CS546   Homework 4 (HPF)

Q.1)   real a(5,5), b(5,5), c(5,5), d(5)

$$a = \begin{matrix} 1 & 2 & 3 & 4 & 5 \\ 6 & 7 & 8 & 9 & 10 \\ 11 & 12 & 13 & 14 & 15 \\ 16 & 17 & 18 & 19 & 20 \\ 21 & 22 & 23 & 24 & 25 \end{matrix}$$

$$b = \begin{matrix} 5 & 10 & 15 & 20 & 25 \\ 30 & 35 & 40 & 45 & 50 \\ 55 & 60 & 65 & 70 & 75 \\ 80 & 85 & 90 & 95 & 100 \\ 105 & 110 & 115 & 120 & 125 \end{matrix}$$

$$c = \begin{matrix} 2 & 4 & 6 & 8 & 10 \\ 12 & 14 & 16 & 18 & 20 \\ 22 & 24 & 26 & 28 & 30 \\ 32 & 34 & 36 & 38 & 40 \\ 42 & 44 & 46 & 48 & 50 \end{matrix}$$

$$d = \begin{matrix} 3 & 6 & 9 & 12 & 15 \end{matrix}$$

(a)   a(2,:) = d

$$a = \begin{matrix} 1 & 2 & 3 & 4 & 5 \\ 3 & 6 & 9 & 12 & 15 \\ 11 & 12 & 13 & 14 & 15 \\ 16 & 17 & 18 & 19 & 20 \\ 21 & 22 & 23 & 24 & 25 \end{matrix}$$ ← d = 3 6 9 12 15

Here, 2nd row of a is replaced by d.

b) a(1:3,:) = b(2:4,:)

$$a = \begin{matrix} 30 & 35 & 40 & 45 & 50 \\ 55 & 60 & 65 & 70 & 75 \\ 80 & 85 & 90 & 95 & 100 \\ 16 & 17 & 18 & 19 & 20 \\ 21 & 22 & 23 & 24 & 25 \end{matrix}$$

$$b = \begin{matrix} 5 & 10 & 15 & 20 & 25 \\ 30 & 35 & 40 & 45 & 50 \\ 55 & 60 & 65 & 70 & 75 \\ 80 & 85 & 90 & 95 & 100 \\ 105 & 110 & 115 & 120 & 125 \end{matrix}$$

c) where (b.eq.c) a=c

if,

$$b = \begin{array}{ccccc} 10 & \boxed{20} & 30 & \boxed{40} & 50 \\ 60 & 70 & 80 & 90 & 100 \\ 110 & 120 & 130 & 140 & 150 \\ 160 & 170 & 180 & 190 & 200 \\ 210 & 220 & 230 & 240 & 250 \end{array}$$

↕   ↕

$$c = \begin{array}{ccccc} 51 & \boxed{20} & 56 & \boxed{40} & 61 \\ 52 & 70 & 57 & 90 & 62 \\ 53 & 120 & 58 & 140 & 63 \\ 54 & 170 & 59 & 190 & 64 \\ 55 & 220 & 60 & 240 & 65 \end{array}$$

↓   ↙

∴

$$a = \begin{array}{ccccc} 1 & \boxed{20} & 3 & \boxed{40} & 5 \\ 6 & 70 & 8 & 90 & 10 \\ 11 & 120 & 13 & 140 & 15 \\ 16 & 170 & 18 & 190 & 20 \\ 21 & 220 & 23 & 240 & 25 \end{array}$$

d) forall (i=2:4, j=2:5)

$$a(i,j) = b(i-1,j-1) + c(i+1,j)$$

a=	1	2	3	4	5
6	7	8	9	10	
11	12	13	14	15	
16	17	18	19	20	
21	22	23	24	25	

$$b = \begin{array}{ccccc} 5 & 5 & 5 & 5 & 5 \\ 6 & 6 & 6 & 6 & 6 \\ 7 & 7 & 7 & 7 & 7 \\ 8 & 8 & 8 & 8 & 8 \\ 9 & 9 & 9 & 9 & 9 \end{array} \qquad c = \begin{array}{ccccc} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{array}$$

a =	1	2	3	4	5
6	6	6	6	6	
11	7	7	7	7	
16	8	8	8	8	
21	22	23	24	25	

e) forall $(i=1:5, j=1:5)$ $b(i,j) = (i+j-1)$

$$
b = \begin{array}{ccccc}
1 & 2 & 3 & 4 & 5 \\
6 & 7 & 8 & 9 & 10 \\
11 & 12 & 13 & 14 & 15 \\
16 & 17 & 18 & 19 & 20 \\
21 & 22 & 23 & 24 & 25
\end{array}
\quad \rightarrow \quad
b = \begin{array}{ccccc}
1 & 2 & 3 & 4 & 5 \\
2 & 3 & 4 & 5 & 6 \\
3 & 4 & 5 & 6 & 7 \\
4 & 5 & 6 & 7 & 8 \\
5 & 6 & 7 & 8 & 9
\end{array}
$$

e.g. $b(i,j) = (i+j-1)$

$b(4,4) = (4+4-1) = 7$

f) forall $(j=1:5)$ $d(j) = sum(c(1:4,j), dim=1)$

$$
c = \begin{array}{ccccc}
1 & 2 & 3 & 4 & 5 \\
1 & 2 & 3 & 4 & 5 \\
1 & 2 & 3 & 4 & 5 \\
1 & 2 & 3 & 4 & 5 \\
1 & 2 & 3 & 4 & 5
\end{array}
$$

$(1+1+1+1 = 4)$

$(2+2+2+2 = 8)$

$(3+3+3+3 = 12)$

$(4+4+4+4 = 16)$

$(5+5+5+5 = 20)$

$d(1) \quad d(2) \quad d(3) \quad d(4) \quad d(5)$

$\therefore \quad d = 4 \quad 8 \quad 12 \quad 16 \quad 20$

g) $a = spread(d, dim=2, ncopies=5)$

$d = 5 \quad 10 \quad 15 \quad 20 \quad 25$

$$
\therefore \quad a = \begin{array}{ccccc}
5 & 5 & 5 & 5 & 5 \\
10 & 10 & 10 & 10 & 10 \\
15 & 15 & 15 & 15 & 15 \\
20 & 20 & 20 & 20 & 20 \\
25 & 25 & 25 & 25 & 25
\end{array}
$$

h) $b = $ spread $(d, \dim = 1, n\text{copies} = 5)$

$$d = 5 \quad 10 \quad 15 \quad 20 \quad 25$$

$$
b =
\begin{array}{ccccc}
5 & 10 & 15 & 20 & 25 \\
5 & 10 & 15 & 20 & 25 \\
5 & 10 & 15 & 20 & 25 \\
5 & 10 & 15 & 20 & 25 \\
5 & 10 & 15 & 20 & 25 \\
\end{array}
$$

i) $a = $ cshift $(b, \dim = 1, \text{shift} = 3)$

$$
b =
\begin{bmatrix}
1 & 2 & 3 & 4 & 5 \\
6 & 7 & 8 & 9 & 10 \\
11 & 12 & 13 & 14 & 15 \\
16 & 17 & 18 & 19 & 20 \\
21 & 22 & 23 & 24 & 25 \\
\end{bmatrix}
$$

$$
a =
\begin{array}{ccccc}
16 & 17 & 18 & 19 & 20 \\
21 & 22 & 23 & 24 & 25 \\
1 & 2 & 3 & 4 & 5 \\
6 & 7 & 8 & 9 & 10 \\
11 & 12 & 13 & 14 & 15 \\
\end{array}
$$

j) $d = $ sum (spread $(d, \dim = 1, n\text{copies} = 5), \dim = 2)$

let $d = 1 \quad 2 \quad 3 \quad 4 \quad 5$

$$
\text{spread} \rightarrow d =
\begin{array}{ccccc|c}
1 & 2 & 3 & 4 & 5 & 15 \quad (1+2+3+4+5 = 15) \\
1 & 2 & 3 & 4 & 5 & 15 \\
1 & 2 & 3 & 4 & 5 & 15 \quad \therefore d = \\
1 & 2 & 3 & 4 & 5 & 15 \quad \text{sum} \\
1 & 2 & 3 & 4 & 5 & 15 \\
1 & 2 & 3 & 4 & 5 & \\
\end{array}
$$

Q.2) a) forall $(i=1:100, j=1:100, i.lt.j)$ $a(i,j) = 0.0$

b)   b = transpose (a)
     or
          forall $(i=1:100, j=1:100)$ $b(i,j) = a(j,i)$

c)   b = spread (a, dim=2, ncopies = 5)

d)   b = cshift (a, shift = 2, dim = 2)

          b = cshift (b, shift = -1, dim = 1)

e)   forall $(i=1:4)$ $b(i) = a(i*2)$

Q.3) a)   !HPF$ PROCESSORS p(4)

              integer a(8)
              ~~!HPF$ DISTRIBUTE a(*BLOCK) ONTO p~~
              ~~!HPF$ ALIGN a(*CYCLIC(5)) WITH p~~
              !HPF$ DISTRIBUTE a(CYCLIC (5)) ONTO p

b)   !HPF$ PROCESSORS p(4)
              integer a(12), b(12,12)
              ~~!HPF$ DISTRIBUTE A(BLOCK),B(*BLOCK) ONTO p~~

       ! HPF $ ALIGN A (:) WITH B (*,:)

       ! HPF $ DISTRIBUTE {A (BLOCK), B(*, BLOCK) ONTO P

Q.4)

```
!
!    Gauss Elimination without pivoting
!    To paralellize the elimination function, first, number
!    of processors are defined and then ALIGN and
!    DISTRIBUTE directives are used to align each row
!    of B with each row of A and cyclic distribution
!    of A respectively.
!    In the parallel algorithm below, two inner loops
!    of elimination function are paralellized.
!    Paralellization is done using forall loop i.e.
!    'do' loop is replaced by forall loop.


         Program gauss
         integer n, row, col, norm
         parameter (n=256)
         real X(n), B(n), A(n,n), mutiplier
         real*8 elapsed1, elapsed2, rtc, elapsedp1, elapsedp2

!HPF$  PROCESSORS  P(16,16)
!HPF$  ALIGN  B(:) WITH A(:, *)
!HPF$  DISTRIBUTE A(CYCLIC, *)
       elapsed1 = rtc()

!------- Initialise all elements to random values
       do row = 1,n
         do col = 1,n
           A(row,col) = (1.0 * irand())/32768.0
         enddo
         B(row) = (1.0 * irand())/32768.0
       enddo
!---------------------
```

```
! parallelized loop
      elapsedp1 = rtc()
      do norm = 1, n-1
      forall (row = norm+1 : n)
         multiplier = A(row, norm)/A(norm, norm)

      forall (col = norm : n)
         A(row, col) = A(row, col) - A(norm, col)*multiplier

         B(row) = B(row) - B(norm)*multiplier
      enddo
      elapsedp2 = rtc()

! ------ backsubstitute
      do row = n-1, 1, -1
         X(row) = B(row)
         do col = n-1, row+1, -1
            X(row) = X(row) - A(row, col)*X(col)
         enddo
         X(row) = X(row)/A(row, row)
      enddo
      elapsed2 = rtc()

! ----------- Check correctness of code
      do row = 1, n
         do col = 1, row-1
            if(A(row, col) .GT. 1e-3)
            print *, "Error in", row, col, A(row, col)
         enddo
      enddo
      print *, "Elapsed Time", elapsed2 - elapsed1
      print *, "Elapsed time in elimination phase", elapsedp2 - elapsedp1
      stop
      end
```