix-vector) product $B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product in the matrix-matrix or matrix-vector $B @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $B @ x$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

is_almost_equal ($other$, $rtol=0.0001$, $atol=1e-06$)

Whether this decomposition is close to passed decomposition.

Parameters

- **other** (`str`) – The decomposition which to compare to this decomposition.
- **rtol** (`float`) – The relative tolerance parameter.
- **atol** (`float`) – The absolute tolerance parameter.

Returns Whether this decomposition is close to passed decomposition.

Return type `bool`

is_equal ($other$)

Whether this decomposition is equal to passed decomposition.

Parameters **other** (`str`) – The decomposition which to compare to this decomposition.

Returns Whether this decomposition is equal to passed decomposition.

Return type `bool`

is_finite ()

Returns whether this is a decomposition representing a finite matrix.

Returns Whether this is a decomposition representing a finite matrix.

Return type `bool`

`is_invertible()`

Returns whether this is a decomposition representing an invertible matrix.

Returns Whether this is a decomposition representing an invertible matrix.

Return type `bool`

`is_permuted`

Whether this is a decompositon with permutation.

Type `bool`

`is_positive_definite()`

Returns whether this is a decomposition of a positive definite matrix.

Returns Whether this is a decomposition of a positive definite matrix.

Return type `bool`

`is_positive_semidefinite()`

Returns whether this is a decomposition of a positive semi-definite matrix.

Returns Whether this is a decomposition of a positive semi-definite matrix.

Return type `bool`

`is_singular()`

Returns whether this is a decomposition representing a singular matrix.

Returns Whether this is a decomposition representing a singular matrix.

Return type `bool`

`is_sparse()`

Returns whether this is a decomposition of a sparse matrix.

Returns Whether this is a decomposition of a sparse matrix.

Return type `bool`

`is_type(type_str)`

Whether this is a decomposition of the passed type.

Parameters `type_str` (*str*) – The decomposition type according to which is checked.

Returns Whether this is a decomposition of the passed type.

Return type `bool`

`load(filename)`

Loads a decomposition of this type.

Parameters `filename` (*str*) – Where the decomposition is saved.

Raises

- `FileNotFoundError` – If the files are not found in the passed directory.
- `DecompositionInvalidDecompositionTypeFile` – If the files contains another decomposition type.

`matrix_both_sides_multiplication(x, y=None)`

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ A @ x$, where A is the composed matrix represented by this decomposition.

Parameters

- **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold $self.n == x.shape[0]$.
- **y** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold $self.n == y.shape[0]$. optional, default: If y is not passed, x is used as y.

Returns The result of $x.H @ A @ y$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

matrix_right_side_multiplication(x)

Calculates the right side (matrix-matrix or matrix-vector) product $A @ x$, where A is the composed matrix represented by this decomposition.

Parameters **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product in the matrix-matrix or matrix-vector $A @ x$. It must hold $self.n == x.shape[0]$.

Returns The result of $A @ x$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

n

The dimension of the squared decomposed matrix.

Type *int*

p

The permutation vector. $A[p[:, np.newaxis], p[np.newaxis, :]]$ is the matrix A permuted by the permutation of the decomposition

Type *numpy.ndarray*

p_inverse

The permutation vector that undoes the permutation.

Type *numpy.ndarray*

permute_matrix(A)

Permute a matrix by the permutation of the decomposition.

Parameters **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be permuted.

Returns The matrix A permuted by the permutation of the decomposition.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

save(filename)

Saves this decomposition.

Parameters **filename** (*str*) – Where this decomposition should be saved.

solve(b)

Solves the equation $A x = b$ regarding x , where A is the composed matrix represented by this decomposition.

Parameters **b** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Right-hand side vector or matrix in equation $A x = b$. It must hold $self.n == b.shape[0]$.

Returns An x so that $A x = b$. The shape of x matches the shape of b .

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

type_str = 'LDL'

The type of this decomposition represented as string.

Type `str`

unpermute_matrix(*A*)

Unpermute a matrix permuted by the permutation of the decomposition.

Parameters *A* (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be unpermuted.

Returns The matrix *A* unpermuted by the permutation of the decomposition.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

4.2.3 LDL decomposition compressed

class `matrix.decompositions.LDL_DecompositionCompressed`(*LD=None, p=None*)

Bases: `matrix.decompositions.DecompositionBase`

A matrix decomposition where LDL^H is the decomposed (permuted) matrix.

L is a lower triangle matrix with ones on the diagonal. *D* is a diagonal matrix. *L* and *D* are stored in one matrix whose diagonal values are the diagonal values of *D* and whose off-diagonal values are those of *L*.

Parameters

- **LD** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – A matrix whose diagonal values are the diagonal values of *D* and whose off-diagonal values are those of *L*. optional, If it is not set yet, it must be set later.
- **p** (`numpy.ndarray`) – The permutation vector used for the decomposition. This decomposition is of $A[p[:, np.newaxis], p[np.newaxis, :]]$ where *A* is a matrix. optional, default: no permutation

D

The permutation matrix.

Type `scipy.sparse.dia_matrix`

L

The matrix *L* of the decomposition.

Type `numpy.matrix` or `scipy.sparse.spmatrix`

LD

A matrix whose diagonal values are the diagonal values of *D* and whose off-diagonal values are those of *L*.

Type `numpy.matrix` or `scipy.sparse.spmatrix`

P

The permutation matrix. $P @ A @ P.T$ is the matrix *A* permuted by the permutation of the decomposition

Type `scipy.sparse.dok_matrix`

as_LDL_Decomposition()

as_any_type(**type_strs*, *copy=False*)

Convert decomposition to any of the passed types.

Parameters

- ***type_strs** (*str*) – The decomposition types to any of them this this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not in *type_strs*, a decomposition of type *type_str[0]* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

as_type (*type_str*, *copy=False*)

Convert decomposition to passed type.

Parameters

- **type_str** (*str*) – The decomposition type to which this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not *type_str*, a decomposition of type *type_str* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

check_finite (*check_finite=True*)

Check if this is a decomposition representing a finite matrix.

Parameters **check_finite** (*bool*) – Whether to perform this check. default: True

Raises *matrix.errors.DecompositionNotFiniteError* – If this is a decomposition representing a non-finite matrix.

check_invertible ()

Check if this is a decomposition representing an invertible matrix.

Raises *matrix.errors.DecompositionSingularError* – If this is a decomposition representing a singular matrix.

composed_matrix

The composed matrix represented by this decomposition.

Type *numpy.matrix* or *scipy.sparse.spmatrix*

copy ()

Copy this decomposition.

Returns A copy of this decomposition.

Return type *matrix.decompositions.DecompositionBase*

d

The diagonal vector of the matrix *D* of the decomposition.

Type *numpy.ndarray*

inverse_matrix_both_sides_multiplication (*x*, *y=None*)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ B @ x$, where *B* is the matrix inverse of the composed matrix represented by this decomposition.

Parameters

- **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == x.shape[0]`.
- **y** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == y.shape[0]`. optional, default: If y is not passed, x is used as y.

Returns The result of $x.H @ A @ y$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

Raises *matrix.errors.DecompositionSingularError* – If this is a decomposition representing a singular matrix.

inverse_matrix_right_side_multiplication(*x*)

Calculates the right side (matrix-matrix or matrix-vector) product $B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product in the matrix-matrix or matrix-vector $B @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $B @ x$.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

Raises *matrix.errors.DecompositionSingularError* – If this is a decomposition representing a singular matrix.

is_almost_equal(*other*, *rtol*=0.0001, *atol*=1e-06)

Whether this decomposition is close to passed decomposition.

Parameters

- **other** (*str*) – The decomposition which to compare to this decomposition.
- **rtol** (*float*) – The relative tolerance parameter.
- **atol** (*float*) – The absolute tolerance parameter.

Returns Whether this decomposition is close to passed decomposition.

Return type *bool*

is_equal(*other*)

Whether this decomposition is equal to passed decomposition.

Parameters **other** (*str*) – The decomposition which to compare to this decomposition.

Returns Whether this decomposition is equal to passed decomposition.

Return type *bool*

is_finite()

Returns whether this is a decomposition representing a finite matrix.

Returns Whether this is a decomposition representing a finite matrix.

Return type *bool*

is_invertible()

Returns whether this is a decomposition representing an invertible matrix.

Returns Whether this is a decomposition representing an invertible matrix.

Return type *bool*

is_permuted

Whether this is a decomposition with permutation.

Type `bool`

is_positive_definite()

Returns whether this is a decomposition of a positive definite matrix.

Returns Whether this is a decomposition of a positive definite matrix.

Return type `bool`

is_positive_semidefinite()

Returns whether this is a decomposition of a positive semi-definite matrix.

Returns Whether this is a decomposition of a positive semi-definite matrix.

Return type `bool`

is_singular()

Returns whether this is a decomposition representing a singular matrix.

Returns Whether this is a decomposition representing a singular matrix.

Return type `bool`

is_sparse()

Returns whether this is a decomposition of a sparse matrix.

Returns Whether this is a decomposition of a sparse matrix.

Return type `bool`

is_type(type_str)

Whether this is a decomposition of the passed type.

Parameters `type_str (str)` – The decomposition type according to which is checked.

Returns Whether this is a decomposition of the passed type.

Return type `bool`

load(filename)

Loads a decomposition of this type.

Parameters `filename (str)` – Where the decomposition is saved.

Raises

- `FileNotFoundError` – If the files are not found in the passed directory.
- `DecompositionInvalidDecompositionTypeFile` – If the files contains another decomposition type.

matrix_both_sides_multiplication(x, y=None)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ A @ x$, where A is the composed matrix represented by this decomposition.

Parameters

- **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ A @ x$. It must hold `self.n == x.shape[0]`.
- **y** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ A @ x$. It must hold `self.n == y.shape[0]`. optional, default: If y is not passed, x is used as y.

Returns The result of $x.H @ A @ y$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

matrix_right_side_multiplication (*x*)

Calculates the right side (matrix-matrix or matrix-vector) product $A @ x$, where A is the composed matrix represented by this decomposition.

Parameters **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product in the matrix-matrix or matrix-vector $A @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $A @ x$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

n

The dimension of the squared decomposed matrix.

Type `int`

p

The permutation vector. $A[p[:, np.newaxis], p[np.newaxis, :]]$ is the matrix A permuted by the permutation of the decomposition

Type `numpy.ndarray`

p_inverse

The permutation vector that undoes the permutation.

Type `numpy.ndarray`

permute_matrix (*A*)

Permute a matrix by the permutation of the decomposition.

Parameters **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be permuted.

Returns The matrix A permuted by the permutation of the decomposition.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

save (*filename*)

Saves this decomposition.

Parameters **filename** (*str*) – Where this decomposition should be saved.

solve (*b*)

Solves the equation $A x = b$ regarding x , where A is the composed matrix represented by this decomposition.

Parameters **b** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Right-hand side vector or matrix in equation $A x = b$. It must hold `self.n == b.shape[0]`.

Returns An x so that $A x = b$. The shape of x matches the shape of b .

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

type_str = `'LDL_compressed'`

The type of this decomposition represented as string.

Type `str`

unpermute_matrix (*A*)

Unpermute a matrix permuted by the permutation of the decomposition.

Parameters **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be unpermuted.

Returns The matrix *A* unpermuted by the permutation of the decomposition.

Return type *numpy.ndarray* or *scipy.sparse.spmatrix*

4.2.4 Base decomposition

class `matrix.decompositions.DecompositionBase` (*p=None*)

Bases: `object`

A matrix decomposition.

This class is a base class for all other matrix decompositions.

Parameters **p** (*numpy.ndarray*) – The permutation vector used for the decomposition. This decomposition is of $A[p[:, np.newaxis], p[np.newaxis, :]]$ where *A* is a matrix. optional, default: no permutation

P

The permutation matrix. $P @ A @ P.T$ is the matrix *A* permuted by the permutation of the decomposition

Type *scipy.sparse.dok_matrix*

as_any_type (**type_strs, copy=False*)

Convert decomposition to any of the passed types.

Parameters

- ***type_strs** (*str*) – The decomposition types to any of them this this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not in *type_strs*, a decomposition of type *type_str[0]* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

as_type (*type_str, copy=False*)

Convert decomposition to passed type.

Parameters

- **type_str** (*str*) – The decomposition type to which this decomposition is converted.
- **copy** (*bool*) – Whether the data of this decomposition should always be copied or only if needed.

Returns If the type of this decomposition is not *type_str*, a decomposition of type *type_str* is returned which represents the same decomposed matrix as this decomposition. Otherwise this decomposition or a copy of it is returned, depending on *copy*.

Return type *matrix.decompositions.DecompositionBase*

check_finite (*check_finite=True*)

Check if this is a decomposition representing a finite matrix.

Parameters `check_finite (bool)` – Whether to perform this check. default: True

Raises `matrix.errors.DecompositionNotFiniteError` – If this is a decomposition representing a non-finite matrix.

check_invertible ()

Check if this is a decomposition representing an invertible matrix.

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

composed_matrix

The composed matrix represented by this decomposition.

Type `numpy.matrix` or `scipy.sparse.spmatrix`

copy ()

Copy this decomposition.

Returns A copy of this decomposition.

Return type `matrix.decompositions.DecompositionBase`

inverse_matrix_both_sides_multiplication (x, y=None)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters

- **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == x.shape[0]`.
- **y** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product $y.H @ B @ x$. It must hold `self.n == y.shape[0]`. optional, default: If y is not passed, x is used as y.

Returns The result of $x.H @ A @ y$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

inverse_matrix_right_side_multiplication (x)

Calculates the right side (matrix-matrix or matrix-vector) product $B @ x$, where B is the matrix inverse of the composed matrix represented by this decomposition.

Parameters **x** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Vector or matrix in the product in the matrix-matrix or matrix-vector $B @ x$. It must hold `self.n == x.shape[0]`.

Returns The result of $B @ x$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

is_almost_equal (other, rtol=0.0001, atol=1e-06)

Whether this decomposition is close to passed decomposition.

Parameters

- **other** (`str`) – The decomposition which to compare to this decomposition.
- **rtol** (`float`) – The relative tolerance parameter.

- `atol (float)` – The absolute tolerance parameter.

Returns Whether this decomposition is close to passed decomposition.

Return type `bool`

`is_equal (other)`

Whether this decomposition is equal to passed decomposition.

Parameters `other (str)` – The decomposition which to compare to this decomposition.

Returns Whether this decomposition is equal to passed decomposition.

Return type `bool`

`is_finite ()`

Returns whether this is a decomposition representing a finite matrix.

Returns Whether this is a decomposition representing a finite matrix.

Return type `bool`

`is_invertible ()`

Returns whether this is a decomposition representing an invertible matrix.

Returns Whether this is a decomposition representing an invertible matrix.

Return type `bool`

`is_permuted`

Whether this is a decompositon with permutation.

Type `bool`

`is_positive_definite ()`

Returns whether this is a decomposition of a positive definite matrix.

Returns Whether this is a decomposition of a positive definite matrix.

Return type `bool`

`is_positive_semidefinite ()`

Returns whether this is a decomposition of a positive semi-definite matrix.

Returns Whether this is a decomposition of a positive semi-definite matrix.

Return type `bool`

`is_singular ()`

Returns whether this is a decomposition representing a singular matrix.

Returns Whether this is a decomposition representing a singular matrix.

Return type `bool`

`is_sparse ()`

Returns whether this is a decomposition of a sparse matrix.

Returns Whether this is a decomposition of a sparse matrix.

Return type `bool`

`is_type (type_str)`

Whether this is a decomposition of the passed type.

Parameters `type_str (str)` – The decomposition type according to which is checked.

Returns Whether this is a decomposition of the passed type.

Return type `bool`

load (*filename*)

Loads a decomposition of this type.

Parameters **filename** (*str*) – Where the decomposition is saved.

Raises

- `FileNotFoundError` – If the files are not found in the passed directory.
- `DecompositionInvalidDecompositionTypeFile` – If the files contains another decomposition type.

matrix_both_sides_multiplication (*x*, *y=None*)

Calculates the both sides (matrix-matrix or matrix-vector) product $y.H @ A @ x$, where A is the composed matrix represented by this decomposition.

Parameters

- **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold $self.n == x.shape[0]$.
- **y** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product $y.H @ A @ x$. It must hold $self.n == y.shape[0]$. optional, default: If y is not passed, x is used as y .

Returns The result of $x.H @ A @ y$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

matrix_right_side_multiplication (*x*)

Calculates the right side (matrix-matrix or matrix-vector) product $A @ x$, where A is the composed matrix represented by this decomposition.

Parameters **x** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – Vector or matrix in the product in the matrix-matrix or matrix-vector $A @ x$. It must hold $self.n == x.shape[0]$.

Returns The result of $A @ x$.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

n

The dimension of the squared decomposed matrix.

Type `int`

p

The permutation vector. $A[p[:, np.newaxis], p[np.newaxis, :]]$ is the matrix A permuted by the permutation of the decomposition

Type `numpy.ndarray`

p_inverse

The permutation vector that undoes the permutation.

Type `numpy.ndarray`

permute_matrix (*A*)

Permute a matrix by the permutation of the decomposition.

Parameters **A** (*numpy.ndarray* or *scipy.sparse.spmatrix*) – The matrix that should be permuted.

Returns The matrix A permuted by the permutation of the decomposition.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

save (*filename*)

Saves this decomposition.

Parameters **filename** (*str*) – Where this decomposition should be saved.

solve (*b*)

Solves the equation $Ax = b$ regarding x , where A is the composed matrix represented by this decomposition.

Parameters **b** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – Right-hand side vector or matrix in equation $Ax = b$. It must hold `self.n == b.shape[0]`.

Returns An x so that $Ax = b$. The shape of x matches the shape of b .

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

Raises `matrix.errors.DecompositionSingularError` – If this is a decomposition representing a singular matrix.

type_str = 'base'

The type of this decomposition represented as string.

Type *str*

unpermute_matrix (*A*)

Unpermute a matrix permuted by the permutation of the decomposition.

Parameters **A** (`numpy.ndarray` or `scipy.sparse.spmatrix`) – The matrix that should be unpermuted.

Returns The matrix A unpermuted by the permutation of the decomposition.

Return type `numpy.ndarray` or `scipy.sparse.spmatrix`

4.3 Errors

This is an overview about the exceptions that could arise in this library. They are available in `matrix.errors`:

The following exception is the base exception from which all other exceptions in this package are derived:

4.3.1 BaseError

exception `matrix.errors.BaseError` (*message*)

Bases: `Exception`

This is the base exception for all exceptions in this package.

If a matrix has an invalid properties, the following exceptions can occur:

4.3.2 MatrixError

exception `matrix.errors.MatrixError` (*matrix*, *message=None*)

Bases: `matrix.errors.BaseError`

An exception related to a matrix.

4.3.3 MatrixNotSquareError

exception `matrix.errors.MatrixNotSquareError` (*matrix*)
Bases: `matrix.errors.MatrixError`

A matrix is not a square matrix although a square matrix is required.

4.3.4 MatrixNotFiniteError

exception `matrix.errors.MatrixNotFiniteError` (*matrix*)
Bases: `matrix.errors.MatrixError`

A matrix has non-finite entries although a finite matrix is required.

4.3.5 MatrixSingularError

exception `matrix.errors.MatrixSingularError` (*matrix*)
Bases: `matrix.errors.MatrixError`

A matrix is singular although an invertible matrix is required.

4.3.6 MatrixNotHermitianError

exception `matrix.errors.MatrixNotHermitianError` (*matrix, i=None, j=None*)
Bases: `matrix.errors.MatrixError`

A matrix is not Hermitian although a Hermitian matrix is required.

4.3.7 MatrixComplexDiagonalValueError

exception `matrix.errors.MatrixComplexDiagonalValueError` (*matrix, i=None*)
Bases: `matrix.errors.MatrixNotHermitianError`

A matrix has complex diagonal values although real diagonal values are required.

If a desired decomposition is not computable, the following exceptions can be raised:

4.3.8 NoDecompositionPossibleError

exception `matrix.errors.NoDecompositionPossibleError` (*base, desired_type*)
Bases: `matrix.errors.BaseError`

It is not possible to calculate a desired matrix decomposition.

4.3.9 NoDecompositionPossibleWithProblematicSubdecompositionError

exception `matrix.errors.NoDecompositionPossibleWithProblematicSubdecompositionError` (*base, desired_type, problematic_lead, subdecomposition=None*)

Bases: `matrix.errors.NoDecompositionPossibleError`

It is not possible to calculate a desired matrix decomposition. Only a subdecomposition could be calculated

4.3.10 NoDecompositionPossibleTooManyEntriesError

exception `matrix.errors.NoDecompositionPossibleTooManyEntriesError` (*matrix, desired_type*)

Bases: `matrix.errors.NoDecompositionPossibleError`

The decomposition is not possible for this matrix because it would have too many entries.

4.3.11 NoDecompositionConversionImplementedError

exception `matrix.errors.NoDecompositionConversionImplementedError` (*decomposition, desired_type*)

Bases: `matrix.errors.NoDecompositionPossibleError`

A decomposition conversion is not implemented for this type.

If the matrix, represented by a decomposition, has an invalid characteristic, the following exceptions can occur:

4.3.12 DecompositionError

exception `matrix.errors.DecompositionError` (*decomposition, message=None*)

Bases: `matrix.errors.BaseError`

An exception related to a decomposition.

4.3.13 DecompositionNotFiniteError

exception `matrix.errors.DecompositionNotFiniteError` (*decomposition*)

Bases: `matrix.errors.DecompositionError`

A decomposition of a matrix has non-finite entries although a finite matrix is required.

4.4.4 0.8

- Approximation functions have been replaced by more sophisticated approximation functions.
- Explicit function for approximating a matrix by a positive (semi)definite matrix has been added.
- Universal save and load functions have been added.
- Decompositions have obtained `is_equal` and `is_almost_equal` methods.
- Functions to multiply the matrix, represented by a decomposition, or its inverse with a matrix or a vector have been added.
- It is now possible to pass permutation vectors to approximate and decompose methods.

4.4.5 0.7

- Lineare systems associated to matrices or decompositions can now be solved.
- Invertibility of matrices and decompositions can now be examined.
- Decompositions can now be examined to see if they contain only finite values.

4.4.6 0.6

- Decompositions are now saveable and loadable.

4.4.7 0.5

- Matrices can now be approximated by decompositions.

4.4.8 0.4

- Positive definiteness and positive semi-definiteness of matrices and decompositions can now be examined.

4.4.9 0.3

- Dense and sparse matrices are now decomposable into several types (LL, LDL, LDL compressed).

4.4.10 0.2

- Decompositons are now convertible to other decompositon types.
- Decompositions are now comparable.

4.4.11 0.1

- Several decompositions types (LL, LDL, LDL compressed) have been added.
- Several permutation capabilities have been added.

CHAPTER 5

Indices and tables

- `genindex`
- `search`

CHAPTER 6

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A

APPROXIMATION_ONLY_PERMUTATION_METHODS
 (in module *matrix.approximation.positive_semidefinite*),
 11

as_any_type() (matrix.decompositions.DecompositionBase
 method), 33

as_any_type() (matrix.decompositions.LDL-Decomposition
 method), 24

as_any_type() (matrix.decompositions.LDL-DecompositionCompressed
 method), 28

as_any_type() (matrix.decompositions.LL-Decomposition
 method), 19

as_LDL-Decomposition() (matrix.decompositions.LDL-DecompositionCompressed
 method), 28

as_LDL-Decomposition() (matrix.decompositions.LL-Decomposition
 method), 19

as_LDL-DecompositionCompressed() (matrix.decompositions.LDL-Decomposition
 method), 24

as_LL-Decomposition() (matrix.decompositions.LDL-Decomposition
 method), 24

as_type() (matrix.decompositions.DecompositionBase
 method), 33

as_type() (matrix.decompositions.LDL-Decomposition
 method), 24

as_type() (matrix.decompositions.LDL-DecompositionCompressed
 method), 29

as_type() (matrix.decompositions.LL-Decomposition
 method), 19

B

BaseError, 37

C

check_finite() (matrix.decompositions.DecompositionBase
 method), 33

check_finite() (matrix.decompositions.LDL-Decomposition
 method), 24

check_finite() (matrix.decompositions.LDL-DecompositionCompressed
 method), 29

check_finite() (matrix.decompositions.LL-Decomposition
 method), 19

check_invertible() (matrix.decompositions.DecompositionBase
 method), 34

check_invertible() (matrix.decompositions.LDL-Decomposition
 method), 24

check_invertible() (matrix.decompositions.LDL-DecompositionCompressed
 method), 29

check_invertible() (matrix.decompositions.LL-Decomposition
 method), 19

composed_matrix (matrix.decompositions.DecompositionBase
 attribute), 34

composed_matrix (matrix.decompositions.LDL-Decomposition
 attribute), 24

composed_matrix (matrix.decompositions.LDL-DecompositionCompressed
 attribute), 29

composed_matrix (matrix.decompositions.LL-Decomposition
 attribute), 24

tribute), 19

copy () (matrix.decompositions.DecompositionBase method), 34

copy () (matrix.decompositions.LDL_Decomposition method), 24

copy () (matrix.decompositions.LDL_DecompositionCompressed method), 29

copy () (matrix.decompositions.LL_Decomposition method), 20

D

D (matrix.decompositions.LDL_Decomposition attribute), 23

d (matrix.decompositions.LDL_Decomposition attribute), 25

D (matrix.decompositions.LDL_DecompositionCompressed attribute), 28

d (matrix.decompositions.LDL_DecompositionCompressed attribute), 29

decompose () (in module matrix), 16

decomposition () (in module matrix.approximation.positive_semidefinite), 10

DECOMPOSITION_TYPES (in module matrix), 17

DecompositionBase (class in matrix.decompositions), 33

DecompositionError, 39

DecompositionInvalidDecompositionTypeError, 40

DecompositionInvalidFile, 40

DecompositionNotFiniteError, 39

DecompositionSingularError, 40

G

GMW_81 () (in module matrix.approximation.positive_semidefinite), 11

GMW_T1 () (in module matrix.approximation.positive_semidefinite), 12

GMW_T2 () (in module matrix.approximation.positive_semidefinite), 13

I

inverse_matrix_both_sides_multiplication () (matrix.decompositions.DecompositionBase method), 34

inverse_matrix_both_sides_multiplication () (matrix.decompositions.LDL_Decomposition method), 25

inverse_matrix_both_sides_multiplication () (matrix.decompositions.LDL_DecompositionCompressed method), 29

inverse_matrix_both_sides_multiplication () (matrix.decompositions.LL_Decomposition method), 20

inverse_matrix_right_side_multiplication () (matrix.decompositions.DecompositionBase method), 34

inverse_matrix_right_side_multiplication () (matrix.decompositions.LDL_Decomposition method), 25

inverse_matrix_right_side_multiplication () (matrix.decompositions.LDL_DecompositionCompressed method), 30

inverse_matrix_right_side_multiplication () (matrix.decompositions.LL_Decomposition method), 20

is_almost_equal () (matrix.decompositions.DecompositionBase method), 34

is_almost_equal () (matrix.decompositions.LDL_Decomposition method), 25

is_almost_equal () (matrix.decompositions.LDL_DecompositionCompressed method), 30

is_almost_equal () (matrix.decompositions.LL_Decomposition method), 20

is_equal () (matrix.decompositions.DecompositionBase method), 35

is_equal () (matrix.decompositions.LDL_Decomposition method), 25

is_equal () (matrix.decompositions.LDL_DecompositionCompressed method), 30

is_equal () (matrix.decompositions.LL_Decomposition method), 20

is_finite () (matrix.decompositions.DecompositionBase method), 35

is_finite () (matrix.decompositions.LDL_Decomposition method), 25

is_finite () (matrix.decompositions.LDL_DecompositionCompressed method), 30

is_finite () (matrix.decompositions.LL_Decomposition method), 21

is_invertible () (in module matrix), 17

is_invertible () (matrix.decompositions.DecompositionBase method), 35

is_invertible () (matrix.decompositions.LDL_Decomposition method), 26

is_invertible () (matrix.decompositions.LDL_DecompositionCompressed method), 30

is_invertible () (matrix.decompositions.LL_Decomposition method), 20

`trix.decompositions.LL_Decomposition`
`method`), 21
`is_permuted(matrix.decompositions.DecompositionBase`
`attribute)`, 35
`is_permuted(matrix.decompositions.LDL_Decomposition`
`attribute)`, 26
`is_permuted(matrix.decompositions.LDL_DecompositionCompressed`
`attribute)`, 30
`is_permuted(matrix.decompositions.LL_Decomposition`
`attribute)`, 21
`is_positive_definite()` (in module `matrix`), 17
`is_positive_definite()` (`matrix.decompositions.DecompositionBase`
`method`), 35
`is_positive_definite()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`is_positive_definite()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`is_positive_definite()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
`is_positive_seminefinite()` (in module `matrix`), 17
`is_positive_seminefinite()` (`matrix.decompositions.DecompositionBase`
`method`), 35
`is_positive_seminefinite()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`is_positive_seminefinite()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`is_positive_seminefinite()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
`is_singular()` (`matrix.decompositions.DecompositionBase`
`method`), 35
`is_singular()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`is_singular()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`is_singular()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
`is_sparse()` (`matrix.decompositions.DecompositionBase`
`method`), 35
`is_sparse()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`is_sparse()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 36
`method`), 31
`is_sparse()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
`is_type()` (`matrix.decompositions.DecompositionBase`
`method`), 35
`is_type()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`is_type()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`is_type()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
L
`L` (`matrix.decompositions.LDL_Decomposition` `at-`
`tribute`), 23
`L` (`matrix.decompositions.LDL_DecompositionCompressed`
`attribute`), 28
`L` (`matrix.decompositions.LL_Decomposition` `attribute`),
19
`LD` (`matrix.decompositions.LDL_Decomposition` `at-`
`tribute`), 23
`LD` (`matrix.decompositions.LDL_DecompositionCompressed`
`attribute`), 28
`LDL_Decomposition` (class in `matrix.decompositions`), 23
`LDL_DecompositionCompressed` (class in `matrix.decompositions`), 28
`LL_Decomposition` (class in `matrix.decompositions`),
18
`load()` (`matrix.decompositions.DecompositionBase`
`method`), 36
`load()` (`matrix.decompositions.LDL_Decomposition`
`method`), 26
`load()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`load()` (`matrix.decompositions.LL_Decomposition`
`method`), 21
M
`matrix_both_sides_multiplication()`
(`matrix.decompositions.DecompositionBase`
`method`), 36
`matrix_both_sides_multiplication()`
(`matrix.decompositions.LDL_Decomposition`
`method`), 26
`matrix_both_sides_multiplication()` (`matrix.decompositions.LDL_DecompositionCompressed`
`method`), 31
`matrix_both_sides_multiplication()`
(`matrix.decompositions.LL_Decomposition`
`method`), 22
`matrix_right_side_multiplication()`
(`matrix.decompositions.DecompositionBase`
`method`), 36

`matrix_right_side_multiplication()`
 (`matrix.decompositions.LDL_Decomposition`
 method), 27

`matrix_right_side_multiplication()` (`ma-`
 trix.decompositions.LDL_DecompositionCompressed
 method), 32

`matrix_right_side_multiplication()`
 (`matrix.decompositions.LL_Decomposition`
 method), 22

`MatrixComplexDiagonalValueError`, 38

`MatrixError`, 37

`MatrixNotFiniteError`, 38

`MatrixNotHermitianError`, 38

`MatrixNotSquareError`, 38

`MatrixSingularError`, 38

N

`n` (`matrix.decompositions.DecompositionBase` *attribute*),
 36

`n` (`matrix.decompositions.LDL_Decomposition` *at-*
 tribute), 27

`n` (`matrix.decompositions.LDL_DecompositionCompressed`
 attribute), 32

`n` (`matrix.decompositions.LL_Decomposition` *attribute*),
 22

`NoDecompositionConversionImplementedError`,
 39

`NoDecompositionPossibleError`, 38

`NoDecompositionPossibleTooManyEntriesError`, 39

`NoDecompositionPossibleWithProblematicSubdecompositionError`,
 39

P

`P` (`matrix.decompositions.DecompositionBase` *attribute*),
 33

`p` (`matrix.decompositions.DecompositionBase` *attribute*),
 36

`P` (`matrix.decompositions.LDL_Decomposition` *at-*
 tribute), 23

`p` (`matrix.decompositions.LDL_Decomposition` *at-*
 tribute), 27

`P` (`matrix.decompositions.LDL_DecompositionCompressed`
 attribute), 28

`p` (`matrix.decompositions.LDL_DecompositionCompressed`
 attribute), 32

`P` (`matrix.decompositions.LL_Decomposition` *attribute*),
 19

`p` (`matrix.decompositions.LL_Decomposition` *attribute*),
 22

`p_inverse` (`matrix.decompositions.DecompositionBase`
 attribute), 36

`p_inverse` (`matrix.decompositions.LDL_Decomposition`
 attribute), 27

`p_inverse` (`matrix.decompositions.LDL_DecompositionCompressed`
 attribute), 32

`p_inverse` (`matrix.decompositions.LL_Decomposition`
 attribute), 22

`permute_matrix()` (`ma-`
 trix.decompositions.DecompositionBase
 method), 36

`permute_matrix()` (`ma-`
 trix.decompositions.LDL_Decomposition
 method), 27

`permute_matrix()` (`ma-`
 trix.decompositions.LDL_DecompositionCompressed
 method), 32

`permute_matrix()` (`ma-`
 trix.decompositions.LL_Decomposition
 method), 22

`positive_semidefinite_matrix()` (*in module*
 matrix.approximation.positive_semidefinite), 9

S

`save()` (`matrix.decompositions.DecompositionBase`
 method), 37

`save()` (`matrix.decompositions.LDL_Decomposition`
 method), 27

`save()` (`matrix.decompositions.LDL_DecompositionCompressed`
 method), 32

`save()` (`matrix.decompositions.LL_Decomposition`
 method), 22

`SE_90()` (*in module* *ma-*
 trix.approximation.positive_semidefinite),
 9

`SE_99()` (*in module* *ma-*
 trix.approximation.positive_semidefinite),
 14

`SE_T1()` (*in module* *ma-*
 trix.approximation.positive_semidefinite),
 15

`solve()` (*in module* *matrix*), 18

`solve()` (`matrix.decompositions.DecompositionBase`
 method), 37

`solve()` (`matrix.decompositions.LDL_Decomposition`
 method), 27

`solve()` (`matrix.decompositions.LDL_DecompositionCompressed`
 method), 32

`solve()` (`matrix.decompositions.LL_Decomposition`
 method), 22

`SPARSE_ONLY_PERMUTATION_METHODS` (*in mod-*
 ule matrix), 17

T

`type_str` (`matrix.decompositions.DecompositionBase`
 attribute), 37

`type_str` (`matrix.decompositions.LDL_Decomposition`
 attribute), 28

`type_str(matrix.decompositions.LDL-DecompositionCompressed
attribute)`, [32](#)
`type_str(matrix.decompositions.LL-Decomposition
attribute)`, [23](#)

U

`UNIVERSAL_PERMUTATION_METHODS` (in module
`matrix`), [17](#)
`unpermute_matrix()` (`ma-
trix.decompositions.DecompositionBase
method`), [37](#)
`unpermute_matrix()` (`ma-
trix.decompositions.LDL-Decomposition
method`), [28](#)
`unpermute_matrix()` (`ma-
trix.decompositions.LDL-DecompositionCompressed
method`), [32](#)
`unpermute_matrix()` (`ma-
trix.decompositions.LL-Decomposition
method`), [23](#)