NAG Library Routine Document

C09ACF

Note: before using this routine, please read the Users' Note for your implementation to check the interpretation of ***bold italicised*** terms and other implementation-dependent details.

1 Purpose

C09ACF returns the details of the chosen three-dimensional discrete wavelet filter. For a chosen mother wavelet, discrete wavelet transform type (single-level or multi-level DWT) and end extension method, this routine returns the maximum number of levels of resolution (appropriate to a multi-level transform), the filter length, the total number of coefficients and the number of wavelet coefficients in the second and third dimensions for the single-level case. This routine must be called before any of the three-dimensional transform routines in this chapter.

2 Specification

```
SUBROUTINE C09ACF (WAVNAM, WTRANS, MODE, M, N, FR, NWLMAX, NF, NWCT,       &
                   NWCN, NWCFR, ICOMM, IFAIL)
INTEGER      M, N, FR, NWLMAX, NF, NWCT, NWCN, NWCFR, ICOMM(260), IFAIL
CHARACTER(*) WAVNAM
CHARACTER(1) WTRANS, MODE
```

3 Description

Three-dimensional discrete wavelet transforms (DWT) are characterised by the mother wavelet, the end extension method and whether multiresolution analysis is to be performed. For the selected combination of choices for these three characteristics, and for given dimensions $(m \times n \times fr)$ of data array A, C09ACF returns the dimension details for the transform determined by this combination. The dimension details are: l_{max}, the maximum number of levels of resolution that would be computed were a multi-level DWT applied; n_f, the filter length; n_{ct} the total number of wavelet coefficients (over all levels in the multi-level DWT case); n_{cn}, the number of coefficients in the second dimension for a single-level DWT; and n_{cfr}, the number of coefficients in the third dimension for a single-level DWT. These values are also stored in the communication array ICOMM, as are the input choices, so that they may be conveniently communicated to the three-dimensional transform routines in this chapter.

4 References

None.

5 Arguments

1: WAVNAM – CHARACTER(*) *Input*

On entry: the name of the mother wavelet. See the C09 Chapter Introduction for details.

WAVNAM = 'HAAR'
Haar wavelet.

WAVNAM = 'DB$\boldsymbol{n}$', where $\boldsymbol{n} = 2, 3, \ldots, 10$
Daubechies wavelet with $\boldsymbol{n}$ vanishing moments ($2\boldsymbol{n}$ coefficients). For example, WAVNAM = 'DB4' is the name for the Daubechies wavelet with 4 vanishing moments (8 coefficients).

WAVNAM = 'BIOR***x.y***', where ***x.y*** can be one of 1.1, 1.3, 1.5, 2.2, 2.4, 2.6, 2.8, 3.1, 3.3, 3.5 or 3.7

Biorthogonal wavelet of order ***x.y***. For example WAVNAM = 'BIOR3.1' is the name for the biorthogonal wavelet of order 3.1.

Constraint: WAVNAM = 'HAAR', 'DB2', 'DB3', 'DB4', 'DB5', 'DB6', 'DB7', 'DB8', 'DB9', 'DB10', 'BIOR1.1', 'BIOR1.3', 'BIOR1.5', 'BIOR2.2', 'BIOR2.4', 'BIOR2.6', 'BIOR2.8', 'BIOR3.1', 'BIOR3.3', 'BIOR3.5' or 'BIOR3.7'.

2: WTRANS – CHARACTER(1) *Input*

On entry: the type of discrete wavelet transform that is to be applied.

WTRANS = 'S'

Single-level decomposition or reconstruction by discrete wavelet transform.

WTRANS = 'M'

Multiresolution, by a multi-level DWT or its inverse.

Constraint: WTRANS = 'S' or 'M'.

3: MODE – CHARACTER(1) *Input*

On entry: the end extension method.

MODE = 'P'

Periodic end extension.

MODE = 'H'

Half-point symmetric end extension.

MODE = 'W'

Whole-point symmetric end extension.

MODE = 'Z'

Zero end extension.

Constraint: MODE = 'P', 'H', 'W' or 'Z'.

4: M – INTEGER *Input*

On entry: the number of elements, m, in the first dimension (number of rows of each two-dimensional frame) of the input data, A.

Constraint: $\text{M} \geq 2$.

5: N – INTEGER *Input*

On entry: the number of elements, n, in the second dimension (number of columns of each two-dimensional frame) of the input data, A.

Constraint: $\text{N} \geq 2$.

6: FR – INTEGER *Input*

On entry: the number of elements, fr, in the third dimension (number of frames) of the input data, A.

Constraint: $\text{FR} \geq 2$.

7: NWLMAX – INTEGER *Output*

On exit: the maximum number of levels of resolution, $l_{\max}$, that can be computed if a multi-level discrete wavelet transform is applied (WTRANS = 'M'). It is such that $2^{l_{\max}} \leq \min(m, n, fr) < 2^{l_{\max}+1}$, for $l_{\max}$ an integer.

If WTRANS = 'S', NWLMAX is not set.

8: NF – INTEGER *Output*

On exit: the filter length, n_f, for the supplied mother wavelet. This is used to determine the number of coefficients to be generated by the chosen transform.

9: NWCT – INTEGER *Output*

On exit: the total number of wavelet coefficients, n_{ct}, that will be generated. When WTRANS = 'S' the number of rows required (i.e., the first dimension of each two-dimensional frame) in each of the output coefficient arrays can be calculated as $n_{\mathrm{cm}} = n_{\mathrm{ct}}/(8 \times n_{\mathrm{cn}} \times n_{\mathrm{cfr}})$. When WTRANS = 'M' the length of the array used to store all of the coefficient matrices must be at least n_{ct}.

10: NWCN – INTEGER *Output*

On exit: for a single-level transform (WTRANS = 'S'), the number of coefficients that would be generated in the second dimension, n_{cn}, for each coefficient type. For a multi-level transform (WTRANS = 'M') this is set to 1.

11: NWCFR – INTEGER *Output*

On exit: for a single-level transform (WTRANS = 'S'), the number of coefficients that would be generated in the third dimension, n_{cfr}, for each coefficient type. For a multi-level transform (WTRANS = 'M') this is set to 1.

12: ICOMM(260) – INTEGER array *Communication Array*

On exit: contains details of the wavelet transform and the problem dimension which is to be communicated to the two-dimensional discrete transform routines in this chapter.

13: IFAIL – INTEGER *Input/Output*

On entry: IFAIL must be set to 0, -1 or 1. If you are unfamiliar with this argument you should refer to Section 3.4 in How to Use the NAG Library and its Documentation for details.

For environments where it might be inappropriate to halt program execution when an error is detected, the value -1 or 1 is recommended. If the output of error messages is undesirable, then the value 1 is recommended. Otherwise, if you are not familiar with this argument, the recommended value is 0. **When the value -1 or 1 is used it is essential to test the value of IFAIL on exit.**

On exit: IFAIL = 0 unless the routine detects an error or a warning has been flagged (see Section 6).

6 Error Indicators and Warnings

If on entry IFAIL = 0 or -1, explanatory error messages are output on the current error message unit (as defined by X04AAF).

Errors or warnings detected by the routine:

IFAIL = 1

On entry, WAVNAM = ⟨*value*⟩ was an illegal value.

IFAIL = 2

On entry, WTRANS = ⟨*value*⟩ was an illegal value.

IFAIL = 3

On entry, MODE = ⟨*value*⟩ was an illegal value.

IFAIL = 4

On entry, FR = ⟨*value*⟩.
Constraint: FR $\geq$ 2.

On entry, M = ⟨*value*⟩.
Constraint: M $\geq$ 2.

On entry, N = ⟨*value*⟩.
Constraint: N $\geq$ 2.

IFAIL = -99

An unexpected error has been triggered by this routine. Please contact NAG.

See Section 3.9 in How to Use the NAG Library and its Documentation for further information.

IFAIL = -399

Your licence key may have expired or may not have been installed correctly.

See Section 3.8 in How to Use the NAG Library and its Documentation for further information.

IFAIL = -999

Dynamic memory allocation failed.

See Section 3.7 in How to Use the NAG Library and its Documentation for further information.

7 Accuracy

Not applicable.

8 Parallelism and Performance

C09ACF is not threaded in any implementation.

9 Further Comments

None.

10 Example

This example computes the three-dimensional multi-level resolution for $8 \times 8 \times 8$ input data by a discrete wavelet transform using the Daubechies wavelet with four vanishing moments (see WAVNAM = 'DB4' in C09ACF) and zero end extension. The number of levels of transformation actually performed is one less than the maximum possible. This number of levels, the length of the wavelet filter, the total number of coefficients and the number of coefficients in each dimension for each level are printed along with the approximation coefficients before a reconstruction is performed. This example also demonstrates in general how to access any set of coefficients at any level following a multi-level transform.

10.1 Program Text

```
    Program c09acfe

!     C09ACF Example Program Text
!     Mark 26 Release. NAG Copyright 2016.

!     .. Use Statements ..
      Use nag_library, Only: c09acf, c09fcf, c09fdf, c09fyf, nag_wp, x02ajf
!     .. Implicit None Statement ..
      Implicit None
!     .. Parameters ..
```

```
      Integer, Parameter               :: nin = 5, nout = 6
!     .. Local Scalars ..
      Real (Kind=nag_wp)               :: eps, esq, frob
      Integer                          :: fr, i, ifail, j, k, lda, ldb, ldd,   &
                                          lenc, m, n, nf, nwcfr, nwcm, nwcn,   &
                                          nwct, nwl, nwlmax, sda, sdb, sdd,    &
                                          want_coeffs, want_level
      Character (10)                   :: mode, wavnam, wtrans
      Character (33)                   :: title
!     .. Local Arrays ..
      Real (Kind=nag_wp), Allocatable  :: a(:,:,:), b(:,:,:), c(:), d(:,:,:),  &
                                          e(:,:,:)
      Integer, Allocatable             :: dwtlvfr(:), dwtlvm(:), dwtlvn(:)
      Integer                          :: icomm(260)
      Character (3)                    :: cpass(0:7)
!     .. Intrinsic Procedures ..
      Intrinsic                        :: max, real, sqrt, sum
!     .. Executable Statements ..
      Continue
      Write (nout,*) 'C09ACF Example Program Results'
      Write (nout,*)
!     Skip heading in data file
      Read (nin,*)
!     Read problem parameters
      Read (nin,*) m, n, fr
      Read (nin,*) wavnam, mode
      lda = m
      sda = n
      ldb = m
      sdb = n
      Allocate (a(lda,sda,fr),b(ldb,sdb,fr),e(ldb,sdb,fr))

      Write (nout,99999) wavnam, mode, m, n, fr

!     Read data array and write it out

      Do j = 1, fr
        Do i = 1, m
          Read (nin,*) a(i,1:n,j)
        End Do
        If (j<fr) Then
          Read (nin,*)
        End If
      End Do

      Write (nout,*) ' Input Data     A :'
      Do j = 1, fr
        Do i = 1, m
          Write (nout,99998) a(i,1:n,j)
        End Do
        Write (nout,*)
      End Do

!     Query wavelet filter dimensions
!     For Multi-Resolution Analysis, decomposition, wtrans = 'M'
      wtrans = 'Multilevel'
      ifail = 0
      Call c09acf(wavnam,wtrans,mode,m,n,fr,nwlmax,nf,nwct,nwcn,nwcfr,icomm,   &
        ifail)

!     Transform one less than the max possible number of levels.
      nwl = nwlmax - 1

      lenc = nwct
      Allocate (c(lenc),dwtlvm(nwl),dwtlvn(nwl),dwtlvfr(nwl))

!     Perform Discrete Wavelet transform
      ifail = 0
      Call c09fcf(m,n,fr,a,lda,sda,lenc,c,nwl,dwtlvm,dwtlvn,dwtlvfr,icomm,     &
        ifail)
```

```
!     c09acf returns nwct based on max levels, so recalculate.
      nwct = sum(7*dwtlvm(1:nwl)*dwtlvn(1:nwl)*dwtlvfr(1:nwl))
      nwct = nwct + dwtlvm(1)*dwtlvn(1)*dwtlvfr(1)

      Write (nout,99997) nwl
      Write (nout,99988) nf
      Write (nout,99987) nwct
      Write (nout,99996)
      Write (nout,99995) dwtlvm(1:nwl)
      Write (nout,99994)
      Write (nout,99995) dwtlvn(1:nwl)
      Write (nout,99993)
      Write (nout,99995) dwtlvfr(1:nwl)

!     Select the deepest level.
      want_level = nwl
!     Select the approximation coefficients.
      want_coeffs = 0

      nwcm = dwtlvm(nwl-want_level+1)
      nwcn = dwtlvn(nwl-want_level+1)
      nwcfr = dwtlvfr(nwl-want_level+1)

!     Allocate space to store the coefficients
      ldd = nwcm
      sdd = nwcn
      Allocate (d(ldd,sdd,nwcfr))

      Write (nout,99986) want_level, nwcm, nwcn, nwcfr

      cpass(0:7) = (/'LLL','LLH','LHL','LHH','HLL','HLH','HHL','HHH'/)
      If (want_coeffs==0) Then
        title = 'Approximation coefficients (LLL) '
      Else
        title = 'Detail coefficients (' // cpass(want_coeffs) // ')  '
      End If

!     Extract the required coefficients
      Call c09fyf(want_level,want_coeffs,lenc,c,d,ldd,sdd,icomm,ifail)

!     Print out the selected set of coefficients
      Write (nout,99985) title
      Write (nout,99989) want_level, want_coeffs
      Do k = 1, nwcfr
        Write (nout,99990) k
        Do i = 1, nwcm
          Write (nout,99991) d(i,1:nwcn,k)
        End Do
      End Do

      Deallocate (d)

!     Reconstruct original data
      ifail = 0
      Call c09fdf(nwl,lenc,c,m,n,fr,b,ldb,sdb,icomm,ifail)

!     Check reconstruction matches original
      eps = 10.0_nag_wp*real(m,kind=nag_wp)*real(n,kind=nag_wp)*              &
        real(fr,kind=nag_wp)*x02ajf()

      e(1:m,1:n,1:fr) = b(1:m,1:n,1:fr) - a(1:m,1:n,1:fr)
      frob = 0.0_nag_wp
      Do k = 1, fr
        esq = 0.0_nag_wp
        Do j = 1, n
          Do i = 1, m
            esq = esq + e(i,j,k)**2
          End Do
        End Do
        frob = max(frob,sqrt(esq))
      End Do
```

```
      If (frob>eps) Then
        Write (nout,99992)
      Else
        Write (nout,99992)
      End If

99999 Format (1X,' MLDWT :: Wavelet  : ',A,/,1X,'         End mode : ',A,/,   &
        1X,'          M        : ',I4,/,1X,'          N        : ',I4,/,1X,   &
        '          FR       : ',I4,/)
99998 Format (8(F8.4,1X),:)
99997 Format (/,1X,' Number of Levels :         ',I10)
99996 Format (1X,' Number of coefficients in 1st dimension for each level :')
99995 Format (8(I8,1X),:)
99994 Format (1X,' Number of coefficients in 2nd dimension for each level :')
99993 Format (1X,' Number of coefficients in 3rd dimension for each level :')
99992 Format (/,1X,' Success: the reconstruction matches the original.')
99991 Format (1X,8(F8.4,1X),:)
99990 Format (1X,' Frame ',I2,' : ')
99989 Format (1X,' Level ',I2,', Coefficients ',I2,' : ')
99988 Format (1X,' Length of wavelet filter : ',I10)
99987 Format (1X,' Total number of wavelet coefficients : ',I10)
99986 Format (/,1X,70('-'),/,1X,'Level : ',I10,'; output is ',I10,' by ',I10,  &
        ' by ',I10,/,1X,70('-'))
99985 Format (/,1X,A)
    End Program c09acfe
```

10.2 Program Data

```
C09ACF Example Program Data
 8, 8, 8              : m, n, fr
 DB4 zero : wavnam, mode
  10.000  31.000  04.000  10.000  13.000  15.000  04.000  06.000
  26.000  24.000  03.000  18.000  17.000  22.000  20.000  05.000
  06.000  05.000  06.000  11.000  22.000  23.000  23.000  01.000
  09.000  15.000  18.000  01.000  30.000  24.000  08.000  01.000
  18.000  04.000  26.000  20.000  31.000  21.000  04.000  06.000
  25.000  23.000  25.000  14.000  13.000  03.000  03.000  29.000
  22.000  29.000  07.000  29.000  13.000  31.000  03.000  12.000
  22.000  03.000  30.000  05.000  10.000  04.000  01.000  19.000

  01.000  02.000  14.000  31.000  19.000  28.000  06.000  15.000
  26.000  25.000  25.000  04.000  05.000  15.000  24.000  05.000
  01.000  29.000  08.000  18.000  22.000  18.000  31.000  23.000
  08.000  04.000  16.000  21.000  14.000  02.000  02.000  21.000
  10.000  03.000  14.000  03.000  25.000  10.000  24.000  15.000
  03.000  16.000  26.000  21.000  16.000  19.000  25.000  27.000
  28.000  29.000  01.000  20.000  03.000  24.000  31.000  28.000
  31.000  28.000  14.000  30.000  13.000  29.000  20.000  04.000

  31.000  26.000  23.000  05.000  22.000  01.000  16.000  08.000
  21.000  01.000  29.000  10.000  23.000  14.000  09.000  03.000
  20.000  10.000  11.000  22.000  26.000  31.000  03.000  21.000
  09.000  24.000  19.000  03.000  04.000  01.000  13.000  29.000
  18.000  16.000  05.000  06.000  09.000  16.000  08.000  16.000
  32.000  19.000  32.000  01.000  06.000  04.000  01.000  17.000
  29.000  29.000  02.000  29.000  27.000  25.000  31.000  06.000
  28.000  15.000  15.000  22.000  18.000  01.000  18.000  14.000

  15.000  09.000  04.000  14.000  26.000  10.000  03.000  28.000
  21.000  24.000  32.000  27.000  01.000  27.000  08.000  16.000
  10.000  27.000  29.000  15.000  13.000  01.000  05.000  16.000
  04.000  01.000  08.000  31.000  14.000  06.000  05.000  27.000
  01.000  19.000  11.000  31.000  12.000  31.000  17.000  26.000
  27.000  01.000  16.000  06.000  18.000  02.000  17.000  17.000
  30.000  09.000  15.000  32.000  32.000  29.000  16.000  02.000
  03.000  11.000  26.000  02.000  23.000  08.000  10.000  31.000

  12.000  07.000  06.000  12.000  01.000  13.000  30.000  26.000
  27.000  27.000  20.000  16.000  30.000  28.000  13.000  30.000
```

```
 29.000  15.000  15.000  05.000  01.000  13.000  31.000  02.000
 31.000  21.000  27.000  30.000  08.000  07.000  11.000  03.000
 17.000  04.000  06.000  01.000  09.000  25.000  03.000  15.000
 12.000  18.000  16.000  05.000  09.000  16.000  06.000  13.000
 03.000  05.000  26.000  30.000  19.000  11.000  32.000  24.000
 06.000  16.000  07.000  15.000  31.000  10.000  20.000  14.000

 20.000  07.000  17.000  11.000  04.000  21.000  25.000  17.000
 18.000  22.000  22.000  06.000  01.000  05.000  15.000  17.000
 25.000  24.000  16.000  13.000  19.000  16.000  23.000  10.000
 01.000  31.000  05.000  13.000  11.000  12.000  01.000  18.000
 01.000  27.000  09.000  05.000  29.000  26.000  23.000  13.000
 02.000  17.000  17.000  14.000  31.000  21.000  16.000  05.000
 26.000  21.000  10.000  21.000  09.000  11.000  01.000  15.000
 08.000  15.000  18.000  04.000  16.000  09.000  03.000  29.000

 26.000  02.000  30.000  26.000  07.000  04.000  09.000  01.000
 15.000  02.000  10.000  22.000  16.000  15.000  04.000  03.000
 04.000  07.000  32.000  27.000  07.000  05.000  17.000  04.000
 22.000  30.000  06.000  18.000  32.000  02.000  01.000  31.000
 15.000  19.000  20.000  12.000  10.000  28.000  27.000  03.000
 26.000  31.000  21.000  02.000  27.000  10.000  22.000  13.000
 32.000  03.000  27.000  23.000  01.000  11.000  04.000  26.000
 03.000  01.000  31.000  21.000  27.000  21.000  14.000  09.000

 02.000  16.000  16.000  23.000  23.000  09.000  27.000  12.000
 15.000  17.000  20.000  27.000  05.000  04.000  18.000  16.000
 29.000  32.000  20.000  08.000  14.000  32.000  11.000  04.000
 28.000  01.000  15.000  19.000  14.000  09.000  30.000  18.000
 20.000  02.000  08.000  11.000  20.000  24.000  14.000  03.000
 18.000  15.000  16.000  03.000  23.000  01.000  19.000  31.000
 32.000  27.000  28.000  09.000  15.000  23.000  09.000  13.000
 01.000  24.000  30.000  04.000  18.000  11.000  01.000  22.000
```

10.3 Program Results

```
C09ACF Example Program Results

 MLDWT :: Wavelet  : DB4
          End mode : zero
          M        :    8
          N        :    8
          FR       :    8

 Input Data     A :
10.0000  31.0000   4.0000  10.0000  13.0000  15.0000   4.0000   6.0000
26.0000  24.0000   3.0000  18.0000  17.0000  22.0000  20.0000   5.0000
 6.0000   5.0000   6.0000  11.0000  22.0000  23.0000  23.0000   1.0000
 9.0000  15.0000  18.0000   1.0000  30.0000  24.0000   8.0000   1.0000
18.0000   4.0000  26.0000  20.0000  31.0000  21.0000   4.0000   6.0000
25.0000  23.0000  25.0000  14.0000  13.0000   3.0000   3.0000  29.0000
22.0000  29.0000   7.0000  29.0000  13.0000  31.0000   3.0000  12.0000
22.0000   3.0000  30.0000   5.0000  10.0000   4.0000   1.0000  19.0000

 1.0000   2.0000  14.0000  31.0000  19.0000  28.0000   6.0000  15.0000
26.0000  25.0000  25.0000   4.0000   5.0000  15.0000  24.0000   5.0000
 1.0000  29.0000   8.0000  18.0000  22.0000  18.0000  31.0000  23.0000
 8.0000   4.0000  16.0000  21.0000  14.0000   2.0000   2.0000  21.0000
10.0000   3.0000  14.0000   3.0000  25.0000  10.0000  24.0000  15.0000
 3.0000  16.0000  26.0000  21.0000  16.0000  19.0000  25.0000  27.0000
28.0000  29.0000   1.0000  20.0000   3.0000  24.0000  31.0000  28.0000
31.0000  28.0000  14.0000  30.0000  13.0000  29.0000  20.0000   4.0000

31.0000  26.0000  23.0000   5.0000  22.0000   1.0000  16.0000   8.0000
21.0000   1.0000  29.0000  10.0000  23.0000  14.0000   9.0000   3.0000
20.0000  10.0000  11.0000  22.0000  26.0000  31.0000   3.0000  21.0000
 9.0000  24.0000  19.0000   3.0000   4.0000   1.0000  13.0000  29.0000
18.0000  16.0000   5.0000   6.0000   9.0000  16.0000   8.0000  16.0000
32.0000  19.0000  32.0000   1.0000   6.0000   4.0000   1.0000  17.0000
29.0000  29.0000   2.0000  29.0000  27.0000  25.0000  31.0000   6.0000
```

```
 28.0000  15.0000  15.0000  22.0000  18.0000   1.0000  18.0000  14.0000

 15.0000   9.0000   4.0000  14.0000  26.0000  10.0000   3.0000  28.0000
 21.0000  24.0000  32.0000  27.0000   1.0000  27.0000   8.0000  16.0000
 10.0000  27.0000  29.0000  15.0000  13.0000   1.0000   5.0000  16.0000
  4.0000   1.0000   8.0000  31.0000  14.0000   6.0000   5.0000  27.0000
  1.0000  19.0000  11.0000  31.0000  12.0000  31.0000  17.0000  26.0000
 27.0000   1.0000  16.0000   6.0000  18.0000   2.0000  17.0000  17.0000
 30.0000   9.0000  15.0000  32.0000  32.0000  29.0000  16.0000   2.0000
  3.0000  11.0000  26.0000   2.0000  23.0000   8.0000  10.0000  31.0000

 12.0000   7.0000   6.0000  12.0000   1.0000  13.0000  30.0000  26.0000
 27.0000  27.0000  20.0000  16.0000  30.0000  28.0000  13.0000  30.0000
 29.0000  15.0000  15.0000   5.0000   1.0000  13.0000  31.0000   2.0000
 31.0000  21.0000  27.0000  30.0000   8.0000   7.0000  11.0000   3.0000
 17.0000   4.0000   6.0000   1.0000   9.0000  25.0000   3.0000  15.0000
 12.0000  18.0000  16.0000   5.0000   9.0000  16.0000   6.0000  13.0000
  3.0000   5.0000  26.0000  30.0000  19.0000  11.0000  32.0000  24.0000
  6.0000  16.0000   7.0000  15.0000  31.0000  10.0000  20.0000  14.0000

 20.0000   7.0000  17.0000  11.0000   4.0000  21.0000  25.0000  17.0000
 18.0000  22.0000  22.0000   6.0000   1.0000   5.0000  15.0000  17.0000
 25.0000  24.0000  16.0000  13.0000  19.0000  16.0000  23.0000  10.0000
  1.0000  31.0000   5.0000  13.0000  11.0000  12.0000   1.0000  18.0000
  1.0000  27.0000   9.0000   5.0000  29.0000  26.0000  23.0000  13.0000
  2.0000  17.0000  17.0000  14.0000  31.0000  21.0000  16.0000   5.0000
 26.0000  21.0000  10.0000  21.0000   9.0000  11.0000   1.0000  15.0000
  8.0000  15.0000  18.0000   4.0000  16.0000   9.0000   3.0000  29.0000

 26.0000   2.0000  30.0000  26.0000   7.0000   4.0000   9.0000   1.0000
 15.0000   2.0000  10.0000  22.0000  16.0000  15.0000   4.0000   3.0000
  4.0000   7.0000  32.0000  27.0000   7.0000   5.0000  17.0000   4.0000
 22.0000  30.0000   6.0000  18.0000  32.0000   2.0000   1.0000  31.0000
 15.0000  19.0000  20.0000  12.0000  10.0000  28.0000  27.0000   3.0000
 26.0000  31.0000  21.0000   2.0000  27.0000  10.0000  22.0000  13.0000
 32.0000   3.0000  27.0000  23.0000   1.0000  11.0000   4.0000  26.0000
  3.0000   1.0000  31.0000  21.0000  27.0000  21.0000  14.0000   9.0000

  2.0000  16.0000  16.0000  23.0000  23.0000   9.0000  27.0000  12.0000
 15.0000  17.0000  20.0000  27.0000   5.0000   4.0000  18.0000  16.0000
 29.0000  32.0000  20.0000   8.0000  14.0000  32.0000  11.0000   4.0000
 28.0000   1.0000  15.0000  19.0000  14.0000   9.0000  30.0000  18.0000
 20.0000   2.0000   8.0000  11.0000  20.0000  24.0000  14.0000   3.0000
 18.0000  15.0000  16.0000   3.0000  23.0000   1.0000  19.0000  31.0000
 32.0000  27.0000  28.0000   9.0000  15.0000  23.0000   9.0000  13.0000
  1.0000  24.0000  30.0000   4.0000  18.0000  11.0000   1.0000  22.0000


  Number of Levels :                  2
  Length of wavelet filter :          8
  Total number of wavelet coefficients :       5145
  Number of coefficients in 1st dimension for each level :
       7        7
  Number of coefficients in 2nd dimension for each level :
       7        7
  Number of coefficients in 3rd dimension for each level :
       7        7

 ----------------------------------------------------------------------
 Level :          2; output is         7 by          7 by          7
 ----------------------------------------------------------------------

 Approximation coefficients (LLL)
  Level  2, Coefficients  0 :
  Frame  1 :
  -0.0000  -0.0000   0.0000   0.0000   0.0001   0.0000   0.0000
  -0.0000  -0.0000   0.0000  -0.0001   0.0000  -0.0007  -0.0000
   0.0000   0.0000  -0.0001  -0.0002  -0.0020   0.0036  -0.0002
  -0.0000  -0.0000  -0.0002   0.0021   0.0025  -0.0124   0.0010
   0.0001  -0.0000  -0.0017   0.0009   0.0928   0.1155   0.0004
   0.0002  -0.0007   0.0013  -0.0063   0.1584   0.0931   0.0096
```

```
 0.0000  -0.0001   0.0003  -0.0006   0.0123   0.0061   0.0014
Frame  2 :
-0.0000   0.0000   0.0000  -0.0000  -0.0010  -0.0005  -0.0000
 0.0000  -0.0000   0.0001  -0.0006   0.0026   0.0035   0.0004
 0.0001  -0.0000  -0.0008   0.0027   0.0133  -0.0064  -0.0032
-0.0002   0.0000   0.0032  -0.0067  -0.0708   0.0073   0.0148
-0.0003   0.0035  -0.0155   0.0406  -0.3676  -0.3434  -0.0682
-0.0011   0.0004   0.0241  -0.0866  -0.4993  -0.5807  -0.0674
-0.0002  -0.0003   0.0048  -0.0128  -0.0800  -0.0731  -0.0045
Frame  3 :
 0.0000   0.0000  -0.0002   0.0005   0.0006   0.0027   0.0005
-0.0000   0.0002  -0.0012   0.0037  -0.0224   0.0005  -0.0006
-0.0002  -0.0011   0.0067  -0.0126   0.0447  -0.0734   0.0068
 0.0008   0.0025  -0.0141  -0.0008   0.0872   0.3261  -0.0494
 0.0012  -0.0173   0.0687  -0.0681   0.5915  -0.1717   0.3943
 0.0016   0.0123  -0.1221   0.4190  -0.5269   1.2295   0.1617
 0.0003   0.0028  -0.0182   0.0396   0.1154   0.2823   0.0102
Frame  4 :
-0.0000  -0.0002   0.0011  -0.0030   0.0059  -0.0102  -0.0026
 0.0000  -0.0010   0.0042  -0.0106   0.0948  -0.0180  -0.0005
 0.0004   0.0061  -0.0296   0.0586  -0.3921   0.3650   0.0134
-0.0018  -0.0155   0.0684  -0.0636   0.5365  -1.4566   0.0298
-0.0070   0.0592  -0.1486  -0.1055  -2.9693   0.1109  -1.4193
-0.0017  -0.0424   0.2595  -0.7280   2.4682  -4.1771  -0.5119
 0.0003  -0.0079   0.0273  -0.0205  -0.1224  -0.9982  -0.0710
Frame  5 :
 0.0001  -0.0000  -0.0005  -0.0015   0.0804   0.1009   0.0139
-0.0006   0.0033  -0.0017  -0.0019  -0.5303  -0.5712  -0.0438
-0.0014  -0.0157   0.0800  -0.1856   0.4182   0.4931   0.0090
 0.0099   0.0522  -0.4140   1.1260   0.6111  -0.0042  -0.1288
 0.0831  -0.4718   0.9591  -2.9510  84.8494  91.3686  10.1751
 0.1599  -0.3194  -0.8962   1.8546 106.1903 117.2751  12.9904
 0.0213  -0.0211  -0.2179   0.4955  12.5323  12.9746   1.3422
Frame  6 :
 0.0002  -0.0004  -0.0006   0.0005   0.0945   0.1342   0.0157
-0.0008   0.0048  -0.0052   0.0013  -0.7012  -0.3668  -0.0231
-0.0006  -0.0125   0.0347  -0.0396   1.3945  -0.2227  -0.1395
 0.0034   0.0166  -0.0246  -0.0495  -3.2417  -0.3508   0.3284
 0.1373  -0.4804  -0.1436   0.6068 105.5811 101.7766  10.0719
 0.1359  -0.6132   0.8736  -2.8616 121.1074 124.4215  13.7050
 0.0068  -0.0939   0.4312  -1.4152  12.9366  13.1259   1.6024
Frame  7 :
 0.0000  -0.0001   0.0006  -0.0024   0.0134   0.0160   0.0014
-0.0001   0.0006   0.0003  -0.0044  -0.0813  -0.0377  -0.0021
 0.0006   0.0002  -0.0206   0.0816   0.0851  -0.0274  -0.0148
-0.0028  -0.0074   0.1035  -0.3488   0.0136  -0.1313   0.0288
 0.0177  -0.0358  -0.0968   0.1416  11.4442  11.6279   0.9779
 0.0187  -0.0759   0.0227   0.1041  13.7268  13.3069   1.5629
 0.0002  -0.0164   0.0748  -0.2042   1.6290   1.2827   0.1547

Success: the reconstruction matches the original.
```