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(Last problem in assignment of finding libraries)

Numpy/ Scipy FUNCTIONS:

1. Solving a system of linear equations using Gaussian Elimination with Pivoting:

2. Solving a system of linear equations using the Jacobi method:

3. Solving a system of linear equations using the Gauss-Seidel method:

4. Solving a system of linear equations using the Relaxation method:

5. Solving a system of linear equations using the Conjugate Gradient method:

6. Obtaining the LU decomposition of a matrix:
   scipy.linalg.lu()
7. Obtaining the QR decomposition of a matrix:
   numpy.linalg.qr, scipy.linalg.qr()
8. Obtaining the singular value decomposition of a matrix:
   scipy.linalg.svd, numpy.linalg.svd()
9. Obtaining the eigenvalues of a real symmetric matrix:
   numpy.linalg.eig(), numpy.linalg.eigh(), numpy.linalg.eigvalsh(), scipy.linalg.eigh(), scipy.linalg.eig(), scipy.linalg.eigvalsh()
10. Obtaining the eigenvalues of a complex Hermitian matrix:
    scipy.linalg.eigvalsh, numpy.linalg.eigvalsh
11. Obtaining the eigenvalues of a general real or complex $n \times n$ matrix:
    numpy.linalg.eig, scipy.linalg.eig

GSL FUNCTIONS:

1. Solving a system of linear equations using Gaussian Elimination with Pivoting:

2. Solving a system of linear equations using the Jacobi method:

3. Solving a system of linear equations using the Gauss-Seidel method:

4. Solving a system of linear equations using the Relaxation method:

5. Solving a system of linear equations using the Conjugate Gradient method:

6. Obtaining the LU decomposition of a matrix:

Lapack's dgetrf() computes a A=P*L*U decomposition for a general M-by-N matrix A.

Example from internet:

```
    int j;
double detp=1.;
for( j=0;j<n;j++){
  if(j+1!=ipiv[j]){
    // j+1 : following feedback of ead : ipiv is from Fortran, hence starts at 1.
    // hey ! This is a transpose !
    detp=-detp;
  }
}
```

*** Source: https://stackoverflow.com/questions/47315471/compute-determinant-from-lu-decomposition-in-lapack

7. Obtaining the QR decomposition of a matrix:

x[, qr$pivot] == Q %*% R.

Example from internet:

```
x <- matrix(runif(10), 5, 2)
q <- qr(x)
is.qr(x)  #  FALSE
is.qr(q)  #  TRUE
x <- runif(10)
y <- rnorm(10)
qr(lm( y~x , qr = TRUE) ) # OK
qr(lm( y~x , qr = FALSE) )
# Error: lm object does not have a proper 'qr' component.
```

*** Source: https://docs.tibco.com/pub/enterprise-runtime-for-R/5.0.0/doc/html/Language_Reference/base/qr.html

8. Obtaining the singular value decomposition of a matrix:

There are many functions for this purpose. I am directly copying the informatons from internet.

subroutine sgejsv (JOBA, JOBU, JOBV, JOBR, JOBT, JOBP, M, N, A, LDA, SVA, U, LDU, V, LDV, WORK, LWORK, IWORK, INFO)

SGEJSV More...

subroutine sgesdd (JOBZ, M, N, A, LDA, S, U, LDU, VT, LDVT, WORK, LWORK, IWORK, INFO)

SGESDD More...

subroutine sgesvd (JOBU, JOBVT, M, N, A, LDA, S, U, LDU, VT, LDVT, WORK, LWORK, INFO)

SGESVD computes the singular value decomposition (SVD) for GE matrices More...

subroutine sgesvdq (JOBA, JOBP, JOBR, JOBU, JOBV, M, N, A, LDA, S, U, LDU, V, LDV, NUMRANK, IWORK, LIWORK, WORK, LWORK, RWORK, LRWORK, INFO)

SGESVDQ computes the singular value decomposition (SVD) with a QR-Preconditioned QR SVD Method for GE matrices More...

subroutine sgesvdx (JOBU, JOBVT, RANGE, M, N, A, LDA, VL, VU, IL, IU, NS, S, U, LDU, VT, LDVT, WORK, LWORK, IWORK, INFO)

SGESVDX computes the singular value decomposition (SVD) for GE matrices More...

subroutine sggsvd3 (JOBU, JOBV, JOBQ, M, N, P, K, L, A, LDA, B, LDB, ALPHA, BETA, U, LDU, V, LDV, Q, LDQ, WORK, LWORK, IWORK, INFO)

SGGSVD3 computes the singular value decomposition (SVD) for OTHER matrices More...

***Source:

http://www.netlib.org/lapack/explore-html/d4/dca/group__real_g_esing.html

9. **Obtaining the eigenvalues of a real symmetric matrix:**

There are many functions in LAPACK for eigenvalue problem. I am just copying the information from internet.

subroutine sgegs (JOBVSL, JOBVSR, N, A, LDA, B, LDB, ALPHAR, ALPHAI, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, INFO)

SGEGS computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine sgegv (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHAR, ALPHAI, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, INFO)

SGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine sgees (JOBVS, SORT, SELECT, N, A, LDA, SDIM, WR, WI, VS, LDVS, WORK, LWORK, BWORK, INFO)

SGEES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine sgeesx (JOBVS, SORT, SELECT, SENSE, N, A, LDA, SDIM, WR, WI, VS, LDVS, RCONDE, RCONDV, WORK, LWORK, IWORK, LIWORK, BWORK, INFO)

SGEESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine sgeev (JOBVL, JOBVR, N, A, LDA, WR, WI, VL, LDVL, VR, LDVR, WORK, LWORK, INFO)

SGEEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine sgeevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, WR, WI, VL, LDVL, VR, LDVR, ILO, IHI, SCALE, ABNRM, RCONDE, RCONDV, WORK, LWORK, IWORK, INFO)

SGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine sgges (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHAR, ALPHAI, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, BWORK, INFO)

SGGES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine sgges3 (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHAR, ALPHAI, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, BWORK, INFO)

SGGES3 computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices (blocked algorithm) More...

subroutine sggesx (JOBVSL, JOBVSR, SORT, SELCTG, SENSE, N, A, LDA, B, LDB, SDIM, ALPHAR, ALPHAI, BETA, VSL, LDVSL, VSR, LDVSR, RCONDE, RCONDV, WORK, LWORK, IWORK, LIWORK, BWORK, INFO)

SGGESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine sggev (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHAR, ALPHAI, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, INFO)

SGGEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine sggev3 (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHAR, ALPHAI, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, INFO)

SGGEV3 computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices (blocked algorithm) More...

subroutine sggevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, B, LDB, ALPHAR, ALPHAI, BETA, VL, LDVL, VR, LDVR, ILO, IHI, LSCALE, RSCALE, ABNRM, BBNRM, RCONDE, RCONDV, WORK, LWORK, IWORK, BWORK, INFO)

SGGEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

*** Source: http://www.netlib.org/lapack/explore-html/d3/dfb/group__real_g_eeigen.html

10. Obtaining the eigenvalues of a complex Hermitian matrix:

subroutine cgees (JOBVS, SORT, SELECT, N, A, LDA, SDIM, W, VS, LDVS, WORK, LWORK, RWORK, BWORK, INFO)

CGEES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine cgeesx (JOBVS, SORT, SELECT, SENSE, N, A, LDA, SDIM, W, VS, LDVS, RCONDE, RCONDV, WORK, LWORK, RWORK, BWORK, INFO)

CGEESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine cgeev (JOBVL, JOBVR, N, A, LDA, W, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

CGEEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine cgeevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, W, VL, LDVL, VR, LDVR, ILO, IHI, SCALE, ABNRM, RCONDE, RCONDV, WORK, LWORK, RWORK, INFO)

CGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine cgges (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, BWORK, INFO)

CGGES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine cgges3 (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, BWORK, INFO)

CGGES3 computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices (blocked algorithm) More...

subroutine cggesx (JOBVSL, JOBVSR, SORT, SELCTG, SENSE, N, A, LDA, B, LDB, SDIM, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, RCONDE, RCONDV, WORK, LWORK, RWORK, IWORK, LIWORK, BWORK, INFO)

CGGESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine cggev (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

CGGEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine cggev3 (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

CGGEV3 computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices (blocked algorithm) More...

subroutine cggevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, ILO, IHI, LSCALE, RSCALE, ABNRM, BBNRM, RCONDE, RCONDV, WORK, LWORK, RWORK, IWORK, BWORK, INFO)

CGGEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine cgegs (JOBVSL, JOBVSR, N, A, LDA, B, LDB, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, INFO)

CGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine cgegv (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

CGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

***SOURCE:
http://www.netlib.org/lapack/explore-html/d4/d8a/group__complex_g_eeigen.html

11. **Obtaining the eigenvalues of a general real or complex n × n matrix:**

I am not sure about this answer. It was given that these are for complex 16 matrix. Now all real matrices are some reduced complex matrices. But this will work for a large no of cases...

subroutine zgegs (JOBVSL, JOBVSR, N, A, LDA, B, LDB, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, INFO)

ZGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine zgegv (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

ZGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine zgees (JOBVS, SORT, SELECT, N, A, LDA, SDIM, W, VS, LDVS, WORK, LWORK, RWORK, BWORK, INFO)

ZGEES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine zgeesx (JOBVS, SORT, SELECT, SENSE, N, A, LDA, SDIM, W, VS, LDVS, RCONDE, RCONDV, WORK, LWORK, RWORK, BWORK, INFO)

ZGEESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine zgeev (JOBVL, JOBVR, N, A, LDA, W, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

ZGEEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine zgeevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, W, VL, LDVL, VR, LDVR, ILO, IHI, SCALE, ABNRM, RCONDE, RCONDV, WORK, LWORK, RWORK, INFO)

ZGEEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine zgges (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, BWORK, INFO)

ZGGES computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine zgges3 (JOBVSL, JOBVSR, SORT, SELCTG, N, A, LDA, B, LDB, SDIM, ALPHA,

BETA, VSL, LDVSL, VSR, LDVSR, WORK, LWORK, RWORK, BWORK, INFO)

ZGGES3 computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices (blocked algorithm) More...

subroutine zggesx (JOBVSL, JOBVSR, SORT, SELCTG, SENSE, N, A, LDA, B, LDB, SDIM, ALPHA, BETA, VSL, LDVSL, VSR, LDVSR, RCONDE, RCONDV, WORK, LWORK, RWORK, IWORK, LIWORK, BWORK, INFO)

ZGGESX computes the eigenvalues, the Schur form, and, optionally, the matrix of Schur vectors for GE matrices More...

subroutine zggev (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

ZGGEV computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

subroutine zggev3 (JOBVL, JOBVR, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, WORK, LWORK, RWORK, INFO)

ZGGEV3 computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices (blocked algorithm) More...

subroutine zggevx (BALANC, JOBVL, JOBVR, SENSE, N, A, LDA, B, LDB, ALPHA, BETA, VL, LDVL, VR, LDVR, ILO, IHI, LSCALE, RSCALE, ABNRM, BBNRM, RCONDE, RCONDV, WORK, LWORK, RWORK, IWORK, BWORK, INFO)

ZGGEVX computes the eigenvalues and, optionally, the left and/or right eigenvectors for GE matrices More...

*** Source:
http://www.netlib.org/lapack/explore-html/db/d55/group__complex16_g_eeigen.html

GSL FUNCTIONS:

1. Solving a system of linear equations using Gaussian Elimination with Pivoting:

2. Solving a system of linear equations using the Jacobi method:

3. Solving a system of linear equations using the Gauss-Seidel method:

4. Solving a system of linear equations using the Relaxation method:

5. Solving a system of linear equations using the Conjugate Gradient method:

6. Obtaining the LU decomposition of a matrix:

There are two functions available:

int gsl_linalg_LU_decomp(gsl_matrix *A, gsl_permutation *p, int *signum)

int gsl_linalg_complex_LU_decomp(gsl_matrix_complex *A, gsl_permutation *p, int *signum)

***source: https://www.gnu.org/software/gsl/doc/html/linalg.html

7. Obtaining the QR decomposition of a matrix:

int gsl_linalg_QR_decomp(gsl_matrix *A, gsl_vector *tau)

*** Source:
https://www.gnu.org/software/gsl/doc/html/linalg.html#qr-decomposition

8. Obtaining the singular value decomposition of a matrix:

9. Obtaining the eigenvalues of a real symmetric matrix:

int gsl_eigen_symm(gsl_matrix *A, gsl_vector *$eval$, gsl_eigen_symm_workspace *w)

***Source: https://www.gnu.org/software/gsl/doc/html/eigen.html#real-symmetric-matrices

10. Obtaining the eigenvalues of a complex Hermitian matrix:

int gsl_eigen_herm(gsl_matrix_complex * A, gsl_vector * $eval$, gsl_eigen_herm_workspace * w)

***Source: https://www.gnu.org/software/gsl/doc/html/eigen.html#complex-hermitian-matrices

11. Obtaining the eigenvalues of a general real or complex n × n matrix:

I couldn't find out any function for real or complex general matrix. But for real non symmatric matrix the following works:

int gsl_eigen_nonsymm(gsl_matrix * A, gsl_vector_complex * $eval$, gsl_eigen_nonsymm_workspace * w)

***Source: https://www.gnu.org/software/gsl/doc/html/eigen.html#real-nonsymmetric-matrices