Package ‘cPCG’

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Type Package

Title Efficient and Customized Preconditioned Conjugate Gradient Method for Solving System of Linear Equations

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Description Solves system of linear equations using (preconditioned) conjugate gradient algorithm, with improved efficiency using Armadillo templated 'C++' linear algebra library, and flexibility for user-specified preconditioning method. Please check <https://github.com/styvon/cPCG> for latest updates.

Depends R (>= 3.0.0)

License GPL (>= 2)

Imports Rcpp (>= 0.12.19)

LinkingTo Rcpp, RcppArmadillo

RoxygenNote 6.1.1

Encoding UTF-8

Suggests knitr, rmarkdown

VignetteBuilder knitr

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Contents

`cPCG-package` *Efficient and Customized Preconditioned Conjugate Gradient Method for Solving System of Linear Equations*

Description

Solves system of linear equations using (preconditioned) conjugate gradient algorithm, with improved efficiency using Armadillo templated 'C++' linear algebra library, and flexibility for user-specified preconditioning method. Please check <https://github.com/styvon/cPCG> for latest updates.

Details

Functions in this package serve the purpose of solving for x in $Ax = b$, where A is a symmetric and positive definite matrix, b is a column vector.

To improve scalability of conjugate gradient methods for larger matrices, the `Armadillo` templated C++ linear algebra library is used for the implementation. The package also provides flexibility to have user-specified preconditioner options to cater for different optimization needs.

The DESCRIPTION file:

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Suggests:	knitr, rmarkdown
VignetteBuilder:	knitr

Index of help topics:

Author(s)

Yongwen Zhuang

References

[1] Reeves Fletcher and Colin M Reeves. “Function minimization by conjugate gradients”. In: The computer journal 7.2 (1964), pp. 149–154.

[2] David S Kershaw. “The incomplete Cholesky—conjugate gradient method for the iter- ative solution of systems of linear equations”. In: Journal of computational physics 26.1 (1978), pp. 43–65.

[3] Yousef Saad. Iterative methods for sparse linear systems. Vol. 82. siam, 2003.

[4] David Young. “Iterative methods for solving partial difference equations of elliptic type”. In: Transactions of the American Mathematical Society 76.1 (1954), pp. 92–111.

Examples

```
# generate test data
test_A <- matrix(c(4,1,1,3), ncol = 2)
test_b <- matrix(1:2, ncol = 1)

# conjugate gradient method solver
cgsolve(test_A, test_b, 1e-6, 1000)

# preconditioned conjugate gradient method solver,
# with incomplete Cholesky factorization as preconditioner
pcgsolve(test_A, test_b, "ICC")
```

`cgsolve` *Conjugate gradient method*

Description

Conjugate gradient method for solving system of linear equations Ax = b, where A is symmetric and positive definite, b is a column vector.

Usage

```
cgsolve(A, b, tol = 1e-6, maxIter = 1000)
```

Arguments

`A`	matrix, symmetric and positive definite.
`b`	vector, with same dimension as number of rows of A.
`tol`	numeric, threshold for convergence, default is `1e-6`.
`maxIter`	numeric, maximum iteration, default is `1000`.

Details

The idea of conjugate gradient method is to find a set of mutually conjugate directions for the unconstrained problem

$$argmin_x f(x)$$

where $f(x) = 0.5b^T Ab - bx + z$ and z is a constant. The problem is equivalent to solving $Ax = b$.

This function implements an iterative procedure to reduce the number of matrix-vector multiplications [1]. The conjugate gradient method improves memory efficiency and computational complexity, especially when A is relatively sparse.

Value

Returns a vector representing solution x.

Warning

Users need to check that input matrix A is symmetric and positive definite before applying the function.

References

[1] Yousef Saad. Iterative methods for sparse linear systems. Vol. 82. siam, 2003.

See Also

pcgsolve

Examples

```
## Not run:
test_A <- matrix(c(4,1,1,3), ncol = 2)
test_b <- matrix(1:2, ncol = 1)
cgsolve(test_A, test_b, 1e-6, 1000)

## End(Not run)
```

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icc *Incomplete Cholesky Factorization*

Description

Incomplete Cholesky factorization method to generate preconditioning matrix for conjugate gradient method.

Usage

```
icc(A)
```

Arguments

`A`	matrix, symmetric and positive definite.

Details

Performs incomplete Cholesky factorization on the input matrix A, the output matrix is used for preconditioning in pcgsolve() if "ICC" is specified as the preconditioner.

Value

Returns a matrix after incomplete Cholesky factorization.

Warning

Users need to check that input matrix A is symmetric and positive definite before applying the function.

See Also

`pcgsolve`

Examples

```
## Not run:
test_A <- matrix(c(4,1,1,3), ncol = 2)
out <- icc(test_A)

## End(Not run)
```

`pcgsolve` *Preconditioned conjugate gradient method*

Description

Preconditioned conjugate gradient method for solving system of linear equations Ax = b, where A is symmetric and positive definite, b is a column vector.

Usage

```
pcgsolve(A, b, preconditioner = "Jacobi", tol = 1e-6, maxIter = 1000)
```

Arguments

`A`	matrix, symmetric and positive definite.
`b`	vector, with same dimension as number of rows of A.
`preconditioner`	string, method for preconditioning: `"Jacobi"` (default), `"SSOR"`, or `"ICC"`.
`tol`	numeric, threshold for convergence, default is `1e-6`.
`maxIter`	numeric, maximum iteration, default is `1000`.

Details

When the condition number for A is large, the conjugate gradient (CG) method may fail to converge in a reasonable number of iterations. The Preconditioned Conjugate Gradient (PCG) Method applies a precondition matrix C and approaches the problem by solving:

$$C^{-1}Ax = C^{-1}b$$

where the symmetric and positive-definite matrix C approximates A and $C^{-1}A$ improves the condition number of A.

Common choices for the preconditioner include: Jacobi preconditioning, symmetric successive over-relaxation (SSOR), and incomplete Cholesky factorization [2].

Value

Returns a vector representing solution x.

Preconditioners

`Jacobi`: The Jacobi preconditioner is the diagonal of the matrix A, with an assumption that all diagonal elements are non-zero.

`SSOR`: The symmetric successive over-relaxation preconditioner, implemented as $M = (D+L)D^{-1}(D+L)^T$. [1]

`ICC`: The incomplete Cholesky factorization preconditioner. [2]

Warning

Users need to check that input matrix A is symmetric and positive definite before applying the function.

References

[1] David Young. “Iterative methods for solving partial difference equations of elliptic type”. In: Transactions of the American Mathematical Society 76.1 (1954), pp. 92–111.

[2] David S Kershaw. “The incomplete Cholesky—conjugate gradient method for the iter- ative solution of systems of linear equations”. In: Journal of computational physics 26.1 (1978), pp. 43–65.

See Also

`cgsolve`

Examples

```
## Not run:
test_A <- matrix(c(4,1,1,3), ncol = 2)
test_b <- matrix(1:2, ncol = 1)
pcgsolve(test_A, test_b, "ICC")

## End(Not run)
```

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